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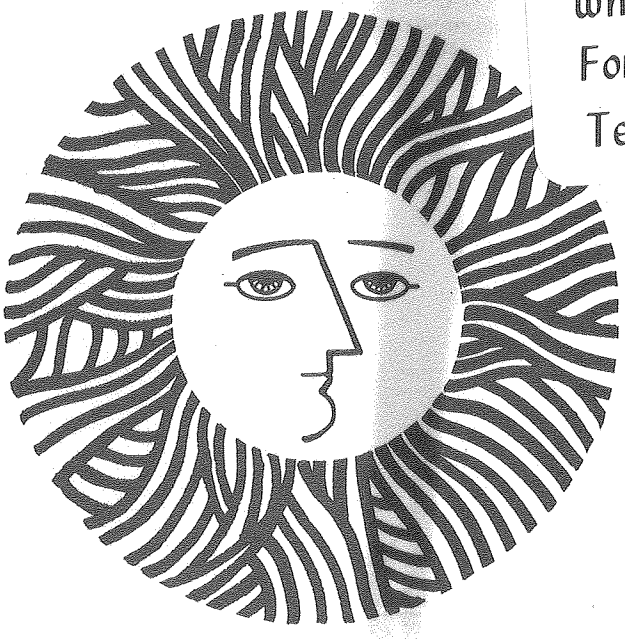

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ENERGY ANALYSIS PROGRAM

chapter from
Energy & Environment Division
Annual Report 1978

Energy & Environment
Lawrence Berkeley Laboratory
University of California
Berkeley, California 94720

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Energy Analysis

Introduction

Energy futures for America will employ an ever widening range of sources of energy and of specific technologies to extract and convert base energy resources into end use energy products. The choices available to the Department of Energy for defining the direction of both the nation's near term and long term energy supply future are rapidly expanding. However, the availability of these choices brings with it the responsibility for the consequences of the path chosen. A growing awareness of the complexity, endurance and interconnectivity of the environmental, socioeconomic and human health impacts of many energy development choices has presented DOE with a requirement to unravel and identify the broad range of impacts of a variety of specific processes and technologies, of individual energy delivery pathways, and of total energy supply packages.

It is this set of strongly interconnected impacts to which the Energy Analysis Program directs its attention, aided by a diverse set of diagnostic techniques, computer models and massive banks of data. In general, energy analyses address a range of impact areas including regional and local economics impacts, water availability and quality questions, air quality, land use changes, siting of facilities, local and regional ecological impacts and human health impacts. Further, these areas are addressed from two perspectives, or levels of study. The first perspective includes assessments of regional and subregional impacts of alternate future energy supply systems and energy growth patterns. For these integrated regional assessments the Energy Analysis group addresses each impact area for the western region (California, Hawaii and Nevada) and addresses one impact area, socioeconomics, at a national scale.

The second perspective embraces the impacts of a specific energy technology, such as coal, geothermal energy or natural gas, and the economics, environmental and institutional constraints on their use. Alternatively, this type of study will address a particular energy end use sector (e.g., agriculture, or heavy industry) and will address the impacts of, and constraints on the use of alternate energy supplies to satisfy the demands of this sector.

The major integrated subprograms arise from national energy policy (contemplated or enacted) and from major energy technology R and D programs pursued by DOE. In conjunction with the other national laboratories, Lawrence Berkeley Laboratory (LBL) has participated in an assessment of the national energy plan. This study, conducted at a national level, produced an overview of the various costs and benefits created by the realization of the national energy plan. LBL's contribution to this study was an assessment of the direct and secondary impacts accruing to each sector of the economy as a result of the investment, direct employment and direct material demands of this plan. A subsequent study, the Regional Issue Identification and Assessment (RIIA), was undertaken to identify the key issues and actors associated with the use of a specified mix of energy supply technologies to supply future energy needs. While LBL conducted an assessment of the national level economic impact of this mix, the primary focus of the RIIA program was at the regional and subregional level. This multifaceted program involves the identification of major energy development issues and of the various regional perspectives on those issues, the quantification of the impacts of the energy supply plan which will influence the outcome of each issue, and the identification of mitigation strategies for major impact areas.

Supporting these detailed environmental, socio-economic and human health assessments, LBL has undertaken the preparation of a detailed regional and state energy and environmental data book. This effort represents a coordinated national program involving the national laboratories to develop consistent, comparable data bases for all regions.

Complementing these continual scenario related programs are studies which address the energy issues and impacts of a single sector of human economic activity, or which address the impacts of a particular energy technology. Energy and water use in agriculture are very closely connected. The 1976-1977 drought forced both substantial water conservation by California's agriculture and an increased shift to the use of ground water for irrigation. The resulting impacts on energy use were complex. Some water conservation measures require increases in energy use; however, some water conservation measures also conserve energy. An increased use of ground water, and a general lowering of the ground water table result in more energy being used for water pumping. LBL initiated a detailed study of the use of water and energy in agriculture and of the relationship between these two vital resources.

A number of energy technology and energy fuel specific studies have been conducted. Changing national and regional priorities for the use of natural gas raised the need for a detailed analysis of California trends in the use of this fuel. The impact and success of federal and state initiatives will depend upon these current trends and the probable effect of selected future actions on the use pattern. The study to address these questions

was undertaken jointly by LBL and Lawrence Livermore Laboratory.

An extensive assessment of decentralized solar technologies has been conducted by several of the national laboratories. LBL characterized and evaluated four renewable resource energy technologies which have been included in the solar program: municipal solid waste, cogeneration, marine biomass system and total solar systems. Additionally LBL is conducting a series of community level assessments through outside contracts. These studies are designed to identify and evaluate impacts which will accrue uniquely at the community or subcommunity level from the deployment of decentralized solar technologies. Still another study has addressed investment potential and alternatives for on-site solar technologies.

Finally, a series of conservation studies has been undertaken. These studies have evaluated the potential energy savings of alternate conservation measures, the capabilities of several conservation oriented energy supply technologies, and the motivations and decision making processes associated with energy conservation. The findings of all of these assessments are intended primarily to aid DOE and other agencies' decision makers in formulating policy and energy technology R&D programs.

Regional Studies Program

Direct and Indirect Economic Impacts of a National Energy Plan Scenario*

J. Sathaye and H. Ruderman

INTRODUCTION

This study assessed the direct and indirect economic impacts associated with future energy supplies as characterized by a scenario based on the National Energy Plan (NEP). Direct impacts refer to the capital costs and manpower skills required to construct and operate energy and energy related transportation facilities to the year 2000. Indirect impacts refer to the secondary employment and value added (income) stimulated by construction of new energy facilities.

Historically, capital and manpower requirements have been increasing rapidly in most sectors of the energy industry, especially since 1971. Capital expenditures in energy-producing industries more than doubled during the six-year period from 1971 to 1977, growing from $21 to $47 billion.[1] Employment in some selected energy industries such as coal mining, oil and gas extraction, and electric utilities also increased rapidly from 1970 to 1975.[2] As the domestic energy industry begins to develop new fuel supplies such as offshore oil or nuclear power, the capital costs may increase faster than their historical growth rate. On the other hand, a slowdown in the rate of growth due to conservation and other measures could slow the rate of increase in capital costs and manpower requirements.

To examine the future economic impacts of energy supply to the nation, it is essential to define the types and quantities of fuels that would be available to meet the anticipated demand. A scenario interpreting the energy supply and demand elements of the National Energy Plan was formulated by the Department of Energy (Fig. 1).

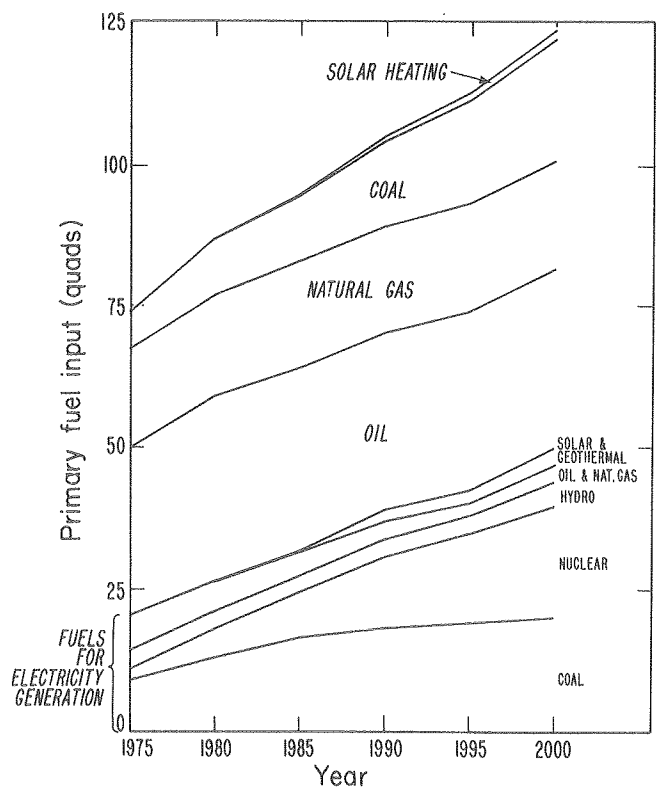

Fig. 1: Energy supply scenario (XBL 792-339).

A modified version of the Energy Supply Planning Model (ESPM)[3] was used to convert the NEP scenario into the number of facilities needed to supply energy up to the year 2000. (The model requires specification for nine

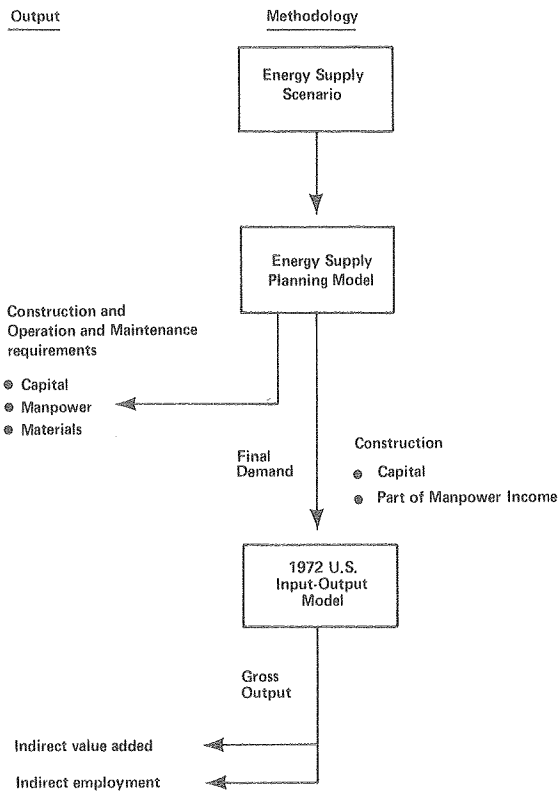

Fig. 2: Analytical methodology (XBL 792-336).

years beyond the last date for which results are computed). From construction and operation data for each type of facility, the model then estimates direct impacts for 150 categories of occupational skills and materials (Fig. 2).

Construction and operation data were based on 1974 equipment designs. Data on costs, working capital, and escalation and interest rates were expressed in constant 1977 dollars. Cumulative five-year effects were estimated, and annual effects were estimated based on the assumption of linear distribution in each five-year interval. Annual effects reported should therefore be interpreted with caution.

Indirect effects from 24 categories of construction manpower, materials, and equipment were calculated by disaggregating them in proportion to the appropriate final demand vector from a 368-sector national input-output table for 1972. Estimates of the output, value added, and employment generated in the 368 sectors by this increase in final demand were then converted to 1977 dollars (for output and value added) by use of GNP inflator of 1.40.[4]

FINDINGS

Capital

Annual investment in the energy industries increases from $50 billion in 1975 to $65 billion in 1985, then declines to $56 billion in 1990. This represents 32 percent in 1975 and 17 percent in 1990 of the projected overall national investment in equipment and private construction in all sectors.[5] Cumulative five-year energy investment increases from $262 billion during 1976-80 to $304 billion during 1986-90. Twenty-five percent of the investment in the first period and 22 percent in the second, will be for coal facilities. Investment in nuclear power plants will remain stable in the range of 20 to 22 percent of total energy investment through 1990, while investment in solar space heating increases four-fold, from 8 percent in 1975 to 30 percent in 1990 (active solar-heating units in new construction are assumed.) It appears that the aggregated capital requirements for energy development will not impose any additional burden on the availability of capital.

In addition to construction capital, energy facilities require substantial expenditures for operation and maintenance. These expenditures, excluding fuel cost, grow steadily from $74 billion in 1975 to $109 billion in 1990; coal facilities account for 5 percent in 1975 and 10 percent in 1990.

Manpower

Manpower requirements for energy industries follow the same temporal pattern exhibited by capital costs: the five-year cumulative requirements increase steadily through 1990. The portion engaged in coal-related activities declines from 23 percent in 1976-80 to 16 percent in 1986-90; annual requirements for coal-related manpower, 20 percent in 1976, peak at 25 percent in 1980, then decline to ten percent by 1990.

A surprisingly large fraction of energy-engaged manpower will be involved in construction of solar space heaters: from 15 percent in 1975 to 48 percent in 1990. In part, this projected increase results from the assumption implicit in the ESPM that all solar heating needs will be filled by active solar units in new construction. Both capital investment and manpower needs may therefore be somewhat overstated, since alternatives (such as passive solar heating) are less capital and labor intensive.

This large fraction of manpower for solar heating also affects the estimates of types of skills needed for energy construction in general. More civil engineers than mechanical or electrical engineers are projected to be required in 1980, but by 1985 mechanical engineers, who are more heavily involved in construction of solar units, rank ahead of all other engineering skills. Manual skills are affected even more strongly: between 1980 and 1985 the requirements for pipefitters, carpenters, teamsters, and laborers for energy-related construction increase 100 percent. Demand for carpenters engaged in constructing energy facilities, for example, increases from about 22,000 in 1980 to about 52,000 in 1985, an annual growth rate of 19 percent; in the same period the total demand for manual labor increases 8.2 percent per year. The maximum growth rate of such demand in the past has been about 7 percent. Despite this high growth rate, energy-engaged carpenters will represent only about 2 percent of all American carpenters in 1980, and 5 percent in 1985. The effect of this growth rate on carpenter

availability will depend on the demand for them from the rest of the economy.

The energy sector accounted for about 6 percent of national construction manpower in 1975, and will account for 9 percent in 1990. The coal sector will account for about 2 percent in 1985 and 1 percent in 1990. In contrast to this decline in coal-related construction, operation and maintenance manpower for coal facilities will increase from 25 percent of such manpower for all energy facilities in 1975 to 33 percent in 1990. Nuclear plants require a large part of the construction manpower, but only about 1 percent of operating manpower in any year.

Indirect Effects

Indirect or secondary effects of constructing energy facilities result from payment of wages to workers and payments to suppliers of materials and equipment. The recipients use these payments to purchase goods and services from all sectors, with resulting stimulation of employment and income (value added) in those sectors.

Indirect effects show the same trends as do the direct effects. For total energy facilities alone they peak between 1981 and 1985 and then decline. The indirect effect of all energy construction will produce income of about $32 billion per year and employment for about 1.4 million persons per year, roughly 1.5 percent of the 1977 GNP and employment respectively. Coal facilities will generate about 29 percent of these increases in the 1976-80 period and about 22 percent in the 1986-90 period.

Expenditures on materials and equipment will produce secondary effects mainly in the primary metals, metal products, and machinery sectors, plus a substantial effect on professional and business services. Labor expenditures will affect mainly the commercial sectors. One of the largest impacts will be on the primary metals industry, in which employment for about 90,000 persons will be generated during 1986-90, about 7.5 percent of total 1990 employment in that industry.

Table 1 summarizes the 5-year cumulative investment in construction of energy facilities and the resulting direct and indirect employment. The ratio of indirect to direct employment decreases over the 15-year period, primarily because of the increase in labor-intensive solar heating construction. Direct employment is due to primary labor expenditures alone, while indirect employment is due to expenditures for both labor and materials.

The secondary effects shown may be somewhat overestimated, because they are marginal effects, which increase more slowly than their average

Table 1. Employment impacts

	1976-80	1981-85	1986-90
Capital Investment (10^9 $)			
Manpower	52	63	76
Materials	30	37	46
Equipment	43	44	42
Other	137	145	140
Total	262	289	304
Employment (thousand man-years)			
Direct Construction	1,751	2,077	2,488
Direct Operation	6,511	7,568	8,977
Indirect[a]	6,208	7,089	7,910
Total	14,470	16,734	19,376
Indirect Employment per 10^6 $ of Total Capital Investment			
In Materials and Equipment	41.6	41.7	41.6
In Manpower	47.8	47.8	47.8
Employment per 10^6 $ of Total Capital Investment			
Direct	6.7	7.2	8.2
Indirect	23.7	24.5	26.0
Indirect/Direct	3.54	3.40	3.17

[a]Indirect employment includes the portion of direct operating required to satisfy the incremental construction requirements. It is not strictly correct to add the direct and indirect figures.

primary values. Construction workers, for example, have above-average incomes and thus (probably) a lower marginal tendency to consume. In addition, the employment coefficients have not been corrected for the trend toward increases of a few percent per year in labor productivity. For these reasons the estimated indirect effects may be 10 to 30 percent too high in 1990.

It should be noted that these results do not necessarily represent net increases in employment and income for the economy as a whole. They would represent net increases if there would otherwise be unemployment in the skill categories required, but in a situation of full employment they would indicate rather the extent of competition by the energy sector for workers.

CONCLUSIONS

In conclusion it should be noted that over the fifteen years, the energy supply scenario calls for a definite shift towards increased expenditure on labor and materials as opposed to equipment, leading to an increase in direct labor intensiveness. Among the manpower skills, requirements for carpenters, pipefitters, teamsters and laborers increase at twice their historical rate of growth after 1980. Whether this will result in a shortage of such skilled manpower will depend on their demand in the rest of the economy.

Indirect impacts amount to roughly three times the direct impacts. Again the overall impacts are small, although as much as ten percent of the employment in sectors such as metal products would be devoted to producing goods for energy facility construction.

In comparing the direct and indirect employment impacts, it should be noted that a dollar spent on personal consumption leads to 15 percent more employment than would a dollar spent on materials and equipment. Consequently construction of energy facilities that are more labor-intensive would lead to more indirect employment.

The study has not identified any absolute economic constraints on implementing the NEP over the period 1975 to 1990. Partly this is because the capital and manpower requirements called for by the NEP represent a small fraction of the total demand placed on these resources by the rest of the economy. If the economy in some future year is at full employment, then these manpower requirements may not be met, or they might be met by transferring workers from other sectors. On the other hand, if the economy were at a high level of unemployment, such energy development could provide employment to significant numbers of skilled workers. Furthermore, there has been considerable occupational mobility in the past so that a shortage in a given skill category can be remedied in the few months or years needed for retraining. Generally speaking, capital investment in a project is based on the expected return and the perceived risk. If the energy facilities called for by the NEP have returns commensurate with the risks involved, there should be minimal difficulty raising the necessary capital.

FOOTNOTE AND REFERENCES

*Condensed from Lawrence Berkeley Laboratory Report, LBL-8454.

1. U.S. Dept. of Energy, Energy Information Administration, "Annual Report to Congress, Vol. II, 1977," DOE/EIA-0036/2, April 1978, p. 50-51.

2. U.S. Dept. of Commerce, Bureau of the Census, "Statistical Abstract of the U.S. 1977," 98th Edition Sept. 77, Wash. DC, pp. 402-404.

3. Bechtel Corporation, San Francisco, California, The Energy Supply Planning Model, Volumes I and II, NSF-C867, August 1975.

4. U.S. Dept. of Commerce, "Survey of Current Business," February 1978, p. S-2.

5. "SEAS National Economic Report," memo from R.J. Kalagher, Mitre Corporation, to Roger Shull, DOE, January 23, 1978.

A Regional Energy — Environment Data Book*

H. Ruderman

The staff of the Energy Analysis Program has compiled and published a databook containing energy, environmental and institutional data for the states of California, Hawaii and Nevada. The purpose of the databook is to provide in a single publication information of use to people who make decisions about energy in the region. Its development was sponsored by the DOE Division of Regional Assessments as an element of their regional studies effort.

Similar databooks covering the rest of the country have been published by five other national laboratories. The laboratories have made an effort to keep the structure, content, and coverage of the databooks consistent by using nationwide sources of data where available. These data were supplemented by data from regional sources. Most of the detailed data are presented for 1975, the latest year for which they are published. The institutional and legal data are current to 1977. Because of space limitations, most tabular data are presented on the state or air or water basin level of detail. Whenever possible maps were used to show more geographic detail.

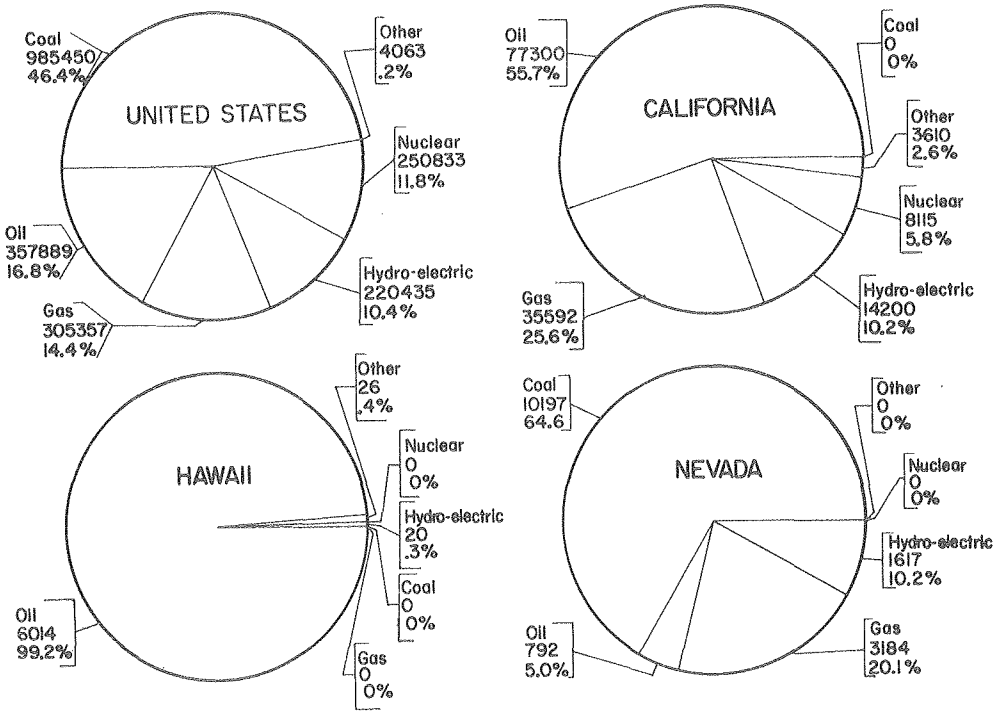

Fig. 1: Production of electricity by source, 1977. Source: U.S. Department of Energy, Inventory of Power Plants in the United States, DOE/RA-0001, December 1977. (XBL 791-7892)

The databook is organized into four chapters. The first presents data on the energy conditions in the region, the second presents data on the environmental conditions in the region, and the third presents information on the institutional conditions in the region. A fourth chapter provides the references, appendices, an index, a glossary, and energy and metric conversion factors. An overview to each chapter provides a regional perspective on the energy, environmental, or institutional situation. The overviews are followed by a discussion of the quality and availability of data for the region. A summary matrix at the end of each chapter attempts to indicate the additional data available but not used in the databook. A typical page from the databook is shown in Fig. 1.

The publication of the databook is part of the Regional Characterization Program in the Office of Technology Impacts under the Assistant Secretary for Environment in the Department of Energy (DOE). Work was started on the databook in March, 1978, a draft was sent to DOE for review in July, and the final version was published in October as LBL-7821. During FY-79 a set of Regional Characterization Reports will be prepared which will include the results of statistical analyses of the regional data as well as more recent energy and environmental data.

FOOTNOTE

*Condensed from Lawrence Berkeley Laboratory Report, LBL-7821.

Regional Issues Identification and Assessment

J. Sathaye, R. Sextro, R. Ritschard, K. Haven, H. Ruderman, S. Smith, M. Henriquez, J. Kooser, Y. Ladson, M. Messenger, M. El-Gassier, K. Tsao, T. Usibelli, and P. Chan

INTRODUCTION

Significant changes in the pattern of the nation's production and consumption of energy are likely to occur during the remainder of this century. The resulting impacts to the environment and the implication for social concerns such as public health and safety, employment or economic growth, vary in effect and importance from region to region and from site to site within regions. The Division of Regional Assessments within the Office of the Assistant Secretary for Environment is responsible for assessing the environmental, health and safety, social, economic and institutional issues and impacts which may occur as a result of Department of Energy (DOE) RD&D efforts and activities associated with the

development and deployment of various energy technologies.

The Department of Energy has developed a set of six national energy scenarios. These future scenarios provide detailed data on the anticipated demand and supply of various forms of energy for each region of the country. The Regional Issues Identification and Assessment (RIIA) project will identify and quantify the potential environmental, social, economic and institutional conflicts which may evolve if the various future energy scenarios developed by DOE were to be implemented. The six national laboratories participating in the project will analyze the scenario impacts for their geographic region of interest. The region studied by LBL includes the states of California, Nevada and Hawaii.

The scenario provided by DOE was regionalized to provide the detailed energy demand information by individual sector for each economic area in the country. The coal mines, refineries and other energy supply facilities were sited by economic area, whereas the power plants were sited by county. The siting of energy facilities was conducted at Oak Ridge National Laboratory based on regional information from the other five laboratories.

ACCOMPLISHMENTS DURING 1978

The first scenario provided by DOE specifies detailed energy demand and supply information for 1985 and 1990. By 1990 the scenario calls for 108 quadrillion (Q) Btu's of national energy consumption, a growth rate equivalent to 2.9 percent/year from the 1975 figure of 71 quadrillion. The largest growth forecast is for the nuclear sector at 12 percent per year, whereas coal supply is forecast to increase at 4.5 percent per year.

A summary of the growth rates within the western region for individual energy sources for this particular scenario, titled the Series C scenario, is shown on Table 1. Table 2 summarizes annual primary energy use within each state for each five year period through 1990. In addition to summaries of primary energy use, the scenario details electrical energy generation by state and county and by the type of fuel used to generate the electricity. Table 3 shows this electrical energy summary for the state of California.

The projections shown in Tables 1 to 3 do not represent a prediction of the future. Rather, they represent what would occur if a specific set of actions, policies and decisions were enacted and if there were no external "surprises" over the life span of the scenario. Thus the analysis of a scenario determines the potential impacts of a set of plausible policy options, and not the impacts of a particular set of development actions (as would be done by an Environmental Impact Statement).

Using the scenario as a starting point, LBL is approaching the regional assessment in a multi-step analytical process. These steps are:

1. Identify regional issues.

2. Make a quantitative estimate of the direct environmental impact of the scenario in each area of environmental quality.

3. Analyze impacts with respect to identified issues and define conflicts arising from implementation of the Scenario.

Analysis of the issues has begun with a detailed assessment of the physical implications of the scenario. New energy related activity

Table 1. Growth rates for selected energy types annual change in percent 1975 to 1990

	California	Nevada	Hawaii
Gasoline	1.6	3.2	1.8
Residual Fuel	-1.2	-4.3	-2.0
Distillate	2.6	4.8	4.4
Jet Fuel	1.0	1.5	0.8
Total Oil	1.2	2.7	0.6
Natural Gas	∿ 0	3.6	8.0*
Coal	3.2	1.0	7.3*
Nuclear	11.2	-	-
Geothermal	7.8	-	-
Total Primary Energy	1.2	2.4	1.6
Electricity Sales	1.6	4.5	-1.1
Population Growth	1.4	3.2	2.0

*1980 to 1990

Table 2. Regional primary energy use summary (10 12 BTU)

California	1975	1980	1985	1990
Gasoline	1276.9	1385.1	1493.3	1625.1
Residual Fuel	714.1	681.1	648.1	595.2
Distillate	263.9	395.3	346.8	392.7
Jet Fuel	324.7	351.6	378.5	379.9
Other Oil	53.3	97.5	141.8	167.3
Natural Gas	1928.8	1848.3	1767.9	1919.2
Coal	54.3	66.5	78.6	88.2
Hydro	407.0	429.3	451.7	457.6
Nuclear	61.0	175.7	290.4	329.3
Geothermal Solar	61.0	111.1	161.2	196.7
TOTAL	5145.1	5451.7	5758.3	6151.1
Nevada				
Gasoline	51.4	61.0	70.6	82.8
Residual Fuel	9.1	6.6	4.1	4.8
Distillate	14.9	20.3	25.6	30.7
Jet Fuel	27.6	29.3	31.0	34.4
Other Oil	2.0	3.3	4.5	6.0
Natural Gas	63.4	80.6	97.7	108.7
Coal	100.4	106.7	113.0	115.8
Hydro	.2	.2	.2	.2
TOTAL	269.2	308.0	346.8	383.3
Hawaii				
Gasoline	35.9	39.1	42.2	46.7
Residual Fuel	67.4	59.3	51.1	50.1
Distillate	15.4	21.3	27.3	29.6
Jet Fuel	78.5	84.3	90.0	88.2
Other Oil	3.5	4.0	4.4	5.2
Natural Gas	0.0	15.9	31.7	32.9
Coal	0.0	.9	1.7	2.0
TOTAL	200.8	224.7	248.6	254.8
REGIONAL TOTAL	5615.1	5677.2	6353.7	6789.2

has been sited to county and water-body level. Ambient (1975-1977) environmental quality has been mapped and areas where new or expanded energy activity could pose a significant environmental concern have been noted. This portion of the analysis has been divided into eight topical areas, each of which is being analyzed separately. These areas are: local and regional air quality, water resource availability (water quantity), water quality, regional and local socioeconomic impacts, land use and solid waste, ecological impacts, institutional impacts, and public health implications. For each of these specific regional impact areas the direct physical implications of the scenario (e.g., acres of land required for various activities, acre feet of water consumed, tons of air emissions, etc.) have been calculated.

In addition to its regional responsibility, each laboratory has been designated to estimate one or more types of impacts nationwide. For example, LBL, as the lead laboratory in analyzing economic impacts, is estimating the impacts on capital investment, employment and secondary income for the scenario. Similarly, Argonne National Laboratory is conducting the air and water quality analysis. These lead laboratory analyses are being made available to each national laboratory for use in its regional impact assessment.

PLANNED ACTIVITIES FOR 1979

The lead laboratory analyses completed this year for each topical area will be evaluated in detail for the region of interest to LBL.

Based on this evaluation, alternate mitigation strategies will be identified. These strategies will be incorporated in future energy demand forecasts and supply plans formulated at DOE.

Table 3. Electricity generation 1975, 1977 and Series C projections for 1985 and 1990 for California

Technology	Technology	1975 Capacity MW	1975 Generation Gwh	1977 Capacity MW	1977 Generation Gwh	1985 Capacity MW	1985 Generation Gwh	1990 Capacity MW	1990 Generation Gwh	Capacity Change, MW 1977-1990
1	Gas Turbine	1349	a	1555[b]	a	2246	1055	2245	1056	+ 690
2	Oil Turbine									
3	Nuclear	1368	6100	1311[f]	8100	5781	29037	5781	32932	+ 4470[f]
4	Combined Cycle	0	0	544	a	1408	6252	1408	9771	+ 864[g]
5	Coal Steam	0	0	0	0	0	0	0	0	0
6	Gas Steam	285	27300	497	35600	2578	13249	3614	14708	+ 3117
7	Oil Steam	21662	48300	22280	77300	18961	48716	18587	42805	- 3693
8	Hydroelectric	8950	40700	8950[c]	14200	9862	45173	9862	45761	+ 912
9	Solar	0	0	0	0	20	69	210	749	+ 210
10	Geothermal	544	6100	675[d]	3600	2300	16120	2700	18919	+ 2025
11	Pumped Storage	200	0	970[c]	0	3095	2361	3655	2782	+ 2685
12	Other	0	0	0	0	0	0	0	0	0
	TOTALS	34358	128500	36782	138800	46251	162032	48062	169483	+11280

a. fuel included in oil and gas steam

b. includes 162 MW Oakland on line and 45 MW Contra Costa on line 1978.

c. generation capacity - dry year capacity 1,500 MW less in 1977.

d. includes geothermal #12 of 119 on line in 1978.

e. includes 5 units at Castaic.

f. Diablo Canyon 2,270 MW completed 1979 and 2,200 MW at San Onofre complete in 1981-83.

g. Coolwater 472 MW in San Bernardino on line in 1978 and Grayson in Pasadena 121 MW in 1979.

Ecological Impacts of Future Energy Development in California, Nevada, and Hawaii*

J. Holdren,† P. Deibler,† and P. Gleick†

INTRODUCTION

Within the structure of the DOE (OTI/DRA) Regional Issue Identification and Assessment program (RIIA),[1] Lawrence Berkeley Laboratory has established a separate group within the Energy Resources Group (ERG) at UC Berkeley to conduct the ecological effects investigation. The efforts of this group have been directed toward identifying and assessing the ecological implications of the increases in electricity generating capacity within California, Hawaii, and Nevada projected by the Department of Energy's MID-MID scenario (the scenario being used for all RIIA assessments).

Because time constraints limit the depth of this assessment, this study will identify only the most critical issues. That is, those most likely to involve ecological impacts severe enough to call into question the viability of the scenario of they are neither avoided nor mitigated. For each such issue, an attempt will be made to characterize the state of relevant data and analysis--what factors are relevant, whether these have been studied systematically, where the information exists (if it does), and what further research is needed to produce necessary information that does not yet exist. In addition, relevant institutional factors that affect or are affected by the ecological impacts will be discussed.

The results from the Ecological Group will be incorporated into a final RIIA report to the Department of Energy, along with the contributions of the working groups on land use, water quality and availability, air quality, health, solid waste, and western long-range transport of sulfur oxides. Our final report will include a completed matrix for qualitative ecological impacts. The matrix format which was developed by the Department of Energy is intended to permit a rapid 'snapshot' overview of each topical assessment.

ACCOMPLISHMENTS DURING 1978

Our approach to assessing the impacts is composed of three stages. The first stage is an examination of each energy technology represented in the scenario to identify problem areas of greatest potential ecological impact. The second stage consists of reviewing the literature concerning the critical problem areas that have been identified. The final stage is the relating of information on critical areas of impact to the specific fuel mixes that the scenario provides for California, Hawaii, and Nevada. In what follows, the term 'problem area' is used to refer generally to identified ecological issues of widely varying types. Care is taken to describe how these problem areas differ.

The crucial step in the above process is the first stage since at this point the decision is made as to which of the identified problem areas will receive concentrated attention. Accordingly, a brief explanation of this winnowing process is included here to aid in tracing the thoughts that connect the scenario to the chosen problem areas. Impact analysis facilitates a disaggregation of the overall ecological effects question into component parts without accidental omissions of pertinent considerations.

Impact analysis commences with a look at the energy supply options represented by the RIIA scenario and with a detailing of the stages of each supply option and of the phases of operation within each stage. This process was undertaken for all nine supply options (with pumped storage included under hydroelectric generation) represented by the scenario. For each of the supply options there are nine stages beginning with exploration and finishing with end use. For the purpose of this study we omitted the marketing and end use stages because our interest extends only through the conversion (electricity producing) stage. Each of the nine stages is composed of five phases beginning with research and development and ending with the management of long-lived wastes.

The next part of the impact analysis involves the use of a framework for tracing all the effects from the source (the particular supply option), and determining the costs imposed by the effects. The framework has been modified for our use to include only the portions pertaining directly to environmental and ecological effects. However, this modification does not exclude damage to those economic goods and services such as crops which are direct ingredients of human well-being.

This framework consists of a six step progression: source, impact, pathway, stress, response, and cost. Impacts include pre-emption or consumption of resources, material effluents, radiation, heat, noise, and direct physical damage or transformation. Pathways are the media through which the inputs reach the environment. The stresses can be characterized as the environmental effects of the inputs. The stresses are reduced resource availability, altered chemical concentrations, altered temperature, loss of habitat, etc. The responses are the ecological result of the environmental changes wrought by the stresses. Responses are economic goods and services lost or forgone, and damage to environmental goods and services such as agriculture and forestry. Finally, the cost criteria for evaluating ecological severity include magnitudes of inputs, stresses, and responses, temporal and spatial distributions of harm, scaling, resistance to remedy, irreversibility, and the quality of evidence of harm.

Utilizing the above framework, the Ecological Group has identified four problem areas for detailed study. The first two areas are hydroelectric and geothermal generating capacity. These two areas are specific sources of impacts whose ecological responses may potentially incur major costs in light of the large additions of such generating capacity in the scenario for California. Issues including seismic activity associated with hydroelectric facilities and wine grape damage from air emissions at the Geysers geothermal site cause geothermal hydroelectric power to be important areas for examination.

The third problem area is crop sensitivity to sulfur dioxide. Sulfur dioxide effects are damage-mechanisms and are an ecological response to impacts imposed by fossil fuel combustion and tapping of geothermal sources for electricity. This problem area is especially important because of the economic role of agriculture in the region under study. Our final problem area of major importance is endangered species. Endangered species are targets of ecological stresses imposed by the impacts created in a number of stages of each supply option. Loss of habitat, for instance, is a stress that is a component part of almost all energy activities and is one with possible irreversible consequences.

In addition, we are including in our study a grouping of problem areas under the label of "uncertainties." At this point two problem areas, acid rain and estuarine degradation are pinpointed for analysis. Acid rain is a response to environmental stresses created by fossil fuel combustion. Estuaries are ecosystems that have suffered from the effects of a variety of energy activities, ranging from decreased flow due to upstream hydroelectric plants to chronic oil pollution. Estuarine degradation and acid rain are both problems of increasing concern in this region.

Analysis of impacts is an objective process within the bounds of our knowledge of the ecological consequences of energy activities. The final stage of choosing problem areas may be subjective to some degree because of the difficulties inherent in comparing and assessing the costs, most of which are not quantifiable. This apples-and-oranges comparability problem is immensely important, but we do not attempt to grapple with it in our study. However, our final report will provide additional justification for our choice of ecological problem areas.

The Ecological Group's progress to date can be summarized with reference to the four questions posed in the second paragraph of this essay. The relevant factors for consideration in each problem area are synonymous with the end product of the impact analysis. In comparing ecological effects from the various stages of each supply option, one is comparing the relevant factors of the problem areas. Thus there is a smooth flow from the impact analysis to the detailed assessment of each problem area. For instance, a potential ecological effect of increased geothermal electricity production is subsidence impacting on irrigation in Imperial County. The generalized effect of subsidence is distilled from the impact analysis, while its specific character in Imperial County results from the relating of our general knowledge to the particular scenario. We have completed the connecting of general relevant factors to the scenario for the problem areas of hydroelectric, geothermal, endangered species, and crop sensitivity to sulfur dioxide. Work remains to be done on this stage for acid rain and estuarine degradation.

The problem areas of interest to us have been studied systematically to widely varying degrees. For instance, the ecological effects of the hydroelectric supply option have been extensively documented over a period of decades on an international basis. Work on geothermal effects, while considerable, is not as extensive. Literature on the other four problem areas is much scantier and has evolved more recently.

Our identification of sources of information for each problem area has progressed almost to completion for geothermal and hydroelectric ecological effects. The existence of information on endangered species and sulfur dioxide effects on crops has been assessed on a preliminary basis with an initial search through the literature. This phase of work has not yet begun for the problem areas of estuarine degradation and acid rain.

Finally, our group has tentatively identified research needed to produce necessary information on hydroelectric effects. One area of needed research, for instance, is the ability of different animal species to adapt to a loss of habitat resulting from the filling of a reservoir in a river canyon. Far too little is known about species displacement due to habitat losses caused by energy activities in general. This final phase of identifying areas for research has not yet begun for the other five problem areas being considered.

FOOTNOTE AND REFERENCES

†UC Berkeley, Energy Resource Group

1. See previous paper ("Regional Issue Identification and Assessment") for more detail on the RIIA program.

2. A more thorough presentation of impact analysis can be found in John P. Holdren, "Environmental impacts of alternative energy technologies for California," in P. Craig, M. Christensen, M. Levine, O. Mukamel, and M. Simmons, Eds., "Distributive Energy Systems in California's Future," LBL-6831-revised, vol. II (Lawrence Berkeley Laboratory of the University of California, Berkeley, March, 1978).

Recent Trends in California Natural Gas Consumption

R. Sextro, I. Borg,† C. Anderson,† and B. Rubin†

INTRODUCTION

Since 1973, total natural gas consumption in California has declined with annual decrements as high at 10 percent. The biggest changes in gas use have been by industrial customers and for electrical generation. In addition there have also been significant changes in residential and commercial use on a per customer basis.

This study has attempted to detail the recent gas consumption trends by end-use sector and to examine possible explanations for the declining consumption. It has proceeded in two phases. The first produced an overview of trends during 1975, 1976 and 1977, and presented several factors thought to influence gas consumption. The second phase extended the data collection to 1973 and 1974, and tracked more recent monthly gas consumption through part of 1978. Additional issues were explored, including the effect of recent changes in gas rate structures. The major factors thought to have influenced changes in gas consumption in California are discussed in the article "Analysis of Recent Changes in California Natural Gas Demand" in this same volume.

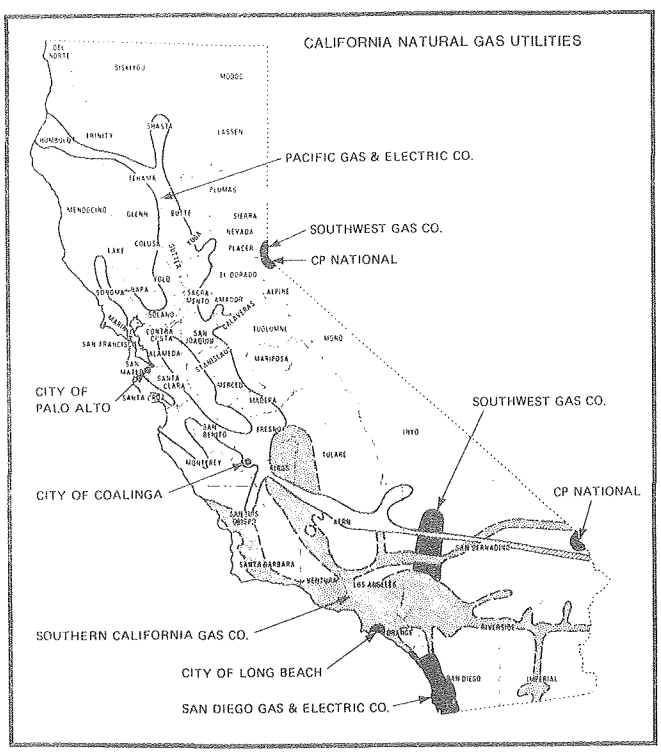

Fig. 1. Gas utility service areas in California. (XBL 789-2284)

NATURAL GAS SALES AND DISTRIBUTION

Three major gas utilities service most of California, as indicated in Fig. 1. About 93 percent of the gas used in California is regulated by the Public Utilities Commission (PUC); 4 percent is used in the production of oil and gas in the state, and 3 percent is sold directly by California producers to industrial customers. With gas production from California fields declining, all but about 10 percent of the gas supplied to the three major utilities has been from out-of-state sources (see Table 1).

While both California and U.S. gas consumption has dropped in recent years, the end-use patterns

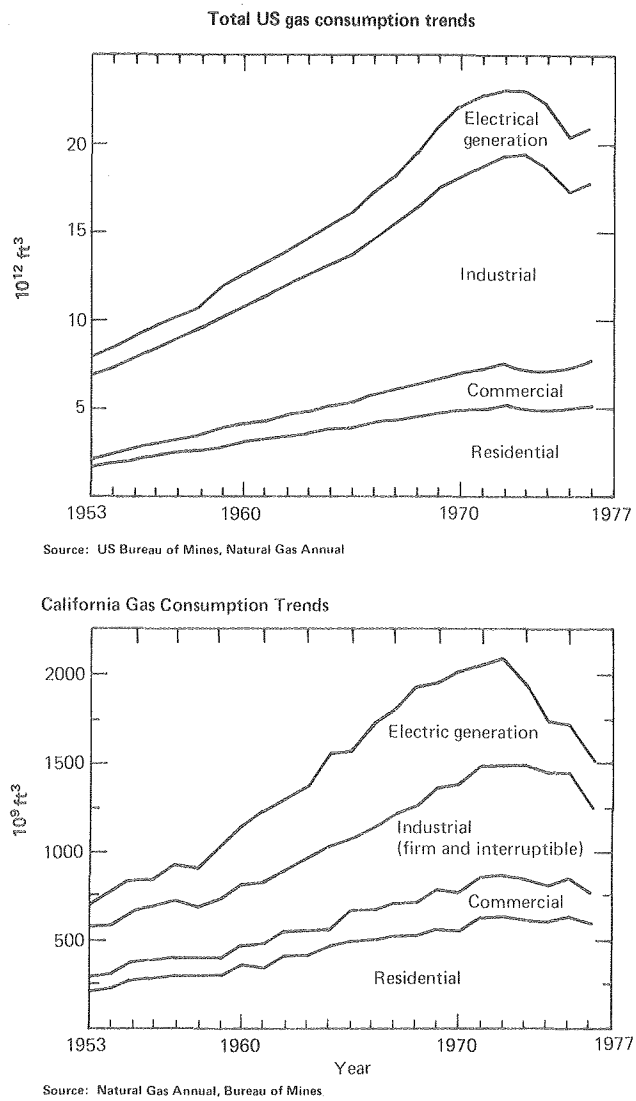

Fig. 2. Comparison of natural gas consumption trends. (XBL 792-455)

Table 1. Source of natural gas purchased by California utilities (109 ft 3).

	1972	1973	1974	1975	1976	1977
SoCal						
California Source[a]	74	53	38	22	24	22
Out of State						
El Paso Natural Gas Co.	636	610	597	586	567	553
Transwestern Pipeline Co.	271	274	240	213	190	187
Pacific Interstate Transm. Co.	-	-	-	-	1	10
PG&E	42	2	-	-	-	-
PG&E						
California Source[a]	238	233	147	139	141	131
Out of State						
El Paso Natural Gas Co.	409	378	384	357	320	296
Pacific Gas Transm. Co. (Canada)	368	374	346	365	376	373
SDG&E						
Other Utilities (Southern California Gas Company)	94	86	80	71	62	61

[a]State and federal.

differ, as indicated in Fig. 2. Nationwide, industrial gas use predominates, while in California residential gas consumption is the largest single end-use. Proportionately more gas was used for electrical generation in California than nationwide until 1973, when electric utilities in the state began using greater quantities of fuel oil. Table 2 summarizes recent oil and gas usage by electrical utilities. Gas sales trends for industrial customers formerly classed as firm and interruptible are shown in Fig. 3. In 1976, a new classification system for gas service based upon end-use priorities was instituted replacing the old price-volume interruptible and firm gas contracts for industrial users. The utilities have maintained the accounting distinction through 1977, enabling comparisons to be made with gas sales prior to 1976. As seen in Fig. 3, firm gas sales have remained nearly constant over the 5 year period (note log scale), while total interruptible sales for PG&E have declined by as much as 10 percent over the 5 year period.

The trends for residential and commercial gas consumption are shown on a per customer basis in Fig. 4. There are similar patterns among the three utilities for both these end use categories. During this same 5 year period, the number of customers increased an average of about 10 percent for these end uses in each service area. There is a net overall decrease in gas consumption by these end uses.

The data for residential and commercial end-use categories are corrected for extremes in weather, by monthly comparison to average heating-degree days for a given month. This is done in order to facilitate a more meaningful comparison of the different years. Residential

Table 2. Fuel oil and natural gas used by electric utilities in California.

	1975		1976		1977 (Preliminary)	
	Gas, 10^9 ft^3	Oil, 10^6 bbl	Gas, 10^9 ft^3	Oil, 10^6 bbl	Gas, 10^9 ft^3	Oil, 10^6 bbl
Pacific Gas & Electric (PG&E)	157	11.4	197	26.9	217.4	35.2
Southern California Edison (SCE)	71	41.3	63	45.0	91.1	57.8
Los Angeles Department of Water & Power (LADWP)	20	13.0	12	12	20.7	16.6
San Diego Gas & Electric (SDG&E)	14	9.4	12	10.8	15.9	12.6
Total	262	75.1	284	94.7	345.1	122.2

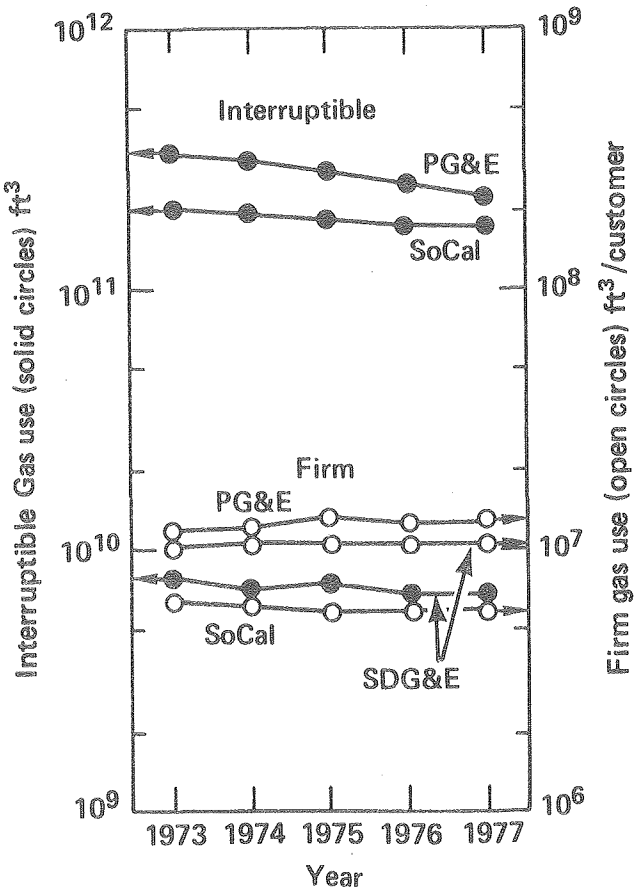

Fig. 3. Recent trends in industrial gas consumption (not temperature adjusted). (XBL 792-450)

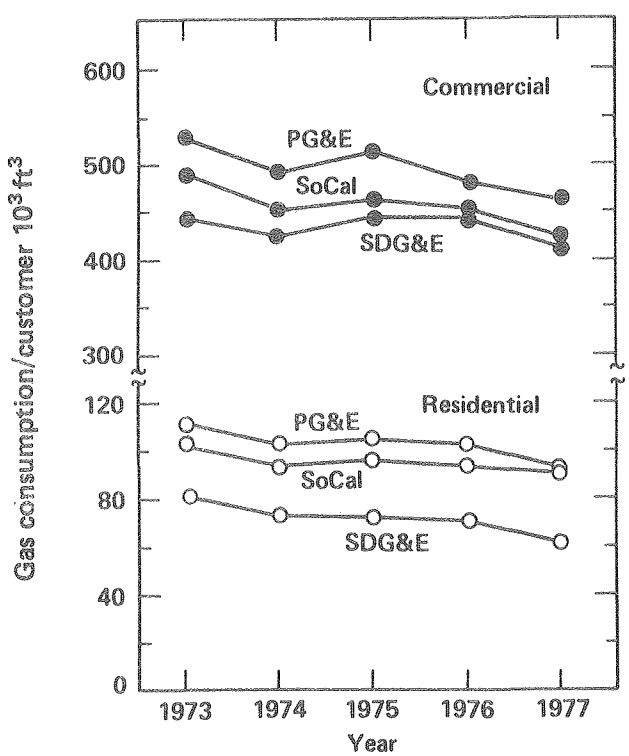

Fig. 4. Recent trends in residential and commercial gas use (temperature adjusted). (XBL 792-451)

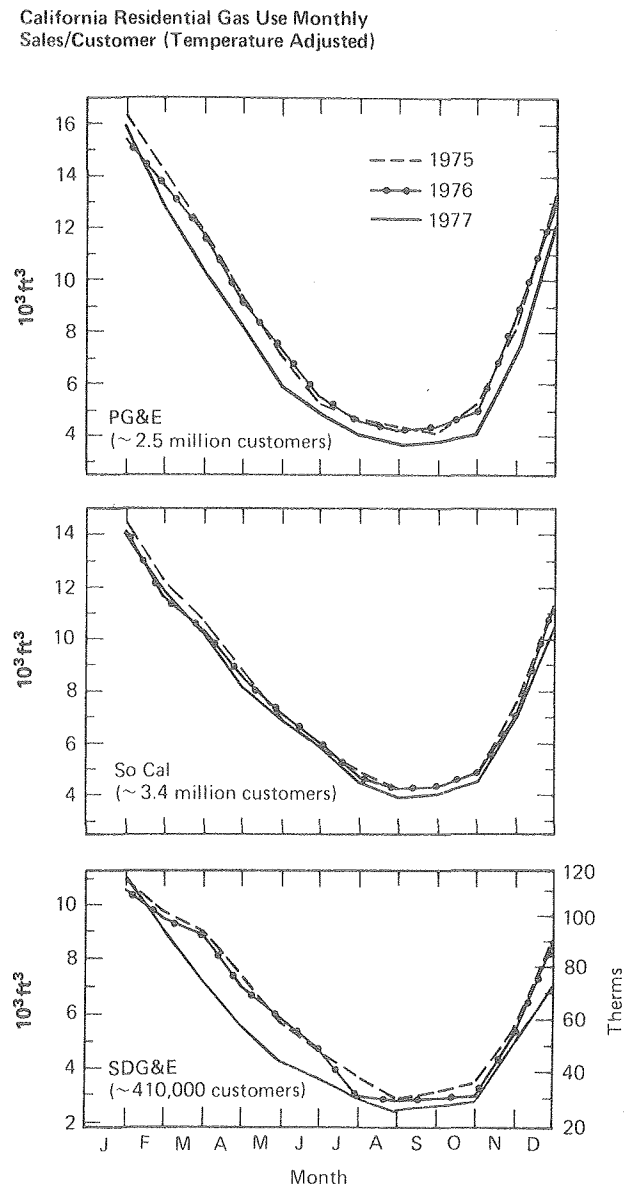

Fig. 5. Comparison of average monthly gas sales. (XBL 792-452)

gas use is predominated by space heating, and will therefore be sensitive to weather conditions. However, the heating-degree day concept relies upon the daily mean temperature, and does not take into account different meteorological conditions such as solar insolation or rapid changes in weather patterns that might also influence actual gas use.

It is useful to compare annual gas consumption data on a monthly basis. Figure 5 shows monthly residential gas consumption for three years (1975-1977) in each utility service area. The 1977 monthly consumption (temperature-corrected) is lower than 1975 or 1976 in almost all cases, with as much as a 20 percent decrease for both PG&E and SDG&E in the late spring and early summer of 1977 over the comparable months in 1976.

DISCUSSION

While a more detailed discussion of possible explanations for the general declining trend in gas consumption is offered in the companion report, several features of the data are discussed here.

The second sequential year of drought began in 1977, and with it came an awareness that water conservation was an essential element of public policy. This had a direct impact on gas consumption in that reduced hot water usage resulted in a decrease in residential gas consumption. This effect would be most pronounced in the summer months when water heating becomes a significant factor in residential gas use as space heating demand declines. Our estimate is that at most a 3 percent effect on annual gas consumption can be attributed to reduced water use.

Other factors relating to the drought include a general increase in the awareness of conservation, which in turn affects other uses of energy. At the same time, fuel shortages in parts of the east coast and midwest during the winter of 1977 heightened public awareness. In order to make available to eastern users some gas destined for California, the California Public Utilities Commission moved to restrict some non-essential uses of gas, such as heating of swimming pools and decorative lighting, and called for the lowering of household thermostats. We estimate that this latter factor could result in an overall savings of about 16 percent in per residential customer use for a 3°F change in thermostat setting.

Thus it appears that behavioral changes might account for some of the savings in gas consumption noted in the residential and commercial sectors. Added stimulus for these changes might have resulted from the general conservation awareness fostered in part by the conservation campaigns of the utilities, public officials and regulatory agencies.

FOOTNOTES

*Condensed from Lawrence Livermore Laboratory Report UCRL-52498.

†Lawrence Livermore Laboratory.

Analysis of Recent Changes in California Natural Gas Demand*

R. Sextro, I.Y. Borg,† C. Anderson,† C. Briggs,† and D. Dorn†

INTRODUCTION

A number of possible factors is offered as an explanation for the recent observed decline in natural gas use in California. As noted in the earlier companion report, conservation campaigns initiated due to the California drought in 1976 and 1977 and to fuel shortages in other parts of the U.S. undoubtedly played a role in the recent decline of gas use. Other events have also had an effect, such as changes in building codes, rate structure alterations, increasing prices, and industrial fuel switching.

It should be noted that these are presented as plausible explanatory factors, without attempting to designate which, if any, is the most important. A number of changes have occurred simultaneously. It is not likely that any single set of cause-and-effect relations could be extracted from such complex circumstances.

CONTRIBUTING FACTORS

Different end-use categories are affected to different degrees by the same factors. The price of gas as discussed below has probably impacted industrial uses to a greater extent than residential customers. On the other hand, residential and commercial users appear to have responded well to calls for voluntary conservation, especially in 1977. In the longer term, price increases will undoubtedly affect residential gas as well as induce greater conservation efforts in other end-use sectors.

Prices and Rate Structure Changes

Over the time period used in this analysis, the California economy has shown continued growth, hence reduced gas usage is not due to a decline in general economic activity. However, there has been a substantial change in gas rate structures, which has resulted in large price increases for non-residential gas users. Prior to 1975, rates for California gas utilities were in declining blocks, so that the larger users paid less per unit of gas than the smaller customers. In 1975, the California Public Utilities Commission (CPUC) began to flatten the rates. The Miller-Warren Energy Lifeline Act was enacted in 1975, and its provisions became effective in 1976. This act placed a ceiling on unit gas prices for gas consumption up to a certain volume by residential customers. These monthly volume limits are dependent upon the time of the year, and the differences in average climatic conditions, and are summarized in Table 1. This lifeline allowance has basically become the first gas block in an inverted rate structure for gas. The prevailing rate structure (as of September

Table 1. Residential lifeline gas allowance (therms/month).

Heating Degrees-Days*	Summer (May through Oct.) Single Family	Summer (May through Oct.) Multi-Family**	Winter (Nov. through April) Single Family	Winter (Nov. through April) Multi-Family**	Typical Services Areas
2500	26	21	81	54	Most of southern Calif.
2500 to 4500	26	21	106	69	Most of northern Calif.; southern Central Valley; San Luis Obispo
4500 to 7000	26	21	141	90	Eureka area; southern Calif. mountain resorts
7000	26	26	166	110	North Lake Tahoe

*65°F reference point.

**Master-meter.

1978) is shown in Fig. 1. Residential gas use falling within the lifeline allowance shows a declining unit price up to the lifeline limit, since the monthly customer charge is also included in these changes. Above the lifeline amount, unit prices rise (very steeply for PG&E and SDG&E), showing the effect of inverted rates. For commercial customers using up to 31,000 therms per month, the unit prices are higher than for residential use (and decline somewhat for higher volumes as the effect of customer charges are spread over a larger quantity of gas). Finally, industrial gas rates generally are higher than those for commercial gas use, with the exception of PG&E's G-50 and G-52 rate schedules.

The lifeline rates have, in effect, insulated a portion of the typical residential gas consumer's bill from rising gas prices. Until September 1978, no major changes in lifeline rates had occurred for any of the three gas utilities, while overall system prices had increased by 40%. However, depending upon the utility involved,

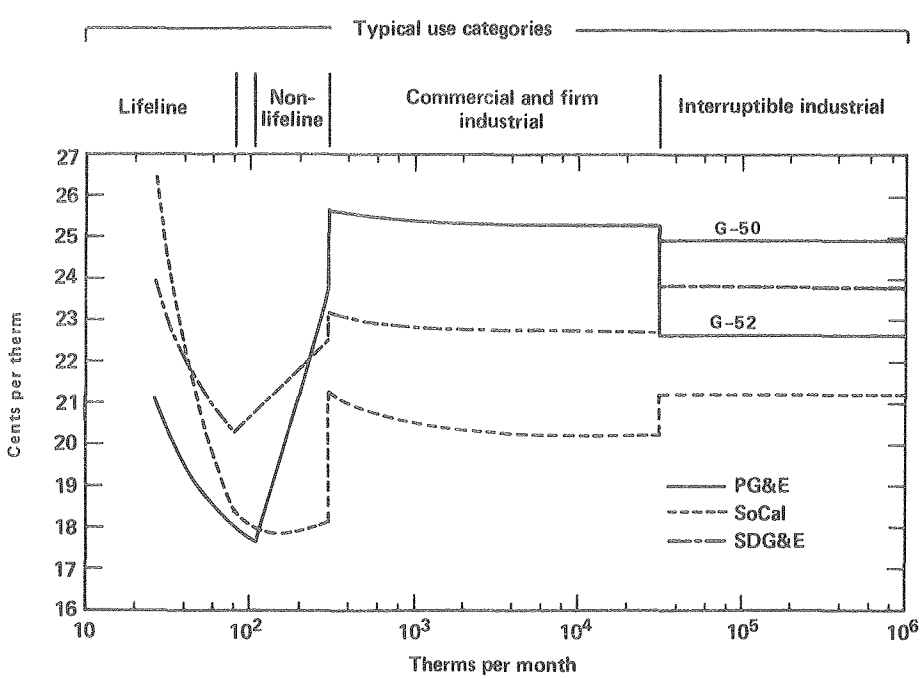

Fig. 1. Utility gas rates as of Sept. 11, 1978. Charges include customer service charge. (XBL 792-454)

few residential customers have monthly gas use less than the lifeline allowance, hence price increases for gas volumes above the lifeline amount will be reflected in customer bills. The wide variation among the utilities in the number of customers whose use is within the monthly lifeline allowance (2-4% for PG&E, 27-31% for SCG and 43-65% for SDG&E, with the range reflecting seasonal differences) indicates that the lifeline allowance is not adequately corrected for variations in average climatic conditions.

A second major problem in the implementation of the lifeline act is that few customers know of its existence, or how it has been applied. Neither the utilities nor the CPUC have embarked on major public awareness campaigns regarding lifeline rates. Most residential customers are not aware that unit gas prices rise significantly for volumes above the lifeline allowance, or that lowest unit prices are achieved by maintaining monthly use below the lifeline allowance. At this point, it appears that price increases have not been a major factor in residential gas use. Prices have played a more significant role in the industrial sector. Most industrial customers have had alternate fuel capability for several years, since the former interruptible service classification generally required back-up fuels. The new end-use priority system is generally based upon the availability and feasibility of stand-by fuels. As unit gas prices began to rise, and early fears of large curtailments in the industrial sector developed due to gas supply shortages, many industrial customers began to prepare for fuel switching. Some industrial customers, (e.g., cement plants) switched to coal, and away from gas entirely. Others acquired or rented larger oil storage capacities for back-up fuels.

Toward the end of 1977, the price of residual fuel oils began to fall as a result of developing West Coast surpluses. Figure 2 shows oil and gas prices for the past three years. Many industrial users with dual fuel capability were able to take advantage of the prevailing low oil prices this past summer. This, in part, was the impetus for the establishment of PG&E's G-52 rate schedule, which set gas prices more competitive with prevailing prices for No. 6 fuel oil.

Recent changes in entitlements and a temporary authorization to export excess residual oil to Japan will likely result in rising spot prices for oil. However it may take some time before the market stabilizes and gas and oil prices equilibrate.

Curtailments

Curtailments have not been a significant factor in the past few years for most industrial users. The electric utilities, with the lowest priority for gas service, have had the largest curtailments in recent years; however, this loss of gas service has been supplanted by the use of oil as fuel for electric generation. The recent trends are shown in Table 2. It is important to note that in California curtailments have meant switching to back-up or alternative fuels rather than involuntary cessation of industrial activity.

During the past year, with relatively mild weather and generally reduced gas consumption due to conservation and fuel switching, there have been no curtailments of industrial customers, and very little curtailment of gas service to electric utilities. In fact, gas use as fuel for electric generation this past year has reversed the declining trend of previous

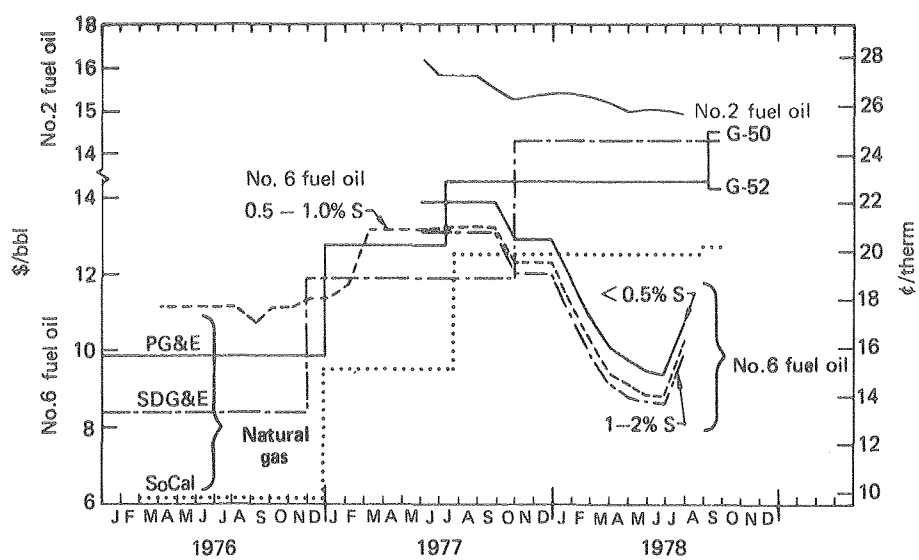

Fig. 2. Comparison of spot fuel oil prices and industrial gas prices (G-50, 52 rate schedules). (XBL 792-453)

Table 2. Gas deliveries and curtailments (10^9 ft^3).

Gas Utility	Year	Industrial Gas Use	Industrial Curtailment Volume	Industrial % of Use	Industrial % of Total Curtailment	Electric Utility Curtailment Volume	Total Curtailment Volume
PG&E	1975	315.4	10.3	3	14	65.6	75.9
	1976	283.7	6.2	2	3	240.8	247.0
	1977	253.0	3.2	1	1	305.8	309.0
SoCal	1975	232.8	37.3	16	12	267.2	304.5
	1976	222.2	36.8	17	11	294.0	330.7
	1977	219.9	10.4	5	2	454.7	465.1
SDG&E	1975	8.76	0.23	3	<1	59.9	60.1
	1976	8.01	0.35	4	1	65.2	65.6
	1977	7.93	0.53	7	1	76.3	76.8

years. While the present surpluses are due, in part, to variables such as weather and market prices that are subject to change, gas demand continues to be winter-peaked. Hence constant year-round gas deliveries from suppliers may lead to load management problems that will require greater in-state storage volumes, reduced interstate deliveries during the summer, or continued use of gas by low-priority consumers.

Factors in Residential Gas Consumption

The companion report describes recent trends in residential consumption of gas and offers some observations on possible explanations. Since comparisons are made using data corrected for changes in weather severity, the temperature correction methodology was investigated. It appears that the degree-day concept does not adequately correct for extreme weather conditions (either much milder or much more severe than the average). It also does not account for differences in weather conditions (cloudy, sunny, etc) which can affect gas consumption (solar gain, wind effects on conductive losses, etc.).

It does appear that real reductions in gas consumption per residential user have occurred, and that changes in building codes and insulation levels have had an effect. Figure 3 documents statewide changes in insulation levels in single-family and multifamily housing due to both new construction standards and retrofit of existing structures. Using these figures and assuming that 90% of the retrofit insulation activity is in single-family housing (consistent with historical activity), the overall effect from 1975 to 1977 represents about a three percent reduction in average gas consumption per residential user.

CONCLUSIONS

Price changes brought about, in part, by rate structure alterations in the last 2 to 3 years

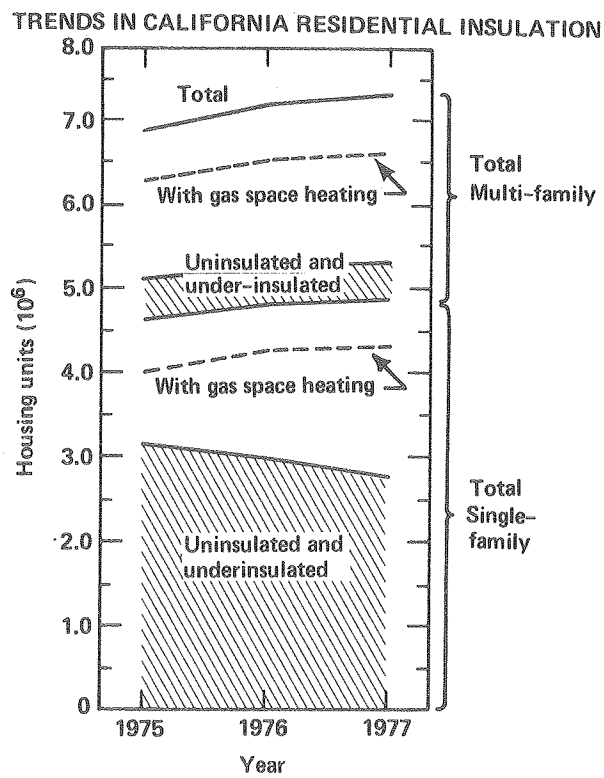

Fig. 3. Single family and multi-family housing stocks. (XBL 792-449)

have had an impact on the rate of gas consumption, and will undoubtedly play a similar role in the future. At the same time, external events such as the extended California drought, recent winter time natural gas shortages in the Eastern U. S., and a short-term West Coast oil surplus have each had an effect on consumption rates. The conservation consciousness which was spurred-on by the drought has probably resulted in many permanent hardware changes

and in voluntary changes in living patterns which may be less permanent, but which have significantly affected gas consumption in the last 2-3 years.

While reductions in natural gas consumption are consistent with national energy policy, several secondary effects will have to be dealt with. Among these are problems in correcting for variations in weather; methods to manage summertime gas surpluses and winter time peak demands; and rate structure designs that are consistent with alternative fuel prices.

FOOTNOTES

*Condensed from Lawrence Livermore Laboratory Report UCRL-52631.

†Lawrence Livermore Laboratory.

Energy & Water Use in Irrigated Agriculture During Drought Conditions*

R. L. Ritschard and K. Tsao

INTRODUCTION

Approximately 9 million acres harvested in California during 1977 were irrigated. Electrical energy is an essential input to this form of agriculture since over 90 percent of the irrigation pumping units in the state are electrical. A higher than normal demand from the agricultural sector for electric power can result from pumping ground water in areas where the surface water supply has fallen below normal as a result of drought conditions.

The authors undertook a study for the Department of Energy (DOE) to define the relationship between water and energy for irrigated agriculture. The objectives of the study were to:

(1) determine water and energy use for agricultural irrigation during the 1977 season,

(2) describe the response of agriculture to the drought conditions of 1977,

(3) identify the present and potential water and energy conservation strategies applicable to California.

The analysis of electricity and water requirements for irrigated agriculture was begun as part of a two-phase project conducted by Lawrence Berkeley Laboratory in cooperation with the San Francisco Operations Office of the DOE.[1] The purposes of that overall study were to assess the impacts of the drought on California electricity supply and demand, to evaluate remedial measures, and to develop a methodology for such assessments.

ENERGY DEMAND FOR IRRIGATION WATER

The methodology used to determine electricity requirements to pump irrigation water focused on the hydrologic basins of the Central Valley. The method employed several factors to calculate the final energy demand for pumping. The factors included: unit energy use to obtain ground and surface water, average water use by individual crop, type of irrigation, and estimated crop acreage planted in 1977. The total energy requirements for pumping in the Central Valley were estimated to be 5.91 billion Kwh, which was slightly higher than the total yearly electrical sales to agriculture reported by PG&E.

Growers used several energy and water use strategies in response to the drought conditions of 1976 and 1977. The strategies included an increased use of ground water, increased irrigation efficiencies, and shifts in cropping patterns. Drought-related losses to irrigated agriculture were minimized as a result of these modifications.

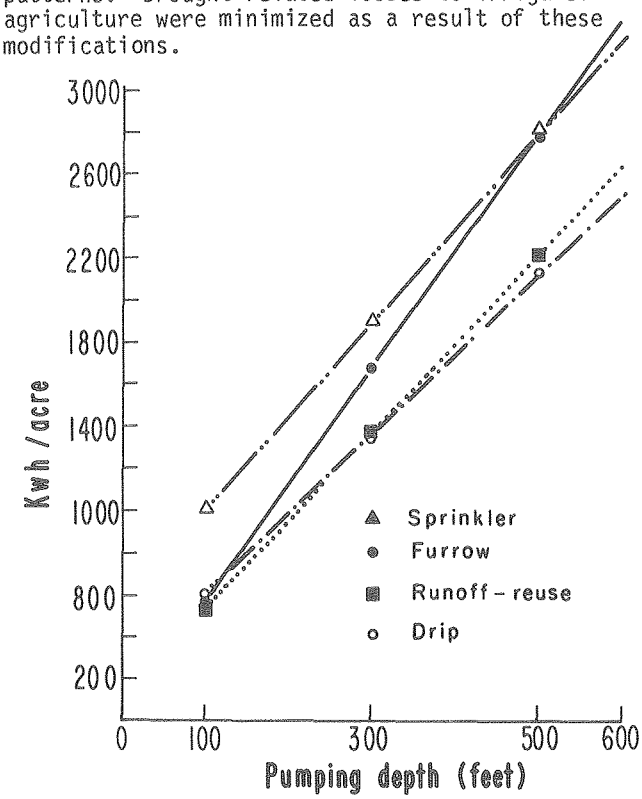

Fig. 1. Comparison of energy demands for different irrigation methods. (XBL 771-11032)

Table 1. Strategies of agricultural electricity conservation.

Strategy	Time of Implementation	Electricity Savings	Implementation Criteria
Maintaining and Augmenting Surface Water Supply:			
Phreatophytic control	now	Through water savings	Ecological alteration
Ditch and canal lining and covering	now or a few months	∿10% water savings	Loss of percolation
Use of reclaimed water	4-8 years	5-10% water saving energy cost in processing	Dependent on basin hydrology & topography
Power Use Efficiency:			
Well maintenance	now	some	Best for new wells, also reactivated wells
Well efficiency	4-7 years	2-10%	
Pump maintenance	now	15-35% probably 15%	Especially for pumps older than 5 years
Pump & motor efficiencies	5 years	2-5%	Big pumps are more efficient
Cogeneration on distribution canals	now	some	Need sufficient drop to generate electricity
Irrigation Efficiency:			
Cutback irrigation	now	Through water savings	Greatly improves water use efficiency of surface irrigation & leaching uniformity
Tailwater reuse	now	See Fig. 1	Benefit depends on basin hydrology, water costs & topography
Sprinkler systems	now	See Fig. 1	Benefit depends on well depth; can increase plant diseases; inefficient in desert areas
Drip	A few months	See Fig. 1	Not for use in extreme soil types; most profitable for high value crops
Gated pipe	months	Through water savings, very small energy cost	Prevents erosion on steep slopes; increases areal distribution from single water source
Irrigation management	now	25%	Limited trained personnel, tailored to site, increased yield offsets fee
Reduced application	now	Through 10% water savings	Allow program depletion of available soil moisture

Ground water pumping increased by over 20 percent during 1977 to compensate for surface deficiencies. There were an estimated 7500 new wells drilled and many dormant wells were reactivated. Use of ground water, however, caused increased pumping costs, a drop in water tables, and overdrafted ground water reservoirs. The overdraft in 1977 was estimated to be 10 million acre-feet as compared to just over 2 million acre-feet in 1975. About 80 percent of the overdraft occurred in the Central Valley.

Farmers increased irrigation efficiencies in several ways. "Cutback irrigation" which diminishes runoff and reduces soil percolation in furrow systems was practiced to a great extent in 1976 and 1977. There were changes in irrigation methods towards such systems as sprinklers and drip systems, both of which improved efficiency. Although a net decrease in water use may have occurred from the use of sprinkler and drip irrigation methods, the implementation of such systems may lead to an increased energy use especially if ground water is used (Fig. 1).

A second efficiency measure practiced during this period was the reduction of water application through "deficit irrigation," which is simply the application of less water than usual. The application of less water reduces both surface evaporation and more importantly evapo-transpiration which accounts for the greatest loss of water by a crop. Associated with this strategy is the concept of "minimized leaching" or using less water to leach the salts from the root profile. Leaching was reduced drastically during the drought. The leaching requirements are dependent upon the salt sensitivity of the crop, soil salinity, soil drainage, and quality of the irrigation water. All of these parameters are very site-specific. Minimized leaching during the summer when surface water supplies were reduced was accomplished by postponement of leaching until the off season or next growing period.

Various changes in cropping patterns were identified during the 1976 and 1977 seasons. Some of these changes may have been related to reduced quantities of available water in addition to other economic factors. Specific examples of cropping pattern changes related to the drought included: reduction in double cropping, substitution of low water demand crops, e.g., oats, safflower, tomatoes, for high water demand crops, e.g., rice, and the increased planting of salt tolerant crops such as cotton.

Some future problems may have been created, however, by obtaining the needed water supplies for 1976-77. These problems include the effects of extensive water pumping on ground water reservoirs and ground subsidence. In addition, reduced water application by less frequent irrigation and changes in irrigation methods may affect the total salt balance picture for future years.

CONSERVATION POTENTIAL

Since the overall purpose of this study was to determine if the information on water and energy savings developed during the drought of 1976 and 1977 would carry over into future years, the present and potential conservation strategies applicable to California were identified and presented. Among the general approaches are: maintaining and augmenting surface water supply, increasing pump and well efficiencies, and improving irrigation efficiencies. Table 1 outlines the various strategies within each general category according to the time of implementation, potential electrical savings, and the implementation criteria.

In the agricultural sector, conserving water and energy are complexly inter-related. The treatment of conservation in this paper emphasizes strategies that could be implemented in the near term. Specific actions suggested for facilitating conservation include: expanded irrigation management system, efficient water delivery at the irrigation district level, improvements in pumping efficiencies and irrigation system design, and support of a statewide water and energy conservation study. Specifically, the individual growers are encouraged to continue their efforts to use resources during periods of normal rainfall as they were under drought conditions.

FOOTNOTES AND REFERENCES

*Condensed from Lawrence Berkeley Laboratory Report, LBL-7866, Energy and Water Use in Irrigated Agriculture During Drought Conditions, R. L. Ritschard and K. Tsao, 1978.

1. P. Benenson, et al., "Effects of the drought on California electricity supply and demand," LBL-6356, June 1977.

Technology Assessment of Solar Energy

Characterization of Solid Waste Conversion and Cogeneration Systems

R. Ritschard, K. Haven, M. Henriquez, J. Kay, and W. Walzer

INTRODUCTION

The Characterization of Solid Waste Conversion and Cogeneration Systems was conducted under the Technology Assessment of Solar Energy Systems (TASE), directed by the Department of Energy, Division of Technology Assessments within the Office of Technology Impacts. The overall purpose of the TASE program is to evaluate the potential environmental and public health impacts and implications of a large scale and wide spread use of decentralized solar energy technologies. The program is being jointly conducted by several of the national laboratories including LBL. Phase I of the program was conducted during FY 1978 and emphasized the characterization of a number of specific solar energy and other renewable energy conservation technologies. This report describes two of the technologies assigned to LBL for phase I characterization: Municipal Solid Waste (MSW) energy recovery, and cogeneration. Four specific processes were evaluated during the course of this study:

1. Pyrolysis of MSW to either pyrolytic oil or gas,
2. Production of Refuse Derived Fuel (RDF) from MSW,
3. Direct combustion of MSW, and
4. Three cogeneration schemes.

The rationale for inclusion of these technologies in the TASE program was two-fold. First, solid waste material and waste heat in various industrial processes represent a significant renewable energy resource. Second, the growing scarcity of available land fill sites and rising costs of MSW disposal are creating solid waste management crises in many municipalities. Combined with the rising costs of conventional energy sources, this makes MSW energy recovery attractive both as an energy source and as a means of solid waste volume reduction.

For each of the four technologies listed above specific typical applications were defined. Capital and operating requirements for material, capital and labor were defined for each application. Environmental residuals created by the operation of each system were identified and the rate of their generation was calculated. Finally, constraints to the expanded use of each technology were identified and discussed. This paper briefly outlines the system designs included in each technology application.

TECHNOLOGY CHARACTERIZATION

Municipal Solid Waste

Three MSW energy recovery systems were selected for analysis, one typical of each of the three major groups of MSW conversion systems which have been tested in the United States. They are: pyrolysis systems, refuse derived fuel (RDF) systems, and direct combustion systems.

Pyrolysis Systems

Pyrolysis is a process in which organic material is decomposed at elevated temperatures in either a low oxygen or an oxygen-free environment. Unlike incineration with air, which is a highly exothermic reaction, pyrolysis is endothermic and requires the application of heat, either through the addition of fuels or through partial oxidation of the pyrolysis reaction. Again, unlike incineration, which produces primarily carbon dioxide and water, pyrolysis produces a complex mixture of combustible gases, oils and solid char residues. The mix of gas and oil produced is variable and is dependent primarily upon reaction temperature.

Pyrolysis offers several significant advantages over MSW energy recovery systems. First, either gas, liquid fuels, or electricity may be produced. Second, pyrolysis has a small atmosphere waste stream for emissions control.

The major drawbacks of pyrolysis are that the technology is still in a developmental stage and has not been demonstrated in a large plant, and that both the capital and operating costs of pyrolysis tend to be higher than other systems.

The Union Carbide PUROX system was the pyrolysis system selected for characterization in the study, based on a number of environmental and operational advantages over other pyrolysis systems. This system is a high temperature (3000°F) slagging pyrolysis process which produces a low to medium Btu gas rated 300 to 320 Btu/scf. The PUROX process provides for ferrous metal and aluminum recovery, using a vertical shaft pyrolysis furnace whose reaction is driven by pure oxygen. Inert slag passing from the bottom of the furnace is quenched and sold as a glass aggregate for construction.

The PUROX system has several specific advantages in addition to the general pyrolysis advantages. These include minimal air emissions, production

of a sellable solid waste stream (slag), and the generation of only one significant waste flow--the aqueous waste stream. Major waterborne residuals from this system include Hg, Zn, Pb, Ni, Cd solubles and sludge.

Refuse Derived Fuel

RDF is a mechanically processed interim product of MSW. It is characteristically uniform in size and consistency, is easy to handle and store, and is used as a supplementary boiler feedstock with traditional fuels (e.g., coal). Several individual processes to produce RDF have been developed and include:

1) wet processing (hydropulping) followed by component separation and dewatering of the fuel fraction.

2) dry processing (shredding) followed by chemical processing to produce what is called ECO-Fuel II. And

3) dry processing (shredding) followed by air classification.

The technology description presented in our report focusses on the finely shredded air-classified fuel, since the major part of the industry experience relates to this technology. The product is combustible with a reasonably high heat of combustion and is being utilized as a supplementary fuel in the utility boilers at several locations. In this system, the refuse is first shredded in a hammermill to 8-13 cm (3-5 in.) particles, and is then air classified. This separates the combustible light fraction (about 80 percent of the input refuse) from the heavy non-combustible fraction. The heavy fraction from the air classifier goes to a magnetic separator which removes the ferrous metals.

The light fraction is sent to a secondary shredder (fine shredder) where it is reduced to final size of 2.5 cm (1-2 in.) particles. This RDF typically comprises 10-20 percent of a boiler feedstock. Pollutant sources at the processing plant include dust from the shredders and air classification systems, sound from equipment operation, odors, water-borne contaminants from wash of storage areas, and residue destined for landfill.

Direct Combustion of MSW

Direct combustion systems generally involve no front end systems but rather load MSW directly into incinerators. They may be differentiated from RDF systems by this absence of pre-processing of received refuse. Heat resulting from the MSW combustion is partially recaptured through boiler tubes. There are two general types of direct combustion systems currently being used in the U. S.: refractory wall incinerators and waterwall incinerators. Steam is the basic energy produce of both systems and can either be used directly or can be converted to electricity in a steam turbine. Waterwall incinerators have the advantages of higher burning temperatures (1700°F to 1800°F) and lower requirements for excess air. The major pollutant flow from these systems are the stack emissions and the solid char residue. Stack gas includes NO_x, CO, HCl, NH_3, particulates and SO_2. The scrubber waste flow is high in dissolved solids; the quench water waste has a pH of approximately 9.9, is also high in suspended solids, and is about 90°C at the outlet.

Cogeneration System

Three separate cogeneration systems were evaluated during this study. As the name implies, cogeneration is a method of simultaneously producing process heat and electricity by matching the heat rejected from a primary process to the heat required by a secondary process. The method has attracted attention because it provides a method to utilize fuel efficiently.

Fluidized bed combustion is a non-conventional method of incineration which is compatible with cogeneration processes. The method employs the rapid flow of air up through a grid plate upon which rests the bed of material to be burned. The air flow is sufficient to introduce turbulent flow to the bed and results in complete combustion of fuel even in quantities as low as 2% of bed volume. If most of the bed material is limestone, SO_2 is efficiently removed as a dry solid. By locating heat exchanger tubes directly within the turbulent bed, high rates of heat transfer can be achieved at relatively low temperatures.

The second cogeneration system characterized during this study involves a methane powered diesel system. Since the report describes a cogeneration process in which methane generated by a biomass conversion process is converted to electricity, heat and pumping power. A reciprocating diesel is combined with a topping cycle waste heat boiler which generates 12.6 Mw of steam at 27.4 x 10^6 Btu/hr. While the system has a calculated efficiency of 37%, it suffers from high NO_x emissions.

The last cogeneration system characterized found application in enhanced oil recovery operations. Because oil well recovery factors are usually one third or less of the oil in place, it has become economically practical to heat subterranean oil by high pressure steam prior to extraction. In this system, inexpensive first tier oil is gasified and used to drive a combustion turbine. The turbine generates very high pressure steam which is used to recover second tier oil which is roughly twice as valuable as the fuel used to operate the turbine. In addition, the turbine produces 260 MWe of electricity.

SUMMARY

A complete description of each of the technology applications introduced in this paper is contained within the project report. These descriptions include detailed process and schematic flow information, capital and operating cost data,

Table 1. Systems output comparison (tons/day/10^{12} Btu steam per year).*

No.	Parameter	Systems							
		LG	GP	PX	DC	RDF	FB	DI	EO
1	Steam (tons)	4.32×10^5	5.97×10^5	0	4.72×10^5	3.34×10^5	2.1×10^5	2.1×10^5	144
2	Electricity (kW-hr)						1.31×10^8	1.76×10^8	2.20×10^8
3	Fuel Oil	0	4.03×10^4	0	0	0	--	--	--
4	Fuel Gas	0	1.97×10^4	0.65×10^4	0	0	--	--	--
5	Ferrous Metal	1.26×10^3	1.61×10^3	8.45×10^3	1.18×10^4	9.73×10^3	--	--	--
6	Non-Ferrous Metal	--	1.58×10^4	1.05×10^3	--	1.39×10^3	--	--	--
7	Glass	3.06×10^4	1.06×10^5	2.96×10^4	8.65×10^3	1.11×10^4	--	--	--
8	Waste H_2O	4.68×10^4	1.32×10^4	4.3×10^4	1.08×10^5	--	--	--	--
9	Char	1.44×10^3	35.05	0	1.73×10^4	4.75×10^4	3.5×10^3	950	2.28
10	Stack Effluent	585	1.06×10^5	1.17	1.63×10^6	4.17×10^4	412	3.15×10^3	101
11	Water Effluent	4.68×10^9		5.6×10^4	335.17	2.78×10^4	--	--	--

LG = Languard pyrolysis
GP = Garrett flash pyrolysis
PX = Union Carbide Purox process
DC = Direct combustion
RDF = Refuse-derived fuels
FB = Fluidized-bed cogeneration
DI = Diesel cogeneration
EO = Enhanced oil recovery (cogeneration)
*blank indicates no available data

and quantitative information for the rates of residual generation.

It was found that while land requirements are minimal for all systems, the recommended RDF system is the most efficient in terms of energy recovery per Btu input and is also the least expensive to build. The report points out that while the fluidized bed system has the highest overall efficiency, the PUROX system uses the least energy and is the only system which does not require process water. Table 1 compares the major systems studied for selected inputs and outputs.

Clearly the potential of MSW makes it worth further study. In this country alone the yearly collection is estimated at 1.25×10^8 tons with an average energy content of 4500 Btu/lb. This provides a total potential resource of 1.125×10^{15} Btu/yr. It would appear sufficient to guarantee MSW a place in our energy future.

FOOTNOTE

*Condensed from Lawrence Berkeley Laboratory Report, LBL-883.

Community Level Studies of Decentralized Solar Energy Technologies

R. Ritschard, K. Haven, and J. Kooser

INTRODUCTION

The Technology Assessment of Solar Energy (TASE) program which commenced in mid-FY 1978 is being conducted cooperatively by six of the Department of Energy national laboratories. The focus of the TASE Program is to provide impact analysis of various solar technologies at the national level. Since local or community impacts (e.g., land use, transportation modes, institutions, labor needs, etc.) may be more important than state, regional or national impacts with regard to solar technologies, a series of community level studies were initiated within the Energy Analysis Program.

The overall objective of the community level studies is to investigate the impacts of various solar-based energy systems on the community environment and its physical and social structure. Furthermore, the studies will identify issues and constraints to local and regional deployment of decentralized solar energy technologies. In order to fulfill this objective the project is divided into three major areas: community impact analysis, threshold impact study and solar city end-state analysis.

ACCOMPLISHMENTS DURING 1978

The major accomplishment during 1978 was the organization, design and commencement of the individual community level studies. The study design for each of the specific areas, for the most part, has been developed by outside investigators. During the latter part of 1978 (September) contracts were awarded to several groups and work commenced. The overall integrated organization, however, has been coordinated by the Energy Analysis Program. In addition, national scenarios based on the Domestic Policy Review Committee's figures were adapted to the community level for use by the individual tasks. A final accomplishment has been the characterization of various solar techologies for deployment at the community level. The technologies, which are consistent with other TASE activities, include: photovoltaics, wind, solar flat plate collectors, compound parabolic collectors, and wood combustion.

PLANNED ACTIVITIES FOR 1979

The specific tasks within each major impact analysis area are given below:

Community Impact Analysis

The objective of this task is to assess the physical, environmental and institutional impacts of solar energy utilization on spatially constrained communities. The approach is to identify impacts through analysis of technology siting and the physical layout. The results of the community impact analysis will be a matrix of impact indicators for various levels of solar penetration and for various community spatial configurations.

The impact analysis is divided into several subtasks which include: identification and characterization of various prototypical land use sectors; determination of energy and use requirements for each land use prototype; identification of the requirements of the various decentralized solar technologies; and an estimation of the feasibility and first-order impacts of implementing solar technologies on site and at the neighborhood scale.

Specifically, the task is taking prototypical land use patterns (varying in configuration, density and type) in the form of aerial photographs from several U. S. cities and determining whether there is a surplus or deficit of area available for solar collectors. Coefficients have been developed to determine the area requirements of solar collectors given different solar con-

tributions. A template is then used to determine whether sufficient area exists on rooftops, in yards or on vacant land. This template also indicates whether shading by vegetation or buildings will be a problem.

Another aspect of the community impact analysis is an exploration of urban morphologies to investigate the ability of future urban forms to "absorb" solar energy systems. This approach will help identify the interaction between urban function and form.

Threshold Impact Study

The threshold impact study is intended to examine in a hypothetical situation the ability of communities to absorb social and institutional changes incurred by adaptation to an energy system heavily based on decentralized solar energy technologies. The approach is to identify, for a particular level of solar penetration to the year 2025, community and institutional impediments and their rate of change over time. A series of scenarios representing a range of U. S. cities and the rates and compositions of solar diffusion were derived to identify the basic impediments or threshold indicators.

Two workshops held with representatives of various shareholder groups will be used to refine the original list of impediments, suggest new ones and propose how new attitudes could remove these impediments. The first workshop will be held in California and will identify impacts based on community scenarios. The second workshop will be conducted in Washington, D.C. and will be based on the impacts of the individual solar technologies. For policy purposes, an impediment or threshold is defined as a delay or identifiable resistance by as much as three to five years under current operating procedures.

Six shareholder groups have been identified by the study team: financial; regulatory and planning; environmental; construction, maintenance, distribution; energy supply; and energy demand. The results of the threshold analysis will be a summary of institutional relationships which determine if various community forms may reach a state of non-adaptability in which they are unable to assimilate further increments of solar energy.

Solar City End-State Analysis

The objective of the end-state analysis is to depict for a prototypical city the possible end-state communities under varying solar growth assumptions to the year 2025. The approach of this study is to present a visualization of the consequences of available choices of community environmental design.

A hypothetical city is assumed to undergo changes with time coincident with absorption of solar energy technologies into its community structure. A city will be analyzed in its end-state after a period of growth (to the year 2025) based on a business-as-usual scenario, which continues present energy supply patterns. Similarly, the same city will be examined in its end-state after a period of growth representing a high solar scenario that substitutes solar technologies up to about 35 percent of the community's energy needs. In a third case, a hypothetical city built "de novo," but maximizing solar energy sources and processing the same characteristics as the other cities in the year 2025 in terms of population, goods and services produced, and energy demand, will be examined in its end-state.

As a part of the "de novo" city analysis, a computer model will be developed that describes the thermal characteristics of different building designs given different climatic conditions. The basic concept is to start with passive design and fill energy needs with "low level" solar technologies first. The next step is to assemble these building designs together to develop the "de novo" solar city.

The results of the end-state analysis will be the presentation of the physical, environmental and socioeconomic characteristics of the emergent cities according to the various growth patterns. These results will address the debate over the desirability of solar energy by providing information that considers the relative attractiveness of the end-state to which such decisions today might lead us in terms of future life style and community structure.

Marine Biomass System: Anaerobic Digestion and Production of Methane*

K. Haven, R. Ritschard, and M. Henriquez

INTRODUCTION

The objectives of this project were to investigate the feasibility of converting marine biomass into energy products, to define a state-of-the art system design for this energy conversion technology, and to estimate the life cycle residuals which would be generated by the operation of the system. The project was undertaken as a part of Phase I of the DOE Division of Technology Assessment (DTA/OTI) program Technology Assessment of Solar Energy (TASE). It is the purpose of this program to assess the impacts and implications to the environment and to

public health and safety resulting from widespread implementation of decentralized solar and selected renewable resource technologies. The analytical efforts undertaken in 1978 for Phase I of the TASE program have been directed toward characterizing various solar technologies and applications for subsequent use in assessing the impacts of a widespread excursion into the use of solar technologies (Phase II).

This project characterized one technology (Marine Biomass) through two specific applications (an oceanic kep farm system, and a natural coastal kelp bed system). Detailed system designs were prepared; the material, capital and labor required to construct and maintain the systems were calculated; and environmental residuals generated by the system operation were estimated. Some of the results and system design information of this project are summarized below.

KELP PRODUCTION

Several aquatic micro-algae have been considered for use in the conversion of incident solar radiation into a useful energy product. However, marine micro-algae make inefficient use of the oceanic water column, require extensive systems to maintain optimal growth (bloom) conditions, and do not result in production yields (kg/acre) of harvestable biomass as large as those attainable from some macro-algae. Of particular interest is the California giant kelp (Macrosystis pyrifera). Typically, this kelp attains annual growth rates in natural coastal beds of approximately 8 dry ash-free (DAF) tons/acre-year.[1] However, this growth rate can be significantly enhanced through the addition of appropriate nutrients. Klaus[2] reported enhanced growth rates of as high as 49 DAF tons/acre year for some experimental beds. Such enhanced yields could make giant kelp an attractive energy crop.

Two systems were considered in this study for enhancing kelp growth rates: an oceanic farm concept, and a nutrient enriched natural coastal bed. The major features of each system are described below.

Ocean Farm System

The oceanic farm system design was based on studies by Wilcox[3] and Dynatech.[4] No oceanic farm has been tested, and the design must be considered conceptual at this time. The oceanic farm employs an artificial substrate to support kelp plants and is located in deep ocean waters. Open ocean siting allows the development of large area farms (hundreds of square miles) and thus sufficiently large masses of annual kelp production to make a significant contribution to the national natural gas supply. Growth rates of kelp plants attached to the artificial substrate will be enhanced by pumping nutrient rich waters up into the kelp growth zone to increase surface water nutrient availability. Nutrient rich waters will be obtained from below the photic zone (500 m-800 m depth).

The major components of the oceanic farm system are the artificial substrate, a series of deep water pipes and pumps, and an anchoring system. Wilcox[3] proposed the use of a modular concept for the oceanic farm using a series of quarter acre modules (QAM). Each QAM would act as an independent mini-farm. Others (e.g., Dynatech) have proposed the use of a single large horizontal grid for the farm substrate. The QAM system was adopted as the system of choice for this study because of its flexible and feasible system designs. A small (11.56 sq. mi) farm was designed and farm yield was estimated to be 4.83×10^6 wet tons/yr (50 DAF tons/acre-yr).

While this system provides the advantages of high yields per acre and can be designed for a large farm size to produce large total yield, it also has several major problems. First, the ability of a large (100 sq. mi) rigid structure to maintain long term structural integrity in an oceanic environment has not been demonstrated. Second, the ability of the mooring/anchoring system to hold the farm on station in several thousand feet of water has not been demonstrated. Third, the system costs far too much to be profitable. The small (1.50 sq. mi) ocean farm system will cost $1.6 billion to construct and locate. Total annual production costs will be as high as $25 to $30 million BTU.

Natural Kelp Bed System

The selected natural kelp bed system uses a small (2 sq. miles) coastal kelp bed. Enhanced growth rates were obtained by using a municipal sewer outfall as a nutrient feed. A numerical model of kelp growth for this system was developed and yields of 12-16 DAF tons/acre-year were achieved. At this yield, 300 tons per day (wet) per square mile of kelp bed are harvested for delivery to a processing plant.

The principal advantage of this system is low capital cost. By using a natural kelp bed there is no cost associated with the production system. The principal disadvantages are the reduced yield, small bed size, and potential problems with trace element uptake from the sewage outfall by the kelp.

Processing System

An anerobic digestion system was designed to convert kelp into methane. Preprocessing steps were designed to reduce water content and to free the volatile solids from the kelp structure. These steps included coarse and fine grinding, a heat and calcium chloride pretreatment, and pressing to remove juices. The remaining cake represented approximately 20 percent of the original mass but included 60 percent of the volatile solids. Gases produced by the anerobic digestion process were 60 percent CO_2 and 40 per cent CH_4. This gas was scrubbed to produce 96 + percent pure methane. Through this process 4.35×10^5 Btu of methane were produced per ton of incoming kelp with a conversion efficiency of approximately

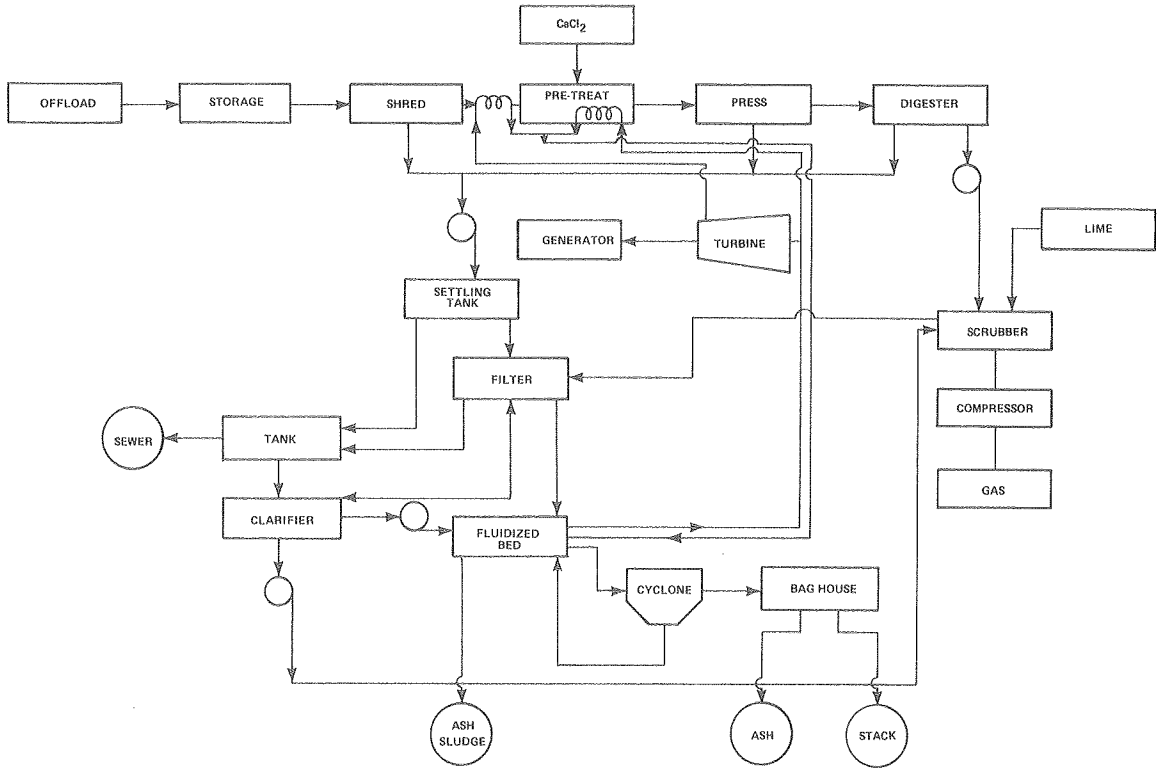

Fig. 1. Kelp to methane processing plant schematic. (XBL 792-337)

65 per cent. Waste flows were not reprocessed to maximize final methane production. Rather, waste flows were used as feedstock for a fluidized bed boiler which provided all process heat and electricity required by the conversion process. Figure 1 shows a schematic of this processing system. Figure 2 shows the unitized material and energy flows through the processing plant. The plant structure is identical for the oceanic system and the natural bed system since modular design allows for plant capacity to be expanded as required to match the anticipated kelp harvest rate.

Residuals for each system were identified and, where possible, quantified. Major residual flows were found to exist as aqueous waste from the processing plant, atmospheric emissions from the ocean farm pump motors and generators, and, to a lesser extent the waste sludge from the fluidized bed boiler and stack emissions from the conversion plant.

CONCLUSIONS

- Neither the ocean farm nor the natural bed system is economically attractive so long as methane is the sole product of the system. Energy costs for the system described in this report are from $10 to $30 per million Btu of generated gas. It is probable that this cost could be reduced to the $5 to $8 per million Btu range for a site-optimized natural bed system.

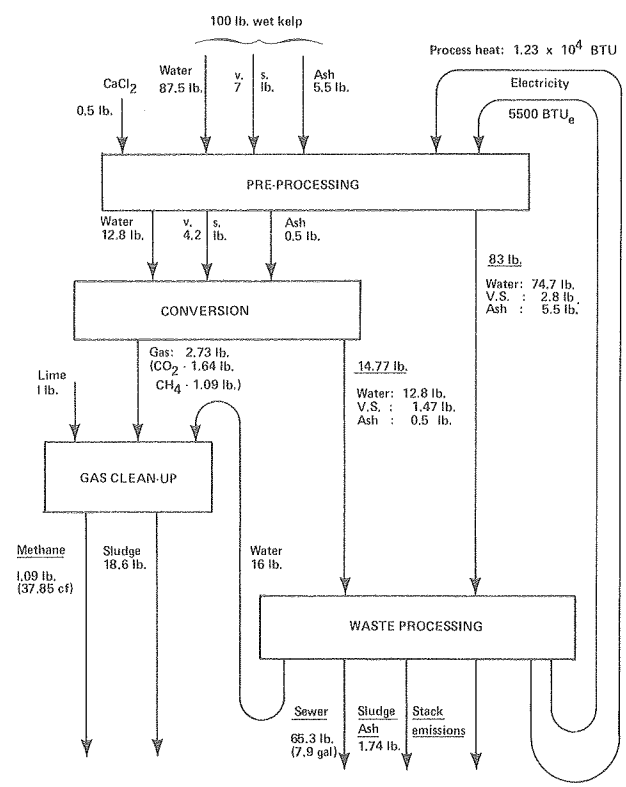

Fig. 2. Materials and energy flow. Kelp to methane system. (XBL 792-335)

- The production of side products (algin and/or feedstocks) appears to be feasible as part of the methane production process and is economically essential in order to produce a commercially viable system.

- Enhanced growth of kelp through the application of treated sewage outfall appears to be feasible and economically attractive. Additional research is required in the area of nutrient dispersion and availability, kelp uptake of heavy metals, and non-nutrient growth limiters for the kelp.

- The environmental impact of the ocean farm system is primarily associated with the deep ocean water pumping system which releases significant quantities of air pollutants and alters surface water characteristics of the entire area of the farm. The major conversion plant residual flow is the waste water flow (160 gal/tons of wet incoming kelp). The pollutant constituents of this flow are not well known but should include a significant presence of heavy metals and BOD.

FOOTNOTES AND REFERENCES

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Design and Characterization of Two Decentralized Total Solar Energy Supply Systems*

M. Henriquez, A. Ghirardi, and K. Haven

INTRODUCTION

The development of thermal and photovoltaic solar energy conversion systems was carried out as part of the Technology Assessment of Solar Energy Systems (TASE), which was conducted by the Division of Technology Assessments (Office of Technology Impacts) of the Office of the Assistant Secretary for Environment (ASEV/OTI/DTA) of the Department of Energy.

Work undertaken during this project resulted in the design and characterization of decentralized commercial and industrial scale systems. However, this study differs from conventional TASE assessments because it was not intended to characterize an entire technology, but rather to define two plausible decentralized solar energy supply systems and to identify environmental residuals associated with the development and operation of these two specific systems.

Unlike most existing or proposed solar conversion systems, the designs developed and characterized under this project were conceived to provide 100% of the support activities: space heating, cooling, electrical and process heat requirements. Furthermore, constraints placed on potential engineering approaches dictated that all discrete components for both systems must represent an existing technology which has been proven to the extent that reliable operating data allow a realistic appraisal of long term performance. Additionally, it was required that all of these components be readily available to the consumer market at rated efficiencies within the next five years.

SYSTEM DESIGN

Accomplishments

- Thermal Collector for Industrial Support

The thermal portion of this study stipulated the use of flat plate collectors to support 100% of a typical modern brewery's space, water, process heat and power requirements. During the preliminary phase of this study, some fifty existing industries with installed solar conversion systems were examined with respect to the employed technology, site, and process requirements. Additionally, some 200 non-industrial solar demonstration projects were similarly evaluated. Next, a number of varying quantitative design approaches were analyzed and finally, the techniques of mathematical systems analysis were employed to set specifications, develop and

optimize a unique system within the limits of project completion.

The system eventually developed had the following features:

1) It satisfied a total load of 1.4 MW electricity, 10,000 lbs/hr process steam at 200°F and 20 psia, and 655 tons of adsorption refrigeration.

2) It contained a concentrating flat plate collector array consisting of conventional collectors assisted by mylar planar reflectors. These reflectors assumed a mild concavity when suspended on the reverse slope of adjacent collector support trusses. Due to the specular reflectance of mylar and the specific mounting orientation, it was shown that concentration factors of 2:1 can be achieved.

3) It contained a mixture of dyphenal and dyphenal oxide (Dow A) for the collector working fluid, and Toluene for the power generation cycle working fluid.

4) A wall mounted Thermic Diode array was used to provide both winter heating and summer air conditioning. Because these solid state liquid devices contain their own thermal storage, they were operated on a separate loop, thus eliminating the possibility of transient process variables degrading environmental quality.

5) While not specifically called for by the load demand profile and not included in the basic plant energy supply system, a seasonal storage system was developed. This involved multiple excavated tank units operated by a third level computer control hierarchy. Because the surface of these structures could be optimized for retention of heat generated by incident solar flux, it is possible to maintain high working fluid temperatures over long periods of time.

6) Conventional storage of latent and sensible heat was provided with a 6×10^8 Btu capacity.

7) Modular design allows easy expansion of the energy supply system to support future expansion of plant capacity.

Figure 1 shows a detailed schematic of the major components of this energy supply system and depicts the plant energy balance using the described collector arrays.

- Photovoltaic Collector for Commercial Application

The photovoltaic system detailed in this report supports the energy requirements of an elementary school and is based on a 3 ft by 8 ft module of silicon cells. Each cell has two covers which are separated by an air gap. The silicon semiconductor is located on an aluminum base under the second cover and is arranged so that a stream of coolant is allowed to flow

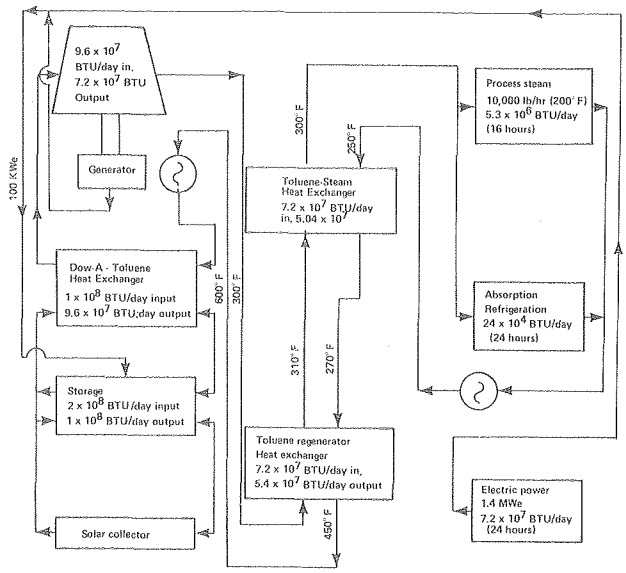

Fig. 1. Industrial total solar energy distribution. (XBL 792-334)

between the rear of the base and the thermal insulation which separates the base from the back cover of the assembly. It should be noted that cell electrical output decreases as cell temperature increases and that silicon semiconductors are liable to heat damage above 60°C. Therefore, maximum electrical output is not achieved by sacrificing thermal output, but rather by increasing thermal transfer in order to maintain the cells at a lower temperature.

As a result, photovoltaic systems can be designed in a cogeneration mode which provides both space heating and electricity. It was shown that the combined system would have an output of 191 kwh/m^2 for electricity and 755 kwh/m^2 for heat. Required collector area for these selected loads was calculated as 45,899 ft^2, which involved mounting the cells on the uppermost six feet of south facing exterior wall and on the entire school roof surface.

The hot water load was activated at 360 gal/day delivered at 50°C. The water is heated in two stages using separate underground tanks of 1.5m^3 and .5m^3 capacity respectively. Hot air from the collectors is used to heat the contents of the first tank to between 20°C and 35°C. The hot effluent is directed to the second tank where its temperature is further raised to 50°C by means of a 10kw resistive heating element.

It was calculated that on clear winter days a minimum interior temperature of 17°C could be maintained by solar cell exhaust circulation alone, while on cloudy days supplemental 180kw resistive space heaters may be required to compensate for the reduced incident thermal radiation.

Storage is provided by lead acid batteries which, in comparison to alternative systems, were found to be an expensive storage system

but did have the advantages of simplicity, familiarity, and availability. The batteries were rated at 1300 amp-hours and were sufficient for two days capacity.

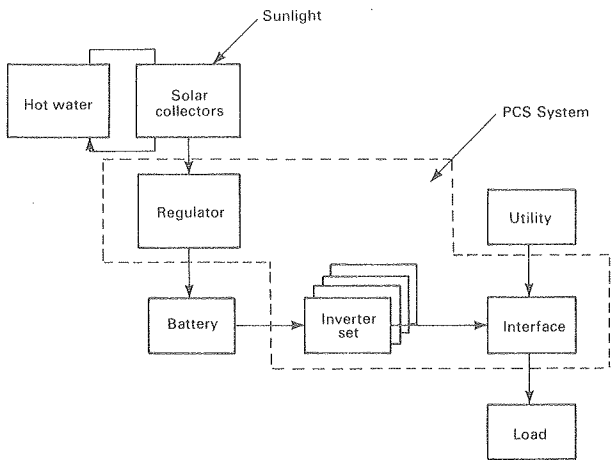

Fig. 2. Electrical system schematic. (XBL 792-338)

Finally a subsystem was developed to interface the various loads and power requirements of the system with existing utility grids. As a result, a power conditioning system was specified which performs the following functions:

1) Regulation; voltage regulator stabilizes photovoltaic output to levels consistent with safe battery charging.

Table 1. Summary of energy flows.

DESTINATION	MWY/YR
Incident on collector	7357
Reflected	1886
Transmitted to structure	1498
Converted to electricity	736
Converted to heat	3237
Electricity generated	736
Stored in the battery	589
Used by the load	288
Heat generated	3237
Lost from electric modules	1295
Lost from combined modules	1752
Transmitted to the load	190
Used by the load	82

2) Inversion; the inverter receives D.C. voltage from the battery and converts it to 60 Hz A.C. for use by load. It can also charge the battery from A.C. supplied by the grid.

3) Interface; controls the switching of load input power between the grid and the solar array.

A systems schematic is presented in Fig. 2 while an energy summary for this system is presented in Table 1.

FOOTNOTE

*Condensed from Lawrence Berkeley Laboratory Report, LBL-8459.

Solar Ownership and Marketing

Utility Investment in On-Site Solar: Risk and Return Analysis for Capitilization and Financing*

E. Kahn

INTRODUCTION

This project is designed to analyze one generic strategy aimed at accelerating the adoption of solar heating by residential consumers. This strategy involves utility financing of the capital investment costs of solar heating. Local utility companies are currently involved in a variety of programs to promote energy conservation. The finance of residential insulation is a close analog to the finance of solar heating.

Despite the potential benefit of such financial activities by utilities, there is concern that these programs would have a harmful effect on competition among home heating suppliers, contractors and lenders in a utility service area. Therefore recent national legislation has provided for regulation of this activity. Developing such regulation will require information about the economic impacts of utility financing of solar heating. This study aims to establish some of the necessary data for the development of efficient regulation.

The research activity is divided into three areas: risk and return analysis for utility finance, analysis of the lender market structure

for solar finance, and analysis of the vendor market structure for home heating. The focus of this activity is oriented to California conditions. The basic issues have been raised in hearings held jointly by the State Public Utilities Commission and the Energy Resources Conservation and Development Commission. Furthermore the California legislature is requiring that policy guidelines be developed for utility participation in the marketing, manufacture and financing of solar energy equipment.

LBL began its work in June, 1978. The first area of investigation was financial analysis of utility investment in on-site solar systems. Starting in 1979 emphasis will expand to include analysis of lender and vendor market structure.

ACCOMPLISHMENTS DURING 1978

Research during 1978 was concentrated on the application of modern finance theory to the analysis of utility involvement in the finance of on-site solar. If such programs are ultimately found to be beneficial on balance, the fundamental problem facing regulation is the determination of an interest rate to be charged for the loans. Underlying the whole strategy of utility solar finance is the intuition that low cost capital ought to be available for this purpose because of the utility's access to the capital market. Yet there has been virtually no analysis to support such propositions or to help determine what "low cost capital" might mean in practice.

To approach these problems through modern financial theory, extensive use was made of the Capital Asset Pricing Model (CAPM). CAPM is a quantitative theory of asset valuation which provides a means of trading off investment risk against expected return. In order to be attractive, riskier investments require higher returns than safer investments. The basic task of financial analysis is to construct a definition of investment risk. Within the framework of CAPM, risk is defined by the co-variance of an asset's earning stream with the average return of the capital market portfolio. This measures the "volatility" of returns; the extent of their correlation with macro-economic fluctuations. This definition assumes that diversification of investment risk is fundamental to the pricing and valuation of assets in the capital market.

CAPM also provides an apparatus for estimating appropriate minimal rates of return for individual projects. This minimal rate of return, called a "hurdle-rate", sets the lower bound on acceptance of projects for profit-maximizing firms. The hurdle rate is expressed as follows:

Hurdle Rate = Risk-free Rate + Risk Premium of Return,

where the Risk Premium is measured by the volatility of a project's return multiplied by the market price of risk. Thus,

$$\text{Risk Premium} = \text{Volatility} \times \text{Market Price of Risk}$$

$$= \frac{\mathrm{Cov}(Rp, Rm)}{\mathrm{Var}\ (Rm)} \left[E(Rm) - Rf\right],$$

where Rp = rate of return on project p

Rm = rate of return of market portfolio

Rf = risk-free rate of return

and E, Cov, and Var are the expectation operator, covariance operator and variance operator respectively.

Although CAPM is a formally complete approach to risk quantification, its application is not straight-forward for projects that are so new that there are insufficient statistics to calculate the co-variance term in the volatility coefficient. For on-site solar projects this is the case. Therefore volatility must be estimated by a method of risk enumeration and impact assessment. The following paragraphs introduce the major risks of utility investment and how they impact the returns on solar.

Solar investment presents utilities with a default risk in addition to the other risks facing conventional utility investment. A reasonable proxy for the default risk is the uncollectible rate on utility bills. Regression analysis shows, however, that this risk is negligible. Compared to that of finance companies for example, the default risk for utility investment is insignificant.

Conventional utility investments are becoming increasingly risky compared to historical risks faced by this industry. These increased risks are due to the uncertain demand in the future, the long lead times required to construct new centralized power plants, and the exposure of these big projects to cost over-runs in excess of inflation. The changing risk structure is reflected in higher requirements for return on utility equity.

Solar investment avoids most of this risk. There is relatively little elasticity of demand for hot water and space heat, so uncertainty is removed. The lead time for on site solar is short, and the potential for cost overruns is correspondingly limited. Solar investments are vulnerable to decreases in future energy prices. Since the likelihood of this appears small, there is little risk from this factor. Finally, solar investment is a long term commitment of capital and as such bears an interest rate risk. To develop an estimate of the interest rate risk, the return on corporate bonds was selected as a reasonable proxy for long run investment. Regression analysis shows that an index of such bonds does exhibit limited volatility in the sense of CAPM.

A preliminary estimate of the appropriate hurdle rate for utility investment in on site solar was developed using estimates of long term values for the risk-free rate of return, the volatility of the investment, and the market

Table 1. Internal rate of return as a function of region, system, lifetime, and taxation.

ASSUMPTIONS: Solar Hot Water Heater Capital Cost = $1500
Annual Maintenance Expenses = $60/yr
Energy Price Escalation Rate = 5.1% (real dollars)/yr
Inflation Rate = 5%/yr

Regional Performance and Value (Energy Displaced and 1978 cost per unit)

San Diego: 4800 kwh, 4.8¢/kwh
Northern California: 2800 kwh, 4.0¢/kwh

Internal Rate of Return

	Lifetime		
	10 yrs	15 yrs	20 yrs
Case 1.			
No Federal Tax			
San Diego	14.5%	20.0%	22.3%
Northern California	0	6.0%	10.0%
Case 2.			
48% Federal Tax			
San Diego	8.8%	13.3%	15.3%
Northern California	0	3.8%	6.8%
Case 3.			
55% State Tax Credit			
33% Personal Income Tax			
San Diego	25.5%	29.5%	30.8%
Northern California	3.5%	11.5%	15.0%

Note: California grants a 55% state income tax credit for solar. This benefit, however, also shows up as a reduced deduction for federal tax purposes. The cost of the reduced deduction is the dollar magnitude of the state solar tax credit times the marginal federal tax rate. These joint impacts can be expressed as a reduction to an "effective" state tax credit by the formula:

Effective Tax Credit = Nominal Credit - Marginal IRS Rate x Nominal Credit

price of risk. These estimates yield a hurdle rate of about 8.5%. Regulatory policy must be set for solar finance programs by estimating expected returns for on site solar investment. Table 1 develops some rate of return calculations for the case in which solar displaces electric water heating.

If the regulators choose to subsidize solar investment, then rates of return less than 8.5% would be acceptable. If the regulators allow utilities to own on site solar devices and the rate of return is more than 8.5%, then the solar investment would be subsidizing other customers unless there were a revenue adjustment. Finally, if the utility were to act simply as a financial intermediary, then the consumer would make the the decision to invest based on his expected return. This latter case would involve California state solar tax credits. Cases 1, 2 and 3 in Table 1 correspond to these choices. That is, cases 1 and 2 represent the extremes of the influence utility capital structure would have on solar rates of return. Case 3 represents the financing option.

PLANNED ACTIVITIES FOR 1979

In 1979 there will be further investigation into appropriate measures of utility investment risk. In addition various regulatory actions will be examined to determine the sensitivity of interest rates for solar finance.

The vendor and lender markets will also be analyzed to determine if in fact there is a role for utility investment in solar that would not be anti-competitive.

FOOTNOTE

*Condensed from Lawrence Berkeley Laboratory Report, LBL-7876.

Distributed Energy Systems in California's Future

P. Craig and M. D. Levine

INTRODUCTION

The Distributed Energy Systems project has as its overall objective the exploration of a broad spectrum of issues relating to the possible implementation of energy systems relying on renewable resources and energy conservation. This objective encompasses research that will shed light on the five major themes of the project:

1. Technical and economic aspects of the renewable energy supply systems and of the renewable energy resource base of the state.

2. Technical and economic aspects of energy use systems (current and future systems).

3. Public policy issues affecting the possible implementation of energy conservation measures and the use of renewable energy resources; assessment of costs, benefits, and distribution of costs and benefits of:

   - measures to increase the symmetry between decisions to expand supply and to reduce demand

   - measures to encourage the use of renewable energy resources.

4. Issues affecting the likelihood and impacts (favorable and unfavorable) of a transition to an energy conserving/renewable energy system in California, including:

   - energy decision making at all relevant levels of society (consumer, energy industry, state and local government, other important sectors that influence energy decisions)

   - changes in the economic, institutional, social and/or political environment of California that are consistent with (or occasioned by) increased use of renewable energy resources and energy conservation.

5. The implications to the United States energy system and policies of the assessment of these California issues.

BRIEF HISTORY OF THE PROJECT

The Distributed Energy Systems study was initiated in August, 1977. The first phase of the work led to the release of a preliminary report, "Distributed Energy Systems in California's Future," in April 1978. The main focus of Volume 1 of the preliminary report was the exploration of outcomes for the year 2025 based on centralized and distributed energy systems, primarily in terms of technical feasibility. A draft summary description of the results of the second phase of the DES project will be available in early January, 1979. The second volume of the preliminary report consisted of a series of issue papers examining particular aspects of distributed energy systems outcomes and certain aspects of the initiation of pathways to such outcomes. The results of these issue papers were summarized in Chapter 7 of Volume 1; no attempt was made at this time to integrate the results of the separate issue papers into the assessment of the 2025 outcome of the first volume.

Some of the major observations in the first interim report about the renewable energy supply/demand balance in 2025 are:

- By paying close attention to conservation, it appears technically feasible to provide almost all of the energy needs of California from indigenous renewable energy resources in 2025, while supporting an increasing affluent population.

- Liquid fuels are a major energy supply problem from any outcome that relies primarily on renewable fuels (or does not have access to conventional sources of oil) and uses liquid fuels in the transportation sector.

- Energy supply from renewable sources to meet industrial and urban needs may pose difficult land use issues.

Several observations regarding the comparison of renewable and conventional energy supply/demand balances in the long term in California were also made in the first interim report:

- The environmental impacts of the energy systems of the 2025 renewable energy "outcome" are expected to be markedly smaller than the impacts of virtually all of the conventional energy systems. This does not mean, however, that the impacts of the renewable systems will not cause some significant problems, particularly regarding aesthetic and land use issues.

- The transition process of any energy scenario in California--be it renewable or conventional--is likely to be fraught with a high degree of organizational and institutional problems and conflicts. However, the different pathways imply

different types and kinds of stresses on institutions.

- Issues of stability of energy supply and reliability of service (and at what cost) are likely to become increasingly important and problematical in any energy future. In a "renewable" future, new attitudes about reliability of energy supply may be required.

- The cultural context--beliefs, behaviors, and attitudes of people--will play a significant role in shaping development of energy systems.

Work since the initial phase (since April, 1978) has emphasized key issues raised in the preliminary report. Major effort was devoted to analyzing critical economic issues, especially those likely to be important in the near term. A computer model was developed to permit the comparison of investment in expanding sources of supply with investment in energy conservation measures. An extensive data base relating to the costs of demand reduction and alternative supply options was assembled. An integrating summary of the research findings of the second phase of the project is nearing completion. The summary indicates ways in which a renewable energy "outcome" in 2025 can be made more plausible by introducing larger quantities of fossil fuels, particularly to meet long term demands for liquid fuels. It also provides an analysis of the economics of energy conservation and renewable energy sources in California. The summary notes that in the near and intermediate term dramatic increases in energy conservation can be accomplished at no increase in net cost to the energy consumer, and assesses the uncertainties in the long term economic potential of renewable energy systems. The summary also addresses several important institutional and political issues related to the transition to a renewable energy future in California. The importance of consumer decision making in effecting energy conservation in the near term is stressed, as is the key factor of investment decision making in the California energy industry. Selected policies for future analysis in these two areas are identified.

In addition to this integrating summary, the project is preparing for release to DOE in January, 1979, technical reports on the following subjects:

- reliability of wind power from dispersed sites

- reliability planning in distributed electric energy systems

- the potential of the California biomass resource base as an energy source

- the economics of scale of biomass energy conservation

- a comparative analysis of the energy efficiency of California and other U. S. industry

- decision making in the California energy industry

- analysis of energy planning at the substate level: Davis, California case study

- environmental assessment of renewable and conventional energy systems

- evaluation of the physical constraints on residential solar energy use

- optimal investment strategies for energy conservation

- economic tradeoffs among conventional space heating systems, active solar systems, and energy conservation in California

- economic implications of alternative energy futures for California

PLANNED ACTIVITIES FOR 1979

As currently planned, the distributed energy systems study will continue its dual emphasis on selected key technical issues related to a transition to a renewable energy future in California, and on an integrated analysis of the results of the technical analyses. The proposed technical analyses for 1979 and 1980 include:

- assessment of passive solar opportunities in California

- quantitative analyses of consumer decision-making as regards energy conserving and energy consuming products

- assessment of the determinants of peak electricity demand

- commercialization studies for industrial solar process heat and biomass collection and conversion systems

- issues of integrating wind and hydroelectric energy systems

- scale economies of photovoltaic systems

- continued analysis of economic and employment impacts of alternative energy futures

- continued analysis of energy industry decision making

- continued analysis of substate energy planning

The project also plans to engage its research staff in several conferences that will permit public review of the work effort in progress.

The integration tasks will focus on near and mid-term policy and institutional issues in a transition to energy conservation and renewable energy sources in California. Increasing attention will be devoted to national energy policy implications of the analysis of California energy futures.

Consumer Decision Making on Energy Consuming and Energy Conserving Products

J. Corfee and M. D. Levine

INTRODUCTION

Analysis to date has underscored the critical role of the consumer decision making process in achieving significant increases in energy conservation in the United States. An example of the importance of consumer decision making is provided in Fig. 1, which shows two sets of energy demand forecasts for residential refrigeration. The top projection (solid line) is based on the assumption of no change in consumer decision making in their purchases of refrigerators in California. The bottom set of projections is based on the assumption that life cycle costing is used. Under this assumption increased initial costs of more energy efficient refrigerators are balanced against the increased energy use of less efficient refrigerators. The dotted line assumes no increase in the real cost of electricity while the dashed line assumes a 2.8 percent annual increase in electricity cost. The difference between the upper projection (decision making as usual) and the bottom set of projections (life cycle costing decision making) represents a dramatic saving in energy demand, and is equivalent to reducing the need for three one thousand megawatt power plants in California over the time frame of the projections.

Large savings in energy use can be shown for many other energy consuming activities if life cycle costing were the major decision criteria of the consumer. For example, space heating demand would decline over time throughout the nation for several decades if the full range of cost effective energy conservation measures were implemented in houses (both new and retrofit).

The dramatic energy savings that are possible at no net increase in cost to the consumer raise important issues about how government policy might be used to encourage the use of life cycle costing. The long term objective of this project is to analyze these policy issues. For the next year, the project will emphasize the first step in analyzing these policy issues: understanding and quantitatively characterizing the factors that have in the past most significantly influenced consumer decision making in purchase of energy consuming and energy conserving products.

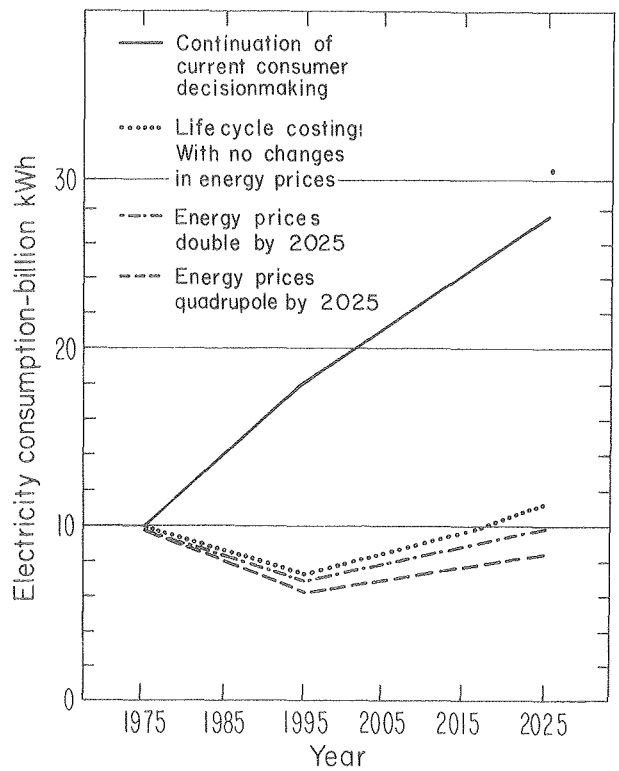

Fig. 1. Projected electricity consumption by refrigerators in California. Two different decision making algorithms. (XBL 792-333)

Perfect information, rational consumers, profit maximizing producers, and perfectly competitive product markets do not exist. In the case of energy related products, information about energy efficiency is not always available or understandable to consumers, nor have producers marketed products that are optimized for energy performance. Although the concept of life cycle costing provides a basis for consumers to make energy and cost efficient choices in the market place, available data suggest that few consumers either use or understand how to use life cycle costing criteria. There is legislation at both the federal and state levels requiring energy labeling of many appliances, but the degree to which this will be

effective in inducing consumers to purchase more energy efficient appliances is not yet clear. Very little analysis has yet been undertaken on such subjects as how consumers value future energy bills associated with products currently purchased, what policies will be effective in increasing the flow of information about energy efficiencies of products to consumers, and what public policies might provide suitable incentives to manufacturers to build more energy efficient products. We hope that by evaluating in a systematic way the available data relevant to the consumer decision making process, we will be able to provide some answers to these types of questions.

THE MODEL

The task of modeling consumer decisions is not an easy one as there are many intangible psychological and behavioral variables to be considered. Consumers have many different sets of criteria for market choices. Some consumers may be interested in minimizing initial cost, others may seek distinctive styles or brands, and still others may wish to obtain as cost effective and energy efficient a refrigerator as possible. Obviously, psychological/sociological factors are governing the distinctly different decisions that consumers make. In our attempt to model consumer decisions, we must first locate tangible, quantifiable variables that will act as indicators of these different types of consumer behavioral patterns.

The first step is to consider a variety of casual (or indicator) factors that describe the consumer decision making process. For example, we wish to know how the likelihood of making energy efficient decisions changes with income level, or with the socio-economic status of the decision maker. We also wish to know if there is a level of fuel costs at which certain classes of consumers begin to take notice of the energy costs of appliance, space heating systems for houses, and other consumer durables. We wish to know how responsive consumers are to manufacturers advertising, and the degree to which their decisions depend on the state of the economy. These questions deal with a few of the many possible factors that have a major influence on energy decisions.

We have chosen to perform an econometric study of energy consuming product market shares and energy conservation behavior of consumers. By using econometrics as the methodology, it will be possible to determine the statistical relationships of the hypothesized behavioral indicators of actual energy decisions. Initially, econometric analysis will be performed using times series data with product market shares represented as a function of product first cost, product energy intensiveness, fuel costs and cost escalation, consumer discount rates, manufacturing marketing effort, specific product attributes (color, size, etc.), and average disposable income. The specific brand/model market share then will be cast as the dependent variable with the detailed brand/model characteristics of the product used as the independent variables. Thus, we have $MS_i = f(LCC_i, ME_i, \vec{X}_i, Y_i)$ where

MS_i = market share of i product type/model

LCC_i = the life cycle cost of i product type/model*

ME_i = marketing effort of the manufacturer for product i

$\vec{X}_i$ = a vector of product attributes

Y_i = the average disposable income

In addition to the standard econometric analysis, we are conducting qualitative analyses of the data. Included in this part of the study is a consideration of factors that can not easily be quantified, or for which we lack data, but which may significantly influence energy decisions. An example of this type of relationship is the rapid rise in American mobility and the resulting shorter payback periods for energy conservation investments. This qualitative analysis will prove to be particularly useful in the study of energy conservation behavior of consumers.

DATA NEEDS

Many of the past consumer models have lacked consistent data. In the last three or four years, California utilities have performed saturation surveys and recently have begun to monitor conservation behavior in their districts. We have obtained the data from these surveys. In addition, industry and trade association statistics will be used extensively, providing the most consistent time series data set available at this time. In addition, the Department of Energy is sponsoring a nationwide survey of households designed to monitor energy related product purchases and conservation behavior in the residential sector. The survey was sent into the field October 30, 1978 and resulting data should be made available late in the summer of 1979. Checking the survey results with utility billing and weather data should increase the accuracy of the resulting data.

DOE has also conducted special tabulations of conservation behavior in the residential sector. These data have special significance as a measure of consumer's responses to the unprecedented rise in fuel costs. The 1975 Washington Center for Metropolitan Studies study of the American energy consumer for the Ford Foundation Energy Policy Project gathered survey data which provided quantitative information about the relation between levels of energy usage and socio-economic characteristics

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*Note that implicit in LCC are fuel cost and consumer discount rate assumptions. The former will be an averaged annual rate varied by region. Consumer discount rates are estimated by using regressions to determine the tradeoff between first cost and operating costs of each product.

of individual households. Many of these data sources will be directly useful to our proposed modeling effort.

USES AND LIMITATIONS OF THE APPROACH

Perhaps the most valuable output from the consumer decision making model will be an improved market penetration algorithm for new products. It is common knowledge that energy efficient products are now offered in the market place, but the rate at which they are purchased and utilized remains an unknown. The availability of new data sources on market/consumer activity is the key to sophisticated development of the algorithm. Once the data have been obtained and analyzed, we intend to use the information as input to one or more energy demand projection models.

We expect to encounter problems in obtaining a consistent set of data for the analysis. Fortunately, past studies have delineated specific data problems from which we can learn.

Econometric methods present additional limitations when analyzing a subject matter that includes qualitative or intangible relationships. As mentioned previously, we intend to supplement the econometric analysis by performing a qualitative review of factors that might be expected to influence consumer decision making.

Energy Conservation: Policy Issues and End-Use Scenarios of Savings Potential*

Project Overview

P. Benenson, R. Codina, B. Cornwall, D. Dornfeld, B. Greene, J. Elliott, W. Kempton, C. Langlois, H. Nelson, J. Nides, F. Rouse, and C. Sullam, (Consultants R. Barnes and N. Bradburn)

The focus of this work[1] was determined in consultation with the Director and staff of the Conservation and Advanced Energy Systems Policy Office, Department of Energy, following their review of our interim report. At that point we agreed on several guidelines for our subsequent work:

1. Take a holistic view of energy conservation policies by describing the overall system in which they are implemented;
2. Provide analytical tools and sufficiently disaggregated data bases that can be adapted to answer a variety of questions by the users;
3. Identify and discuss some of the important issues behind successful energy conservation policy;
4. Develop an energy conservation policy in depth.

In addition to these guidelines, we selected five specific subjects to investigate:

1. Residential and Commercial Buildings: an examination of court cases against new energy efficient building codes and suggestions for avoiding future litigation.
2. Recreational Travel: information strategies to effect a modal shift to public transit for the recreational trip.
3. Industrial Decision Making: a methodology to identify potential barriers to energy conservation by analyzing how a conservation measure's attributes interact with the characteristics of an industrial subsector.
4. Recycling: an analysis of the energy, economic, and environmental tradeoffs between landfill and combined programs of resource recovery and energy generation from waste.
5. End Use Energy Conservation Data Base: completion of energy conservation scenarios by calculating the energy conservation potential of specific measures applicable to particular end uses.

Our current work results from the application of the overall guidelines to the above subjects. For example, we have described the system in which each policy or issue is set by the use of flowcharts and accompanying text. In some cases, the flowchart describes a physical activity (constructing buildings or recycling waste materials). In other cases, it describes a decision-making process (industrial investment or transportation modal choice). The following

five articles summarize the major findings of each of these investigations.

FOOTNOTES AND REFERENCES

*Condensed from Lawrence Berkeley Laboratory Report of the same title in six parts, LBL-7896.

1. Contained in "Construction of Energy Conservation scenarios: Interim Report of Work in Progress," LBL Report 7834, June 1978.

Energy Efficient Buildings: The Causes of Litigation Against Energy Efficient Building Codes

W. Kempton, B. Cornwall, and H. Nelson

INTRODUCTION

Unlike traditional building codes which have been imposed to regularize construction practices, some new energy efficient codes attempt to mandate change. These new codes require as much conservation as is cost effective for the home occupant. Compared with traditional codes, such new codes are usually more rigorous, increase costs, and are more disruptive to the building industry. This paper discusses three industry suits against building codes. Two suits claimed that supposedly cost-effective codes were too rigorous (the California Residential Building Code and the Farmers Home Administration standards). The third suit claimed that the code (the California nonresidential code) was overly prescriptive. The specific objections made in the litigation against these three codes are listed, and the industry conditions and beliefs behind the objections stated in court are discussed. Other cases attempting to strengthen building codes, such as Polrized Corporation's current suit against ASHRAE 90-75, are not examined in this paper.

FINDINGS

Three objections against rigorous codes are based on anticipated higher costs of building under the new codes: (1) appraisals would not be raised enough to compensate for higher construction costs, especially in the FmHA program; (2) low-income buyers would be priced out of the market, and (3) capital shortages in the loan market and higher costs would reduce availability of loans. Builders also claimed that the computed payback periods were too long. They felt that the additional costs of conservation measures should pay back to the first buyer, rather than paying back over the life of the building. They also argued that materials, such as glass fiber insulation, are unavailable, and that industries such as electric resistance heating will collapse.

One source of difficulty in adapting to new standards is the diffuse nature of the industry. There are many small independent builders who are not in close contact with professional associations. New information may not reach them and adjustment to new requirements will be difficult. But for the same reasons, change would be very slow without building codes. Builders will experience hardships in the transition to new mandated practices, and may be inefficient until they have rethought old practices and adjusted to the new ones. For example, the proposed California code requires two inch by six inch framing in many parts of the state to accommodate R-19 insulation. While builders could minimize cost increases by changing from two-by-four studs on 16 inch centers to two-by-six on 24 inch centers, they may instead minimize changes in layouts by installing two-by-sixes on 16 inch centers. Such failures to optimize quickly will increase costs considerably in the transition period.

Two general beliefs not stated in court are behind many of the explicit court allegations. The first unstated belief is that the market, not the government, should determine what is built. The second is that the buying public does not want more efficient buildings.

Implementors of new building codes can increase their acceptability by: (1) working with lending institutions prior to implementation, (2) making cost calculations understandable to the public, and (3) insuring that the codes are truly performance-based. Occupants of efficient buildings have lower utility bills and thus more money available for mortgage payments or rent. Also, their bills undergo smaller seasonal fluctuations. If lenders had good information about these advantages, they might permit more favorable loan terms for such buildings. Next, if the cost calculations on which the codes are based are correct and widely understood by the public, special interests would be more reluctant to impede them. Finally, codes must be based on performance, allowing alternatives to prescriptions of materials and techniques. But many local building inspection departments are unable to evaluate innovative conservation or solar techniques. Thus, to be true performance codes, code implementation must provide for staff and facilities to approve innovative plans without inordinate delay.

Two issues underlie many policy questions about energy conservation building codes. One is whether market forces will make the necessary adjustments without codes. Many factors suggest that they will not. These include: (1) market

decisions are based on currently low energy prices; (2) homebuyers are not always rational economic actors with respect to energy consumption (for example, prestige or comfort often supersede economic considerations; (3) builders overestimate the costs of change, perpetuating current practices, and (4) given current energy prices and public awareness, the seller of a higher-priced efficient home is at a competitive disadvantage. The second underlying issue is whether or not governments should use building codes to accomplish long-range planning. Building codes which maximize cost effectiveness for the occupant depart from past codes and attempt to effect a change in building practices. The failure of market forces, the longevity of housing stock and the large amount of energy involved argue for such mandated change. But if such mandated change is perceived as unfair, then many of the objections that have arisen in the past are likely to be made again. Initiators of such codes should be prepared for these objections.

A DESCRIPTION OF THE BUILDING PROCESS

In conjunction with this work, a flow chart was developed that provides an overview of the building process and that can be used to assess the impact of proposed policies. The chart is composed of two major elements: a base chart and a transparent overlay chart. The base chart diagramatically portrays the current building process from inception through construction, occupation and eventual demolition. Included are the links, the actors, resources, policies, decisions, information and regulations of the process with an emphasis on how information about energy efficient buildings is currently incorporated.

The base chart is divided both horizontally and vertically. The vertical divisions represent the major sequential activities in the building process: (a) programming, (b) development planning/design, (c) construction, (d) completion/delivery, (e) occupancy/maintenance, and (h) destruction and replacement. The horizontal divisions both above and below represent the inputs flowing to these stages of the building process: Policies/regulations/standards, actors and motivations lead to the provision of either the resources or the information necessary for the completion of any stage in the building process. The diagram expands only some areas, emphasizing points where a change could encourage energy conservation. Once such a point is identified, the policy designer can trace the consequences of this change back through the actors providing the information or resource, the policies and standards affected.

Energy Efficient Recreational Travel

B. Cornwall and C. Sullam

INTRODUCTION

Energy consumed for recreational travel is an important component of total transportation energy consumption. Most of this recreational travel takes place in the automobile, which not only consumes energy, but also pollutes, makes noise, and causes other environmental stress which may diminish the recreational experience for the very travelers who use it. Accordingly, how to bring about a modal shift to a more efficient means of transportation for recreational trips is an appropriate policy issue. An examination of the traveler's decision-making process indicates that information is a weak link in the modal choice decision. Moreover, the information is biased toward the private auto. In this report, we focus on an information policy designed to bring about a modal shift toward public transit for the weekend recreation trip.

We begin by summarizing the policy and placing it in the context of the issues it addresses. Following that, we develop in detail an information policy to link use of national parks with transit for the weekend trip. This policy derives from an examination of the importance of the recreational and weekend trips in terms of trip numbers, purposes, modes, and energy consumption. We then describe verbally and graphically the traveler's decision-making process. Several potential problems and policy targets are revealed, of which the information link is one. Finally, we present a broad spectrum of information policy suggestions that would strengthen this link.

FINDINGS

The information policy we developed emphasizes the joint roles of the National Park Service (NPS) and the Department of Energy (DOE). Although the policy could be implemented by various agencies including DOE, the policy is couched primarily in terms of NPS's role because of recent legislation, described below, that authorizes them to address transportation and energy conservation issues. DOE's potential role is discussed after the structure of the policy is described.

In the past, the purpose of the NPS was to preserve natural resources rather than to bring people into park areas. The agency had neither the authority nor the funding to address problems of access to the parks. Very recently, however, Congress passed legislation (P.L. 95-344) authorizing the NPS to formulate transportation plans and implement transportation programs.

The purpose of the act is to support modes other than the automobile for access to and within national parks and thus preserve the parks and conserve energy. Included in the legislation's mandate is the need to establish information programs to notify the public of alternative travel modes.

In the spirit of the recent legislation, we suggest three components for the NPS to develop in its initial information dissemination program.

1. An inquiry and response system to centralize the multiple sources of recreational and transit information. This system could include the following features:

   - a mail service, consisting of a preprinted card with blanks for name, address, recreation area, travel constraints and requirements and special information.

   - a telephone service, consisting of a toll-free telephone number, preferably an acronym such as FUNTRIP.

   - a walk-in service at each park (e.g., a visitors' center), which emphasizes transit for on-site travel.

2. Brochures and pamphlets to convey information in an effective manner which should include:

   - clear, specific and up-to-date transit facts, such as routes and schedules.

   - detailed information about the site so recreationists do not feel compelled to maximize their flexibility by travelling in an auto.

3. Media campaigns to tap into the many and varied information conduits that exist today. Strategies should include:

   - a speakers bureau to orient specific market segments to recreational transit.

   - maps and displays in the telephone book, an information source widely used for trip planning.

   - site condition reports, such as ski or surf bulletins, which mention transit opportunities.

DOE could strengthen this program in several ways. First, it could supplement NPS funding and analysis of park transportation. Data on energy consumption and energy conservation potential could be gathered and analyzed. Second, it could coordinate the information system; operation of the toll-free telephone number could build upon the experience of DOE's Solar Division with a toll-free public information number for solar energy. Third, it could develop public relations material on recreational travel. Fourth, it could initiate a demonstration project for recreational transit to determine energy savings. And finally, it could support research and development on energy-efficient public transportation systems.

DECISION MAKING FOR THE RECREATIONAL EXPERIENCE

The design of the policy described above is based in part upon an analysis of decision-making for a recreation trip. We developed a flow chart to describe this experience, which is represented as a system--a set of components and their interrelationships. Decision makers can use the flow chart to aid in determining which components of the system could be altered to achieve a greater balance between the automobile and other modes for recreational travel.

The system depicted in the flowchart divides the recreational experience into five phases. During the PLANNING phase, the recreationist makes most of the major decisions of the trip: where and when to go, what mode to use, who will go, what to do, etc. During the TRAVEL TO phase, travel time is often an important variable in the selection of mode and route. However, travel time can become a less critical variable if the trip itself is enjoyable. ON SITE experiences are the portion of the trip most often associated with "recreation." TRAVEL FROM, the fourth major phase, resembles the "travel to" phase in terms of origin and destination; however, the route and time spent in transit may vary considerably. RECOLLECTION, the final phase, generally forms the basis for planning and making decisions for the next recreational experience.

We use the flowchart to identify which aspects of the recreational system need to be addressed to alter the modal distribution, increase the use of public conveyances, and conserve energy in recreational travel. Our analysis reveals that the modal decision occurs after two other decisions, "Where to Go" and When to Go." These first two decisions may determine the modal choice for the recreational trip and possibly eliminate transit as an option.

As a result of this analysis, we suggest the following objectives and strategies for public policy on recreational travel:

1. Create and/or strengthen the links between transit information and that of other recreational sources.

2. Design a centralized system of recreation/transit information, and

3. Stress the recreational potential of transit trips when developing information systems.

Policy Barriers and Investment Decisions in Industry

J. Nides, R. Barnes, D. Dornfeld, P. Benenson, and J. Elliott

INTRODUCTION

The industrial sector provides policy-makers with substantial opportunity for effecting energy conservation. Each year decisions are made regarding investments in conservation measures that could substantially reduce energy consumption. Many of these decision outcomes could be influenced by applying the appropriate government action (e.g., financial incentives, regulatory restrictions, or information provision). Government intervention should be confined, however, to situations where it is both necessary and likely to be effective. To this end we have developed a methodology to aid policy-makers in the recognition of such situations and facilitate understanding of the barriers that block conservation efforts.

The methodology employs two flow charts and a matrix. The flow-charts detail the principal participants, information flows, and criteria and constraints which underlie the investment decision-making process. The matrix expands upon the set of criteria and constraints given in the flowcharts and analyzes how characteristics of the particular sector and attributes of the measure in question interact to form barriers to conservation efforts.

FINDINGS

Industrial decision-makers consider a number of factors before deciding whether or not to invest in a conservation measure. Each factor or attribute can increase the likelihood of a measure's adoption or pose a barrier to it. We have identified seven primary attributes:

Attributes

- cost effectiveness,
- relative cost,
- unreliability (expected unscheduled downtime),
- disruption to install,
- technical sophistication needed to install the measure,
- environmental impact,
- change in dependency of the firm on outside fuel supplies.

During a preliminary examination, it may appear that a particular attribute increases the desirability of a given conservation measure. For a particular industrial subsector, there may exist, however, other factors (economic, regulatory, or technical) which can alter the attribute's impact on the investment decision. We refer to these other factors as subsector characteristics and have identified nine:

Characteristics

- market growth,
- capital intensity,
- energy intensity,
- access to credit,
- rate of return on investment,
- regulatory restrictions,
- age of plant,
- availability of fuels, and
- technical complexity.

We have, therefore, broken down the investment decision into a three stage analysis to include considerations of the effects and interactions of attributes and characteristics. First, decision-makers consider the influences of the conservation measure attributes on the desirability of implementing the measure. Second, they estimate the impacts of the industrial subsector characteristics on each attribute. Finally, they re-evaluate the influences of attributes in light of the impact of characteristics.

To incorporate this three stage analysis into our methodology, we developed a matrix which arrays columns of attributes against rows of characteristics for the selected conservation measure. First, each attribute is qualitatively rated. Second, the effects of each characteristic on the evaluation of each attribute are determined and are entered in every cell of the matrix (i.e., the interface of an attribute and a characteristic). Finally, attribute columns can be examined for ratings which might alter the favorable impact of an attribute on the investment decision. By inspecting the matrix, one can determine:

1. Which conservation measures have no apparent barriers in a given subsector and therefore require no government action.

2. Which conservation measures have so many apparent barriers in a given subsector that only massive government intervention appears as a solution for achieving implementation.

3. Which conservation measures are reasonable targets for government policy after further investigation of the barriers revealed by the methodology.

Policy-makers may then refer to the flow charts to ascertain which participants in the decision-making process are most likely to be concerned with the particular barriers which have been identified. By knowing the nature

of barriers and the identity of participants concerned with them, policy-makers can more easily select the most effective policy to influence the outcome of the investment decision. The final choice of an effective policy is not uniquely determined by this analysis; rather, the set of choices is substantially reduced.

To test the methodology, we selected four conservation measures--Improved Housekeeping, New Plant Construction, Waste Heat Recovery, and Process Change/Major Renovation--and three industrial subsectors in California--steel, chemicals, and petroleum. The conservation measure attributes describing Improved Housekeeping and New Plant Construction were arrayed against subsector characteristics for the steel and chemical subsectors; attributes associated with Waste Heat Recovery and Process Change were arrayed against the chemical sector characteristics.

We found none of the conservation measures to be completely free of potential barriers requiring government action. Nor did we find measures that had so many barriers that only massive government intervention could achieve implementation. They were all likely targets. Potential barriers indicating the need for more quantitative work to decide if governmental action should be taken were identified in individual matrix cells (i.e., in the attribute/characteristic interfaces).

Our report traces, with the aid of flow charts, the process of investment decisions. The flow charts and text portray large corporations as the model for industrial organization because such firms account for the bulk of industrial energy use. An abbreviated discussion is provided for small firms. The decision areas important for the installation of conservation measures differ if the equipment is to be retrofitted or included in the design of new facilities; consequently, two flow charts were formulated.

Categories of major factors in the decision process are listed on each chart: information, actors, criteria and constraints, and motivations. The horizontal headings of each chart (Concept Introduction or Conceptualization and Design), Analysis and Decision, and Implementation) represent the three broad stages of the decision process. The specific factors which are important at each stage (who the actors are, which particular criteria and constraints they apply, what their motivations are, and what kind of information they receive) change as the decision process advances. The pertinent factors can be located by examining the interfaces of factor categories and decision stages. In addition, the charts reveal the points in the decision-making process at which policies can be applied; given a particular obstacle to conservation, the charts suggest the most likely points and the general types of policy to achieve successful implementation.

Tradeoffs of Municipal Solid Waste Processing Alternatives

R. Codina and C. Langlois

INTRODUCTION

Solid waste generation in the United States is expected to increase from the 1975 level of 3.4 pounds per person per day to five pounds per person per day in 1990. Many strategies have been proposed to cope with the anticipated increase. The objectives of this report are to assess the performance and advantages of several processing and disposal techniques, and to examine the issue of large scale recycling of waste material.

Five general methods of solid waste disposal and processing are discussed: close-in landfill, remote landfill, refuse derived solid fuel (RDSF), pyrolysis and incineration. Landfilling is the most prevalent disposal technique in use. The method is inexpensive, requires small capital outlays, and is relatively energy efficient. But close-in landfill sites are nearing capacity and additional close-in sites are either unavailable or extremely expensive.

Landfills can also be an environmental hazard through water contamination, odor, occupation of land, and production of explosive methane gas. Moreover, landfilling represents the disposal of energy-rich materials and recyclable resources. Remote landfill is costly since operating costs for landfill increase dramatically with distance from the area served. Increasing attention has therefore been given to the possibilities offered by the recycling of source-separated materials.

The importance of such issues is exemplified by the number of states implementing waste disposal policies. For example, California has implemented over 130 recycling programs in different communities, while six major cities which cumulatively comprise the bulk of the state's population are considering the creation of large-scale resource recovery facilities.

The major issue at this time concerning municipal solid waste disposal is whether to continue landfill operations as the primary method, or to use some combination of source separation, resource recovery and energy generation with landfill. The constraints surrounding this issue are capital and labor costs, technical feasibility, environmental impacts (especially air pollution), marketability of the derived

energy and recycled resources, and public cooperation.

DESCRIPTION OF THE RESOURCE RECOVERY PROCESS

The recovery of energy from municipal solid waste (MSW) through source separation programs and resource recovery facilities occurs at the back end of a long process. Virgin materials are transformed into consumable products, distributed, used, and ultimately disposed of as solid waste. The large diagram which accompanies our main report presents an overview of this process and emphasizes other points in the resource stream where energy recovery from materials reclamation can occur.

Structurally, the diagrams consist of the following components: (1) the main activities and associated actors and resources; (2) existing government policies related to these activities; and (3) the motivational concerns of the main actors.

The main activities, resources, and actors comprise the underlying skeleton of the whole schematic. The six main activities are: mining and harvesting, manufacturing, converting, distributing, consuming and disposing. Resources are processed at each of these six stages and their identities change as a result. From different points along these resource paths, scrap materials can be removed and recycled into the main resource flow.

FINDINGS

It is not possible to determine on a generic level which of the three techniques--RDSF, pyrolysis and incineration--is more economically advantageous. Only site specific analysis can determine the best choice of techniques. Three variables (design options, financing arrangements and marketing arrangements) differ too greatly from site to site to allow generalization of their effects on the choice of process.

Recycling of glass, aluminum and ferrous metals is compatible with energy generation whether done mechanically at the recovery plant or by the public prior to MSW collection. This holds because these materials must be removed prior to energy production. Of these recycliables, ferrous metals are most efficiently recovered through mechanical means. At present, glass and aluminum appear to be best recovered through public recycling and source separation programs, although this situation is subject to state-of-the-art developments, in recovery equipment, local market conditions and the costs of local collection. Newsprint can be either recycled or converted to energy, but the former appears more energy efficient.

An effective source separation program, in a high participation scenario, can reduce the MSW by 15%. It is important to consider this potential in planning resource recovery options since any reduction in the MSW stream will have a bearing on the size of the facility that will be necessary. The location of waste processing facilities is the most important factor in assessing the pros and cons of any particular process. MSW processing plants are of obvious interest in densely populated areas where pollution problems (in particular air pollution) are most severe. Preference for one process rather than another does not necessarily reflect data derived from market forces alone. California, for example, has imposed stringent regulations on air population--hence preference in this state is given to pyrolysis despite economic disadvantages (both capital and operating costs), since air pollution from this system is negligible. Also under consideration in California are low-cost package incinerators but use of these is contingent upon federal and state evaluation of their air quality impact.

The separate collection of recyclable materials is generally compatible with garbage reprocessing centers. The degree of compatibility, however, is dependent on several factors, including the types of materials collected by each system, the market value of the recycled products, the cost of collection and the efficiency of the mechanical recovery equipment.

End Use Energy Conservation Data Base and Scenarios

D. Dornfeld, B. Greene, P. Benenson, and R. Barnes

INTRODUCTION

The end use energy conservation scenarios discussed below show the combined effect on energy consumption of implementing a number of conservation measures. The scenarios serve two overall purposes. First, they contrast nonconservation cases based on assumptions of growth rate and appliance saturation with conservation cases based on similar assumptions. Second, they provide detailed data and documentation for the savings potential of each conservation measure, the stock affected, and the calculation of total energy savings. Included are conservation measures of both a behavioral nature (e.g., night thermostat setback) and a technological nature (e.g., better hot water heater insulation). Several water conservation measures and the associated energy savings were also incorporated to demonstrate how water conservation could be factored into a comprehensive energy conservation program.

The scenarios include assumptions about economic, demographic, behavioral and technological variables, such as population, growth and decay of energy using stocks, appliance saturation, and conservation implementation levels. Some assumptions are imbedded in projections used as input to the scenarios. These assumptions cannot be changed directly and are so noted in the main report. Other assumptions form the basis of calculations made and can be changed to construct alternative scenarios. These also are indicated.

Assumptions can be changed to reflect different conditions, such as attitudes regarding family size, durability estimates of energy using stocks, or lifestyle changes that affect the purchase or use of a given appliance or transportation mode. The implementation level of a conservation measure also can be changed to reflect a variety of responses to a given policy. In addition, conservation measures can be combined and new ones added. Quantitative estimates of energy consumption and conservation potential in the major residential and commercial end-uses, transportation modes, and industrial subsectors have been made.

SCENARIO FINDINGS

Computer software was developed to construct scenarios that calculate the cumulative effect of various conservation measures. The basic approach for the conservation scenario construction is to quantify base year unit energy consumption by end use, travel mode or industrial subsector; reduce unit consumption by the estimated conservation potential in the appropriate year; adjust for saturation; and extrapolate to account for growth and decay of the appropriate energy using stock. The projections were made for 1980, 1985, 1990, 1995, 2000 and 2020.

The behavioral and technological measures that are incorporated in the scenarios were selected on the basis of their potential for effecting large energy savings in the major end uses within each sector. The measures included in the scenario are as follows:

1. Industrial Sector--housekeeping (leak-plugging, equipment maintenance, insulation); process improvements; waste heat recovery; new, more efficient facilities; in-plant recycling.

2. Commercial Sector--building and appliance efficiency standards for water heaters, spaceheaters, and air conditioners in new and old buildings; low-flow devices to reduce water consumption, and solar water heaters with efficient backups; and reduced task lighting in new buildings and delamping in old buildings.

3. Residential Sector--solar water heating systems with efficient electrical backup heaters designed for loads reduced by water conservation; building and appliance efficiency standards for space heating and air conditioning; and replacement of frost-free refrigerators and freezers by non-frost-free units.

4. Transportation Sector--reduced travel speed; smaller and lighter weight automobiles with improved engines; continuously variable transmissions and streamlining of trucks with emphasis on diesel engines; airplanes with high by-pass engines on narrow bodies and improved passenger load factors; and streamlined, lighter passenger and freight trains with improved passenger load factors and reduced empty freight car back hauling.

The scenario results show a more gradual growth of energy consumption in the conservation case compared to the base case, with a widening gap between the two cases over time in the total amount of energy consumed. By extrapolating the growth variables, a gap results between the two cases by the year 2020 of approximately 6.3 quads, which is 115% of 1975 energy consumption. Total energy consumption increases from 5.5 quads in 1975 to a 2020 estimate of 13.2 quads with conservation and 19.5 quads without conservation. The largest savings occur in the industrial and transportation sectors (2.7 and 2.4 quads respectively) and the smallest savings in the commercial sector (0.6 quads) and the residential sector (0.7 quads). The sectors with the largest savings are the ones with largest consumption.

No analysis of the growth rates of the variables that partially determine the magnitude of energy consumption in each sector (e.g., per capita value of industrial shipments, travel demand, rate of increase in commercial floor space or number of residential housing units) has been made to determine the most likely rates. Varying the growth rate for one such variable will change the amount of energy consumption and energy savings. A change in the rate of growth could be attributable, for example, to a change in population, fuel availability, attitudes or values. These in turn may result in changing preferences for the type or density of housing, demand for goods and services, and derived demand for intermediate and primary industrial production.

The data upon which the results are based are presented in tabular form in the main report and its appendices. For each sector the tables for a base and conservation scenario are included. The resulting scenarios indicate the energy consumption by end use, fuel type, transportation mode, industrial subsector and utility service areas that can be aggregated into two climate zones (northern and southern California) permitting application to many other areas of the United States. The scenarios are not intended to provide point estimates of energy consumption in a particular year, but rather to contrast two conditional consumption scenarios and evaluate the potential savings due to energy conservation.

Inventory of Energy Conservation Potential in California*

C. Blumstein, K. Hudson, P. Kuhn, and C. York

INTRODUCTION

The purpose of this project is to assist the California Energy Commission (CEC) in establishing a system for organizing and analyzing information on energy conservation opportunities. This information is needed by the CEC to plan its conservation programs efficiently and to forecast the effect of all conservation activities, including CEC programs, on future energy requirements. To demonstrate the inventory system, we are preparing inventories of energy conservation potential in selected portions of the manufacturing sector of the California economy. Drawing on existing literature as well as primary data collection, these inventories will provide estimates of energy conservation potential as well as information on the technical aspects, economic costs, and environmental considerations of individual energy conservation measures. While a complete inventory covering the manufacturing sector, let alone the entire state's economy, is beyond the resources of this project, the limited inventories will be useful in a) providing a model for the inventory system and b) increasing the scope and coherence of the CEC's information on energy conservation potential.

The approach we are using to estimate energy conservation potential in California's manufacturing sector emphasizes the detailed technical and economic aspects of energy conservation measures and the equipment or processes to which they might be applied. Our primary objective is to provide as realistic and accurate a picture as is possible of the technical and economic feasibility of conservation measures and the savings they might provide. The results of our project should prove useful in econometric studies of conservation potential or in modelling future energy use, but such analysis lies outside the present scope of our project.

ACCOMPLISHMENTS DURING 1978

To date we have developed a plan for an inventory system and demonstrated it by compiling inventories of energy conservation potential for boilers and steam supply equipment in manufacturing plants and for the cement industry.[1,2]

The plan for the inventory system includes topics for the initial work, to be done at LBL, and a format for presenting the information, both of which have been selected in close cooperation with the CEC to maximize the usefulness of the project's output. The topics chosen for inventories to be done at LBL are 1) boilers and steam supply equipment in manufacturing plants, 2) cement plants, 3) pulp and paper mills, 4) fruit and vegetable canneries, 5) sugar refineries, and 6) glass factories. The inventory system has a three-part structure with increasing levels of detail provided in each part. The format begins with a summary report, followed by more in-depth reports on individual conservation measures, and ends with an indexed collection of references. This structure allows individual parts of the system to be easily updated to reflect new information. Within each of the reports, the format allows quick access to the various kinds of information the user might require, including the conclusions and estimates of conservation potential, background information on the energy-using equipment or system that is the topic of the report, explanations of the technical aspects and costs of the conservation measures, environmental considerations, and calculations.

The two inventories that have been completed demonstrate two approaches for analyzing energy conservation potential. The first considers a class of equipment e.g., boilers and steam supply equipment to which the same group of energy conservation measures could be applied. This approach discounts the fact that the equipment is employed in "systems" for the production of quite different goods and services. A boiler, for example, can be tuned to save fuel regardless of whether it provides steam to melt tallow or to make tomato paste. The second approach considers a system for the production of a homogeneous good, e.g., the cement industry, that incorporates many types of equipment. A set of energy conservation measures for the associated equipment may then be evaluated in the context of their interaction within the system.

The two approaches are necessary to achieve the project's goal of providing information on the full range of energy conservation potentials in California. The equipment-oriented approach yields the most detailed information on possible increases in the efficiency of specific energy-using devices, the costs of the improvements, and other pertinent considerations. The system-oriented approach, on the other hand, can consider the effects of substitutions among devices, choice of feedstocks, cogeneration, and other measures that cannot be covered by the equipment-oriented approach.

In a more practical sense, the two approaches are made necessary by the limitations of available information. Information on the energy-using characteristics of some industries is too sketchy to permit proper treatment of the industry with the system-oriented approach; for these industries conservation potential for part of their energy use can be analyzed by the equipment-oriented approach. The opposite case is even more prevalent. Data on stocks of many types of equipment in California, including electric motors and pumps, is presently so inadequate that no estimate of energy conservation potential can be produced by the equipment-oriented approach. By considering the equipment as part of systems, however, conservation measures for the equipment can be evaluated in the context of the applications of that equipment in a

particular system. A part of the conservation potential in electric motors, for example, would be captured in a study of the chemical industry, a major user of electric motors for pumps and fan drives.

The following summaries of the case studies will highlight only the estimates of energy conservation potential and other important conclusions. More complete information can be found in Refs. 1 and 2.

Boilers and Steam Supply Systems

This equipment is used to convert fuel energy into the thermal and mechanical energy content of steam and to distribute steam to a variety of equipment for end use. About 40% of the fuel purchased by the manufacturing sector for heat and power (i.e., excluding 'waste' fuels and feedstocks) is consumed in this equipment. In 1976 most of this fuel was natural gas. We have estimated that between five and ten percent of this fuel could be saved by more efficient tuning of burner controls and by recovering heat from stack gas and from the blowdown water expelled from boilers to prevent build-up of impurities in the water used to generate steam. At 1976 rates of consumption, these savings would amount to between 8 and 16 billion cubic feet of natural gas and 180 to 360 thousand barrels of oil per year. Additional savings could be achieved by measures including insulation of steam lines, maintenance of steam traps, and returning more condensate to the boilers to recover heat. However, available data do not permit an estimate of these savings.

Cement Plants

This industry is one of the largest in state industrial energy consumers. In 1976 the twelve cement plants in the state accounted for nearly 9% (44 trillion BTU) of the fuel and 3% (1 billion kWh) of the electricity purchased by all manufacturers. Energy costs now account for up to half the total costs of production in the plants. This situation, coupled with the current storage of production capacity, has induced a number of the companies to plan replacements or expansions of their plants with more efficient equipment. If the installations occur as scheduled, we estimate that the industry's average fuel consumption rate per ton of cement will decline to 4.4 million BTU/ton in 1982. In 1976 it was 5.3 million BTU/ton. Although the new equipment will have slightly higher electricity requirements, installations of cogeneration equipment that are being considered could effect a modest overall reduction in the industry's average electricity consumption rate from 124 kWh/ton of cement in 1976 to 115 kWh/ton in 1982.

PLANNED ACTIVITIES FOR 1979

By June of 1979, we expect to complete inventories of energy conservation potential in California paper and pulp mills, fruit and vegetable canneries, sugar refineries, and glass factories. These inventories, together with the two completed in 1978, will be assembled into a final report.

FOOTNOTES AND REFERENCES

*Work supported by the California Energy Commission Contract No. 400-088(7/8) .

1. P. Kuhn, K. Hudson, C. Blumstein, C. York, "Preliminary Report on an Inventory of Energy Conservation Potential in California: The Cement Industry," in preparation.

2. P. Kuhn, K. Hudson, C. Blumstein, C. York, "Preliminary Report on an Industry of Energy Conservation Potential in California: Boilers and Steam Supply Systems," in preparation.

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