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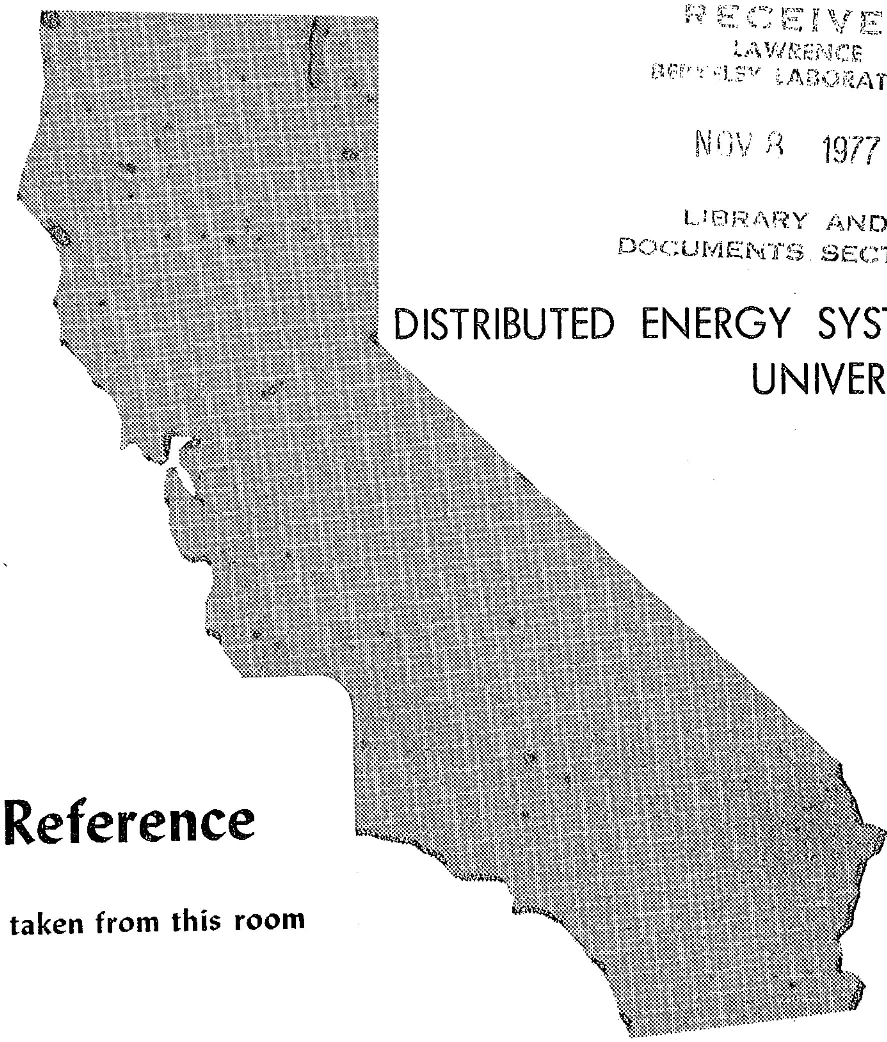
DISTRIBUTED ENERGY SYSTEMS IN CALIFORNIA'S FUTURE:

A PRELIMINARY REPORT
VOLUME 2

DISTRIBUTED ENERGY SYSTEMS STUDY GROUP
UNIVERSITY OF CALIFORNIA



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Interim Report

DISTRIBUTED TECHNOLOGIES IN CALIFORNIA'S ENERGY FUTURE

VOLUME 2

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CHAPTER IX

ENVIRONMENTAL IMPACTS OF ALTERNATIVE ENERGY TECHNOLOGIES FOR CALIFORNIA

9.1 INTRODUCTION

The construction and use of energy technologies produce environmental and social consequences that are neither desired nor, for the most part, incorporated in the economic costs charged for the energy supplied. Although it is now essentially universally recognized that these "externalities" or (broadly defined) "social costs" must somehow be taken into account in the processes by which society chooses among alternative energy options, it is less widely appreciated that these costs--not resource limits or narrow economics--actually define the energy dilemma in the long term.* It is important to try to make clear at the outset why this is so.

The energy problem resides fundamentally in the fact that the relation between energy and well-being is two-sided. The application of energy as a productive input to the economy, yielding desired goods and services, contributes to well-being; the environmental and social costs of getting and using energy subtract from it. At some level of energy use, and for a given mix of technologies of energy supply, further increases in energy supply will produce incremental social and environmental costs greater than the incremental economic benefits--that is, growth begins to do more harm than good (Holdren, 1977; Committee on Nuclear and Alternative Energy Systems, 1977). This level can be said to define a rational "limit to growth", as distinct from a strictly physical one.

---

* This perception underlies Lovins' proposals (1976, 1977) and is the justification for their radical character.

That such a level, beyond which energy growth no longer pays, exists in principle for any mix of technologies of supply and end-use is easily shown from basic economics and physical science; predicting its magnitude exactly is much harder, the more so because social costs even less quantifiable than environmental ones may dominate. Lovins (1976, 1977) evidently believes that the United States is already near or beyond the point, given the "hard" energy technologies on which it relies, where further growth hurts more than it helps. Whether he is right or wrong about exactly where we are now, however, or in specific judgments about the merits of "hard" versus "soft" technologies, it is clear that energy policy for the long term should be shaped by awareness that social-environmental costs, not exhaustion of resources, will limit the amount of human well-being derivable from energy. Maximizing this quantity will require striving for technologies of energy supply with low social and environmental costs per unit of energy delivered, and fostering patterns and technologies of energy end-use that squeeze from each such unit the maximum contribution to human well-being.

This perspective, then, elevates environmental and social characteristics to the top of the list of criteria used to select supply technologies from the menu of genuinely long-term options--fission breeder reactors, fusion, direct and indirect harnessing of solar flows, and possibly some forms of geothermal energy. It rationalizes the possibility that society will choose to pay more (in economic terms) for a more benign energy source than for a less benign one. And it argues for using, as a criterion for selecting short-term and transition energy sources, the extent to which these promote and facilitate the transition to a longer term energy future built on more benign sources and efficient end-use.

Given a perspective that places environmental and social impacts at the heart of the energy predicament rather than on the periphery, it becomes essential to compare the impacts produced by alternative energy options systematically, comprehensively, and objectively. The information needed to do this properly, even for a limited set of technologies and a limited geographic and cultural context (e.g., California), unfortunately does not exist. What is attempted here, therefore, is to outline a logical framework for such a comparison, and to hang on that framework the partial information that is available on the environmental impacts of some major conventional and nonconventional energy options for California. (Although the emphasis in this study is on the latter, the most sensible yardstick to give meaning to the results is provided by the former.) The objective is to permit at least some partial and preliminary conclusions about this aspect of the "soft" energy options, and to identify those areas where additional knowledge is most badly needed. In this analysis sociopolitical impacts are mentioned from time to time for completeness, but the emphasis is on impacts on physical resources and on the physical environment; impacts on institutions and social systems *per se* are treated more thoroughly in other papers in this project.

9.2 A FRAMEWORK FOR IMPACT ANALYSIS

One of the greatest pitfalls in cost-benefit comparisons of all kinds is leaving something important out of the accounting. A useful precaution is to develop a logical framework for ordering the subject, to help assure at least that the right questions are asked. I am concerned in this paper only with costs, the benefits of energy availability having been amply and enthusiastically described by others (see, e.g., Cook, 1976, for a balanced treatment), and more specifically with costs arising from energy's impacts on the biological, geophysical, and social environments. (The last is treated only cursorily here, as noted above.) It is useful in this connection to structure environmental analysis of energy options around the following sequence, leading up to the costs themselves:

(1) identification of the sources of effects on the environment, in the form of specific technological systems and activities;

(2) identification and characterization of the inputs to the immediate environment that are produced by these sources, where "input" is taken to encompass what is put into, taken out of, or done to the surroundings;

(3) analysis of the pathways by which the inputs lead to stresses on the components of the environment at risk;

(4) characterization and quantification of these stresses;

(5) analysis of the responses of the components at risk to the stresses imposed;

(6) identification and quantification of the costs to human well-being associated with these responses.

9.2.1 Sources

Listed in Table IX-1, column 1, are the alternative and conventional energy supply options considered here as sources of environmental effects.

Table IX-1

Sources of Environmental Effects

A. ENERGY SUPPLY OPTIONS

- INCREASED END-USE EFFICIENCY
- SOLAR HEAT
  - passive
  - active space & water
  - industrial process
- SOLAR COOL
  - passive
  - active
- SOLAR THERMAL ELECTRIC
- WIND TURBINES
  - on site
  - central
- HYDRO
  - existing large dams
  - new small dams
- BIOMASS
  - waste
  - energy farms
- GEOTHERMAL
  - heat
  - electric
- COAL
  - central electricity
  - small fluid bed
  - gasification
  - liquefaction
- NATURAL GAS
  - domestic
  - imported
- OIL
  - domestic
  - imported
- OIL SHALE
- NUCLEAR LWR
- NONFUEL OPTIONS
  - on-site storage
  - central storage
  - industrial cogeneration
  - district heating

B. STAGES WITHIN AN OPTION

- EXPLORATION
- HARVESTING
- CONCENTRATION
- REFINING
- CONVERSION
- TRANSPORTATION*
- STORAGE*
- MARKETING*
- END USE

*may occur more than once

C. PHASES WITHIN A STAGE

- RESEARCH & DEVELOPMENT
- COMMERCIAL CONSTRUCTION
- OPERATION & MAINTENANCE
- DISMANTLING
- MANAGEMENT OF LONG-LIVED WASTES

In the general case, a supply option is characterized by a sequence of stages through which the energy passes between discovery and final application, and each stage must proceed through several phases, from research and development to management of wastes that outlive the facilities themselves; these stages and phases are listed in Table 1, Column 2. Each phase, moreover, may entail management, monitoring, and regulation as well as the core technical operations, and a complete accounting must recognize the possibility that significant environmental effects may be generated by any of these activities. (Not all options actually involve all the stages listed of course, and not all stages for a given option entail all the phases listed.) I have listed increased end-use efficiency in parallel with other supply options, for it is true that a barrel saved is a barrel earned; in terms of stages and phases, it is less complicated than most of the others. Some other nonfuel options--on-site and central storage, industrial cogeneration, and district heating--are also listed as "supplies" because they reduce needs for other energy supplies and have characteristics substantially independent of the fuels with which they are coupled.

9.2.2 Inputs, Pathways, Stresses

A classification of inputs, pathways, and stresses is given in Table IX-2. The inputs can range from acute, sudden and unexpected (as in the case of accidents, natural disasters, or malicious intervention) to chronic, continuous, and predictable (as in the case of effluents from the routine combustion of fossil fuels). The inclusion of "consumption or pre-emption of resources" in the "inputs" category may seem curious at first in what is essentially a tabulation of externalities of the use

Table IX-2

Inputs, Pathways, Stresses

INPUTS TO THE IMMEDIATE ENVIRONMENT

CONSUMPTION OR PRE-EMPTION OF RESOURCES (land, water, energy, nonfuel materials)
MATERIAL EFFLUENTS (solid, liquid, gaseous, including radioactive materials)
ELECTROMAGNETIC RADIATION (ionizing, microwave, other)
HEAT
NOISE
DIRECT PHYSICAL DAMAGE & TRANSFORMATION (blast, terrain modification, vegetation removal, erection of structures)
SOCIOPOLITICAL INFLUENCES (redistribution of population, redistribution of income, altered vulnerabilities, weapons temptations)

PATHWAYS TO COMPONENTS AT RISK

media	processes		
AIR	DIFFUSION	EVAPORATION	TRANSPORT IN AND BY ORGANISMS
WATER	CONDUCTION	RAINOUT	
ICE	CONVECTION	SUSPENSION	
SOIL/ROCK	RADIATION	FALLOUT	

STRESSES

REDUCED RESOURCE AVAILABILITY
ALTERED CHEMICAL CONCENTRATIONS IN AIR, WATER, SOIL, BIOTA
ALTERED TEMPERATURE
ALTERED METEOROLOGY
ALTERED HYDROLOGY
ABSORBED RADIATION DOSE
PERCEIVED NOISE
LOSS OF HABITAT
SOCIOPOLITICAL STRESSES

of energy technology, since the resources listed--land, nonfuel materials, water, the energy invested to build energy facilities--usually are paid for by the operations of the energy technology and incorporated as part of the (internalized) costs of energy supply. The basis for considering these resource uses to have an externality component is the distortion introduced by subsidies, failure to price resources at long-run replacement value, and other market imperfections, all of which probably occur quite nonuniformly across the range of different technologies. This makes it instructive to disaggregate from potentially deceptive dollar values the actual physical quantities used--tons of material, square kilometers of land, cubic meters of water, megajoules of energy.

The pathways listed in Table IX-2 between inputs and the components of the environment that are at risk are not relevant to all of the kinds of inputs, some of which are translated essentially immediately and on the spot into stresses; a classification of possible pathways for some inputs is given here mainly for taxonomic completeness. It is not fruitful to dwell in the present abbreviated context on pathway analysis for environmental impact assessment, although it is in fact a difficult and critical component of the thorough environmental assessments that eventually must be done for both "hard" and "soft" alternatives (see, e.g., Budnitz and Holdren, 1976).

The inputs, translated through elaborate pathways or not, turn up sooner or later as stresses at points of potential vulnerability--for example, concentrations of air pollutants where urban populations must breathe them, or alteration of rainfall patterns in regions where crops are grown. A classification of such stresses is given at the bottom of Table IX-2.

9.2.3 Responses and Criteria for Assessing Severity

It is the responses of the various components of the environment subjected to energy-related stresses that define the real impact on human well-being. A classification of these responses, or kinds of damage, is given in Table IX-3. It is worth noting that although the bulk of society's attention to environmental matters so far has been concentrated on the first two categories, namely death and disease caused directly by effluents and accidents, there is reason to believe that the graver energy-related threats to human well-being on a large scale reside in two other categories: war, and the undermining of environmental goods and services essential to the support of the world's population as a whole (Holdren and Ehrlich, 1974; Ehrlich, Ehrlich, and Holdren, 1977).

It is of course not enough only to identify the various ways in which energy-related environmental effects damage human well-being; it is essential also to find ways to assign costs for these damages (or threats of damages) or to evaluate their relative severity in other ways. In seeking such criteria of severity over a wide range of impacts of a wide range of technologies, one encounters problems both of quantifiability of damages and of comparability between damages of qualitatively different kinds--the well-known "apples and oranges" problem. (A more detailed discussion than can be given here is in Holdren, 1977.) A listing of the most used (and/or most useful) criteria for evaluating the severity of environmental impacts is given in Table IX-4. Some comments on these follow.

Table IX-3

Responses to Environmental Stresses

DEATHS FROM ACCIDENTS & SABOTAGE
- occupational
- public

DIRECT PRODUCTION OF ILLNESS & DISABILITY

occupational	somatic
public	genetic

ECONOMIC GOODS & SERVICES LOST OR FOREGONE
- direct damage to crops (by, e.g., air pollution)
- direct damage to property
- goods & services foregone because resources needed to produce them were used to produce energy instead
- damage to recreation and tourism

DAMAGE TO ENVIRONMENTAL GOODS AND SERVICES
- damage to agriculture and forestry due to
  - climate change
  - disruption of nutrient cycles
  - loss of natural pest controls
  - soil loss
  - disruption of environmental water storage and flow regulation
- damage to ocean fish and shellfish production (e.g., by oil spills and destruction of estuaries)
- disruption of natural controls on agents & vectors of human disease
- accumulation of toxins by undermining environmental purification processes
- damage to other protective environmental processes (e.g., ozone shield)
- loss of genetic information (hence opportunities for new drugs, crops, etc.)

AESTHETIC LOSS & NUISANCE (impaired visibility, ugly structures, diminution of environmental diversity)

PSYCHOLOGICAL DISTRESS (e.g., among persons displaced by energy technology, or fearful of other costs before they materialize)

UNDESIRABLE SOCIAL & POLITICAL CHANGE (e.g., increased centralization of political power, loss of civil liberties)

WAR (e.g., over access to energy, or pursued with energy-related technology)

Table IX-4

Costs and Other Criteria for Evaluating Severity

MAGNITUDES OF INPUTS (tons of pollutants or material resources, cubic meters of water, square kilometers of land, joules of energy, curies of radioactivity)

MAGNITUDES OF STRESSES
- ambient concentrations ($\mu g/m^3$ in air, ppm in water, g/m^2 on soil)
- secondary indicators of concentrations (biochemical oxygen demand, pH change)
- concentrations in organisms (ppm, total body burdens)
- rads of absorbed radiation dose
- resource use as a fraction of available flow (renewables) or stock (nonrenewables)
- temperature change
- perturbations in natural processes, as a fraction of natural flows or stocks

MAGNITUDES OF RESPONSES
- expected deaths, days of life lost, dollar "values" of same
- expected cases of disease, days of activity lost, dollar "values" of same
- dollar value of resources used (measures intensity of competing demands)
- dollar value of economic services lost or foregone
- dollar "value" of lost environmental goods & services (cost of resulting damage to human health or economic goods & services, cost to replace environmental service with technology)

TEMPORAL DISTRIBUTION OF HARM (instantaneous vs. protracted, sooner vs. later)

SPATIAL DISTRIBUTION OF HARM (concentrated vs. dispersed)

COINCIDENCE OF RISKS AND BENEFITS (do the same people pay as benefit?)

SCALING (is the scaling of response to stress linear or nonlinear, with or without threshold?)

RESISTANCE TO REMEDY (are there easy ways to prevent the damage?)

IRREVERSIBILITY (time needed to effect repairs once damage is done)

QUALITY OF EVIDENCE OF HARM (speculation, theory, extensive data; how much uncertainty?)

Magnitudes of inputs are the most often used indices in comparisons of the environmental impacts of energy technologies. Indeed, these are often the only data that can be found in reasonably reliable and unambiguous form. Unfortunately, the numbers are often not very instructive; knowing that a ton of SO_2 or a curie of plutonium is emitted is a long way from having a measure of the harm to health or ecosystems that may result. Certain prescriptions for making input magnitudes somewhat more meaningful are in widespread use. One is to divide the input quantity of a pollutant by the ambient concentration of that material permitted by government standards; this quotient is the volume of air or water needed to dilute the input to the level required by law, and thus affords some comparability between qualitatively different pollutants. (The considerable pitfalls in this procedure are discussed in Holdren and Smith, 1977)

Magnitudes of stresses are in general much more difficult to specify for a given energy technology than are magnitudes of inputs. For most pollutants, the problem of deriving ambient concentrations from a given pattern of emissions is still substantially unsolved. Two approaches to this problem are of some value, although tedious and expensive: statistical correlations based on extensive historical data (where available) on emissions and ambient concentrations; and increasingly sophisticated computer models of the interaction of pollutant plumes with local meteorological patterns. A useful index for certain environmental stresses is the ratio of the human effect to a characteristic scale of the affected process--e.g., human sulfur input to the atmosphere compared to biological and geophysical sources (about 0.50), or accumulated anthropogenic CO_2 compared to the preindustrial atmospheric reservoir (about 0.10).

Magnitudes of responses to environmental stresses are generally even more difficult to quantify, owing largely to imperfectly known stress-response relationships in both human health and other environmental processes. The result of this ignorance is very large uncertainties (often understated even in the professional literature) in the expected damages from such energy-related stresses as elevated atmospheric sulfate concentrations. And even where expected numbers of deaths and cases of disease (or, better, lost days of life and productive activity) can be stated with some confidence, attempts to make these costs internalizable by expressing them in dollar equivalents are hobbled by the lack of agreed-upon prescriptions for doing so. Quantifying loss of environmental services is also difficult, both because the nature and value of the services themselves is poorly known and because the cost of replacing them with technology (where this is feasible at all) is hard to pin down.

With respect to temporal distribution of harm, instantaneous damages (e.g., from accidents) seem to be perceived as more severe than the same total damage spread over a longer period, and later is generally perceived as being better than sooner (unless later means subsequent generations, i.e., genetic effects, in which case perceived severity is high). Similarly, in the case of spatial distribution, the same total damage is perceived as less severe if spread out than if concentrated.

On the related question of coincidence of risks and benefits, a distinction may be made among: (a) workers in the specified energy industry (high coincidence of risks and benefits, since their livelihood comes from the technology in question); (b) members of the public who use, directly or indirectly, the energy produced (rather high risk-benefit coincidence); (c) other members of the public now alive (rather low coincidence); (d) future generations (lowest risk-benefit coincidence). A given amount of damage is perceived as more severe the lower it takes place in this heirarchy.

With respect to scaling of response to stress, it seems clear that those damages must be judged more severe which threaten to escalate faster than linearly with increasing input or stress, or for which there is reason to believe that a threshold exists beyond which damages change for the worse in a qualitative way. (The possible effect of atmospheric CO_2 in upsetting established climatic patterns is an example of the latter kind of threat.) Application of this criterion is difficult in practice because stress-response relationships are in general so poorly known, as already noted.

Resistance to remedy--meaning the difficulty of preventing the damage in the first place--is an important criterion too often overlooked in simple-minded tabulations of environmental hazards. A major reason nuclear power's social costs seem so troublesome to many observers is that their resistance to remedy appears to be high; in this particular case the resistance arises in large part because of the prominence of unpredictable or uncontrollable human (as opposed to technical) factors in the most serious problems--proliferation, diversion, sabotage. The occupational accident hazard of underground coal mining, by contrast, has probably been weighted too heavily in most environmental comparisons, due to failure to appreciate how amenable to remedy this hazard actually is. (There is a difference of about a factor of five in accident rate between the safest and least safe companies operating in similar conditions; at the lower rate, which could easily be made the norm by suitable regulations, backed up by enforcement, underground coal mining is not an unusually hazardous occupation.) The criterion of resistance to remedy will likewise be seen to be important in the evaluation of environmental risks of "soft" technologies, where many conceivable pitfalls turn out to be rather easily circumvented by straightforward means.

Irreversibility is rarely absolute,* but the term as used here refers to the amount of time required for society or nature to repair or recover from damages that have occurred. Degree of irreversibility is governed by such factors as the time spans over which pollutants remain toxic and accessible to life forms, the characteristic time scales for ecosystems to restore imbalances, and the time that would be required for human society to adjust its agriculture to substantial climatic change.

Quality of evidence of harm varies widely across the spectrum of technologies and environmental impacts of potential concern, and must somehow be taken into account in any systematic comparison. Speculation about a possible adverse impact of one technology should hardly be given equal weight with the highly documented damages of another. It would be wise to remember, however, that uncertainty cuts two ways;

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* The extinction of a species is an exception.

some things may turn out to be worse than we not think, while others turn out better. It would be imprudent to assume that a future energy source, not yet available for testing, will be better than today's known flawed ones simply because its enviornmental impacts are necessarily still somewhat speculative.

9.3 SOME SPECIFIC IMPACTS OF "SOFT" AND "TRANSITION" TECHNOLOGIES

The obstacles and pitfalls in the way of systematic environmental assessment even of well-established energy technologies, as described in Section 2 above, are especially formidable when one considers technologies deployed so far only on a small scale or not at all. Nevertheless, the framework provided facilitates asking some of the right questions about environmental impacts of the "soft" and "transition" technologies, and consideration of the criteria proposed for evaluating severity permits at least some tentative conclusions.

A listing of impacts of possible importance identified in this and previous studies of alternative energy technologies is given in Table IX-5. In what follows, I compare some of the principal soft and transition energy options to more traditional energy supplies with respect to some of the major categories of stresses/responses outlined in Section 2: land use, water use, use of nonfuel materials, occupational accidents and disease, risk to public life and limb through small accidents, risk of large accidents and sabotage, effects of routine emissions on public health, effects on climate, ecological effects, aesthetic effects, and military threats.

9.3.1 Land Use

Real land-use effects of dispersed nonelectric energy options are difficult to pin down persuasively. It is often asserted that solar heating and cooling, including passive systems, will have the significant land-use impact of encouraging urban sprawl, because these systems favor a high surface-to-volume ratio and wide spacing between buildings to minimize shading and other interference. Lovins (1977) has argued

Table IX-5

Some Possible Environmental and Social Impacts of Alternative Energy Sources*

ACTIVE/PASSIVE SOLAR HEAT/COOL	passive	active heat	active cool
construction materials--resource demand & pollutants from their production	x	xx	xx
accentuation of grid peak in poor weather	x	x	
relatively high land use to minimize shading	x	x	x
accidents/injuries in rooftop collector maintenance		x	x
leaks of working fluid - health(?) & property damage		x	x
leaks of storage medium - property damage		x	x
removal of shade trees		x	
aesthetic intrusion		x	x
water use for cooling			x
ON-SITE/CENTRAL WIND SYSTEMS		on-site	central
land use for low interference & transmission grid		x	xx
aesthetic intrusion		x	xx
accident risk - sudden blade failure		x	x
bird catching		x	x
TV interference		x	x
aircraft navigation hazard			x
microclimate effects thru energy extraction & redistribution			x
WASTE/FARM BIOMASS SYSTEMS	waste	fuel farm	electricity farm
impacts of transportation in collection	x		
land use for collection		xx	xx
land use for transmission grid			xx
fertilizer and pesticide effects		xx	xx
irrigation water		xx	xx
particles, NO_x, CO, HC from combustion	xx	xx	xx
explosion in gasifier	x	x	
fire in fuel storage	x	x	x

*Two x's mean there is a reasonable probability on present evidence that the problem is serious.

Table IX-5 (continued)

GEOTHERMAL HEAT/ELECTRICITY	heat	electricity
land use for harvesting - subsidence	xx	xx
land use for transmission grid	x	xx
water consumption for cooling		xx
salts - water pollution	xx	xx
H_2S - air pollution	xx	xx
noise		x
SMALL/LARGE HYDROELECTRIC DAMS	small	large
significant evaporation loss of water	x	xx
loss of flowing river habitat/recreation	xx	xx
potential for catastrophic dam failure	x	xx
land use/population displacement	x	xx
DISPERSED/CENTRALIZED FLUIDIZED BED COAL BURNERS	dispersed	centralized
mining impacts	xx	xx
noise & accident risk in coal distribution	xx	x
water use for cooling	x	xx
air pollution from combustion	xx	xx
land use for electricity transmission		xx
INCREASED END-USE EFFICIENCY		
materials substituted for energy--resource demands & pollutants from their production	x	
aggravation of indoor air pollution through reduced ventilation	x	
smaller cars → higher fatality rates	x	
user must think more about details	x	

that this problem is much smaller for the neighborhood-scale systems now receiving increased attention than for individual-building units, inasmuch as (a) if each building does not need its own collector, the high surface-to-volume criterion does not apply, and (b) most existing neighborhoods, even in densely populated cities, have enough large surfaces with good sky exposure (e.g., roofs of schools, parking garages, hospitals, shopping centers) to accommodate the needed neighborhood-scale collectors. (This question deserves more systematic attention from professionals in urban design and planning, working with solar specialists.) Land-use for neighborhood storage of solar energy in, e.g., large (thousands of cubic meters) insulated water tanks may be a problem in already built-up urban regions, where even the small amounts of land needed for this purpose are likely to be scarce and expensive. In new communities, such storage could be designed in with negligible land-use impact.

To the extent that dispersed solar heating and cooling systems are deemed to have some residual adverse land-use impact through encouragement of sprawl, it may be noted for symmetry that another "appropriate" technology--district heating using heat from small-to-medium-scale electricity generators fueled by coal or biogas--has the opposite (beneficial) effect; it would encourage clustered, high-density housing to minimize heat losses in distribution. The question in communities already built up is whether the rather modest land requirements for the district generators themselves (and their fuel storage) could be found at all. Again, as with solar-energy storage, in communities designed from scratch this should pose little problem.

The first-order land-use impact of supplying fuel by biomass in the form of waste materials is small and in some cases even beneficial. In the case of sewage, municipal garbage, agricultural wastes, and forest and lumbering waste, of course, the land producing the primary "resource" is under intensive use whether the resource is harvested for energy or not; incremental land-use for collection and transportation is modest (municipal garbage, for example, must be collected anyway); and only the land-use needed for conversion to a convenient fuel is of importance* (existing distribution systems for gaseous and liquid fuels presumably can be used). There is some solid or sludge residuum from waste conversion that requires land for disposal, but this requirement in most cases is smaller than that which would have arisen from proper disposal of the waste had the energy content not been harvested--hence the potential land-use benefit from deriving energy from biomass in the form of waste.

Larger uses of land for production of heat and fuel arise from geothermal heat systems (100 to 200 km^2 per quad per year, based on dry steam from the Geysers and neglecting distribution losses; Pigford et al., 1974) and biomass plantations (30,000 km^2 per quad per year for eucalyptus in California, at 1% sunlight-to-biomass and

*I did not find any data on land requirements for biogasifiers or liquid fuel plants of various types and sizes in the time available, but such data should be obtainable. A relevant comparison would be with oil refineries (about 15 km^2 per quad per year for 500,000 bbl/day refineries operating at 92% capacity factor), and to some extent oil fields (30 km^2 per quad per year) and pipelines (170 km^2 per quad per year at 1970 U.S. average oil transport by pipeline) (Pigford et al., 1974).

0.55 biomass-to-fuel; see Chapter V in the present project). Strip mining wester coal for gasification or liquefaction, for comparison, would use 30 to 100 km^2 per quad at 5000 to 10,000 tons of lignite or subbituminous coal per acre and 0.65 coal-to-fuel conversion. To put this on a comparable basis with area per quad per year (as computed for renewables), one can assume a mean time for reclamation of 10 years and derive a figure of 300 to 1000 km^2 per quad of coal-based synfuel per year. A 100-year reclamation time would give 3000 to 10,000 km^2 per quad per year.

Geothermal heating of buildings is most feasible if the system is built in when the community is built, and in this case the land-use impact of the (presumably underground) steam pipes would be small. Biomass plantations would require transportation of the fuel products by pipeline or truck from the conversion site to some input point to the existing fuel distribution networks, but the incremental land requirements for this step should be small compared to the growing area.

In the case of electricity, all central generating systems make significant demands on land in the form of transmission grids connecting plants and load centers. Around 1970 the land occupied by transmission lines in the U.S. (60 kilovolts or greater) amounted to 60 km^2 per electrical gigawatt (GWe) of installed capacity (using an industry-wide average land requirement of 13.3 acres per mile of right of way; Pigford et al, 1974). This land is not completely excluded from other uses, however. Farming, grazing, and some recreation goes on under transmission lines and will continue to unless the high electromagnetic fields that exist there are eventually shown to be harmful.

A solar-thermal-electric power plant using the central receiver concept would require 20 to 40 km^2 of land area for 1 GWe of intermediate-load (6 to 12 hours/day) generating capacity and perhaps 50 to 100 percent for more for this amount of baseload capacity (Davidson and Grether, 1977). The actual collector areas would be 0.25 to 0.50 of these land areas. A system of large wind generators equivalent in annual electricity output to a 1 GWe plant operating at 65% capacity factor (5700 GWh/yr) would occupy 1300 km^2 of land* in the better wind provinces in California, if spaced (to avoid interference effects) on a lattice of equilateral triangles whose sides equal 10 blade diameters (from data in Chapter V of this project). At this spacing the land would be far from fully occupied, and it would be usable for other purposes not ruled out by some residual chance of missiles from sudden blade failure on a windmill. The land-use requirement for geothermal steam-electric power production at the Geysers is 20 to 35 km^2 per GWe of base load capacity (capable of delivering somewhat more than the 0.65 GWe-yr per year of a typical 1 GWe coal or nuclear station). For comparison, surface-mined western coal feeding conventional coal-fired generating stations would disrupt 1.5 to 5 km^2 of land to generate 0.65 GWe-yr, which means a steady-state "reservoir" of disrupted land of 15 to 50 km^2 per GWe of installed baseload capacity, if the mean reclamation time is 10 years.

The amount of land occupied by the reservoirs behind hydroelectric dams varies greatly from site to site; the present average in California

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* The actual peak power from those windmills would be greater than 1 GWe and the operating hours per year less than 5700.

is on the order of 200 km^2 of reservoir area per currently installed GWe of generating capacity. A simple geometric argument suggests that the area covered per unit of capacity will be somewhat greater for a typical large dam (i.e., high one) than for a typical small one.*

Use of biomass plantations for generating electricity, as opposed to making portable fuels, seems too foolish an idea to be seriously entertained. If plantations are used at all, we will almost certainly need the fuel much more than the electricity, considering the relative abundance of alternative ways to get the latter; and the land-use requirement for an "electricity plantation" in California would be on the order of 2000 km^2 per GWe if eucalyptus biomass capturing 1 percent of incident sunlight could be converted into electricity at 25% efficiency.

9.3.2 Water Use

Under this heading I consider only consumptive use of water, that is, uses that either cause water to be evaporated and thus lost for the time being from surface and groundwater flows and reservoirs, or that so pollute the water that it cannot be allowed back into the normal hydrological cycle except by evaporation (e.g., in tailings ponds). Nonconsumptive water use with return of (perhaps somewhat polluted) water to surface flows is another matter and is considered briefly under "emissions" below.

For passive solar heating and cooling of buildings, and for active heating, the only significant consumptive water use is that which is

* For simple topography, area increases with the square of the dam height, but generating capacity only with the first power of height; hence the ratio of area to power should increase proportional to the height. This is probably compensated only partly by the weak increase of turbine efficiency with head.

associated with the extraction of the extra raw materials used to construct these systems, and in the fabrication/construction process itself. I have not seen or done a detailed analysis of the quantities of water involved, but simple arguments suffice to show that they must be much smaller than, say, the water needs for cooling an electric power plant whose output performed the same heating and cooling functions.* Leaks from pipes and storage systems would certainly be negligible as demands on water resources. For solar-driven absorption air conditioners, on the other hand, wet cooling towers appear to be necessary (Simmons et al, 1977). If such a system extracts an amount of heat equal to that supplied by the sun and rejects the total by evaporation in a wet tower, the water use will be 40 liters per hour for a 2-ton (24,000 Btu/hr) air conditioner. (This is comparable to what would be evaporated at a wet-tower-cooled nuclear power plant driving ordinary compression air conditioners, on a per-unit-air-conditioning basis.) District heating with geothermal energy should entail no significant consumptive water use, except during venting at the beginning of each well's life.

Production of fuels from waste biomass entails some consumptive use of process water, but I have not yet found data on how much. Fuel production on irrigated biomass farms would be very water-intensive, about 30 x 10^9 cubic meters per quad of fuel assuming eucalyptus irrigated

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* The main argument goes as follows: Many net energy analyses have shown that the energy investment in materials and fabrication for solar heating systems is paid back in a year or two, hence represents perhaps 5 to 10 percent of the useful energy delivered by the system in its lifetime. An upper limit on consumptive water use in the materials and fabrication steps is probably obtained if one assumes all the energy used in these steps evaporates water. This means the water use for materials and fabrication does not exceed an amount that could be evaporated with 5 to 10 percent of the collector's useful output. An electric power plant with a wet cooling tower, by contrast, evaporates water with about <u>twice</u> its useful energy output.

at 3.5 feet per year.* For comparison, consumptive water use in oil refineries ranges from 2×10^7 m^3/quad (newest designs) to 4×10^8 m^3/quad (older refineries) (Pigford et al., 1974); consumption of process water for coal gasification and liquefaction processes appears to be in the range of 1×10^8 to 5×10^8 m^3/quad (Newkirk, 1976; University of Oklahoma, 1975), which dominates the maximum of 1×10^7 m^3/quad needed to mine and clean the coal feed (Pigford et al, 1974).

Of electricity-producing systems considered here, wind systems have the smallest consumptive water use, theirs being restricted, in both the dispersed and the centralized modes, to the modest water requirements of construction materials and fabrication. All thermal electricity generating systems, by contrast, have very large water consumption if they must be cooled evaporatively. Assuming a central-receiver solar-electric system can achieve the thermal-to-electric conversion efficiency of a light-water reactor (32%) its consumptive water use in a wet cooling tower would be the same as the LWR's, at about 2.5×10^7 m^3 per GWe-yr (counts evaporation and drift but not blowdown, which is returned with some contamination to surface water; Pigford et al. 1974). This is about 2.5×10^8 m^3 per quad of energy input to the boiler, and 1.6×10^7 m^3 per plant-year at 1 GWe and 0.65 capacity factor. Once-through cooling reduces the evaporative water loss by a factor of about two** but is not likely to be available at many solar-power-plant sites in California. Dry cooling towers can reduce this loss essentially to zero, but at some penalty in construction cost and power-plant performance;

*Of course, the formidable water requirement of land-based biomass plantations would not exist for offshore salt-water systems—kelp seems the main possibility—if these were to prove feasible.

**The loss is still so high because of enhanced evaporation from the heated plume.

the performance penalty is especially severe (but perhaps not intolerable) in the hot climates where solar-electric plants are otherwise most interesting.

Geothermal electric power plants operate at a thermal efficiency of only about 15 percent, owing to the relatively low temperature of the geothermal steam; hence the evaporative water loss for wet cooling is very high--about 6×10^7 m^3 per GWe-yr, or 4×10^7 m^3 per 0.65 GWe-yr. At the Geysers, the condensate from the geothermal steam itself is evaporated, so the consumptive water use is not a drain on other supplies. At more advanced plants this probably will not be done, however, owing both to the threat of subsidence if condensate is not reinjected* and to the pollutants, notably ammonia and hydrogen sulfide, released if the geothermal steam itself is evaporated. Such advanced, closed-cycle plants would have to place the full burden of their evaporative cooling requirements on surface water; they almost certainly could not use dry towers because the fractional performance penalty on their low-temperature steam turbines would be too great.

Although hydropower is not a thermal generating system, its water use is not negligible. The evaporation losses from California's reservoirs at their normal levels have been estimated by Hagan and Roberts (1973) as 1,600,000 acre-feet per year. With a normal year's hydropower output of 4.6 GWe-yr this figure translates to about 4×10^8 m^3/GWe-yr.** This is only about 5 times smaller than the staggering

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*About 15% is reinjected at the Geysers.

**It is somewhat unfair, of course, to charge all of California's evaporative reservoir losses to hydropower, because (a) most of the reservoirs in question serve other functions, such as irrigation and flood control, as well as power generation, and (b) the evaporation losses are smaller than what would be lost to human applications during the flood season if the dams did not exist. The last point leaves aside the positive ecological functions of floods.

amount of water that would be needed to irrigate the eucalyptus to generate a GWe-yr of electricity in a wood-burning power plant, which as already noted seems the epitomy of foolishness.

9.3.3 Use of Nonfuel Materials

The use of nonfuel materials--steel, aluminum, concrete, glass, plastics, and so on--is important not only as a drain on resources for which there may be competing needs but also as a source of occupational accidents, emissions, and other environmental impacts in the extraction and processing of the materials. Some numbers for basic materials requirements for the production of selected energy supply technologies of roughly equivalent production capacity are given in Table IX-6. It should be noted that any central-station electricity system will have a substantial materials requirement for its transmission grid--concrete for transmission-tower foundations, steel for the tower structures, copper or aluminum for the cables.

It has been suggested that the materials requirements for a grid of wind generators would be similar to those of a transmission grid needed for a remotely sited nuclear power plant of about the same capacity (Ryle, 1977). Hydroelectric dams doubtless vary significantly in their requirements for concrete and steel per unit of generating capacity, depending on site and construction method; no survey has been attempted here. Since the best hydro sites in California have already been exploited, it is probably fair to assume that any future ones will be more materials-intensive per unit of capacity than the existing average. Geothermal plants are probably considerably less materials-intensive

Table IX-6

Some Materials Requirements for Energy*

	rooftop flat-plate collectors	central-reciever solar electric**	light-water reactor**
steel	2000 - 4000	10,000	700
concrete	none	40,000	3000
copper	2000 - 4000	modest	modest
glass	5000 - 15,000	1000	negligible

*Thousand metric tons per quad per year of useful heat or, for electric systems, per quad per year of fossil-fuel-equivalent input to electricity generation.

**Power plant only; excludes transmission grid.

Sources: Calculated from data in Caputo (1977), Davidson and Grether (1977), Office of Technology Assessment (1977).

than the nuclear plant described in Table IX-6, having no need to contain particularly high above-ground pressures or energetic missiles. Systems for harnessing biomass from waste should not be more materials-intensive than analogous facilities handling oil and natural gas; in the specific case of energy recovery from municipal garbage there may be a net materials benefit, owing to ancillary recovery of steel and aluminum when combustibles and noncombustibles are separated. Biomass plantations on the other hand, would be materials intensive in one important sense: the heavy demands likely to be made on fertilizer and chemical pesticides under pressure to maximize yield per unit area.

A more systematic and quantitative survey of materials requirements for energy than has been given in this brief survey should not be difficult and would be one logical piece of a continuation of the present work.

9.3.4 Occupational Accidents and Disease

For passive and active solar heat and cool, and for on-site wind systems, the main occupational accidents and disease that must be considered are those that arise in the production of the needed raw materials and their fabrication into energy systems. It should be possible to arrive at an estimate of the size of these effects by collecting data from the major materials and fabrication industries involved, but I have not found or performed such an analysis for this report.* Some accidents during installation

* One can easily reach the preliminary conclusion, based on the materials numbers presented in Table IX-6, that occupational hazards in extracting these materials will be smaller than those associated with mining coal for an equivalent amount of energy. Producing a quad of coal per year for 25 years means mining a billion tons of coal. The materials-intensive central-receiver solar plants of Table IX-6 require (assuming 25-year lifetime and use of the minimum grades of ores now mined), on the order of 100 million tons of ores and other raw materials to produce an equivalent amount of energy.

and professional maintenance of the systems must also be expected; data from the roofing industry might be relevant.

For central-receiver solar power plants, one analysis (Caputo, 1977) gives an estimate of 7.7 premature deaths due to materials acquisition and construction per GWe of solar capacity, versus 2.3 such deaths for nuclear and 1.8 for coal-fired capacity. Person-days lost (PDL) to nonfatal illnesses and accidents in materials acquisition and construction are estimated in the same study to be 50,000 for solar, 9000 for nuclear, and 6600 for coal, per GWe of capacity. (This assumes 50 PDL lost per injury and nonfatal illness, except cancer which counts 100 PDL.) The occupational PDL in operating the coal plant over its lifetime, however, in which the main contribution is accidents and illnesses befalling coal miners, are given by this study as 300,000 to 900,000. (This includes accidental and other premature deaths valued at 6000 PDL per death.) The range given for operating a nuclear power plant over its lifetime is 23,000 to 61,000 PDL. (The details of the calculations for coal and nuclear are given in Smith, Weyant, and Holdren, 1975.) The solar plant probably would have much smaller occupational effects than these in routine operation, although without experience no definite figure can be given.

No data on occupational risks associated with central-station wind, hydro, or geothermal electric systems have been assembled or derived for the present report. The absence of both noxious chemicals and steam in the cases of wind and hydro suggests their occupational hazards after construction will be relatively small, although falls in maintenance are a possibility in both cases.

Production of fuel from waste biomass would involve some presumably modest occupational risks in collection and separation, as would biomass plantations in cultivation and harvesting. Both would perhaps entail some exposure to noxious compounds at the gasification or liquefaction stage, and this potential problem bears closer investigation. No quantitative estimates are offered here. It may be noted in passing that synfuels production from coal is now thought to entail a high probability of significant occupational exposure to carcinogens.

Despite the uncertainties, none of the occupational hazards associated with "soft" technologies seems likely to approach those of mining and processing coal. At the same time, it should be noted that the hazards of the workplace in general, in the energy industry and in others, are often inexcusably high--by which I mean reducible by modest investments of diligence, technology, and money (Ehrlich, Ehrlich, and Holdren, 1977, Ch. 10). Comparisons of one energy source with another on the criterion of occupational hazards tend to illuminate not so much the intrinsic characteristics of the processes as the most urgent needs for correction of past inattention.

9.3.5 Risk to Public Life and Limb from Small Accidents

It is sometimes suggested that large numbers of people will be killed or injured falling off their roofs while trying to clean or repair their solar collectors. This seems one of those problems highly amenable to both technical and social solutions: collectors on sides of buildings or otherwise accessible from ground level, long-handled sponge-mops, neighborhood systems maintained by professionals, service contracts with professionals for individual rooftop units. Most of us have learned not to try to repair our own gas furnaces, after all, and if those collectors that must go on roofs prove as dangerous as some people think, we will learn to hire professionals to fix them, too.* (The professionals' risk was mentioned in the previous section, and presumably is amenable to being estimated quantitatively from experience with other rooftop work.)

Another question of some interest is how safe the modern, high-speed windmills will prove to be, in terms of sudden failures in which a blade or a piece of one breaks off and becomes a missile. Large margins of safety should not be hard to achieve technically, but pressures to make windmills less expensive and more efficient push in the opposite direction. If this is a safety problem at all, it is bigger in the decentralized mode, in which the windmills are where the people are. Of course, it would still be a big economic problem if it were a regular occurence in a system of large windmills remotely sited.

Neighborhood biogasifiers may be capable of malfunctioning in ways that permit an explosion. I have not seen an analysis and do not offer any here.

Perhaps the most important kind of small accident across the spectrum of energy supply alternatives is the class associated with the transportation of fuel. The public damages from collisions between coal trains and automobiles at grade crossings have been estimated (Smith et al., 1975) as 74,000 person-days lost per 1 GWe-plant lifetime (equivalent to 25 years' operation at 0.65 capacity factor). This suggests grade crossings should

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* Lovins' criteria of decentralization and comprehensibility clearly do not mean everyone is required to repair his/her own energy system, but only that there are advantages of more individual control and understanding of where the energy is coming from, compared to the situation with many "hard" options.

be made safer, but also makes one ask what the numbers would be for trucks hauling biomass to conversion sites or coal to neighborhood fluidized-bed combustors. (As noted earlier, of course, much biomass waste would have to be collected and transported in any case, even if the energy content were not being reclaimed.) Some rough numbers presumably could be derived without much difficulty from U.S. and/or California transportation statistics.

9.3.6 Risk of Large Accidents and Sabotage

Any large electric power plant and any electricity grid is subject to accidents, natural disasters, or sabotage, the end result of any of which may be serious damage to the facilities themselves and at least temporary loss of electric service to a large number of customers. For the purposes of the present discussion I exclude such events--they and their counterpart risks in decentralized systems are considered elsewhere in this project under reliability. Here I consider only events with the potential to kill and injure large numbers of people outright as the direct consequence of damage to the facility, as distinct from loss of electric power. I define a "large" accident/disaster somewhat arbitrarily as involving more than 10 public deaths at one time and place.

By these groundrules, few of the technologies based on renewables pose significant problems, the notable exception being hydropower. The sudden failure of even a small hydro dam can produce a flood killing some scores of people, under adverse circumstances, and estimates of the possible death toll from the failure of one of the larger and more adversely situated dams in California (e.g., Folsom Dam, above Sacramento) run into the hundreds of thousands (Okrent et al., 1974).* This is at least comparable to the worst disasters envisionable with the nonrenewables: major accident or sabotage at a large, poorly sited nuclear reactor; explosion of an LNG tanker in a big-city port; fire at an oil refinery under inversion conditions near a population center.

Conceivably, large windmills could be "aircraft catchers" as well as "bird catchers", presumably mainly in bad weather. Working out the odds that an airliner that would have missed the mountain will fly into the windmill may occupy the devotees of probabilistic risk analysis for some time.

On a much smaller scale, the catastrophic failure of a very large windmill in a densely populated region conceivably could kill more than 10 people, but such siting seems unlikely. Conceivably, too, gas produced from biomass and stored in a large quantity in a city could explode and kill some tens of people, as has happened on rare occasions with natural gas.

9.3.7 Effects of Routine Emissions on Public Health

Under this heading I consider damages to public health from the direct toxic effects of air and water pollutants on people. The possibility of effects in which damages to public health result from damages done by effluents to environmental processes is discussed below under other headings. Of greatest concern in the present subsection are causation and aggravation of respiratory disease and aggravation of heart disease by air pollution, and carcinogenesis, mutagenesis, and teratogenesis

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* I do not find these estimates completely convincing, but neither have I seen any substantial attempt to refute them.

(production of cancer, genetic effects, and birth defects) by pollutants in air, water, and food.

The most important air pollutants in terms of respiratory disease and heart disease appear to be particulate matter, oxides of sulfur, oxides of nitrogen, and carbon monoxide. Representative values of emissions of these pollutants (including from acquisition of materials and construction of facilities) for several alternative and conventional energy systems are shown in Table IX-7.

That solar systems have a large advantage over the fossil fuels with respect to oxides of sulfur and nitrogen is apparent from the table. There is, however, also an advantage that is not apparent, in the case of particulate matter. Specifically, the particles produced in the acquisition of raw materials have a size distribution centered around very large particles, which neither remain very long in the atmosphere nor pose a large health hazard while there, because they do not penetrate far into the lung. The particles which escape the control systems in fossil-fuel plants, by contrast, are mostly "fines" of diameter 1 micron or less. These have a very long residence time in the atmosphere, do penetrate readily deep into the lung, and tend to carry a high concentration of toxic heavy metals; they are far more dangerous on a per-unit-mass basis than the particulates released in the production of solar equipment.

The high entry in the table for geothermal's sulfur emissions is also somewhat deceptive. These emissions are in the form of H_2S, which is much easier to scrub than is SO_2. The quantity emitted is large mainly because no serious attempt has been made to apply technologies that could reduce it.

Table IX-7

Some Major Air Pollutants from Energy Systems*

	particulate matter	oxides of sulfur	oxides of nitrogen	carbon monoxide
flat-plate solar collectors	20 - 30	10 - 20	7 - 20	3 - 6
geothermal electric[b]	0	600[c]	0	0
central-receiver solar electric	20 - 90	20	10	3 - 80
coal electric w. scrubbers	20 - 700	70 - 700	200 - 500	10 - 40
electricity from residual fuel oil	5 - 40	40 - 700	100 - 200	10 - 20

*Lifetime emissions, including construction[a], for 1 GWe at 0.65 capacity factor for 25 years, or its thermal equivalent assuming 0.32 thermal-to-electric conversion. Units are thousands of metric tons, rounded to one significant figure.

[a] Neglects construction of transmission grids.

[b] Geysers; does not include construction.

[c] Emitted as H_2S; converted here to equivalent tonnage of SO_2.

Sources: Calculated from data in Caputo (1977), Smith et al. (1975), Davidson and Grether (1977), Pigford et al. (1974), Office of Technology Assessment (1977).

Translating the foregoing kinds of emission figures into estimates of illness and premature death among members of the public is a largely unsolved problem, as noted above in Section 9.2. The most substantial attempts have considered only oxides of sulfur in the presence of particulates, and the uncertainty range covers more than two orders of magnitude (e.g., from 3 to 600 premature deaths per 1 GWe-plant lifetime, in the case of coal with sulfur scrubbers; Smith et al., 1975). Some oxides of nitrogen are suspected mutagens or pre-mutagens (i.e., they are converted into mutagenic compounds by chemical processes within the body), and some hydrocarbons and some heavy metals present in particulate matter are known or suspected carcinogens. None of this can yet be sorted out quantitatively. (For a review of current knowledge of mutagenesis, carcinogenesis, and the likely relation between the two, see Ehrlich, Ehrlich, and Holdren, 1977, Ch. 10.)

There are many forms of waste and plantation biomass and many ways to convert and burn it. All will produce some air pollution, including perhaps some exotic and worrisome hydrocarbons. As seems to be the case with synfuels from coal, it may be possible to keep the nastiest compounds in the conversion plant while producing relatively clean fuel for distribution, thus reducing disease effects in the public at the expense of the workers.

The fluidized-bed coal systems, which in small sizes might be used for decentralized electricity generation and district heating, are said by their proponents to have the potential for very low emissions. Others argue that air pollution from any kind of combustion will always be easier to control, monitor, and regulate at a few large sources than at many small ones; hence, that if small fluidized beds are a good idea, big ones will be better. If air pollution were one's only criterion for deciding on scale, this might be so; but even then one would have to look at the relation between scale and the total amount of fuel burned. If decentralization permits utilizing heat that otherwise would be wasted, total air pollution can go down even as air pollution per unit of fuel burned goes up.

In the same connection, it would be nice to know quantitatively how disease effects vary with the way a given amount of effluent is released over a given population; i.e. from a few big sources or many small ones. To do this problem requires good dispersion models, which are becoming available, and rather good information about the shape of dose-response curves, which is not.

Analysis of energy-related damage to public health through water pollution is in even poorer shape than the analysis of air pollution's effects. Qualitatively, one knows that, among standard technologies, the effects on water quality of coal mining and oil refining are especially severe. Of the newer or renewable technologies, geothermal systems and biomass plantations are likely to have big effects (the latter through pesticide and fertilizer residues); materials acquisition for solar facilities should have moderate to small effects; and wind and hydro systems should have small effects. Utilization of some forms of biomass will have water-quality benefits.

9.3.8 Effects on Climate*

Energy systems are capable of influencing climate mainly in the following ways: (a) altering the properties of the atmosphere with respect to transmission and absorption of solar and terrestrial radiation, by influencing the atmospheric concentrations of particulate matter, water vapor, carbon dioxide, and other gaseous compounds and aerosols; (b) altering the properties of the surface-atmosphere interface with respect to moisture-transfer and energy-transfer properties (e.g., evaporation rate, absorptivity and reflectivity, frictional energy-transfer properties), by means of e.g., terrain modification, vegetation removal, construction of strucures and pavement, and oil spills; (c) adding to climatological energy flows a quantity of energy mobilized from long-term storage (fossil and nuclear fuels, geothermal heat in excess of natural flows); and (d) redistribution of natural energy flows in space, time, and character, by converting and releasing, in one pattern of locations, times, and forms, energy flows that in the natural climatological system would have been converted and released in a different pattern.

Phenomenon (c) is a property of nonrenewable energy sources, phenomenon (d) is a property of renewable ones. Whereas (c) is probably already significant in urbanized regions on a scale of up to 10^5 km^2, (d) is presently significant at most on a much more localized scale, owing to the relatively small role of renewables in civilization's present energy use. Both could become significant globally if energy use increased by a very large factor.** Although (c) can produce global average warming and

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* The best review of energy's effects on climate is that of the CONAES working group on this topic (Schneider et al., 1977). See also SMIC (1971).

** Whether a factor of 10 (from 8 thermal terawatts to 80) would be enough is uncertain, but a factor of 100 certainly would produce significant global effects.

(d) cannot, this advantage of renewables has probably been overstated in the general debate. Anthropogenic changes in large-scale circulation patterns are more important and more imminent than anthropogenic changes in global average temperature, and these could be produced by (c) or (d), that is, by nonrenewables or renewables. For the long time frame in which such changes are plausible at all, however, one can say flatly that dispersed renewables would create much smaller problems in category (d) than would centralized renewables.

In the shorter term, effects in categories (a) and (b)--which in general can be created by renewables and nonrenewables, dispersed and centralized, are much more important than effects under (c) and (d). The only possible significant effects of human energy technology on climate on a scale bigger than about 10^6 km^2 at present arise from these first two categories. The main such effects are those of CO_2 and particles from combustion (category a) and surface/vegetation modification by agriculture, a "solar" energy technology of sorts (category b).

The other solar technology with the highest potential impact on climate is the one most resembling agriculture--namely, biomass plantations. These could alter the surface reflectivity, aerodynamic roughness, and moisture-transfer properties over very large areas, and the conversion and combustion of the photosynthetic product would produce particles and gaseous contaminants that could become particles. Use of biomass in the form of waste would also produce air pollutants capable of affecting climate, but without the large-scale surface modification of plantations. The effect of biomass harvesting on atmospheric CO_2 should be minimal; carbon dioxide would be removed from the atmosphere during growth and added in equal quantity upon combustion. The present evidence is that climatic effects of particles from energy technology are and will be local to (perhaps) regional, not global as is the case for fossil-fuel produced CO_2.

The principal climatic effects of hydropower arise from an enormous increase in evaporation rate over the surface area covered by the reservoir and the attendant increase in humidity in its vicinity. These effects are local to regional, the latter only in the case of very large reservoirs. In the case of remote hydropower with long-distance transmission to load centers, there is a potential effect through spatial redistribution of a natural energy flow, but the limited potential of hydropower in absolute magnitude guarantees that his effect will remain small.

Central-station solar power plants would alter surface properties, particularly absorptivity of incident energy and moisture-transfer characteristics, over areas that are significant although smaller than for biomass plantations and hydropower (see section on land use, above). The effects would be local to perhaps regional in the event of large-scale solar development in desert areas. If very lare-scale development of centralized solar systems were to take place, the effect of spatial redistribution of natural energy flows might become appreciable. Dispersed solar systems would have much smaller effects in two respects: the systems would be added for the most part to surface environments already highly modified compared to natural conditions (i.e., urban regions), and the energy would be used near the collection site, make redistribution effects minimal.

Harnessing windpower on a large scale clearly could have climatic effects on a local and eventually regional scale, by virtue of extracting energy directly from the atmospheric circulation and releasing it in a different form (and, in the case of centralized systems, redistributing it spatially). At levels of wind power extraction that seem conceivably achievable over the next several decades, the effects are likely to be negligible. But it must be admitted that knowledge of atmospheric kinetics is sketchy, and more careful analysis of potential effects of wind power is called for.

Geothermal systems of the type now in use in California (dry steam at the Geysers) are qualitatively similar to the use of fossil fuels in their main potential climatic effects. The Geysers plant releases CO_2 from long-term storage, although at a level about 10-fold lower than a coal plant generating the same amount of electricity. The emissions of ammonia, hydrocarbons, and sulfur compounds, which can form atmospheric aerosols of climatic significance, are comparable to or greater than those from an oil-refinery/residual-fuel-oil-power-plant combination producing the same electrical output (Pigford et al., 1974). Emissions characteristics of other geothermal systems were not reviewed for the present paper.

Any coal-burning system, dispersed or centralized, contributes to the global climatic risk associated with increasing the reservoir of CO_2 in the atmosphere. Oil and natural gas are only modestly better in this respect on a per-unit-energy basis. The CO_2 emissions for all the fossil fuels are much to big to control--two to three tons of CO_2 per ton of fuel, with fuel use running in the millions of tons per GWe-yr. Emissions of particles from fossil-fuel burning (which as noted above may be of local climatic significance) are much more susceptible to control than are emissions of CO_2, except that the smallest particles (diameter $<$ 1 micron) largely escape--and they are precisely the ones of greatest potential climatic significance.

As noted in the previous subsection, sizable quantities of particulate matter and other air pollutants that can become particulates are produced in connection with materials acquisition and fabrication operations for some of the solar-based technologies, notably flat-plate collectors and central receiver power plants. The massive particles from these operations are of little significance for climate because of their short residence time in the atmosphere, and the particle-forming gases, of which the most important is SO_2, are produced in considerably smaller quantities than in the combustion of coal and oil (refer to Table IX-7).

Finally, the concentrated release of heat itself at any central-station thermal power plant is a potential source of local climatic effects. ("Power parks" of the sort envisioned by some for nuclear power conceivably could produce regional effects by this mechanism.) The size of this input is a simple function of the thermal-to-electric conversion efficiency, η. Specifically, waste heat per unit of electric output varies as $(1 - \eta)/\eta$. This means the impact rises drastically as efficiency falls. A geothermal electric plant with $\eta = 0.15$ releases 5.7 times its electrical output as heat; the ratio for a coal plant with $\eta = 0.38$ is 1.6. The effect is somewhat ameliorated for central-station solar plants in that some of the energy would have been absorbed by the ground and released in similar form in the immediate area even had the power plant not been there. In all cases where a wet cooling tower is used (see subsection on water use, above), the local climatic effect of the water vapor is likely to equal or exceed that of the heat itself.

9.3.9 Ecological Effects*

Concern over damage to ecosystems can arise out of reverence for nature and related ethical and aesthetic considerations, but the case for

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* By far the most thorough treatment available of the impacts of conventional and alternative energy technologies on ecosystems is Energy and the Fate of Ecosystems, Report of the Ecosystems Impacts Resource Group of the Study of Nuclear and Alternative Energy Systems (Harte et al., 1977).

taking damage to ecosystems seriously does not rest on those relatively intangible issues alone. As noted in Section 9.2, ecosystems must be recognized as providing goods and services that contribute directly and indirectly to human material well-being--goods and services which, although "free" in the strict market sense, would have to be paid for dearly if technological society had to take over their provision because of having undermined the capacity of ecosystems to provide them.

Climate change of the kinds discussed in the preceding section can impair ecosystem function, as can land-use (subsection 3.1), consumptive water use (subsection 3.2), and chemical pollution of the kinds discussed in connection with direct damage to human health (subsection 3.7). I limit myself here to features of these inputs and stresses not discussed above, including especially alteration of soil and nutrient cycles, and destruction of habitat. Direct toxic effects of chemical emissions on vegetation and animals may be expected to arise in rough proportion to the size of the emissions of human-health significance, summarized above, except for some locational effects (e.g., if mining and smelting, or geothermal operations, take place in regions particularly sensitive ecologically). No attempt has been made here to assess these possible locational effects systematically.

The ultimate consequences of damages to ecosystems include (Harte et al., 1977): decreases or greater fluctuations in the availability of food and fiber from unmanaged or lightly managed ecosystems; decrease of fertility of agricultural lands; increased incidence of human and crop diseases and noxious pest outbreaks; poorer air and water quality; greater vulnerability to fire and flood; and fewer options for future innovation and improvement of the human condition.

Of the renewable energy forms considered here, one of the most destructive ecologically is hydropower, which of course refers much more to the construction of new dams than to possible enlargement of generating capacity at existing ones. Hydro facilities drastically alter ecological systems not only in and around the area occupied by the reservoir, but in the entire river and estuary environments downstream (Harte et al., 1977; Hagan and Roberts, 1973). What disappears immediately is a form of habitat already in danger of extinction in California and the U.S. as a whole--the free-flowing river--to be replaced by habitat already present in superabundance--the hydro reservoir. Owing to the general relation between dam height and reservoir area mentioned above in connection with land use, it is a reasonable generalization (doubtless with significant exceptions) that small hydro dams are less destructive per unit of electrical capacity than large ones. (A more careful study of this point should investigate the effect of smaller dam's presumably lower capacity factor--due to smaller storage--on the conclusion.)

The other renewable resource at the top of the list of ecological threats is biomass plantations, owing not only to the large areas that would be devoted to monoculture (reducing regional biotic diversity) and the heavy consumptive water use, but also to the large quantities of fertilizers that likely would be used to maximize output and the large quantities of pesticides likely to be used to protect the monoculture from invasion and collapse. As is well known from conventional high-yield agriculture, both the pesticides and the fertilizer residues can be expected to produce significant impacts off-site (Ehrlich, Ehrlich, and Holdren, 1977, Ch. 11).

Use of waste biomass, by contrast, is likely to produce some ecological benefits related to nutrient flows. Collection and processing of crop residues to extract their energy leaves the nutrients in a more compact form than in the original residues, hence these nutrients are more likely to be redistributed to the fields (reducing the need for inorganic fertilizers).

Collecting and processing of feedlot wastes keeps them out of waterways, reducing an important contributor to eutrophication.

While present practice in geothermal development produces air and water pollutants in ecologically significant quantities, most of these are amenable to control by moderate changes in technology. The only situation that now appears really intractable is when the spent brine cannot be re-injected; the ecological effects suggest foregoing geothermal development when this is the case (Harte et al., 1977).

Central-station solar power plants and large wind generators share the disadvantage that they are likely to be sited in fragile and/or especially prized environments (deserts for the solar plants, coastal promontories and high Sierra ridges for the wind generators). The effects on habitat of building the associated transmission lines and access roads must also be considered.

Solar heating and cooling systems and on-site wind generators appear to be ecologically the most benign of the renewable technologies, having mainly the impacts of the associated materials production to consider; as noted earlier, these invariably are smaller than the impacts of burning fuel to provide the same useful energy. On-site wind generators may be rather devastating bird catchers, however.

For comparison, the worst offenders ecologically among conventional energy technologies are coal and petroleum-based fuels. Oxides of sulfur and nitrogen from burning both coal and oil produce acid rain, which alters the acidity of soil and surface water over large regions. Coal mining disrupts fragile ecosystems physically and chemically. Oil transport, refining, and drilling offshore threatens fragile estuarine and coastal ecosystems with construction of facilities and with oil leaks and spills. Nuclear power, by contrast, poses direct ecological risks much smaller than those of other conventional energy technologies and comparable to those of some of the better renewables. Areas required for mining are smaller than for coal (although this could worsen if very low quality uranium ores such as the Chattanooga shales eventually were used in light-water reactors); there is no contribution to acid rain; and ecosystems are appreciably less sensitive to radioactivity and radiation than are people (Harte et al., 1977). Nuclear's high consumptive water use for evaporative cooling (subsection 3.2) can pose ecological problems where water is scarce, however, and as with all central-station electricity generation the impacts of the transmission grid may be important in fragile regions.

9.3.10 Aesthetic Effects

This category is by its nature almost impossible to discuss quantitatively, and is made the more difficult because people's tastes differ as to what is ugly and what is attractive. Accordingly, only a few qualitative observations will be offered here about potential impacts on the visual environment, and even briefer comments about noise and smells.

Passive solar heat and cool seem to present only modest visual impact, since structures utilizing this approach probably will not be found unattractive by most people. Constraints on the placement of windows might be found a drawback in some situations. Active solar heat is perhaps a slightly bigger problem, to the extent that some people find rooftop, sidewall, and free-standing collectors a visual nuisance; but many will be out of sight except to aircraft. Solar cooling by absorption air conditioning is another increment worse by virtue of the necessary wet cooling system's obtusiveness structurally and the white plume of water droplets condensed from vapor that exist under many meteorological conditions. Passive solar systems are of course silent in operation; active systems should be almost so.

Heavy use of on-site wind generators could produce what approximates a forest of steel towers and whirling blades in built-up areas, presumably an even bigger blight than the forests of TV antennas that exist in many such regions now. The impact of centralized wind genrators far from load centers would also be substantial because these bigger generators could be seen from a great distance and because the windiest provinces in California are also among the most scenic. Noise effects for both dispersed and centralized wind systems would be nonzero but presumably modest. The idea that windmills were objects of aesthetic appreciation in old Holland strikes me as small consolation in the very different context under consideration here.

Hydroelectric dams and their reservoirs, although some people find them aesthetically pleasing, almost certainly should be considered to have very adverse aesthetic impacts "at the margin". That is, a new hydro facility, at this point in California's development, adds a kind of beauty (the dam and lake) that is already commonplace in the state, while destroying a kind of beauty (free-flowing river, mountain valley) that is increasingly scarce. To the extent that most people can agree on diversity as an ingredient of an aesthetically pleasing environment, this loss is surely a bad thing. The wildlife impacts of hydro development also have an aesthetic dimension. Because of the area to power relation mentioned earlier, small hydro dams probably are not as bad as big ones aesthetically, but their impact is still significant. Noise effects for hydro are negligible (except for flowing river sounds!).

Central-station solar power plants probably would be sited in desert environments considered by many people to have high aesthetic value, and the towers for the central-receiver approach would be visible for long distances in the flat desert terrain. Cooling towers and their plumes would contribute to the visual nuisance, as is probably the case for any kind of additional thermal-electric generating capacity in California. Transmission towers marching across the desert and other scenic terrain are another debit, again true of any centralized electricity-generating system, solar or not. Noise effects of central-station solar should be very modest, consisting most significantly of the crackling and buzzing of transmission lines.

Use of waste biomass as a fuel resource should have small aesthetic impact, limited mainly to the facilities where the conversion to fuel takes place and to storage facilities. There may be some aesthetic benefit to disposing of part of municipal garbage this way. Gasifiers and liquefiers for waste biomass should not be uglier, noisier, or smellier than oil refineries, but they will have to be more numerous for a given energy output. The impact of the waste-biomass system on the coastline and estuarine environments of such great importance in California should be smaller than that associated with oil and imported LNG. Biomass farms, on the other hand, have significant potential aesthetic impacts, depending on the nature of the area subjected to these intensive cultivation/forestry practices.

Geothermal systems for both heat and electricity produce a considerable visual blight over sizable areas (see subsection 3.1) and they present odor problems (mainly from H_2S) and are noisy when new wells are being vented. Additional odor problems arise when condensate from geothermal steam is used for evaporation in wet cooling towers as part of geothermal-electric operations.

Use of coal may produce significant visual impact through vegetation removal and terrain disruption in surface mining, through the intrusion onto the landscape of large synfuels plants and giant coal-electric plants with their tall stacks and plumes of particulates, and through the large cooling towers and transmission grids characteristic of centralized thermal electricity generation. Decentralized use of coal in, for example, neighborhood-scale fluidized-bed combustors producing electricity and heat will bring some of the noise, congestion, and ugliness of coal transportation and storage to built-up areas.

9.3.11 Aggravation of Military Threats

Any centralized energy system has certain vulnerabilities as a military target, but I wish to consider under this heading only active linkages of energy technology with military events. This means ways in which the use of particular energy technologies contributes to the development of military weapons or the chances that weapons will be used, that is, the chances of war.

It is in this category that the renewables have their most striking and qualitative advantage. A plausible active link to military threats has not been identified for any of them. The contrasts are too obvious to need more than enumeration here: the link of nuclear power with the proliferation of nuclear weapons, the international political/military ramifications of heavy dependence on imported oil (especially from the Middle East), and, to a somewhat lesser extent, the analogous problems that could arise if there materialized a heavy U.S. dependence on imported liquefied natural gas.

9.3.12 Summary Ranking of Environmental Impacts of Energy Supply

Nothwithstanding the many gaps in the foregoing discussion, necessitated in part by the incomplete state of knowledge on these matters and in part by the limitations of time and resources available for this work, it is nevertheless irresistible to attempt a rough, qualitative, and of course arguable ranking of energy supply alternatives in terms of the impacts considered here.

Such a ranking, embodying my own attempt to reflect the points made in this section and the criteria for evaluating seriousness discussed in Section 9.2, is presented in Table IX-8. No assertion is made here about the relative importance of the different categories of impact; a 5 (worst impact) in one category (say, occupational health) should not be considered to be necessarily an equivalent liability to a 5 in another category (say, aesthetic effects).*

*It might be of interest, however, to see what agreement could be found among a variety of analysts as to the relative weight these categories should have.

Table IX-8

Tentative Rankings of Enviornmental Impacts of Alternative Energy Technologies for California*

	LAND USE	WATER USE	USE OF NONFUEL MATERIALS	OCCUPATIONAL HEALTH	SMALL ACCIDENTS (PUBLIC)	LARGE ACCIDENTS/ SABOTAGE	EMISSIONS/PUBLIC HEALTH	EFFECTS ON CLIMATE	EFFECTS ON ECOSYSTEMS	AESTHETIC EFFECTS	DIRECT LINKS TO WAR
PASSIVE SOLAR HEAT/COOL	1	1	2	1	1	0	0	0	1	1	0
ACTIVE SOLAR HEAT	2	1	4	2	2	0	1	1	1	2	0
ACTIVE SOLAR COOL	2	2	4	2	2	0	1	1	1	2	0
SOLAR THERMAL ELECTRIC	4	3	5	2	1	0	1	2	2	3	0
ON-SITE WIND	2	0	2	1	3	1	0	1	2	4	0
CENTRAL WIND	4	1	3	2	2	1	1	2	3	5	0
LARGE HYDRO	4	5	3	1	1	5	1	2	4	5	0
SMALL HYDRO	3	4	3	1	1	3	1	2	3	3	0
BIOMASS WASTE	1	1	1	3	3	1	2	1	2	1	0
BIOMASS FARM	5	5	1	3	3	2	3	2	4	3	0
GEOTHERMAL HEAT	3	1	2	2	1	1	2	2	3	2	0
GEOTHERMAL ELECTRIC	3	4	3	2	1	1	3	3	3	3	0
COAL CENT. ELECTRIC	4	3	3	4	4	1	5	5	5	4	0
COAL FLUID BED	4	3	2	4	5	1	4	5	4	4	0
COAL GASIFICATION	4	3	2	5	4	3	2	5	4	3	0
COAL LIQUEFACTION	4	3	2	5	4	3	3	5	4	3	0
GAS DOMESTIC	2	1	2	2	2	3	2	4	2	2	0
GAS IMPORTED LNG	3	1	3	2	2	4	2	4	3	3	3
OIL DOMESTIC	3	2	2	3	3	3	3	5	4	3	0
OIL IMPORTED	3	2	2	3	3	4	3	5	4	3	5
OIL SHALE	4	3	2	4	3	3	4	5	5	4	0
NUCLEAR LWR	2	3	3	3	2	5	2	2	2	2	5

*In each category, 5 denotes the most severe impact in this category, of the technologies considered. Thus there is always at least one 5, and the other values are scaled to it. 0 = negligible, 1 = small, 2 = moderate, 3 = considerable, 4 = large, 5 = worst. The divisions are necessarily coarse; identical numbers should not be taken to mean exactly identical magnitude of impact.

9.4 SOME OBSERVATIONS ABOUT INCREASED EFFICIENCY

The preceding section considered environmental effects of specific technologies of energy supply, except for "supplying" energy by reducing that part of the energy flow through society that is not providing useful goods and services. Obviously energy conservation, which I here consider synonymous with increased efficiency in the sense just described, is not completely free of environmental effects. It can be said, of course, that the first-order environmental consequence of any measure that saves fuel is to reduce the impacts associated with getting and using that fuel--coal that is not mined, processed, and burned will use no water, deface no land, produce no respiratory disease, and so on. But the same approach--namely, counting as a benefit of one alternative the absence of the costs of the alternatives it replaces--would be equally valid for assessing the consequences of replacing coal with nuclear power. That is, one could argue that the first-order consequence of nuclear power is avoiding the consequences of using coal. It goes without saying, then, that if we choose conservation it is because we think we are replacing something worse (in the sense of the sum of economic, environmental and social costs). But to know this, we must tally up any environmental and social costs of conservation and compare them on equal footing with those of new supply.

There is, of course, one respect in which increased efficiency is always superior to additional energy supply, even if that supply comes from the hypothetical (and impossible) source that is completely free of all environmental and social impacts up to the point of end-use. This is that all the energy that is used, as well as that which is wasted en route to use, is ultimately dissipated in the environment as heat, which at some magnitude must itself become an ecological and climatological problem.

Beyond this, attention must be paid to the modes by which energy end-use is applied to the satisfaction of human wants and needs. Thus an increase in efficiency of interpersonal communication by means of substituting the movement of information electronically for the movement of people and paper is preferable to an increase in efficiency by means of improving the fuel economy of autos, trucks, and aircraft. This is so because of certain kinds of damage done by vehicles and their supporting systems, essentially irrespective of how efficient they are in their use of energy. As a perhaps more dramatic example of the need for discrimination in <u>how</u> efficiency is increased: an innovation that increased the fuel efficiency of off-road vehicles would save fuel but would probably damage wilderness (Harte et al., 1977).

I have not been able to undertake here any systematic or quantitative survey of the possible adverse environmental impacts of identified energy-conservation measures. Some impacts that have been mentioned in the literature are: district heating utilizing heat rejected from dispersed, small, fossil-fueled electricity generators may increase urban residents' exposure to air pollutants by discharging these where the people are, and because dispersed sources may be harder to control than decentralized ones; materials toxic in their production or use may be employed for insulation; indoor air pollution from fuel-burning appliances, smokers, cleaning compounds and so on may be aggravated by reduced ventilation rates; lighter automobiles may be more dangerous in accidents. Most of these seem very amenable to substantial amelioration or avoidance with a modicum of technology and good sense, (e.g., technologists already know how to make autos much lighter without making them less safe), especially by comparison with the difficulties of ameliorating, except by abstinence, some of the impacts of traditional energy sources (e.g., CO_2, proliferation).* Still, the whole area of environmental impacts of increased efficiency needs much closer investigation.

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* That sudden curtailment of energy supplies can have severe environmental and social impacts is not in doubt, but this is not what anyone sensible means by "conservation".

9.5 NEEDS FOR FURTHER WORK

This preliminary discussion of environmental impacts of alternative energy technologies has been intended to establish some semblance of a logical framework for the needed assessments and to hang on that framework some of the information that is already available. Not surprisingly, as many questions were raised as answered. Social impacts, although formally in the framework, have been treated for the most part in other segments of this project, by those more competent than I to do so. In many other areas, lack of time and resources in this preliminary phase of the work has prevented assembling and making sense out of relevant data that are easily accessible in the literature (e.g., quantitative impacts of geothermal system other than dry steam, net energy characteristics of alternative technologies).

The obvious needs for further work divide themselves into three categories: (1) problems that are easy, given modest investments of time and resources; (2) problems that are harder, but still amenable to significant illumination in the short term given somewhat greater commitment of resources; (3) important but highly intractable problems that will be on the agenda of the environmental-science community for a long time. Some examples in each category follow:

(1) easy problems (mostly literature search)

--flat-plate collectors, central-station solar, wind, hydro: fill in tabulations of materials requirements and associated water use, emissions to air and water, occupational health impacts, and compare to analogous impacts of fossil fuels and nuclear

--transmission grids: tabulate materials requirements (steel, copper, aluminum) plus occupational risks in maintenance

--maintenance of rooftop systems: investigate likely hazard of professional maintenance using data from other rooftop work

--geothermal systems: tabulate from existing studies the materials requirements, land use, water use, and emissions to air and water of all geothermal technologies plausible for California

--storage options: preliminary investigation of possible environmental effects, to identify issues and problem areas.

(2) harder, but illuminable problems

--biomass (waste): investigate land, materials, and process water requirements for waste conversion, plus likely occupational exposures to toxic compounds in operation, plus emissions to air and water in operation, plus explosion hazards

--windmills: investigate safety against blade failure (design margins, prototype experience, etc)

--transportation risks for decentralized technologies: investigate accident hazards in transport of waste biomass and coal for neighborhood combustors, using available statistics and traffic analysis

--urban solar collectors: investigate topological-geometric aspects of solar collector siting at individual-building and neighborhood scale in urban areas

--ecological impacts of energy-related chemical emissions in California: coincidence of emissions and sensitive areas under alternative scenarios

--small vs. large hydro dams: use data on existing facilities in California and elsewhere to investigate relationship of project size to effects on land use, water use, and ecosystems per unit of capacity and per unit of delivered energy (including systems effects, i.e., more than 1 dam on a river)

--end-use efficiency: survey potential environmental effects and amenability to remedy systematically

--passive solar systems; investigate materials requirements and associated impacts

--scenarios: compare principal environmental impacts in so far as possible for alternative scenarios for future pattern of energy supply and demand in California

(3) highly intractable problems

--public disease effects of decentralized versus centralized sources of air pollutants; combine computer models of effluent dispersion under real meteorological conditions with dose-response models for principal effects

--disease effects of water pollution: identify main mutagens and carcinogens and the dose-response relations

--climate effects of concentrated disruptions; improve models of meteorological phenomena to resolve effects of large area sources of heat, moisture, wind-energy extraction

9.6 A VIGOROUS ASSERTION

Notwithstanding the imposing agenda of work that lies ahead, this preliminary survey supports a strong tentative conclusion as follows: The environmental impacts of certain of the "soft" technologies--notably increased end-use efficiency, active and passive solar heating and cooling with individual building or neighbohood units, fuel production from biomass in the form of wastes, and dispersed on-site wind generators--will prove markedly smaller than those of virtually all of the traditional "hard" technologies, as well as smaller than those of the more centralized technologies for harnessing renewables.

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CHAPTER X

LAND USE CONFIGURATIONS AND THE UTILIZATION OF DISTRIBUTED ENERGY TECHNOLOGY

10.1 INTRODUCTION

10.1.1 Overview

Historically, neither the actors who have affected the form of land use development - land use planners, developers, and purchasers and land use regulatory bodies nor those who have determined the structure of the energy system - utilities, oil companies and manufacturers of automobiles and household appliances, have had to consider the land use implications of producing and consuming energy. This is not to say that the two areas of decision-making did not interact. The current patterns of land use in and around Amercian cities could only have developed in the presence of a long and extended period in which various forms of energy were available at comparatively low prices. The existence of such spread out patterns of land use, commonly referred to as urban sprawl, also depended on the plentiful availability of highly flexible energy carriers such as oil, natural gas, and electricity. At the same time, the nature of the centralized energy production-distribution systems that did develope was partly in response to demands imposed on the energy system by 1) the structural elements in the development of open land that required the use of the automobile, and 2) life styles compatible with large amounts of personal space both inside and outside the home. But, in the sense that these patterns of land use development were not constrained by energy prices and the forms of energy delivery, there was little need to focus attention on the land use implications of alternative energy systems.

In analyzing the potential for satisfying a major fraction of the future projected energy demands of the state of California and the nation with the use of distributive energy technologies (DETs), we must understand these past conditions are no longer likely to hold. Moreover, we must understand that the current structural elements in the patterns of community and regional energy demand have been inextricably linked to how land use has come to be used as a result of this past energy environment. The fact that community and regional energy use profiles vary to a large extent with such land use characteristics has been documented in a number of studies. Not only is energy use in inner city urban areas significantly less than in the suburbs, its composition is very different. Much more of the cities' energy is consumed in industrial activities, whereas in the suburban areas, energy is consumed mainly in the residential and commercial sectors. Energy use in transportation in the more densely populated cities is much less than it is in the suburbs.

The point to be made is not merely the trivial one that the composition of energy consuming activities varies from one location to another. It is rather, that these activity mixes are tied to one another through the prevailing land use patterns and, as such, they are changeable, under normal conditions, only over long time periods. It follows, therefore, that in order to estimate the potential for widespread utilization of DETs we must understand more fully how the employment of such technologies will alter current land use patterns and the trends that have been developing toward new varieties of land use development. We must also attempt to identify the organizational arrangements and administrative procedures of the various decision-making groups that will be necessary to accommodate these distributed energy systems. More specifically, we will have to consider

- designing new linkages between these groups and the energy industry and equipment manufacturers - currently non-existent.
- formulating new standards for "good" planning design criteria.
- reevaluating current relationships between community and regional and state land use regulatory authorities.
- reassessing trade-offs between land usage for energy support facilities and other needs (agriculture and recreation).

This inference that substantive alterations in both the ways we now choose to use land, and the manner in which its usage is allocated, will be necessary to accommodate wide-spread utilization of DETs, but is not intended to convey the idea that land use implications of DET will be necessarily negative in the sense that such changes will be undesirable. Rather, it is intended to focus attention on the kinds of changes that may be necessary. Some of these changes are, in fact, already taking place. Siting requirements to allow building orientations to take advantage of passive solar systems are being built into new community planning designs and zoning regulations. Sun rights legislation has been introduced in several states. Changes in state energy regulatory policies to allow utilities to own and manage on-site energy generation equipment is already underway. One should also not infer from our suggestion that land use-energy utilization relationships have evolved slowly in the past, that this slow rate of accommodation will necessarily continue into the future. Should the world wide shortages and/or increased prices of petroleum and natural gas develop as predicted for the late 80's or 90's, increased rates of change in land use development would be expected to reflect these "crisis" conditions.

10.1.2 Approach

A major difficulty in attempting to particularize the kinds of changes in land use development, practices and regulatory procedures that will have to accompany the wide-spread utilization of on-site support systems, is the spatial conceptualization of how communities and indeed regions to be served entirely by such systems will appear.

Can one imagine, for example, an entire San Francisco Bay Area, or a Los Angeles Metropolitan Region served in large part, or even entirely by DETs? How will the transition from their current dependence on centralized energy systems (CES) take place? Or what about smaller cities like Santa Cruz or Bakersfield? What about new areas now developing on the fringes of the state's large metropolitan areas? Will the major land use sectors - residential, commercial, industrial, public service, and transportation continue to be segregated geographically? What are the potential areas of jurisdictional conflict between different state agencies and local municipalities? What will the impact of DET utilization be on land values?

To obtain a more concrete portrayal of the effect of wide-spread utilization of DETs on the mix and spatial arrangement of land use activities at the community and regional level, we have analyzed the land use requirements of a"self-contained" community designed to rely exclusively on the use of DETs for meeting its stationary energy demands. The self-contained community is not intended to represent, in any sense, a prototypical community. It is, rather, a construct in which we include an agglomeration of residential dwelling types, commercial and public services, and industrial activities sufficient to house and employ the population, to provide it with public services, and to satisfy their shopping requirements. The mix and allotted acreage for each activity is based on planners' design criteria used in community layouts.

For a variety of different DETs, we produce a community energy resource-demand balance and a "schematic map" showing the pertinent acreage requirements for the on-site energy systems employed. Three modes are adopted in utilizing the community renewable resource inputs to meet its energy demands. Mode A insists that each structure must be energy self-sufficient; Mode C, that all demands are satisfied by a single community system; Mode B is a mixture of A and C, in which high rise apartments commercial buildings and industry utilize one or more facilities and single family residences use on-site energy systems. Taken together, the tables showing energy flows and acreage requirements, and the "maps" showing spatial interaction of the component activities provide a picture of allowable land use configurations. They also yield information on the changes in planning design criteria necessary to accommodate the DETs - employees/acre, residential population/acre, etc. They also suggest the impacts of the resulting community design on neighboring and more distant land use activities.

It is worth repeating the caveat, noted above, that these results are not meant to predict how, or if, these particular technologies will be employed. They have been fashioned exclusively to focus attention on the dynamics of the interactions between the use of DETs and land use. Economics is not considered, nor are other community design objectives.

The methodology employed in developing these results together with the sources utilized and assumptions made in carrying out the analysis are described in Section 10.2. This section also elaborates on what the results mean in terms of land use development on a community basis.

In Section 10.3, we utilize the conclusions drawn in the community analysis to explore 1) the problems of scaling up to the regional scale, 2) the restrictions on the regional development such scaling up would infer, and 3) the problems of affecting a transition from current land use patterns to those required for the distributed energy system usage. In considering these problems, we have paid attention to the effects of the following:

- variations in physical terrain and the ambient availability of on-site resources (solar insolation levels, wind conditions, etc.).

- changes in the composition of land use activity mixes.
- the inclusion of activities such as energy-intensive industries not included in the community analysis.
- the required flows of energy (direct and indirect) in and out of the region.
- conflicts between locally and regionally "optimal" solutions.
- impacts of increased requirements for planning on a regional level.

Finally, Section 10.4 deals with conclusions and recommendations.

10.2 COMMUNITY LAND USE IMPLICATIONS OF UTILIZATION OF DISTRIBUTED ENERGY TECHNOLOGIES

We have divided analysis of the community land use - distributed energy technologies utilization relationships into four separate issues: 1) a description of the community needs and land use patterns, 2) the community energy demands, 3) energy supply delivery to the community through the use of DETs, and 4) the land use requirements of the resulting support and delivery systems. It is important to emphasize two critical assumptions which underly the work here that distinguishes it from much of the literature concerning decentralized or distributive technologies.

The introduction of on-site energy technologies such as solar and wind energy, is often assumed to occur within the context of purely residential and/or commercial development. Industrial development is by and large ignored. While such examples are certainly representative of existing land use patterns and thus, are useful for estimating the potential for the introduction of such technologies, they are of limited use in considering integrated or self-contained communities. It is often the industrial sector, for example, which provides employment (directly and indirectly) for the community residents. To separate these out, or to ignore the character and magnitude of their demands produces, in our view, somewhat misleading results. We, therefore, have chosen to define our community as an integrated residential - commercial - industrial area, which is capable of both "scale-up" and/or replication to create large scale regional development.

The community land use design chosen for analysis is based on an average population density of 6300 persons per square mile, which is typical of that found in communities in the San Francisco Bay and Los Angeles metropolitan areas. The size of the community is one having a population of 10,000 persons. This particular figure was chosen primarily for convenience. The community land use parameters adopted are shown in Table X-1. Family size is typical of suburban development, ranging from four (4) per household in single family to two (2) per household in high-rise structures. The labor force participation rate is 1.1 employees per household, which is again typical of a suburban area under conditions of reasonable economic stability. The community itself requires some 925 acres of which about 2/3 is in residential development and the rest split between commercial and industrial activity. We assume a housing mix which is 60% single family, somewhat below that typical of present suburban development. The commercial and industrial employment and floorspace requirements are established under existing planning design criteria, as well as overall requirements for the infrastructure of supporting roads, utility rights of way, schools, parks, and other public facilities and services.[1] The overall land use requirements have been derived assuming fully saturated use of land. Saturation typically runs from 20% at suburban fringe areas to above 90% for inner-city areas. Were the population of the community to be scaled up to 50,000

Table X-1

Community Land Use

POPULATION			10000
HOUSEHOLDS			3000
Average family size			3.3 per househld.
EMPLOYMENT			3300
Labor force participation rate			1.1 per househld.
LAND USE			
Residential			640 acres
Commercial			120
Industrial			165
		total	925 acres
AVERAGE POPULATION DENSITY			6300 persons/sq. mi.
HOUSING MIX	No. Units	Househld/acre	Acres
Single Family	1800 (60%)	4	450
Apt./Twnhouse	600 (20%)	12	50
High rise	600 (20%)	20	30
Infrastructure	-	-	110
			640 acres
COMMERCIAL MIX	Employment	Floorspace	Acres
Local Shop.	510	820 K sq.ft.	30
Mall	810	810	48
Office	540	550	22
Infrastructure	-	-	20
			120 acres
INDUSTRIAL MIX	Employment	Floorspace	Acres
Light Industry	800	430 K sq.ft.	50
Heavy Industry	500	740	85
Infrastructure	-	-	30
			165 acres

persons and above, the overall proportions of land use would remain much the same, though some shifts toward additional high-rise housing and the formation of downtown shopping areas might be expected.

The unit energy load for residential, commercial, and industrial activity in the community is shown in Table X-2. Two general features of the energy supply system determined, to a large extent, the form in which energy demand is expressed. First, available input resources, i.e., sclar insolation and average wind energy delivered can fluctuate widely. We have assumed energy storage capability will be readily available within the supply system. Consequently, it is the 24-hour average energy demand for various land use activities that is the important determinant of energy support configurations.* Second, the sizing of solar collectors and other supply equipment will be dependent upon the maximum seasonal 24-hour average demand for heating, cooling, and electricity requirements. The data in Table X-2 is based upon estimates of such peak average daily demands adapted to the specifics of the San Francisco Bay area (3000 heating degree days, 500 cooling degree days).

Residential heating and cooling loads are based on new construction practices which include R-11 ceiling and R-7 wall insulation values. The houses are assumed to be 1500 square feet of living space on 1/4 acre zoned parcels. The single family residential heating load shown in Table X-2.

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* The land use implication of energy storage systems have been ignored. This means, in effect, location of storage facilities underground.

Table X-2

Unit Load
(24-hour average demand per square meter floorspace)

	Process Heat	HEAT(1)	COOL(1)	ELECTRICITY
RESIDENTIAL				
Single Family		.95 kWh/m^2	1.25 kWh/m^2	.16 kWh/m^2
Apt./Twnhouse		.95	1.25	.16
High rise		.73	.96	.16
COMMERCIAL				
Local Shop		1.95	5.8	.36
Mall		1.35	2.9	.36
Office		1.35	2.9	.36
INDUSTRIAL				
Light Industry	4.1 kWh/m^2	5.6	.70	3.5
Heavy Industry	14.0	3.0	.50	6.5

(1) Without solar passive design.

.95 kWh/m^2, corresponds to a heat loss about 12 Btu/hr-sq.ft. Similarly, the cooling demand is about 18 Btu/hr-sq.ft. These values are typical of those used for design and evaluation of solar installations in the coastal areas of California.[2] While heating and cooling demands fluctuate somewhat over a daily cycle, electricity consumption in residence is subject to much larger variations, and the daily peak in electricity consumption will generally be twice the value shown in Table X-2. Commercial energy demands are somewhat similar to those for residential structures, with the exception of construction practices that normally lead to heating demands double those in the residential sector and cooling demands considerably larger than for residential structures. In addition, the commercial heating and cooling loads are less subject to variation due to degree-day differences because of large internal heat loads from people, machinery, and other equipment for commercial buildings. Similary, the electricity requirements in shopping and office buildings are generally larger because of the wide use of relatively high lighting levels.

Industrial energy demands are somewhat more difficult to estimate because they are dependent on the type of manufacturing industry, its specific plant site, industrial process used, and equipment employed in the manufacturing process. Again, a variety of planning and design data may be used to prepare a profile of industrial energy demands.[3] Input/output analysis in which energy sectors are disaggregated can be used to establish an approximate breakdown of process heat, space heat, air conditioning, electricity, and other industrial needs such as that shown in Table X-3. For example, for many heavy industries, the annual energy demand clusters in the vicinity of 1070 million Btu per employee, or about 2.4 kWh/m^2. Similarly, we use a combination of electrical equipment and miscellaneous manufacturing to represent light industry. These have an average annual energy demand of about 200 million Btu per employee or 1.4 kWh/m^2. Utilizing planning design values of eight persons per acre for heavy industry and twenty-eight persons per acre for light industry, we find the disaggregated unit energy demands for industry shown in Table X-2. In making the transition from site-space to floorspace we assume approximately 20% built space for typical industrial development.

In Table X-4, we summarize the community energy demands. In the preparation of community energy demand in Table 4 we have included a 20% reduction in the heating and cooling demand to take account of passive designs. Since little is known of the real capability for achieving reduction of energy demand through the passive design of structures on a community or regional basis, we adopt an average figure of 20%. This may be somewhat conservative, at least during the latter stage of the transition to DETs. It should be noted that the total peak demand of 5-6MW which would be derived from the electricity loads in Table X-4 is consistent with estimates of actual system operations for typical utilities.

The choice of specific DETs to be employed is based on the listing of most attractive and least attractive technologies used in the overall California study. These fall within the definition of environmentally

Table X-3

Industrial Energy Demand

	HEAVY INDUSTRY		LIGHT INDUSTRY
	Rubber Products (BEA 32)	Electrical Machinery, Equipment & Supplies (BEA 58)	Miscellaneous Manufacturing (BEA 64)
Process Heat	60%	46%	23%
Space Heat	12%	23%	50%
Airconditioning	1%	5%	1%
Electricity	25%	25%	26%
Other	2%	1%	-
	100%	100%	100%

Table X-4

Total Load
(24-hour average demand)

	Process Heat	HEAT	COOL	ELECTRICITY
RESIDENTIAL				
Single Family		210 Mwh	260 Mwh	43 Mwh
Apt./Twnhouse		67	90	14
High rise		53	69	14
		330 Mwh	459 Mwh	71 Mwh
COMMERCIAL				
Local Shop.		120	360	28
Mall		91	195	30
Office		61	135	21
		272 Mwh	690 Mwh	79 Mwh
INDUSTRIAL				
Light Industry	200 Mwh	215	27	170
Heavy Industry	1030	180	30	480
	1230 Mwh	395 Mwh	57 Mwh	650 Mwh
TOTAL	1230 Mwh	395 Mwh	1206 Mwh	800 Mwh

benign technologies used by Lovins and others.[4] The list of such preferred technologies includes solar, wind, hydroelectric, biomass, and geothermal. Some of these are not generally available for local use, and therefore they were not considered suitable for this purposes of this study.* Table X-5 shows the selected DETs. The technologies chosen are also designated according to an energy form which they will be supplying since it will be important to select an appropriate mix of sources able to satisfy heating, cooling, and electricity demands. As noted above, solar passive design has been included as an element in the community energy loads. Solar insolation requirements for industrial process heat are also included. We assume throughout, that efficient energy storage capability can be put into place to support smoothing or demands on heating, cooling, and electricity supply systems. Central community installations for wind electricity and/or solar thermal electricity offer few benefits over on-site installations from an energy supply view, but their land use implications can be significantly different. Integrated solar heat/cool/electricity systems (cogeneration systems) may provide some overall improvements in efficiency depending upon the balance of heating, cooling, and electricity loads so they have been included.

The prescription of appropriate technologies for the distributed energy system from Table X-5 outlines only the general character of a technology. Further elaboration is required to describe the specific land use require-

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* It is an open question if this applies to wind, but we have included it because of the general high level of interest shown in its use.

Table X-5

Selected Technical Options for Formulation of Distributed Energy Systems

	Process Heat	Heat	Cool	Electricity
Most Desirable				
Passive Solar Design		X	X	
Active Solar Heat		X		
On-site Wind				X
Slightly Less Desirable				
Solar Process Heat	X			
Solar Co-generation system	X	X		X
Central Station Wind				X
Less Desirable				
Active Solar Cooling			X	
Solar Thermal Central Electric				X
Undesirable				
–				
Unsuitable				
–				

Reference: P. Craig and M. Simmons, "Formulation of Energy Delivery Systems", (University of California, Berkeley, 7 August 1977) unpublished memo.

ments for providing energy to the community. In the case of solar thermal applications, the collector and thermal storage and its exchange systems are sufficiently simplified that they can be characterized quite easily. However, consideration of solar absorption cooling systems becomes somewhat more complicated since differing air conditioners may be selected which have coefficients of performance (Btu removal/Btu in) which range from .5 to above 1. Even more complicated is the consideration of integrated solar heat/cool/electricity for which turbine cycles may be chosen at a wide variety of temperatures and associated efficiencies. In addition, the thermal/electric load balance becomes a determinant in making the choice of appropriate turbine cycle. While such considerations are critical to the design of the energy system for a specific community, they are less important in a first estimate of the overall land use requirements to support the energy system. Consequently, we adopt straight forward design examples for solar and wind systems, and use the appropriate efficiencies for devices associated with these systems.

The energy supply system is described in Table X-6. The basic resource available is 1.8 kWh/m^2 of solar insolation in winder and 7.2 kWh/m^2 in the summer for the San Francisco Bay area.[5] Wind availability is estimated at .81 kWh/m^2.[6] The basic heat source is solar thermal. Such a system includes a flatplate collector and thermal storage system. With the efficiencies[7] shown in Table X-6, the overall conversion efficiency from solar heat is 48%. These solar thermal systems provide low grade heat (less than 200°F). To provide air conditioning at reasonable efficiencies requires heat engines driven at somewhat higher temperatures, in the range of 200-400°F. Consequently,

Table X-6

Sources

RESOURCE(1)	Winter	Summer
Solar Insolation (24 hr. avg. energy/collector area)	1.8kWh/m2	7.2kWh/m^2
Wind(2) (24 hr. avg. energy/blade area)	8.1kWh/m^2	
HEAT/COOL		
Solar Thermal		
Flatplate collector (60%) Thermal Storage (80%)	.86kWh/m^2	—
Solar Absorption Cooling (.31)		
Parabolic trough (70%) Thermal Storage (80%) Air conditioning (COP .55)	—	2.2kWh/m^2
ELECTRICITY		
Solar Thermal Electricity (.11)		
Parabolic trough (70%) Turbine (Rankine cycle 20%) Thermal Storage (80%)	.20kWh/m^2	.80kWh/m^2
Wind (.24)		
Electric Storage (60%)	16.kWh/m^2	
Photovoltaic (.072)		
Collector (12%) Electric Storage (60%)	.13kWh/m^2	.51kWh/m^2
HEAT/COOL/ELECTRICITY		
Integrated Solar System		
residential & commerical (.30)	.54kWh/m^2,	-
industrial (.24)	.43 kWh/m^2	-

(1) San Francisco-Bay Area

(2) Wind energy 1kW/m^2 and capacity factor of .34. This wind flux is 10 times the average available in San Francisco-Bay Area

we change the collectors to parabolic troughs and utilize thermal storage to drive the system in hours when direct solar energy is not available.

The provision if solar thermal electricity[8] is based upon heat utilized to drive a turbine producing electricity rather than utilized as a direct heat source. The system requires somewhat higher temperature, in the range of 400-500°F, and consequently, the collector systems must be of higher quality. The efficiencies for collector, turbine, and thermal storage in the system are indicated in Table X-6. The overall system efficiency for the conversion of solar to electricity is taken to be 11%. A number of different turbine cycles may be used with efficiencies between 20% and 40%. As input temperatures rise, the turbine efficiency improves. In individual unit application to residential and/or commercial structures, we might anticipate the use of relatively low temperature systems as represented in Table X-6. However, in solar thermal central electricity applications, collector systems might shift to the heliostate types of systems which yield high temperature steam and raise turbine efficiency to the range 30-40%, typical of current operations of central utility systems.

Wind turbine systems to provide electricity are in common use in a number of remote areas and special applications. For community needs here, however, large amounts of electric storage to cover periods of no wind will be required, and the overall entry/recovery efficiency for electric storage systems is typically 60%. As noted in Table X-6, wind flux in the San Francisco Bay area is 100 W/m^2, which is considered somewhat below the limit for efficient, economical utilization of wind power.[9] We have, however, adopted a figure of 1000 W/m^2 as more typical of coastal areas where wind would receive serious consideration. For optimized systems, the percentage of time over which the generator operates at effective full capacity is about 35-50%. Blade dynamics permit about 40% of the average wind power resource to be captured and this is further reduced by entry/retrieval efficiency in electric storage devices. Since the turbines must be spaced by 10 diameters to assure non-interference, the power per unit of land use is about 1/100th that available from the turbine generator.

Integrated solar heat/cool/electric systems as shown in Figure X-1 offer advantages in reduced collector areas over separate heating, cooling, and electric generation. For absorption cooling, the summer energy delivered is 2.2 kWh/m^2 whereas the winter solar thermal provided is .86 kWh/m^2. That is, the solar system provides 2.5 times as much energy per unit collector area in the summer to satisfy cooling loads in Table X-3, which are at best 1.2 -- 2.0 times greater than heating loads. Consequently, solar insolation levels and balance of heat/cool loads permit cooling systems to rely upon collector areas sized for adequate heat. Utilization of waste heat from a solar thermal electric turbine as shown in Figure X-1, allows sharing of thermal and electric system collector areas to give an overall reduction of collector area by 15-25% from that which would be required in separate thermal and electric systems. In Table X-6 the energy per collector area for integrated solar systems

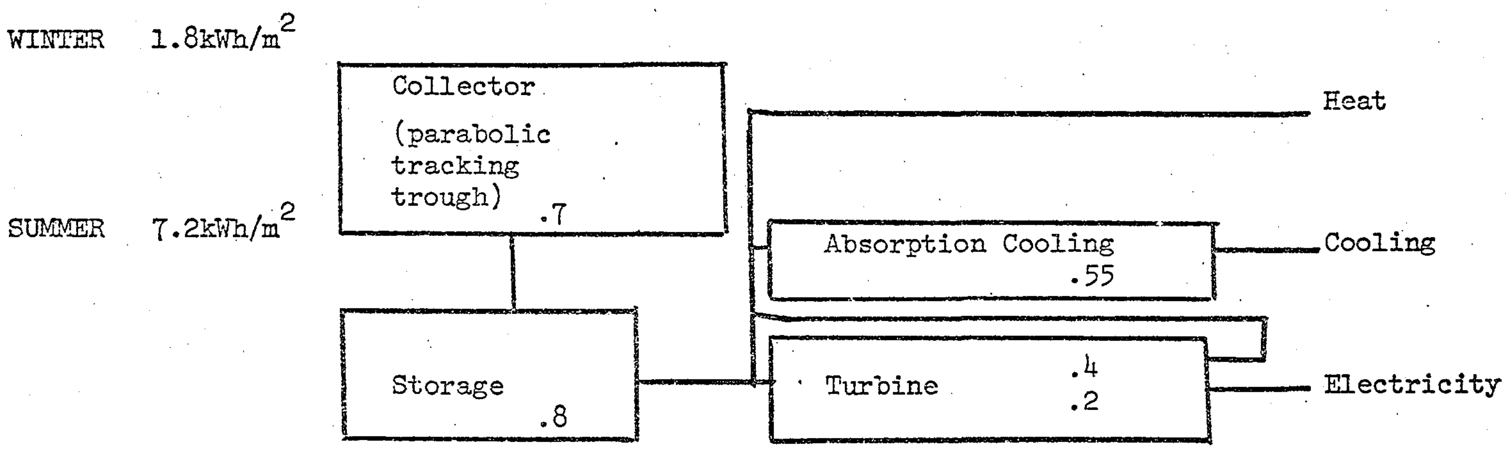


Figure X-1. Integrated Solar System

reflects the thermal/electric load balance[10] for the various land use sectors.

Solar photovoltaics as an electrical energy source are included in Table X-6. While the cost is high and mass production potential limited at present, these factors are almost certain to improve.[11] Because photovoltaics are capable of electricity generation per unit of collector area at 12% efficiency, comparable to solar thermal electric and considerably in excess of wind power, they represent an interesting potential source from the point of view of lowering land use requirements.

The decentralized energy technologies to be utilized for the energy supply system to the community have been expressed in Table X-6 as energy per unit of effective land use area required. Consequently, these energy source values can be divided into the load profile for the community in Table X-4 to obtain total collector area requirements to meet heating, cooling, and electricity needs for each sector and the effective land area for non-interference between wind turbines. It should be noted that the thermal heating and cooling systems share the same collector area since they operate in different seasons. However, electricity requirements represent collector area in addition to that required for solar thermal heating and cooling applications. The integrated solar systems discussed above offer some opportunities for reduction in total collector area.

The description of land use requirements for the utilization of the DETs is shown in Tables X-7A, B and C. The utilization of these specific technologies led to two basic assumptions used in the analysis. First, sufficient thermal and/or electric storage is available and can be placed underground so it has no actual land use requirement. Second, installed systems must utilize their own storage to smooth supply over daily cycles and longer i.e. there is no utility back-up. As a result, 24 hour average demands are met and peak/off-peak power requirements are not an issue. Co-location of residential, commercial, and industrial activity may offer advantages in shared land use areas but the analysis is not based upon peak/off-peak energy exchange between the various land use sectors.

In the analysis above, we assumed short-term thermal storage. Should seasonal storage become available, the daily-average design becomes one utilizing average-annual energy demands. Since energy collection and strage then extend throughout periods of modest heating and/or cooling demand, the collector areas for residential and commercial sectors shown in Tables X-7A and X-8 would be reduced by 40%. On the other hand, large-scale seasonal storage to support industry needs is unlikely, and as a result total land use requirements for the community energy system would be reduced by less than 20% through seasonal storage. In addition, since 60% of residential and commercial collector areas are for heating and cooling needs, additional solar passive design to a level of 30% below that in Table X-4, would reduce those collector areas by only 20% and requirements for the total energy system by less than 10%. Consequently, land use implications of DETs, while not insensitive to the particular technical features of elements of

Table X-7A

Community Energy Balance
Mode A: Distributed Systems

LAND USE	Gross	Built	INTEGRATED SOLAR	SOLAR-WIND	SOLAR THERMAL-PHOTOVOLTAIC
Residential					
Single family	450 acres	63 acres	91 acres	610 acres	130 acres
Apt./townhouse	50	10	29	200	43
High rise	30	4	22	200	40
Infrastructure	110	-	-	-	-
Commercial					
Local Shop	30	18	51	400	82
Mall	48	19	40	430	78
Office	22	13	27	300	54
Infrastructure	20	-	-	-	-
Industrial					
Light Industry	50	11	110	2400	360
Heavy Industry	85	17	330	6900	1010
Infrastructure	30	-	-	-	-

Table X-7B

Community Energy Balance
Mode B: Mixed

LAND USE	Gross	Built	INTEGRATED SOLAR	SOLAR-WIND	SOLAR THERMAL-PHOTOVOLTAIC
Residential					
Single family	450 acres	63 acres	91 acres	6100 acres	130 acres
Apt./townhouse					
High rise					
Infrastructure	180 acres	64 acres	170 acres	1530 acres	270 acres
Commercial	130 acres (infrastructure)				
Local Shop					
Mall					
Office					
Infrastructure					
Industrial					
Light Industry	30 acres	(infrastructure)			
Heavy Industry	135 acres	28 acres	440 acres	9300 acres	1370 acres
Infrastructure					

Table X-7C

Community Energy Balance
Mode C: Central System

LAND USE	Gross	Built	INTEGRATED SOLAR	SOLAR-WIND	SOLAR THERMAL-PHOTOVOLTAIC
Residential					
Single family					
Apt./townhouse					
High rise					
Infrastructure	765 acres	155 acres			
Commercial	160 acres	(infrastructure)	700 acres	11400 acres	1770 acres
Local shop					
Mall					
Office					
Infrastructure					
Industrial					
Light Industry					
Heavy Industry					
Infrastructure					

the community energy system, are determined for the most part by the need for large land areas to harness substantial quantities of solar and/or wind power.

The three specific energy delivery modes noted in Table X-7 as A, B and C, are defined below:

MODE A - Integrated solar, solar-wind, or solar thermal-photovoltaic systems supplying all homes, businesses, and industrial plants on an individual basis

MODE B - Energy is supplied to individual units in the single family residential sector. Community centralized systems of varying sizes are used to supply energy to high density residential-commercial and industrial areas.

MODE C - Centralized solar, solar-wind or solar thermal-photovoltaic plants supplying the entire community over a thermal/electric distribution grid.

For comparison of land required for the energy system to that of the regular community usages, we show both gross and net built on acreage in each land use category in Table X-7.

The relationship between the community land use allocation and requirements for the DETs of Mode A based upon integraged solar thermal/electric technology is shown in Figure X-2. The community bounded by solid lines is divided vertically into land use sectors and horizontally into the categories of land use activity within each sector. The built space is denoted by shading, and shaded plus unshaded areas represent gross acres allocated to the specified land use. Collector areas, shown by heavy dotted lines, exceed the built space in most of the land use sectors. Indeed, total collector requirements approaches the gross acreage in use in all areas, with the exception of single family residential areas.

The introduction of some centralization of the energy supply system in Mode B, Table X-7B, relaxes the boundaries between land use secotrs. In this instance, collectors may be rearranged from the configuration shown in Figure X-2. Similarly, complete centralization offers no great benefits in terms of land use requirements unless the energy system is actually removed from the community. Finally, we note the land use acreages of solar-wind combination and solar thermal-photovoltaic systems are even larger than those shown in Figure X-2.

Several immediate conclusions can be drawn from Table X-7 and Figure X-2:

1) Solar energy land use for collector space is modest but conflicts with the built environment in many instances. For example, integrated solar system collector areas for shopping malls in Table X-7A exceed built floorspace by a factor of 2 and would cover vitually the entire gross acreage dedicated or zoned for mall development.

2) On a community basis, large areas must be dedicated to collector space. The community central energy systems described in Table X-7C would require, for example, a minimum of 700 acres dedicated to

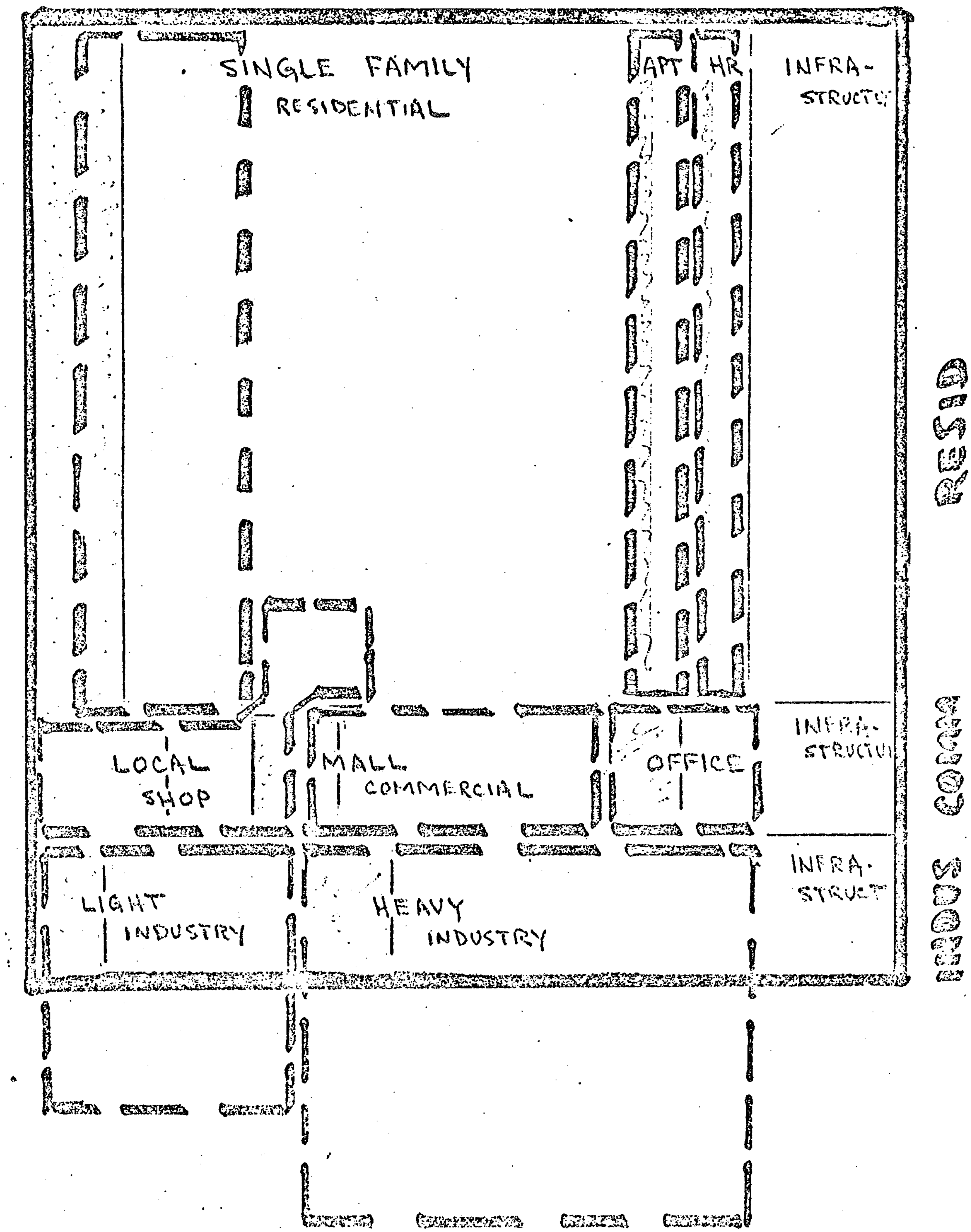
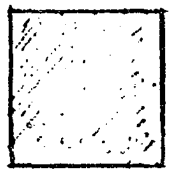
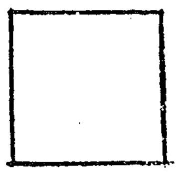

SINGLE FAMILY
RESIDENTIAL
APT
HR
INFRA-
STRUCT
LOCAL
SHOP
MALL
COMMERCIAL
OFFICE
INFRA-
STRUCT
LIGHT
INDUSTRY
HEAVY
INDUSTRY
INFRA-
STRUCT
RESID
COMM
INDUS

Figure X-2

Key for Figure X-2



Built area



Open area

Total area for land use category "a"

Community boundary

Collector area boundary (integrated solar system) collector area, or 75% of the land area of the entire community.

3) Satisfying industrial energy needs, particularly for process heat applications, constitute a large component of the land use demands within a complete self-contained community.

4) For those systems in which wind is utilized as an energy source, very large areas will be required. Thus, wind fits within the context of existing land use planning only if density decreases substantially and/or wind turbines are located at remote sites. Even in the latter case, the community of 10,000 persons we envision would require some 25 or more 1-2 MW machines (each with 300 ft. diameter blades) scattered over a very wide area.

A more comprehensive descriptive view of the potential impact of DETs on the present community land use development practices is itemized in Table X-8. These include the possible impacts of DETs upon national resources, environment, and aesthetics of the community. They specify impact range and the physical appearance of the distribution grid from a community station to possible displacement of greenbelts adjacent to residential areas.

In general, the employment of distributed energy systems will be controlled through local building codes, land use density standards, subdivision regulations and other mechanisms related to the activities of individual and corporate land use developers. The centralized community energy system comes closest to leaving the existing land use planning and development practices and regulations intact. However, annexation of additional required space for use by the community may become an issue. In addition, community energy sources could lead to modification in community infrastructure requirements to accommodate the energy distribution system. District heating for thermal distribution, for example, will affect interspersion of community land use activities. The placement of fields of collectors and wind turbines would conceivably interfere with normal planning practices and guidelines for access to different parts of the community. Finally, integrated solar, solar-wind, and solar-thermal-photovoltaic energy systems place demands on land use that clearly do not easily fit into present land use planning design criteria.

In effect, through their associated land use requirements in a renewable resource-based distributed energy system, energy demands have been converted to land use demands. As such, these activities must compete with all present and projected land use activity and becomes subject to the broad range of economic, political, social, and institutional constraints traditional in governing the use of land. The implications of these trade-offs between energy and land when scaled up to a regional level are explored below.

10.3 SCALING UP TO THE REGIONAL BACKGROUND

10.3.1 Background

Our approach of utilizing conclusions drawn from hypothetical community designs to discuss the implications of distributive technologies on a regional scale is open to a number of criticisms.

Table X-8

Potential Impacts of the Community Energy System

	MODE A Individualized Energy System	MODE B Mixed*	MODE C Community Integrated Energy System
LAND USE DEVELOPMENT			
annexation			X
building code	X	X	
density	X	X	
natural resources	X	X	X
public facilities		X	X
subdivision standards	X	X	
sun rights	X	X	
PLANNING DESIGN CRITERIA			
access		X	X
asthetics	X	X	X
environment	X	X	X
greenbelt		X	X
housing mix	X	X	
infrastructure	X	X	X
interspersion		X	X

*Individual systems in single family units and centralized systems in other land use activities

1. It fails to take into consideration the greater diversity of land use activities existing in communities in a large metropolitan area. Many of these have not been included in the self-contained community. For example, highly energy-intensive industries such as metal processing, paper and chemical manufacturing, etc., have not been considered. Nor has the variation in the mix of activities that currently occurs from one geographic area to another within the regional metropolitan area. The presence of a "downtown" commercial and retail sector, for example, has not been acknowledged.

2. It does not distinguish between the differences in the age of the existing building stock, the variations in physical terrain, the income distribution of the resident population, all of which will affect discussion of both the possible end states associated with a state energy support system based on distributive technologies.

3. On a more technical level, the use of the notion of a "self-contained" community in which energy employment, shopping and recreational needs are satisfied within the community ignores the high degree of movement of people and goods and services (and energy) between communities within a larger region.

We would counter these arguments by noting that such the "idealized" community as described in Section 10.2, while oversimplified, offers a more concrete basis for exploring problems to be faced in change-over to a distributed energy system than other approaches which have confined their attention to purely residential and/or commercial land use activities. It reveals, for example, the difficulties of accommodating a more diverse set of land use activities generating different energy demands to a set of somewhat limited energy supply technologies.

The use of "idealized" region for initiating the examination of the land use implications of utilizing distributed energy support systems is an alternative possibility. Such a scale, however, does not, in our view permit one to examine the micro-structure of the changes in land use patterns that may be necessary to accommodate distributed energy support systems. The regional energy resource-demand balances obtained for such a system tend to highlight technically feasible solutions at the expense of submerging the difficulties of implementation. Regional maps, based on such analysis, also produce a picture which has less clarity and definition thereby obscuring the effects of variation in terrain and local climate conditions. Thus, while it is important to acknowledge the caveats that go with our community-region scaling-up approach, we regard it as better for the purpures of preliminary analysis. Later, as studies aimed at improving the definition of the land use- distributed energy systems relationships are needed, more detailed models based on other approaches should undoubtedly be explored.

10.3.1 Approach

We have chosen to consider two modes in scaling up our community results to the regional level.

Variation I: Scaling is considered by picturing the region to be served by distributed energy systems as evolving out of the proliferation of smaller separate approximately self-contained communities - each ranging in size from 10-50,000.

Variation II: Scaling is portrayed as coming from the continuous growth of contained communities which over a period of time grow from 50,000 to 100,000 to 500,000 in population.

Our reason for characterizing the scaling-up process in terms of these two particular variations derives from the need to direct attention to the transition processes involved in moving to regional land use layouts consistent with energy being provided by an assortment of DETs. Any real transition will, of course, be a complex mixture of both variations. But by characterizing them in terms of these two extremes, we will better understand the likely outcome and the transitional difficulties. For example, "islands" approximating our self-contained communities could be located in areas lying on the fringes of existing built-up areas or in areas within these cities available for redevelopment. Over an extended period of time the number of these islands would increase in number until finally, the entire region becomes an assemblege of contiguous islands.

On the other hand, if we consider new areas for development which are now not yet built-up, or which are occupied by only scattered residences, entirely new mini-cities could be built (Columbia, Maryland and Reston, Virginia offer examples). These mini-cities might range anywhere from 50,000 to 300,000 in population. They would contain a mixture of commercial and industrial activities to employ and service most of the population. Such "cities" might eventually contain a sizeable fraction of the state's population.

Another consideration which has affected our choice is the need to include the question of the role of central systems employing non-renewable energy sources in the final outcome. Although we have intentionally presumed in the community designs discussed in the previous section that no central system will be available for back-up, even on an emergency basis, in seeking to accommodate the substantially greater diversity of energy consumers in a region, as opposed to the community, we may wish to consider under some circumstances construction of moderate sized central stations with accompanying grids. The two modes allow us to examine how and why we may wish to employ such systems. In Variation I, for example, the "assemblege of islands" - we may choose to place special communities containing industries having unusually high demands for high temperature process heat close to those able to effectively untilize the output of lower grade heat residuals. In the case of Variation II, the "larger self-contained cities", we may - on the other hand - choose to exclude some energy-intensive industries.

A final reason for our selection is that we wish to emphasize the need to consider redevelopment as well as new area development in our discussion. Most of the discussions concerning the land use implications of DETs, such as solar and wind-based technologies, have over-emphasized development in areas now sparsely settled or vacant. The results of these analyses can be misleading in that they do not deal with change in land areas now occupied. Urban redevelopment, though controversial, does exist as one process for change in such areas. These changes involving the shift in land use patterning from residential to commercial and industrial. Although their inclusion raises difficult problems for DETs, to ignore them would not provide a balanced assessment of the issues.

To bring out these and other land use problems and issues which are likely to be associated with satisfying energy demands by DETs, we address five questions. They were chosen deliberately to provoke discussion. Again, caution must be expressed that in emphasizing the difficulties to be faced in arriving at a land use configuration which is servable by DETs, there is no intention to connote that such an outcome is impossible or even improbable. Where one to consider the problems of satisfying regional energy demands with large scale centralized systems, other than those using oil or natural gas, there would be similar difficulties attached.

Question 1: Are the DET technologies which have been employed in the community analyses and the modes chosen for energy delivery applicable in a variety of physical terrains and on-site energy resource inputs? If not, what are the regional implications?

Discussion: In the community analyses described in Section 10.2, the distributed technologies employed were 1) active solar heating and cooling systems, 2) wind electric generators, 3) solar photovoltaic electricity systems, and 4) community solar-thermal central electric systems. Three modes were considered - (a) satisfying the energy demands of activities in individual buildings by only on-site systems, (b) satisfying all stationary energy demands in the community by the use of community-wide systems, and (c) a mixture of the two.

It is clear that local physical conditions will affect the amount of solar and wind energy input both on a local and seasonal basis. It will also determine the extent to which building settings and architectural designs can be utilized to take advantage of passive solar systems. Moreover, in the case of community energy systems, the ability to distribute energy on an economical basis will also be affected by the local terrain. Finally, if there are a scattering of existing structures already present, they may preclude obtaining sufficient acreage to dedicate to community energy facilities. From the regional perspective, there are several implications of such variations from one community site to another.

1) If we assume that a mix of land use activities may come to be dictated by energy considerations, locations having accessibility to the higher inputs of solar or wind may come to be reserved for the more energy-intensive commercial and industrial activities in the region. Locations having lesser resource inputs would have to be restricted to activities with correspondingly lower energy requirements such as single family residences. These considerations may result in land areas having high aesthestic and convenience value being restricted to energy production activities. The result may mean locating industries in areas now reserved for residential and recreational uses.

Clearly, the scaling-up to the regional scale by Variation I discussed above would be difficult if the energy self-contained islands had to accommodate these differences within each community. On the other hand, if we consider scaling-up to the regional level through the transformation of small islands to large mini-cities, as in Variation II, zoning regulations effecting the use of land covering the larger areas would have to include considerations of how much sun and wind each site obtains or is likely to obtain after development.

2) For the region as a whole, there may not be sufficient numbers of high resource input locations to accommodate the energy demands of the land use activities that normally would be attracted to the region as a result of considerations based on non-energy related factors. For example, if we calculate the acres of open land required for a number of energy-intensive industries in order for solar systems to provide their process energy requirements, they would need land areas two to five times their current requirements. Even under these conditions, these kinds of industries would be forced to fill the entire open space around the plants with solar collectors. What this may mean is that prior to designing master plans for the region, an evaluation of maximum energy "load" that each area could take, would have to be evaluated, and the potential for locating industries with a variety of energy demands established. The alternative is to enlarge the region by competing for land on its perimeter. The implications of this development, while significant, go beyond the scope of this analysis.

3) While we have elminiated from consideration the use of non-renewable resources such as coal, and nuclear power in our community analyses on a regional basis, this may not prove possible, or even desirable. Excluding

certain types of industrial and commercial activities from which local employment is derived from the entire region, on the basis that there are insufficient local resources of renewable energy resources, but which could use coal and/or nuclear derived fuels is not likely to be a politically acceptable solution.

Question 2: How sensitive are the modes used in the community analysis to produce and distribute energy and the technologies employed to the exact mix of land use activities assumed? Where they are sensitive, what problems does this present for land use planning at a regional level?

Discussion: At the outset of this report we noted the current lack of interaction between decisions affecting land use and those affecting energy production and delivery. In point of fact, the situation encountered in utilizing DETs represents almost an opposite extreme. Section 10.2 clearly demonstrates the interaction between mixes of land use activities and energy systems needed to meet their demands. These are minimized in Mode A, where energy support systems are exclusively located in or around individual buildings. As long as zoning regulations are such that this requirement will be met, then as already noted in Section 10.2, there is considerable flexibility in adopting the mix of land use activities to community needs and desires. This assumes, of course, that all areas within the community are receiving equal inputs of energy resources. However, as soon as we deal with the matching of resources to demand imposed by Modes B and C where energy support systems are located on one or several sites separated spatially from where the energy produced is to be consumed, then the sensitivity of the community energy production distribution system to the land use mix increases substantially. Not only must such systems take into consideration the energy demands of existing land use activities, but that which will exist in the future. These differences between Modes A,B, and C will have a number of implications for regional land use development, and in particular for the variations we have considered in making the transition.

1) Planning at the regional level currently involves a number of separate municipalities, each of whom regulates land use in their own areas. This makes regional planning a relatively 'loose' affair. To be able to move to a future in which all, or most, of the regional energy requirements are being met by DETs, will most likely require a much higher degree of control over land use at the regional level. For each land use parcel in the region, the energy loads of the activities allowed to locate on such sites will have to be specified. Moreover, the mode for satisfying this demand will also have to be specified if sufficient numbers of community energy sites are to be selected and set aside for later use. As noted above, industries requiring large land areas to produce energy to meet their demands will have to receive special attention.

Given these conditions, it is somewhat difficult to picture the transition to a regional distributed energy system taking place in an already built-up area by the proliferation of energy self-contained communities without an extensive region-wide system of land use planning and control. Failing this, development may shift to outlying areas where larger tracts of open land already exist, and where flexibility to the individual developer will be somewhat higher. We must emphasize that our inferences regarding regional development patterns are based on energy factors being the dominant motivator for locational decisions. This is unlikely ever to be the case.

2) Mode A, where energy demands are met by on-site systems on a building-by-building basis is likely to be favored over shared facilities because it permits somewhat greater flexibility to the land owner and the building occupants to change energy demand loads. It also provides added flexibility to the land use planning and the regulatory authorities. For community systems to provide this flexibility they would have to build in such a way that their capacity could be expanded or contracted easily. On the other hand, this may lead to a situation in which newly constructed single family dwellings adopt individual systems, while older housing stock is forced onto community systems because of the difficulty in retrofitting for passive and active solar systems, and multi-family units because of the added acreage requirements fall into the same category.

On a regional basis, this division may result in a number of disadvantages if not regulated. The concept of self-contained communities utilizing community energy systems may not be technically and economically feasible if the load provided by the single family units are removed. Whereare the acreage taken up by individualized energy systems on the single family unit sites are small compared to the total acreage allotted such land use activities using current planning design criteria, this is not true for high-rise, commercial, and industrial activities. The competition for the 'unused' land in single family areas, may become severe. Put another way, the need for increased land in the region to satisfy all of its stationary demands may not permit this 'wastage.'

3) As a final point, we return to the issue of using coal and/or nuclear power to supply industries in the region which require large amounts of process heat. In terms of possible final forms for the arrangement of regional land use activities, much depends on this decision. If these fuels are allowed and optimum use is made of their excess capacity for electric production and degraded process heat, then substantial amounts of land areas could be saved by locating high-rise apartments and office buildings near such units. This, in turn, would reduce the need for insistence on 'balanced' community development throughout the region. It would also permit greater numbers of lower density residential areas in the region.

Question 3: What conflicting land use objectives exist between the region and the local community if we agree to satisfy energy demands with DETs?

Discussion: Focussing attention on the transition from our current system for satisfying regional energy demands to one dependent on DETs rather than the outcomes, allows us to identify the potential for these conflicts.

It is evident that any transition of the magnitude we are discussing here will result in a renewal of much of the current building stock in existing metropolitan areas. Although this renewal may take place over a period of

50 or more years, it will involve not merely construction in sparsely settled areas, but redevelopment of areas already densely occupied. This follows in large part because of the increased scarcity of open land. Unlike the situation at the end of World War II, there are no longer large empty tracts of usable land adjacent to the large metropolitan areas. Thus, while this may not preclude new area development in areas remote from existing metropolitan areas, it suggests most of the population of the state in 50 years will be housed , employed, and shop in geographic areas already developed.

A transition strategy involving redevelopment of built-up areas rather than ones based on new area development results in different sets of consideration. Redevelopment seldom has resulted in accessibility to very large vacant areas. It usually involves replacement on a structure-by-structure basis, or on a block-by-block basis. Moreover, where larger areas are opened up, they have been in older downtown areas. A continuation of these renewal practices would restrict the manner in which DETs could be used to displace contralized energy systems. For example, the land area of the self-contained community of 10,000 people used in the analysis in Section 10.2 requires approximately 1600 acres. Such an area is not likely to be available under current redevelopment policies. Nor is there any assurance that the vacant land which does become available will be located on sites of high resource input due to the local physical terrain or nearby building obstructions. Moreover, unless zoning laws are revised there may be no possibility of including a sufficient diversity of activities needed to optimize the utility of community DET support systems. Finally, in many 'downtown' areas, the existing density of land use is such that insufficient acreage can be set aside for energy collectors. We discuss below three of the many implications these difficulties are likely to lead to in terms of conflicts between the community and regional levels.

1) From a community perspective, there always has been serious questions raised as to who reaps the benefits of redevelopment. This question will become more of an issue if the occupants of new structures in redeveloped areas served by DETs do not represent groups who have been displaced. But, this may not be possible if lower land use densities required for DETs lead to higher costs for purchasers or rentees. Moreover, because DET community systems work most efficiently with a 'balanced' load of energy demands, their use may necessitate replacement of residential units with commercial and/or industrial activities with no guarantee that these activities will provide employment to the local residents. From a regional perspective, should a transition strategy to DETs be adopted which involves the use of the self-contained communities concept described above, the displacement of residential neighborhoods will be an inevitable result.

2) It is evident that the existing central energy systems and the newer distributive energy systems will have to coexist over an extended period. To effect a smoother transition, the jurisdiction of the land use planning boards will almost certainly have to be extended to the central as well as the dis-

tributed energy systems. This follows because of the substantial need to coordinate the activities of the two systems during the transition. Neighborhoods served by the central or distributive systems may have to be chosen not by their competitive economic advantages, but simply as a matter of public benefit. For example, in the case of certain older neighborhoods containing declining building stock, there may not be merit in trying to meet their energy demands by DETs until the building stock reaches a point where it can be replaced. The difficulty with adopting such a measure as general policy is that it may produce a situtation in which older neighborhoods in the region end up being served by an unreliable central system which is in the process of being phased out. The issue of how communities are to be identified as the first in line, and the last in line, for conversion to DETs has, therefore, considerable potential for producing conflicts between local community groups and the regional planning authorities.

3) Jurisdiction in allowing new land use activities to be attracted into a community or to exclude others is a jealously regarded local perogative. While municipalities retain the authority to make many such decisions through local zoning laws, the political process within the municipality insures community expression will not go unheard. Normally such decisions are made on the basis of such considerations as local revenues to be derived, employment opportunities for local citizenry, compatibility with surrounding communities, and conformity to an overall master plan. None of these factors include

energy, nor is the situation likely to reach a point where energy becomes more than one more of the factors influencing such decisions. Under such circumstances it is clear that non-energy related factors will often dictate decisions on the part of one community and/or municipality to exclude or include a certain kind of land use activity and a completely different decision in another. But, the toleration of such flexibility may come to be in conflict with a regional plan for effecting a transition to the DETs. The need to preserve this freedom of choice on the part of individual communities and at the same time to satisfy what will be substantially greater requirements for regional coordination of community land use decisions is one of the primary challenges facing strategies designed to implement distributed energy technologies.

Question 4: To what extent must land use planning aimed at achieving the regional utilization of distributive systems take place in advance of implementation?

Discussion: Throughout the discussion above we have emphasized the need for governmental planning units to have knowledge of 1) the energy loads associated with land use activities on specific sites, 2) the site-specific input of energy resources, and 3) the mode and the technology used by each land user, and possibly their neighbors, to satisfy their energy demands. Furthermore, we have noted that once certain DETs are in place, their presence interacts with options for satisfying energy demands in other areas. This is particularly true for industrial users and for areas being served by community DET systems. It is evident that under such circumstances it will be essential to adopt regional master plans for implementing any strategy to meet a major fraction or all of the regional energy demands by DETs. Such a master plan will have to identify well in advance

1) the desired form of the final outcome as it may relate to other regional development objectives
2) the general strategy to be followed in effecting the transition to such an outcome
3) the definition of land use regulatory and building code guidelines to be followed by the municipalities and communities included within the region.

It will also, under current arrangements, have to deal with regional land use policies as they relate to higher state and federal jurisdictions involved in, for example, coastal management, water resources, environmental control, highways, and mass transit systems supervision.

Unlike many existing master plans, this one will require a mechanism for its supervision and enforcement. Authority to override local decisions may be required in instances where, for example, larger tracts of vacant land useable for placement of community energy facilties could be located, or industries requiring large amounts of acreage for generating their process heat requirements. Authority to extend their jurisdiction beyond current regional boundaries may also be necessary if additional land is required on which to locate collectors, or to prevent the loss of industries with high potential for waste heat utilization to surrounding areas.

All in all, the degree of regional control called for vastly exceed what is available to most regional bodies in the country today. Moreover, it implies a level of land use control and regulation from a central authority which goes beyond what is now generally acceptable. This additional regimentation may not only be associated with the specific intent to implement the wide-spread use of DETs. Should energy resources such as coal and nuclear power become unacceptable to the public as replacements for oil and natural gas, it is clear that the level of conservation that will be required in 30-40 years, the time scales being considered here, in the United States will necessitate much more severe restrictions on land use activities than presently exist. In any case it is fair to say that new legislation will have to be written in this area and new organizations created for formulating and implementing such regional plans.

Question 5: When energy flows into the region to satisfy indirect energy demands are considered, what effects do they have on the final land use energy system couplings?

Discussion: The discussion of the regional scale impacts of DETs, up to now, has ignored one important energy component - the energy flows between the region and surrounding and more distant areas. Because much of the energy input into, and to a lesser extent out of, any metropolitan region is in the form of energy embodied in food, clothing, housing materials, equipment, raw materials for manufacturing, etc., there is a need to consider the means used to produce the energy included in these products.

The issue involves not only state-wide and national questions of whether centralized or distributed systems are to be employed in producing these imported goods and services, but what effect would be the adoption of either system outside the region have on land use within and near the region. Three examples illustrate this interaction:

1 If we picture an outcome in which all or most of the project state's energy demands are to be met with DETs, this may lead to an outcome in which sufficient land areas will have to be designated to supply

(a) biomass for conversion to liquid fules for transport, and

(b) energy to be generated for agricultural producing and processing and the high processing heating demands of energy-intensive industries like synthetics, paper, chemical fertilizers, materials preparation. The total land area required to supply such activities could end up competing with added land use needs for meeting urban energy demands. It should be noted that total associated land demand could remain small compared to the total available and still lead to problems. For example, competition will become particularly severe in geographic areas where the large land areas required for energy generation interfere with the ability to satisfy other regional needs. Metropolitan areas adjacent to agricultural or recreational land areas offer examples. The same is true for coastal areas in warmer regions of the state if off-shore biomass production is utilized. The alternative is to use desert areas to generate electricity and other intermediate fuel forms and transport it to where it is needed. This would present few land use problems but would require the support of a large state-wide grid network.

2 Satisfying the regional and state transportation energy demands is one of the more difficult technical problems associated with a distributed energy system future, particularly if liquid energy forms remain a requirement. An alternative is to move toward the use of electricity. While the demands for electricity would be minimized by shifting transport demands to mass transit systems, it is probably not possible to satisfy all regional transportation requirements by this means. In any case, to produce this added electricity through the use of DETs will involve additional land areas either within the region or close to it. Moreover, because grid systems for the distribution of electricity are viewed as non-existent in the region other than on a community basis,(except for public service purposes such as street lighting, water distribution, mass transit, etc.,) electricity for personal vehicles and trucks for business and industry will have to be provided for by community energy systems. This will impose substantial additional land use requirements on these community systems. Also, worthy of note is that the implied lower

densities of land use make it more difficult to operate mass transit systems efficiently.

3 Large energy-intensive industries are not likely to find land areas sufficiently large, or to be able to afford them when they do, within or near the regional development to satisfy their energy demands. This could lead to an out-migration of such industries together with their secondary and tertiary off-shoots. Such an outcome would result in either an extensive commuting of regional inhabitants to the areas where such facilities are to be located. Alternatively, the households to whom these individuals belong may decide to move. If, however, these industries are allowed and/or are able to satisfy their energy demand with coal and/or nuclear power situated in or near the region, the problem would be alleviated. In either situation, there are direct and indirect land use and regional development impacts that depend upon the choice of coal/nuclear versus distributive renewable energy systems to satisfy these demands.

10.4 CONCLUSIONS AND RECOMMENDATIONS

This report was intended to define the implications and issues which arise out of the interaction between the use of land and the widespread utilization of distributed energy systems. As the above discussion then makes abundantly clear, the land use implications issues involved in effecting such a transition are numerous, complex, and have many legal, institutional, political, and economic impacts. Many of the most important have not been dealt with. We have only touched on the inevitable changes in land values that will accompany such a transition, and how such changes will impact on the movement of various elements in the population, industry and businesses into and out of settled regions. We have failed to discuss in any detail the ramifications of the differential effects on poorer and more densely populated neighborhoods in the inner city and higher income suburban areas on the outskirts of metropolitan areas. With sizeable plots of open space scheduled to become a premium in any of the DET outcomes, we have not even mentioned the pressure to convert existing recreation areas to other "more practical" uses. Nor have we considered the aesthetics of the final urban forms. Finally and most seriously perhaps, we have not mentioned how such a region would 'work' – how efficiently it would be able to provide municipal services, what would be its effect on existing mass transit systems and those being planned in the physical environment, and on its general 'livability'. These omissions only confirm the need for much more detailed analysis.

What has been shown however, from even this preliminary analysis, is that the technical and economic analyses of solar energy utilization, where they have considered land use requirements, have been much too narrow in scope. They have tended to regard land use as simply one additional resource - not to be impacted on too severely. As such they tend to minimize broader institutional, economic, social, and political problems encountered in moving from analytical results based on a cluster of buildings to a total balanced community.[8] Such studies demonstrate that solar energy is, or will soon be, a practical method of providing for stationary energy demands for many energy demand situations. But, as this report has tried to make clear, such analyses tell us rather little about implementation of such systems at a larger scale of land use. To prepare the way for the steps that will be required in the public and private sectors if distributive systems using renewable resources are to become a major means of satisfying end-use demand on a regional level, we will require much more analyses of the land use - energy utilization inter-dependencies. The conclusions listed below together with the recommendations that follow are intended to suggest an analytical agenda for continuing this process.

All land use strategies for achieving regional energy systems based totally, or in large part, on DETs appear to involve one or more of the following:

(1) changeover in current land usage: This will mean wide-spread conversion of land now used for one purpose to another. In areas already built-up this will mean redevelopment or renewal. In

undeveloped or more sparsely developed areas, it will mean changes in zoning.

(2) development of land areas currently not built on around metropolitan regions: Because of the lowered average densities of land use associated with the regional wide use of DETs, the need for additional land will be substantial.

(3) modifications in current community, municipal, and regional zoning laws and regulatory jurisdictions: Not only will zoning have to be more specific regarding the energy loads of the activity permitted on a tract of land, but it may have to define the mode (on-site or community delivered) in which energy will have to be provided. A strengthening of regional control vis-a-vis the individual municipality and/or community will be required.

(4) changes in patterning of land use: Pronounced alterations in mix, interspersions, and densities of various land use activities will be required to accommodate DET systems on a regional scale. As noted above, land use occupancy densities will be lower on the average. If the transition to widespread use of DETs takes place via a proliferation of self-contained or balanced communities, each of more or less equal composition, the resulting regional pattern of land uses may be much more homogeneous than now exists. If, however, regional development employing DETs takes place through steady growth of a few nucleation

sites in or near the region there will probably be somewhat less uniformness but still much more spatial justapositioning of disparate activities.

(5) increased community and regional requirements for anticipating and planning for future energy demands: Master plans encompassing areas substantially larger than those now occupied by urban activities will be necessary to implement DET regional strategies. They will have to more closely identify regional parameters related to projected energy demand and regional resource inputs. This will mean the interpretation of regional developmental goals and targets and preferences in terms of their implied energy requirements. It will also require an enlarged capacity to monitor and enforce the implementation of the plan.

(6) Our final conclusion is based on the intimate tie between community and regional land use requirements and the design and construction of new buildings. Should building codes provide requirements for maximizing the use of passive solar systems and low heat loss material and construction practices, then the land use requirements, for all the DETs considered here, would drop substantially.

Our recommendations are confined to those dealing with the need for more detailed analysis. This call for additional analysis should not be interpreted, however, as indicating that the current information base is too meager to consider more active steps. Already evident are the directions in which zoning law modifications will have to occur and building codes be altered to accommodate

DETs. It is also clear that regional energy plans of one kind or another will be required. Finally, it is also apparent that incentives provided by the National Energy Plan, while they have the potential for altering conditions for implementing a regional distributed energy system strategy, do not go nearly far enough.

Obviously, however, much more analyses of land use and DET utilization is needed before we can move from the descriptive and somewhat speculative arguments enumerated in this report to more definitive conclusions. We list below several areas meriting such study.

i. Land use - energy utilization models are needed to stimulate regional land use development patterns using a variety of DETs under varying local conditions. These models should allow both generic and site-specific analyses to be undertaken.

ii. Analysis of new organizational formats for bringing together representatives from regional planning offices, appropriate state agencies, communities and energy suppliers to prepare Regional Master Energy-Land Use Plans should be undertaken.

iii. The economic impacts of regional DET strategies on land values should be analyzed.

iv. Given the major demands such a strategy places on redevelopment as well as new area development, the socio-economic impacts of a transition to a DET regional system on various income groups must be addressed.

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CHAPTER XI

LAND USE IMPLICATIONS OF A DISPERSED ENERGY SYSTEM

11.1 INTRODUCTION

This working paper explores the land use implications of an energy policy which favors energy conservation and the use of "soft" energy sources. In addition, the constraints and opportunities presented by the California land use planning framework are addressed.

For the purposes of our analysis, we have proceeded by researching the environmental and land use impacts of those technologies identified by LBL as being "desirable" (see Table XI-1). The result of this work is organized by energy source in Section 11.2.

Energy conservation has not been explicitly addressed by the research project as a whole, but it is essential in our discussion. Energy-conserving building design and land use patterns are receiving increasing attention from land use planners and decision-makers. Several communities, counties and states have initiated programs designed to foster energy conservation in building design (i.e., new building codes) and urban spatial forms (i.e., infilling policies and planned-unit-development design guidelines). However, urban forms designed to conserve energy may or may not be compatible with arrangements designed to enhance the utilization of soft energy technologies. As a first step in the evaluation of this relationship, a summary of current research regarding land use forms and energy conservation is included in Section 11.2.

Section 11.3 identifies nine major issues inherent in the existing land use planning process that set the context for implementation of the soft path.

Energy is but one variable in a set of loosely defined criteria for particular land use decisions. Economics, aesthetics, recreation, mobility, and a host of other concerns may often prove to be more significant to the public and their elected and appointed decision-makers. But energy considerations may not be involved in current decisions due to a lack of concrete methods for evaluation. In Section 11.4, an eleven-step process toward local energy-oriented land use planning along a soft path is presented.

Table XI-1

Grouping of Technical Options for Formulation of Distributed Energy Systems

MOST DESIRABLE

Passive solar design of buildings
Solar water heaters
Active solar space heating
Wind turbines for on-site applications
Existing hydroelectric facilities
New small hydroelectric facilities
On-site energy storage (various forms)
Biomass waste utilization

SLIGHTLY LESS DESIRABLE

Solar industrial process heat
Solar total energy (cogeneration) systems
Wind turbines feeding into a grid
Geothermal energy for non-electrical applications

LESS DESIRABLE

Active solar cooling
Geothermal energy for electrical generation
Centralized energy storage (various forms)
Solar thermal central station electricity
New large hydroelectric facilities
Biomass from energy farms
District heating systems

UNDESIRABLE

Natural gas
Coal used in cogeneration
Coal gasification
Coal liquefaction
Idigenous oil

UNSUITABLE

Imported oil
Imported LNG
Oil shale
Nuclear electricity
Coal central station electricity

Source: LBL, 1977

11.2 SOME LAND USE IMPLICATIONS OF A DISPERSED ENERGY PATH

In analyzing the land use implications of various soft energy sources we identified their physical characteristics, environmental impacts, land use requirements, and resultant planning implications. Since the physical descriptions are addressed by LBL and myself and the environmental impacts by Holdren, we will concentrate our discussion on land use issues.

11.2.1 On-Site Solar Systems

On-site solar technologies are described as either passive—utilizing the design of the building envelope to provide climate control with little or no mechanical equipment—or active—utilizing collectors to gather solar energy to heat water or air which is stored and from which heat energy is extracted for water or space heating or heat-activated space cooling.

The major land use considerations related to installation of on-site active solar energy systems on a large scale include: sufficient surface area on which to locate collectors at the optimum orientation and angle and sufficient space in which to locate a storage facility. A report prepared for the State Energy Commission (Hirshleig, 1977) has estimated that only about 65 percent of existing residential units can be retrofitted with solar spaces and/or water heating systems. "The 35 percent differences between feasible and maximum potential is the result of problems caused by the shading of the roof area for solar collectors as well as the poor orientation of the slope of many single family units."

The assumption that collection modes will be primarily roof-mounted on existing structures—presumably including garages and carports. Limitation of collectors to rooftops does have the advantage of not preempting land which could be used for other purposes. However, including non-rooftop locations in the picture could greatly increase the potential for retrofitting and additional collection area. Other potential locations for collectors include newly constructed patio or deck covers with the appropriate slope and orientation, fences, south-facing slopes and berms.

(The potential for grouping collectors to serve more than one structure will be considered in the subsequent discussion of solar grid district heating.)

A report by the Office of Technology Assessment (1977) lists average collector and storage specifications for on-site solar systems which could provide 100 percent of the space and water heating requirements as 440 ft^2 and 1,000 gallons for single family dwellings and 45,000 ft^2 and 6 million gallons for a 196-unit high rise. These estimates would be lower if computed specifically for California since its climate is milder than that of the U.S. as a whole; moreover, if it is assumed that only 75 percent of the supply is provided by solar with backup from some other sources, collector and storage requirements drop considerably. ERDA's Pacific Regional Solar Heating Handbook (1976) indicates that for 75 percent water and space heating for a 1,600 sq. ft. single family unit with a thermal load of 8 Btu's/degrees/day/sq. ft. floor area, the building's thermal load will be 12,800 Btu/degree-day. In Santa Monica space heating would require approximately 150 ft_c^2; water heating would require less than 100 ft_c^2. In Fresno space heating would require approximately 380 ft_c^2 and water heating less than 100 ft_c^2. These collector area requirements could be met by almost all single family homes with some yard area—if not on roofs of houses then on garage roofs, walls, patio covers, fences or ground area in yards.

As density increases, few opportunities for non-rooftop collection are available. If roof angle and orientation cannot be adapted to accommodate collectors without prohibitive cost, if sufficient surface area for collector placement is unavailable or if available roof or ground space is shaded by neighboring structures, a solar system would not be feasible. If 400 ft_c^2 were required for each 1,200 sq. ft. unit of apartment complex, then there would be sufficient collector area on the roof for only three stories of units. In some cases, existing mid- and high-rise structures are surrounded by parking lots which could be covered with collector roofs to increase available collector area.

Storage requirements are more easily accommodated, particularly if only four days water heating backup is required. Active system installation will entail fewer difficulties in new developments than will entail fewer difficulties in new developments than will occur in retrofitting existing structures since passive design techniques can reduce the thermal load substantially and the system can be designed into the structure. However, the prospect of implementing passive solar design techniques on a large scale has led to several land use-related concerns. One is that it will result in rows of structures all facing the same direction with similar or identical roof configurations (Schoen, et al., 1975). The other is that it would require lower density development so that potential energy savings from high density reduced construction and heating costs and reduced transportation requirements could not be realized.

These concerns can be dealt with through development that is designed to meet performance standards rather than prescriptive regulations. Necessary flexibility can be provided by the decreased use of traditional lot subdivisions with setbacks, bulk and height restrictions, and the increased use of land use management tools such as planned unit developments coupled with energy performance standards. Proper orientation, collector location, protection of solar rights and other potential constraints have been demonstrated to be surmountable within the context of these more flexible planning techniques.

These same tools provide a framework in which to deal with the second concern, i.e., a limitation on density in order to protect solar rights and to provide adequate collector area for each structure. When buildings are designed in relationship to one another rather than relative to fixed lot lines, they can be located so as not to infringe on one another's solar rights and at the same time to take advantage of energy conservation techniques. In addition, since there is no reason why collectors have to be located on rooftops only, clustering of structures would provide larger areas of open space, parts of which could be dedicated to solar collection.

New high-rise structures can be designed to incorporate solar collectors into walls as well as roofs where adequate open space around the structure allows for access to sunlight. In high density areas with high-rise structures, however, on-site solar may remain infeasible in many cases.

Provision of backup energy for less-than-100-percent on-site solar systems also raises land use planning and management questions. In what form should power be provided—as electricity or gas? At what scale should production occur—neighborhood, metropolitan area, region or state? The answers to these questions will vary from one place to another depending upon available resources and the existing infrastructure.

11.2.2 District Solar Heating

The use of a system of solar collectors as the energy source for a district heating system is a relatively new concept. The grouping of collectors to provide space and water heating for small clusters of units has been suggested by McClemon, *et al.*, (1977). A further extension of this concept of shared solar collection to a larger scale has been referred to as solar grid district heating. A series of collectors would heat a single large water supply which would be used to supply space and water heating by traditional district heating methods. LBL provides the following data concerning storage and collector requirements for district solar heating systems:

	San Francisco	Los Angeles
Population	677,000	933,000
Solar Resource	0.16 MMBtu useful heat/ft^2	0.19 MMBtu useful heat/ft^2
Collector Requirements (Range)	$24.5\text{-}52.7 \times 10^6 ft^2$	$25.8\text{-}42.0 \times 10^6 ft^2$
Storage Requirements 4 days hot water backup* no space heating backup*	190,000-271,000 gal	163,000-244,000 gal

*Backup to be provided by bioconversion (methane).

If neighborhoods are defined as having a population of 1,000, using typical land use requirements for various housing types (Real Estate Research Corporation, 1974), numbers of units and gross acreage required to comprise a neighborhood of 1,000 residents for various types of development can be determined:

	Single Family Tracts	SF Cluster	Town-house Cluster	Walkup Apt.	High-Rise Apt.	Mix 20%@
Foot Area/Unit	1,600	1,600	1,200	1,000	900	1,260
Persons/Unit	3.5	3.5	3.3	3.3	2.8	3.3
Residential Density						
Units/Gross Acre	3	2.5	3.3	5	10	3.3
Units/Net Res. Acre	3	5	10	15	30	6.9
Units/Neighborhood	290	290	300	300	360	306
Gross Acreage	150	116	94	94	36	94

LBL's data indicate that 28,000 to 46,000 ft_c^2 would be required to provide for a neighborhood of 1,000 people.

Collection. Collectors for district heating could be located in a number of different ways. They could be located on a single area of a size ranging from 3/4 to 1 plus acres or the equivalent of 3 to 5 1/4-acre tract lots scattered throughout the neighborhood. They could be limited to rooftops in which case they could be constructed on adaptable existing units and new units, community facilities such as libraries, schools, community centers, and parking structures. The most likely locational approach in either new or existing neighborhoods would consist of a combination of the above possibilities. Since the distribution and storage facility with its backup system would require at least half an acre, its roof area and surrounding land area could provide a sizable portion of the total required area.

Storage. Storage facilities could be located either at a central location with a backup heating system or dispersed along the district's loop depending upon which proved most efficient in conjunction with the collection system organization. Basements of community facilities such as schools, churches and libraries could provide relatively large spaces for storage. Location of storage tanks beneath street intersections has been proposed by some.

Heating. Both radiant and forced air systems could be utilized in a district heating scheme. Neighborhood distribution lines would have to be installed in existing neighborhoods and appropriate dwelling unit heating systems adapted or installed. Electrical power lines could be undergrounded at the same time.

Distribution. In new developments distribution lines could be laid along with other utilities. If natural gas pipelines were no longer installed, the overall cost of utility installation would not have to increase significantly since the amount of piping would remain constant. The cost effectiveness of retrofitting existing neighborhoods would depend upon the availability of collector area, vacant land on which to locate the facility and the density of the development. A great deal more distribution piping would be required in a single family tract development covering 150 gross acres than a neighborhood of high-rise apartments covering 36 acres. However, in the latter case piping would have to be installed throughout each structure as well.

Municipal governments appear to have the jurisdiction to deal with the land use requirements of installing and operating community solar grid district heating. A report prepared by the law firm of Wilson, Jones, Morton and Lynch (1976) details the legal implications and approaches to implementation of solar heating and cooling systems by municipal corporations, establishing the legal authority of the municipality to undertake such a program concurrent with provision of conventional power by utilities.

In new developments approved under the Subdivision Map Act, i.e., detached units or condominiums of more than four lots, dedication of land and exaction of fees to provide public services can be required as conditions for approval. Subdividers are routinely required to construct roads to city standards, install sewage and water supply systems and dedicate land for parks and schools. To provide a solar grid district heating system, installation of necessary distribution piping and dedication of land needed for collectors and backup facilities could be required as conditions for subdivision approval.

In existing developments, distribution piping could be installed along the same rights of way utilized for other utility lines. If land area (ideally vacant) on which to locate the backup facility could not be purchased outright from a willing landowner, the municipality can exercise the power of eminent domain to obtain such land as is needed, providing just compensation to the owner. The location of storage facilities and collectors on private land, if necessary, would probably be best achieved through acquisition of easements. In some cases easements might also have to be acquired for the distribution system itself.

Clearly, it would be considerably easier and less costly in terms of energy and other resource consumption and labor as well as capital costs to municipalities to install district heating at the time a subdivision or other development is being planned and constructed rather than later. Therefore, if the solar grid were determined to be more efficient than on-site solar installations and adopted as an eventual energy source by municipal policy, it would be logical to require provision of necessary piping and dedication of land for storage, collector and backup facilities as a condition for subdivision map approval. Requiring that new dwelling units be fitted with equipment adaptable to district heating could perhaps be addressed at this decision point but might be more logically dealt with at the point of building permit approval. A municipal ordinance, state statute or provision as part of the State Energy Commission's regulations are all vehicles by which that requirement could be interjected.

In addition to potential economies of scale in efficiency, cost and resource consumption, the solar grid has other potential advantages over on-site solar systems:

- Problems that my be encountered in retrofitting existing structures, many of which defy adaption to solar systems (at least at economically viable costs), can be avoided.
- The potential obstruction of insolation, i.e., the issue of solar rights, will be minimized. Rather than having to create a solar "envelope" around each dwelling unit, restricting the location and height of adjacent structures and trees, only the few locations in which the collective collectors have been placed would need to be protected. Solar rights legislation

would not necessarily be required to do this; it could be assured by acquisition of adequate land or easements by the municipality. (However, assuming on-site solar systems would be appropriate to some sites, solar rights legislation in some form might be required.) On the other hand, if it were found that on-site solar was appropriate primarily for low-density single family dwellings with district heating appropriate for other densities, the likelihood of obstruction from neighboring structures and trees becomes minimal.

- The potential conflict between relatively inflexible solar rights zoning and the desirability of setback flexibility for passive solar design is also reduced.
- The solar grid could be applied to high-density neighborhoods where on-site solar systems are unavailable.
- A potential advantage of the district heating system over on-site solar relates to backup heating. If conventional sources, i.e., electricity, are relied upon for backup, sufficient capacity to meet peak load demand for periods of prolonged sunlessness would have to be provided by the utility. As an alternative, energy produced from biomass be utilized to heat the district storage system. A backup system attached to the district heating system would eliminate the need for each household to provide adequate storage for a 100 percent solar supply or to obtain backup power from conventional sources.

It should be apparent from the previous discussion of on-site and district heating solar systems that careful matching of technological mixes to the needs of each neighborhood is essential to the workability of a soft technology system. In existing low-density single family neighborhoods it may be best to utilize on-site solar installations with backup from the electrical grid and from natural gas or methane. The extent to which new solar systems are adapted depends in part on the life expectance of the structures involved. Where it is short, it may be best to continue utilizing conventional energy sources until the structures are replaced. If a large portion of the structures are of the same age and can be torn down simultaneously, a PUD with district heating might be a logical replacement. If all the buildings have limited life expectancies but those expectancies are sufficiently varied, replacement with on-site systems may be the appropriate solution.

For a single structure being constructed in an established neighborhood, the approach to heating that unit would depend upon the scheme determined to be most appropriate to the neighborhood. For example, if the life expectancies of buildings in the neighborhood were variable but long enough overall to justify installation of solar systems, site and economic analyses of the neighborhood might reveal that on-site solar was not feasible for a large portion of the structures. Therefore, a district heating system would appear most appropriate. However, there may be a time lag between the point at which the solution is identified and the point at which it is implemented. In such a circumstance, the developer of the single lot would be faced with the choice of delaying construction until the district heating system is installed, building a structure which can be adapted to the district heating system when it is installed but which actually operates on conventional power or installing an on-site solar system.

The potential developer's choices may be restricted by policies established by government or utilities. The local government or neighborhood government might place a moratorium on building until the district heating system is installed; or the utility supplying conventional energy might place a moratorium on further hookups. Such regulations would result in directing development to areas in which renewable energy sources are being utilized. By such means, land development could be effectively managed if tied to a land use/capital improvement plan.

11.2.3 Biomass Conversion

Biomass conversion or the production of energy from organic materials can be described initially in terms of sources. Two major types exist: 1) organic waste materials ranging from agricultural field and lumber industry residue to municipal solid waste and sewage; and 2) energy farm production, i.e., cultivating plant material solely for its energy content. Several processes for energy conversion are available for application to each source. The process selected depends in part on the end use it is intended to serve; the scale of the processing plant similarly depends in part on the end use. These in turn influence land use and resultant environmental impacts. Table XI-2 summarizes potential sources of biomass (from waste products only), applicable energy conversion processes and products together with collection and distribution requirements, corresponding end uses, environmental impacts, and alternative uses of those energy sources. It also provides the maximum energy supply potential for each source (as determined by LBL). Given the relatively limited potential of this resource and the alternative uses available, it becomes apparent that careful attention must be given to determining the most appropriate use or uses of these resources within a dispersed energy system. Consequently, the section will focus on the tradeoffs between various alternatives in terms of their effect on the rest of the system as well as land use and environmental implications.

Large-scale bioconversion will have substantial land use and environmental implications. According to Davidson, et al. (1977), assuming 1 percent photosynthesis conversion efficiency, 12 percent of total U.S. land area would be required to produce current U.S. energy needs. This assumes a production rate comparable to that of agricultural crop production. Consequently, it would require comparable amounts of energy, water, fertilizer, pesticides, and mechanical support if it were carried out on comparable soils. As the quality of the soil decreases, increased inputs are required. Because so much prime agricultural land has been converted to urban development, marginal land is already being put into production. If the population of California doubles by 2025, a corresponding increase in agricultural production can be expected.

California's limited water supply serves as a constraint on cultivation of biomass by conventional means. Environmental impacts of energy farms would be similar to those associated with food production, i.e., nutrient depletion of soil, erosion, nitrogen runoff affecting water quality, monoculture leading to the reduced biological capability of the ecosystem, vulnerability to destruction by viruses and pests, and increased dependencies on pesticides.

Table XI-2

Biomass Conversion

SOURCES	1975 TONS	1975 10^{15} BTUS	2025 TONS	2025 10^{15} BTUS	COLLECTION	PROCESSES	PRODUCTS	END USES	ENVIRONMENTAL IMPACTS	ALTERNATIVES
Municipal Solid Waste (MSW): 14% Garbage, 10% Yard Waste, 52% Paper, 8% Glass, 1.5% Aluminum, 6.5% Ferrous Metals, 8% Other (Source: 25)	15.5	0.171	28.5	0.313	Municipal Service[1]	Incineration with Heat Recovery	Steam	District Heating - Full Time or Solar Backup or Process Heat	Air and Water Pollution	Recycling Resources & Compositing Organics
						Fluidized bed Incinerators	Electricity	On Site or Grid		
						Pyrolysis	Fuel Gas (Methane)[2] with Some Liquids and Solids	Natural Gas Substitute		
							or Pyrolytic Oil (No. 6 Fuel Oi with Solids	Turbine Generators, Other Fuel Oil Uses		
							or Methanol	Liquid Fuel (Transport)		
And Industrial Waste 40% Organics						Shredding, Etc.	Refuse Derived Fuel (RDF) (Supplemental Fuel)	Backup for Solar Grid Process Heat		
						Anaerobic Digestion (Organics)	Methane	Natural Gas Substitute		
Sewage	0.7	0.014	1.3	0.026	Municipal Waste-water Treatment System	Anaerobid Digestion Pyrolysis	Methane Methane	Natural Gas Substitute Natural Gas SUbstitute		Composting Privies Or Other On Site Facility
Dairy and Feedlot Waste	3.6	0.061	4.4	0.075	Conce..trated as Function of Operation	Hydrogasification Anaerobic Digestion Pyrolysis[4] Hydrogenation[3] Bioconversion	Methane Methane Fuel Oil Fuel Oil Methane	Natural Gas Substitute or Electrical Generation for On Site Operations		Fertilizer
Timber Harvesting Residues	4.5	0.072	5.6	0.090	Already Concen-trated	Combustion	Steam	On Site Process & Space Heating		Burned or Left in Place[1] (100%)
Lumbermill Residues	2.0	0.032	2.5	0.040		Combustion	Steam	District Heating of Nearby Towns		Wood Products[1] (35%) Energy Use On Site[1] (35%)
Other Wood Residues (MSW or Industrial)	6.9	9.111	8/6	0.138		Combustion	Steam			
Agricultural Industry Wastes:	0.9	0.016	1.4	0.025	Concentrated as Function of Operation	Incineration with Heat Recovery	Steam	On-site Process Heat, Electrical Generation	Loss of Soil Conditioners	1. Livestock Feed (81%)[1] Returned to Soil (9%)[1]
1. Dry Mill Trash and Hulls	< 1/2									
2. Vegetable Packing Wastes										2. None, but High Moisture Content may Limit Use
3. Food Industry Waste	> 1/2					Pyrolysis	Fuel Oil			3. ?
Agricultural Field Residue:	8.6	0.151	13.8	0.243						
1. High Moisture	~ 5/8				1. Baling or Chop-ping & Stacking	Anaerobic Disgestion (combined with Sewage)	Methane	Natural Gas Substi-tute		1. Feed (37%)[1] Returned to Soil (63%)[1]
2. Low Moisture	~ 2/8				2. Costly; diffi-cult for rice					2. Returned to Soil (83%)[1]
3. Vegetable	< 1/8				3. Difficult					3. Returned to Soil (100%)[1]
4. Orchard Prunings	~ 1/8				4. Compact and Chip					4. Burned
TOTALS										
TOTALS	42.7	0.627		0.950						

Notes: 1) Current Practice (Percentage Used); 2) 1 Ton MSW —(2 million BTU (900°C))→ 8 million BTU (Useful Energy); 3) 1 Ton —— 50 Gals Fuel Oil (15,000 BTU/lb); 4) 1 Ton ⟶ 40 Gals Oil + 160 lb. Char + Gas (10,500 BTU/lb).

An alternative to land-based energy farms is the cultivation of algae in ponds or kelp in the ocean to provide biomass. A report by A.D. Little estimates the productivity of the former (see Wilson, 1974), concluding that assuming an energy content of 10,000 Btu's per pound of algae, a 100-acre pond would yield the fuel equivalent of only 5 tons coal/day—enough to power a 600 kW electrical generating plant. Furthermore, Odum has calculated that on the basis of A.D. Little's findings, the energy required to build and maintain the plant, to control the growth of cultures and to harvest the algae exceeded the energy yield in organic material.

An impact of using municipal solid waste as a source of energy production lies in the loss of opportunity to recycle those materials that are used, i.e., paper which comprises approximately 50 percent of municipal solid waste, yard wastes which comprises about 25 percent, and wet garbage. Paper products can be recycled to produce more paper, and garbage and yard wastes can be composted to produce fertilizer. Perhaps more importantly, this alternative creates a reliance on the "production" of waste. Paper product wastes are combusted to produce energy to produce paper products that will become waste. Using compost for fertilizing landscaping and food crops by homeowners would reduce the needs for the energy-intensive production of chemical fertilizers. In addition, the 25 percent reduction in volume of municipal solid wastes (MSW)(assuming composting is done at the household or neighborhood level and fewer waste paper products are utilized) would reduce the energy requirements of MSW collection.

Industrial wastes could provide 6,600-7,300 Btu/pound as a potential energy source for internal use.

Utilization of sewage as an energy source raises a large number of questions with respect to alternatives methods of disposal whose energy savings would greatly outweigh potential energy production. Current waste water management consists of removal and dewatering of sewage sludge from combined household greywater, human urine, and industrial wastes; treatment of the waste water to be released into waterways or more extensively to be recycled for irrigation purposes; and disposal of the sludge. The EPA's waste water management program is providing treatment facilities. (Roughly $26.5 billion was just approved by the U.S. Senate for 75 percent federal grants.)

Within the context of this system, if sludge were converted to methane by anaerobic digestion, two problems would be partially solved: 1) disposal of sludge and 2) production of energy. However, Moins and Hess (1975) have pointed out that for the cost of modernizing most municipal sewage treatment facilities (probably in terms of energy as well as dollars), in-house, non-water carrying disposal systems could be installed in almost all houses, eliminating the problem of municipal sewage disposal altogether. Furthermore, if industrial wastes were not fed into the municipal waste water system, the remaining greywater inflow could be reused for irrigation with minimal treatment. The energy savings of this alternative are obvious. However, once the EPA's wastewater treatment goals are achieved so that every municiaplity has an adequate conventional sewage treatment facility, the adoption of such an alternative will be a moot point.

Along with the availability and distribution of the biomass source, the end uses to which it is directed will influence the scale of the operation and transport requirements of new materials and energy products. Table XI-2 summarizes some likely possibilities.

If it is decided that as much biomass as possible be converted to methanol to provide liquid fuel for transportation, it might be most appropriate to collect all resources at a regional plant and undertake a single large-scale operation from which fuel can be distributed in the conventional manner. On the other hand, there may be sufficient quantities of resources within each municipality (if MSW is converted to energy rather than recycled), or at each production site, to operate a small-scale conversion plant to supply fuel for that area's transportation needs. If methanol were produced in quantities only sufficient to supplement gasoline, each local facility would have to possess the capability to obtain and mix gasoline with the methanol it produced.

If, on the other hand, it were decided that biomass would provide backup for on-site solar and/or solar grid district heating, neighborhood or municipal plants could be constructed to process waste materials. In a high-density area, methane or RDF could provide fuel line district heating as is currently the case in many European cities.

11.2.4 Wind

Power can be extracted from wind to generate mechanical energy to pump water, turn milling stones or generate electricity. It is in this last application that wind has spurred renewed interest in the United States. The many wind-driven water pumps and electrical generators once found in rural counties have, over the years, been replaced by grid-supplied electricity. The form of supply proposed now is generally on a large scale, involving many hundreds of wind generators.

The intermittant nature of the wind resource requires storage facilities to reserve off-peak energy for peak load periods. In considering the feasibility of individual wind units, it has been the high cost and relatively short lifetime of battery storage that have made this form of electricity prohibitively expensive. Storage suggested for large-scale wind energy conversion includes pumped hydraulic storage, compressed air storage, flywheels, synthetic fuels (hydrogen), and the electrical grid itself.

Generators. Wind generators are of two classes; depending on whether they are horizontally or vertically mounted. Most people's image of a wind generator corresponds to a small-scale, multi-bladed horizontally mounted generator. These are typically mounted on a 17-meter tower (comparable in height to a telephone pole). Another horizontal design is termed a wind turbine, which is basically a propeller (2 or 3 blades) mounted on a tall (approximately 110 meters) tower. For the large-scale generation of electricity, wind generators would be sited in an array, located a distance 10 times the blade diameter from each other. LBL has estimated that 5,000 small wind generators (22-meter blade diameter), covering 200 km^2 or 100 large (150-meter diameter) wind generators covering 100 km^2 would be necessary to produce 100 MW of electricity.

Vertically mounted wind generators are of two types: the Savonius rotor and the Darrieus "eggbeater." Operation of these generators is independent of wind direction. The Darrieus rotor in particular has been mentioned for potential siting on urban rooftops to generate electricity.

Storage.

1. Batteries. Individual systems, as mentioned earlier, typically rely upon lead-acid batteries for storage. Large-scale battery storage is many years and dollars from development.
2. Pumped hydraulic storage. See the section on hydropower.
3. Compressed air storage. This option is highly site-dependent as underground caverns are utilized.
4. Synthetic fuel storage. The production of hydrogen by electrolysis and the collection and storage of hydrogen gas has been suggested by Heronemus (see Penner and Icerman, 1975). This gas can be used directly or transported and converted into electricity by fuel cells. This option is not site-dependent.
5. Electrical grid. The grid itself can act as a storage medium, suffering only from typical transmission losses. Electricity can be moved to areas which need it immediately, with peaking power provided by a variety of facilities. Because of rural electrification, the grid reaches quite remote areas.
6. Flywheels. Small-scale application of flywheels has already been demonstrated. Large-scale flywheels would likely be located underground to avoid mishap from high stress components and would therefore be sited in underground caverns. Development of large flywheels is not expected until the 1990's.

Land Use Impacts. Although nonpolluting in the traditional sense (i.e., no air or water pollution) wind conversion systems have a wide variety of adverse land use and environmental effects. Those identified in the literature are: 1) noise, both audible and infrasound; 2)aesthetics; 3) microclimate effects; 4) possible tree removal; 5) hill alteration to promote winds; 6) pre-emption of agricultural lands; 7) risk of personal or property injury from flying blades, tower accidents, etc; 8) TV signal interference; 9) hazards to birds and other wildlife through collision or disorientation; 10) navigation hazard from ships if offshore and aircraft if on mountain tops; 11) construction impacts of ancillary facilities, i.e., roads, transmission lines, storage systems, out buildings; 12) restriction of further building in an area that might block winds; 13) fencing and other security measures to protect generators from vandalism.

These impacts are largely mitigated if sites remote from urbanized areas are utilized. In this case, questions of land area pre-empted and the potential for multiple use are more important than nuisance problems. Purchase or condemnation of an area surrounding a wind energy conversion system may be the best way to guard against nuisance complaints.

Planning Considerations. Presently, a wide variety of land use planning regulations affect possible siting of wind energy conversion systems. If located in coastal areas, the California Coastal Commission policies as enforced by local government will regulate visual impacts, access, and competing interests, such as agriculture, recreation and open space, and energy facilities. Local government may enforce certain height restrictions, structural standards, zoning requirements and nuisance laws that would tend to discourage siting in urbanized areas. The State Energy Commission would regulate power plant facility siting. The State Lands Commission may be involved in access questions if state lands are involved. The Federal Power Commission may regulate certain structural characteristics of the wind system. OSHA would be concerned with worker safety. Areas preserved for their wildlife or scenic value would probably be off limits. The EPA would be responsible for noise impacts. If government lands were used, a variety of agencies could conceivably be involved, i.e., the Forest Service, Bureau of Land Management, National Park Service.

11.2.5 Cogeneration and Solar Thermal

Cogeneration, waste heat recovery, and total energy systems are terms used to describe various combinations of electrical generation, process heating, and space conditioning designed to utilize energy more efficiently. Topping cycle technologies refer to the utilization of heat exhausted from an electrical generating plant which is used in industrial processes or for space conditioning. Bottoming cycle technologies refer to the use of heat exhausted from an industrial process. If the temperature is sufficiently high, as in the case of cement plant kiln gases, the exhaust heat may be used to generate electricity which can be used on-site or fed into the grid. Or, exhaust heat may be used for space conditioning or for industrial processes requiring low-temperature heat.

Utilization of cogeneration during the transition to a soft energy system could provide electricity to be fed into the grid which would otherwise have to be generated in new central power plants. Or, in the end state envisaged by the LBL group, industry would make extensive use of solar heat for process temperatures up to 350°F and most industries with large electrical requirements (would be) able to combine on-site solar thermal generation of electricity with the use of waste heat for other applications. To achieve this proposed end state, industries whose combined energy needs most efficiently matched production from an optimally-sized solar thermal plant, e.g., 10 MW, would have to co-locate. Furthermore, in order to maximize electricity generation it would make sense for industry to locate in the sunbelt of the southern part of the state. Similarly, in the case of industries using on-site solar for low- and medium-temperature process heating, it would make sense to locate in those areas with constant and high insolation.

The land use and planning implications of such optimization of industrial land use patterns are substantial. Particularly if industry becomes increasingly concentrated in the southeastern part of the state removed from urban concentrations, increased transportation of raw materials and produced goods would be necessary. It might be found that given a concentrated geographic distribution, a major rail system connecting industrial centers with primary resource areas and consumers would provide an efficent means of transportation. The provision of water creates a particularly difficult problem in this arid region. Since the state water demand is already expected to exceed the supply, the additional demand resulting from the creation of supporting population centers in the southeast could only exacerbate that shortage.

Existing designs for 10 MWe solar plants require a field size of at least 527 square meters (McDonnel-Douglas) or approximately 72 acres. The availability and cost of such quantities of land in the Los Angeles-Orange County-San Diego areas adds additional support to the proposition that those industries requiring solar thermal production capabilities be located in outlying areas.

It should be noted that continued reliance on the electrical distribution grid would minimize many of these land use constraints at the cost of increased energy loss and environmental and health hazards associated with the grid.

The complexities involved with industrial siting may require an increasingly centralized planning process. In order to optimize the use of energy, transportation systems and other resources, the state or region may have to designate industrial parks, indicating the range of industries that may locate there and perhaps regulating the growth of supportive facilities. This might require the sharing of tax revenues derived from state- and regional-located industry to maintain an equitable distribution of monetary resources.

Competition for large areas of land capable of supporting industrial parks is likely to intensify in urbanized areas. If regional or municipal governments compete for industry to provide tax revenues, more appropriate uses of land, e.g. for agriculture, may be ignored in favor of use as an industrial site with solar thermal capacity.

In addition to land consumption, solar thermal production also requires consumption of other resources and of energy to convert them into usable form. The primary material requirements of solar themal plants are concrete, steel and sand. Production of both cement for concrete and steel require high-heat temperatures and are, thus, important consumers of the energy to be produced by solar thermal plants.

11.2.6 Hydroelectric Power

In terms of land use and environmental implications, hydroelectric power may be classified into three categories: 1) damming an entire river or stream in order to use the force of released falling water to generate electricity, 2) pumped storage of water from an existing reservoir or stream to a small erservoir at a higher elevation via pipes containing pump turbines, and 3) off-stream reservoirs which would not require damming of the entire stream.

The impacts of the first type are most severe, particularly for facilities of a very large scale. Potential impacts include: pre-emption of alternative uses, e.g. cultural land; water loss through evaporation from the surface of the reservoir; destruction of the spawning grounds of migratory fish such as salmon; raising of the water table behind the dam which may raise surface salts and minerals and, thus, reduce soil quality; triggering of earthquakes resulting from increased weight; destruction of homes; elimination of wildlife habitate and in some cases, direct or indirect destruction of the wildlife itself; and elimination of the recreational opportunities of whitewater rivers. The best location for hydroelectric dams are narrow gorges through which some of the fastest flowing, most beautiful rivers flow. The Wild and Scenic Rivers Act prohibits the federal government from licensing power facilities affecting designated rivers. A further disadvantage by hydroelectric power is the limited life expectancy of reservoirs. In a period of a century or two, and considerably less in some cases, most man-made reservoirs became completely filled with sediment deposited by the river or stream (Clark, 1975). Furthermore, the reduced sediment load of the river will obviously have an effect downstream from the dam, generally increasing the rate of erosion.

Because the upper reservoir is relatively small and the lower one is generally an existing lake or stream, the impacts of pumped storage facilities are generally less severe for conventional hydroelectric power production. The concept of off-stream reservoirs would require diversion of water from a river via a channel to a small reservoir; water released from behind the dam to generate electricity could be channeled back into the river. This concept appears to combine the advantages of the first two techniques, having the reduced environmental impact of pumped storage without the energy consumption and the capability of a conventional hydro-plant to supply a continuous source of electricity.

The adverse environmental impacts of conventional hydroelectric power and particularly public opposition to their use on whitewater rivers in California suggests that the latter two techniques may be more realistically applied to a soft energy future. Pumped storage could be used in conjunction with energy sources which may produce surplus power during off-peak demand periods (e.g. wind, solar, thermal, geothermal or hydroelectric) to provide backup power as well as baseline electricity requirements. The application of these techniques on a large scale throughout California would require a thorough inventory of available sites and their electrical generation potential.

Potential land use planning implications of hydroelectric power production are closely related to the level of government at which agencies would develop small hydroelectric facilities and to the character of the distribution system. If the resource were developed on a statewide basis, perhaps by the State Department of Water Resources, and tied to a central grid, planning impacts should be minimal. If each region were to develop its own resources, hydroelectricity would become a regional resource. Movement by industries with high electricity demand to regions with available hydroelectric resources might result. Accurate assessment of the resource potential would become a critical responsibility of the region's planning agency to ensure that this limited resource is not over-allocated. If development of hydro resources were left to individual municipalities, competiton for sites would occur. Those cities or counties close to rivers or having an existing link to water resources, e.g. Los Angeles Department of Water and Power's power production system in the Owen's Valley, would have a distinct advantage. Regulation by state and regional water resources agencies to coordinate resource use would be essential.

11.2.7 Geothermal

Geothermal energy figures prominently in California's energy future. The two geothermal resource areas which hold the most promise, the Geysers region and the Imperial Valley, demonstrate the variation found in both the quality of the resource and its environment. The Geysers region yields a dry steam-dominated vapor, and PG&E operations there represent the largest in the world. The region is mountainous and fairly remote with a relatively large amount of surface water available. The Imperial Valley region is underlaid by a wet steam-dominated vapor which contains a corrosive salt brine. While the Imperial Valley is an excellent agricultural area, water is imported through an extensive irrigation project. Water is therefore of paramount concern and may be a limiting factor in future development.

Geothermal power has been touted as a relatively pollution-free energy source. While this is true in comparison with the air pollution impacts of fossil fuel combustion, geothermal energy is certainly not benign in its environmental effects. Problems of waste water disposal, noise, air pollution, aesthetics, pre-emption of other uses, terrain modification, subsidence, and seismic hazards present very real, albeit for the most part localized, impacts. Advances in technology may help to mitigate many of these effects. Weres (1976) has suggested that current technology is "primitive" and accounts for the resultant impacts.

The following section discusses the various applications of geothermal energy, the environmental and land use impacts, and the extensive regulatory regime surrounding research, exploration, development, and operation of geothermal energy facilities. (The topic of simulation by chemical and nuclear explosives has been omitted.)

Applications.

Electricity - Geothermal steam is used to run turbines at or near the well-site. Electricity is then transferred via transmission lines to the grid. PG&E currently operates a facility at the Geysers with 502 MWe of generating capacity.

Process Steam and Hot Water - Hot water has been successfully utilized for district heating in Iceland. Kruger and Otte (1973) report that water has been transported up to 18 km with a temperature loss of about 5°C. If water quality from the well is poor, a heat exchanger with domestic water sources is needed. There is great potential for refitting present domestic heating apparatus for geothermal district heating.

In geothermal regions with low mineral content in the fluid, direct use of water for bathing, washing, and swimming is possible. Process steam and hot water have a variety of industrial and agricultural applications; among these are: drying fish, timber, pulp and paper processing, canning, chemical recovery and processing from the geothermal sources, greenhouse heating, heating and steam cleaning animal quarters, and aquaculture.

Desalination - In areas with water shortages and a briney geothermal resource, such as the Imperial Valley, desalination is mentioned as a possibility. This proposal suffers from two major problems: overdrafting of the water table, which may cause subdidence, and the accumulation of large quantities of mineral solids. This last problem may present an opportunity if economically recoverable mineral resources are present.

Environmental and Land Use Considerations. The environmental impacts associated with geothermal development are relatively localized (see Holdren, 197). Land use impacts, on the other hand, could be quite extensive; the effect of industrial location on a geothermal site and the resultant pre-emption of current users and growth-inducing impacts could radically transform a region. The construction of roads, wells, pipelines, power plants, power lines, and industrial facilities can result in extensive use of hot springs, etc.), grazing and cropland, forestry, mining, watersheds, and residences. The potential for multiple use and in what proximity to the geothermal resource needs further exploration.

Regulatory Regime. Geothermal power has attracted regulatory attention in three areas: land, energy and environment. Many overlapping jurisdictions may have hindered development. At the local level, the city and county are most concerned with nuiscance impacts, pre-emption of present users, and growth-inducing impacts.

The California State Lands Commission handles the leasing program on state lands for exploration under the Geothermal Resources Act of 1967. The Geothermal unit of the Division of Oil and Gas regulates drilling practice, blowout prevention and well abandonment. Regulation of power plant development is under the jurisdiction of the State Energy Commission. Air quality is the concern of the local Air Pollution Control District and the Air Resources Board. If the project were in the coastal zone, the Coastal Commission would have review power but not veto power over power plant development. Water quality is the concern of the

Regional Water Quality Control Boards, and possible health effects from radon gas are the concern of the California Department of Health.

On the federal level, several organizations promote research and development, including the NSF, NASA and ERDA. The Interior Department controls a great deal of potential geothermal leases through the Bureau of Reclamation, the Bureau of Land Management, the Bureau of Mines, the National Park Service, and the Bureau of Indian Affairs. The U.S. Forest Service in the Department of Agriculture will also be important in this regard. The U.S. Geological Survey in Interior is responsible for classifying known geothermal resource areas (KGRA). Both the EPA and OSHA will regulate environmental and occupational hazards.

11.2.8 Land Use and the Potential for Energy Conservation

In the search for energy conservation strategies, many researchers have begun to explore potential energy savings that might result from rearranging urban form. Interest lies in: 1) housing densities, 2) spatial location of housing and trip generating activities like work and shopping, and 3) the relative efficiencies of commercial establishments.

Research in these areas is rather tentative. Qualitative relationships can be stated with some certainty, but the extent of actual energy savings is highly site-specific. In addition, other trends in urban growth, such as the decline in the birth rate and the cost of housing may prove to be decisive in forming our future land use pattern.

Of particular importance to this study is the relationship between the land use pattern implied by an energy conservation strategy and that implied by pursuing a soft energy path. For example, the densities at which a district heating scheme would best function might preclude low-density single family dwellings.

Below we summarize several land use/energy studies, mostly based on the exploration of transportation energy savings from alternate urban forms.

The Costs of Sprawl. Real Estate Research Corporation for CEQ, HUD, EPA, April 1974. This study developed six prototypical neighborhood types arranged into six community development patterns (see Table XI-3). These prototypical developments were meant to be "typical of high standard, new suburban construction, housing the average "urban fringe" population ..." Relationships between communities and the rest of the metropolitan area were ignored.

> Three sources of energy consumption were analyzed: space heating and cooling, household appliances, and transportation. The amount of energy required for space heating and cooling depends significantly upon significantly upon the type of dwelling unit. Denser housing, both because the floor area is smaller and because heat is lost through outside walls and roofs, use (much) less energy for this purpose. The total use of energy for non-transportation purposes is over 65 percent higher than for high-density developments. Non-transportation energy is not affected by planning
>
> Energy consumption for transportation, however, is affected by planning, although again, there is a bigger difference between high-density developments and low-density developments than between planned and unplanned developments of the same density. Changing from planned to unplanned development may increase gas consumption by 50 percent, but changing from high-density planned to low-density planned increases gasoline consumption by over 60 percent. Going from high-density planned to low-density unplanned increases gasoline consumption by 100 percent.
>
> The results are summarized in Table XI-4.

Energy, Land Use and Growth Policy: Implications for Metropolitan Washington, James Roberts, Real Estate Research Corporation for the Metropolitan Washington Council of Governments, June 1975. Residential and automobile energy consumption were compared for six alternative development scenarios: 1) wedges and corridors; 2) dense center; 3) transit oriented; 4) wedges and corridors with income balance; 5) sprawl; and 6) beltway oriented. The comparison of areawide energy consumption is summarized in Table XI-5. Their major conclusion is:

Table XI-3

Neighborhood Housing Types

	A Single-Family Conventional	B Single-Family Clustered	C Townhouses Clustered	D Walk-Up Apartments	E High-Rise Apartments	F Housing Mix (20% Each A-E)
Dwelling Units	1,000	1,000	1,000	1,000	1,000	1,000
Average Floor Area Per Unit (square foot)	1,600	1,600	1,200	1,000	900	1,260
Total Population	3,520	3,520	3,330	3,330	2,825	3,300
Persons per Unit	3.5	3.5	3.3	3.3	2.8	3.3
Total Acreage	500	400	300	200	100	300
Residential	330	200	100	66	33	145
Open Space/Recreation	45	90	90	73	32	66
Schools	29	29	26	26	15	26
Churches	5	5	5	5	5	5
Streets and Roads	75	60	45	30	15	45
Vacant	16	16	34	0	0	13
Residential Density						
Units per Gross Acre	2	2.5	3.3	5	10	3.3
Units per Net Residential Acre	3	5.0	10.0	15	30	6.9

Community Development Patterns

	I Planned Mix	II Combination Mix (50% PUD, 50% Sprawl)	III Sprawl Mix	IV Low Density Planned	V Low Density Sprawl	VI High Density Planned
Dwelling Units	10,000	10,000	10,000	10,000	10,000	10,000
Housing Types	20% - Type A 20% - Type B 20% - Type C 20% - Type D 20% - Type E	Same as I.	Same as I.	75% - Type B 25% - Type A	75% - Type A 25% - Type B	10% - Type B 20% - Type C 30% - Type D 40% - Type E
Total Population	33,000	33,000	33,000	33,000	33,000	33,000
Total Acreage	6,000	6,000	6,000	6,000	6,000	6,000
Residential	1,450	1,450	1,450	2,333	3,000	733
Open Space/Recreation	660	530	400	660	400	660
Schools	260	260	260	260	260	260
Other Public Facilities	140	140	140	140	140	140
Streets and Roads	530	530	530	720	790	380
Vacant, Improved	152	213	278	206	459	109
Vacant, Semi-Improved	456	922	1,390	617	951	326
Vacant, Unimproved	2,352	1,955	1,522	1,064	0	3,392

Source: Real Estate Research Corporation (1974)

Table XI-4

Community Energy Consumption

	Community Development Pattern (10,000 Units)					
	I Planned Mix	II Combination Mix 50 Percent PUD, 50 Percent Sprawl	III Sprawl Mix	IV Low Density Planned	V Low Density Sprawl	VI High Density Planned
Annual Consumption of Energy						
Natural gas, billion BTUs per year	999.418	999.418	999.418	1,347.090	1,347.090	795.177
Electricity, billion BTUs per year	751.020	751.020	751.020	1,007.610	1,007.610	604.960
Gasoline, billion BTUs per year	1,066.043	1,284.313	1,531.053	1,385.540	1,705.037	857.263
Total Billion BTUs per year	2,816.481	3,034.751	3,281.491	3,740.240	4,059.737	2,257.400

Source: Real Estate Research Corporation (1974)

Table XI-5

Comparison of Areawide Energy Consumption
Assoicated with Alternative Land Use Patterns
(percent increase from base year; all fuel
forms on a Btu equivalent basis)

	(A) "Wedges and Corridors"	(B) "Dense Center"	(C) "Transit Oriented"	(D) "Wedges and Corridors with Income Balance	(E) "Sprawl"	(F) "Beltway Oriented"
Residential	+41	+34	+36	+41	+46	+42
Transportation (Automobiles only)	+51	+30	+28	+40	+60	+44
Total	+46	+39	+39	+44	+51	+46

Source: Real Estate Research Corporation, James Roberts (1975)

> ... energy efficiency seems to require extensive use of public transportation, combining land uses into clusters and complexes, and locating activities so that less energy is expended to complete them.

"Energy Thrift in Urban Transporation: Options for the Future," Margaret Fels, Michael Munsun, Princeton University in The Energy Conservation Papers, Robert H. Williams, editor, Cambridge, Mass.: Ballinger, 1975. This study was a part of the Ford Foundation Energy Policy Project. Conceptually, the study consisted of three consecutive steps: 1) qualitative development of options, 2) quantitative evaluation of energy consumption from each option, and 3) assessment of results. The Trenton, New Jersey SMSA was used as the source for statistics regarding urban density and transportation characteristics. The time frame for the study was from 1975 until 1985 and 2000.

Three qualitative scenarios were developed: A, in which current trends continue or level off; B, which considers innovative automotive technologies; and C, based upon life-style changes which result in changes in housing density, housing location in relation to work areas, and a conservation ethic.

Overall energy consumption for the various scenarios at present, in 1985 and in 2000, was plotted on the basis of average daily gas consumption per capita. The results are displayed in Figure XI-1. This is further broken down into regions in Table XI-6. Region 1 is characteristic of the dense urban core, Region 2 the inner suburbs, and Region 3 the less dense affluent suburbs.

The authors have concluded: 1) no single strategy will work; 2) solutions will vary across densities; 3) the degree of automobile use will be a major determinant in planning strategies; 4) estimates of potential energy savings from mass transit must account for probable trends and desires in the formation of land use patterns; 5) the important variable is where people live in relation to their place or work, shopping facilities and recreation; and 6) the greatest savings in energy would come about from a scenario which includes more efficient automobiles, greater use of transit, altered living arrangements in which people live closer to work, neighbors, shopping, and an energy conserving ethic.

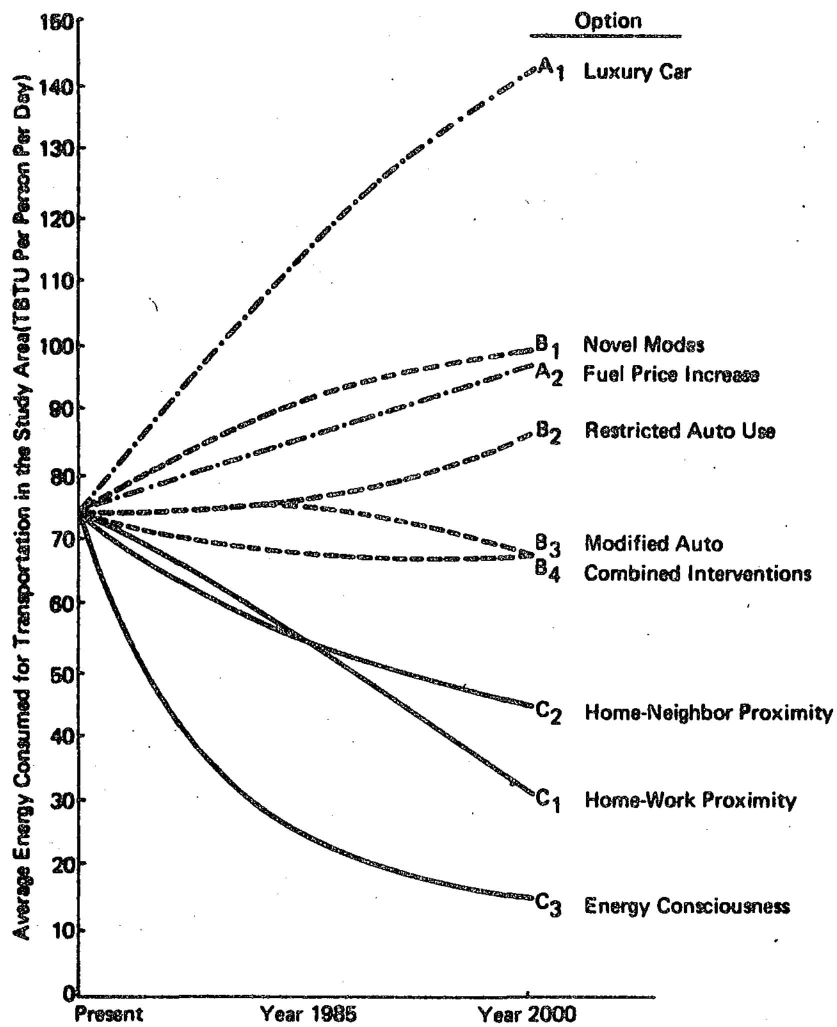

Figure XI-1. Per-Capita Energy Consumed for a Day's Transportation in the Study Area, for the Present and for Each of the Nine Options in 1985 and 2000

Table XI-6

Per-Capita Energy Consumption for the Purposes of an Average Weekday's Transportation in the Study Area (TBtu per person per day, for the present and in 1985 and 2000 according to the options for the future)

		Scenario A: Continuation of Current Trends		*Scenario B: Technological Innovations*				*Scenario C: Lifestyle Changes*		
Option:		A_1	A_2	B_1	B_2	B_3	B_4	C_1	C_2	C_3
		Luxury Car	*Fuel Price Increase*	*Novel Modes*	*Restricted Auto Use*	*Modified Auto*	*Combined Intervention*	*Home Near Work*	*Home Near Neighbors*	*Energy Consciousness*
Average auto:[a]		*Super-big*	*Big*	*Big*	*Big*	*Medium*	*Medium*	*Medium*	*Medium*	*Small*
Year 1985	**Early 1970s**[b]									
Region I	**(38.6)**	59.4	44.4	49.2	39.3	39.3	35.5	28.3	29.7	12.6
Region II	**(89.1)**	127.0	91.8	96.3	80.2	80.6	71.3	54.6	54.3	21.2
Region III	**(99.7)**	145.7	117.4	126.6	106.1	102.7	93.9	86.0	86.4	41.0
County average	**(74.1)**	114.3	86.0	91.8	76.5	75.4	67.9	55.3	55.0	24.2
Year 2000										
Region I	**(38.6)**	71.0	51.9	57.7	49.5	36.9	45.1	18.4	30.7	8.9
Region II	**(89.1)**	144.4	95.6	100.0	86.4	67.2	71.7	29.7	44.7	14.7
Region III	**(99.7)**	187.0	129.7	130.7	111.6	90.8	82.9	46.8	64.5	20.1
County average	**(74.1)**	141.3	96.3	99.7	85.7	67.6	68.9	32.1	45.1	14.7

Source: Fels and Munson (1975)

Land Use and Energy Utilization—Interim Report. Carrol, Beltrami, Kydes, Nathans, Palmedo, Brookhaven National Laboratory Institute for Urban Studies Research, SUNY at Stony Brook, October 1975. This report is part of the BNL/SUNY land use-energy utilization project. Recent work includes the publication of an Energy Planners' Notebook and computer modelling of interactions between urban form and "soft" energy paths.

In this study two land use scenarios for the Nassau/Suffolk region of Long Island, New York, are compared in terms of energy consumption: urban sprawl and the development of corridors, clusters and centers (CCC). A time frame from 1972 until 2000 is used and changes in urban design are assumed to occur only in undeveloped areas. The study area is characterized as a fast growing suburban region at the periphery of the nation's largest city. Parameters for the two development patterns and a summary of energy consumption for each in various sectors are presented in Tables XI-7 and XI-8. The study concludes:

> ... from this very preliminary analysis that in a region such as Long Island, total incremental energy consumption can be reduced by 15-25% by altered patterns of growth. While the largest percentage differences may appear in the transportation sector, larger absolute savings may result from different residential construction patterns associated with more clustered development. To the degree to which savings in petroleum are more "important" than savings in other fuels. The transportation sector, essentially completely dependent on oil, becomes even more prominent.

"Relationships between Transportation Energy Consumption and Urban Structure: Results of Simulation Studies". Jerry Edwards and Joseph Schoper in Transportation Research Record 599, Transportation Research Board, National Academy of Sciences, Washington, D.C., 1976. Studying transportation energy consumption, the Lowry land use model (as in the BNL/SUNY study) is applied to fixed city attributes (population, employment patterns, housing densities) which are resettled into four basic urban forms: 1) concentric, 2) pure linear, 3) polynucleated and 4) pure cruciform.

The study concludes: 1) energy savings would be maximized by channeling development into higher density, nucleated forms; 2) there

Table XI-7

Regional Development Parameters

	1972	2000
Population	2,674,000	4,080,000
persons/household	3.58	3.09
number of households	747,600	1,320,000
Commercial Floorspace 10^6 sq. ft.	345.7	601.9
Number of Industrial Employees	160,000	189,000
Total Vehicle Miles Traveled ($x10^9$)	13.4	

	Existing Land Use Variables	Urban Sprawl	Corridors, Clusters and Centers
Housing Mix (%)			
Single family detached	84	84	25
Single family attached	7	7	25
Low rise	5	5	25
High rise	4	4	25
Residential Heating			
Fuel Mix (%)			
Oil	79	100	100
Electric	2	-	-
Gas	19	-	-
Vehicle Miles Traveled			
by Mode and Purpose (%)			
Auto-Work	100	100	44
Bus-Work	-	-	56
Auto-Shopping	100	100	20
Bus-Shopping	-	-	80
Auto-Social/Recreation	100	100	100
Bus-Social/Recreation	-	-	-
Auto-School	100	-	40
Bus-School	-	-	60
Total Vehicle Miles Traveled ($x10^9$)		21.4	17.0

Source: Carrol *et al.* (1975)

Table XI-8

Summary of Land Use Energy Scenarios for Nassau-Suffolk
(fuel use[a] in 10^{12} Btu)

Sector	Use in 2000 Due To 1972 Population	Incremental Fuel Use in 2000: Urban Sprawl	Incremental Fuel Use in 2000: CCC	Percent Difference	% of Total Difference
Residential	121.1	82.6	70.5	15	34
Commercial	87.1	63.9	60.8	5	9
Industrial	28.9	5.5	3.6	35	5
Transportation	60.5[b]	35.8	17.2	52	52
Total	297.6	187.8	152.1		100
Total Use in 2000		485.4	449.7		

[a]includes electricity at 3413 Btu per kWh

[b]fuel in 2000 to provide the number of vehicle miles of travel used in 1972

Source: Carrol *et al.* (1975)

should be less concern with centralizing employment than with centralizing housing population; 3) land area or extent of development is an important factor in transportation energy consumption; 4) the concentric ring requires the most energy but provides the greatest accessibility. Linear forms offer the next best accessibility; 5) Keyes (1977) adds that the most desirable patterns implied by the results call for balanced population and employment distribution.

An Overview and Critical Evaluation of the Relationships between Land Use and Energy Conservation. W. Curtiss Priest and Kenneth M. Happy, Cambridge, Mass.: Technology and Economics, Inc., 1976. This report for the FEA reviews federal, state and local land use law as it relates to energy conservation and summarizes land use/energy research. They conclude that short energy-saving land use patterns entail: 1) more multifamily residences; 2) more densely populated activity centers to promote transit use; and 3) rearranging industrial, commercial and residential activities to promote the utilization of waste heat.

Urban Trends and the Energy Situation and Suburban Sprawl and the Energy Situation. These two documents qualitatively discuss factors that might influence energy consumption in the future. They were produced by the Committee on the Investment Impact of Urban Trends, convened by the Conference Boards (a New York business management research group) and the Ford Foundation.

This group advances the opinion that factors other than energy conservation will form our future urban development pattern. They point to the present increase in multifamily dwellings in suburban areas and relocation of industries to the outlying urban regions as examples of the push towards establishing activity centers of balanced residential and employment opportunities. As for the urban area, they have identified five non-energy factors leading towards an increase in urban density: 1) a decline in the birthrate which results in less new housing which usually occurs in suburban areas; 2) an increase in one or two person living units which are locating in adult-oriented urban districts; 3) the expansion of urban-based service industries; 4) an increase in renovating existing housing; and 5) the long-term decrease in disposable income as a result of increased energy cost leading to a housing squeeze towards multifamily units.

Metropolitan Development and Energy Consumption. Dale Keyes and George Peterson, Land Use Center Working Paper 504945, The Urban Institute, Washington, D.C., March 23, 1977. This is a well presented, critical presentation of the findings of the previous research projects in the areas of transportation energy consumption and land use and also the conservation potential of increased housing densities. The authors feel that these transportation energy/land use studies have only confirmed the assumptions inherent in the models they used and have not helped to quantify the potential energy savings. They suggest that other strategies which rely on changing the modal split of transportation forms, the total miles of vehicle travel, occupancy levels, and travel speeds offer greater energy savings without increased density, loss of privacy, and more stringent land use controls.

The authors also summarized four studies on the energy efficiency of different dwelling types. There is a trend towards greater energy efficiency with greater housing densities until the services (elevator, extensive lighting) required for skyscrapers outweight the decreased space conditioning required due to shared walls and smaller units.

Conclusion. The research reports summarized above have confirmed hypotheses as to several qualitative urban spatial relationships intended to conserve energy. There is a need for further modelling which takes into account the embodied energy in urban infrastructure, changes in mobility patterns when people resettle into alternative urban forms, inter-regional transfers in energy through manufactured items and information, and the relationship between land use patterns designed for energy conservation and potential future energy infrastructure requirements.

11.3 THE PLANNING FRAMEWORK: ISSUES AND OBSTACLES

11.3.1 Introduction

The decision to follow a soft energy path requires that land use be managed in such a way as to establish a framework in which soft technologies will work. Conversely, decisions made now and in the near future regarding land use may result in a context to which applications of soft technologies will be difficult. Thus, if a soft energy path is to be pursued, a link has to be made between the coals to which the path is directed and the process by which land use decisions can aid in reaching these goals.

How might a dispersed energy system fit into our land use regulatory framework? According to Amory Lovins (1977):

> ... The ends sought are so fine grained, locally tailored, dispersed, and small-scale, and the means—the policy tools—can be chosen, according to practical and ideological convenience, from such an enormous array of options, that the choice can fully respect pluralism and voluntarism. Indeed, so diverse are our societies, and hence the local conditions to which soft path innovations must adapt, that a centralized management approach to a soft path simply would not work.

This statement suggests that deployment of a soft technology system should be undertaken by each individual locality so that the end product will be suited to its particular needs.

The idea that the structure and process of land development and regulation would prove a problem to implementation of the soft path has received little attention. Lovins makes brief mention of obsolete building codes and recalcitrant labor unions, but he does not consider land use issues to be of great import. While we have not had an opportunity to make an exhaustive study of this topic, we feel it is useful to set forth certain obvious issues based on our experience in other aspects of the land use planning field and our explorations into the land use planning implications of soft energy paths.

11.3.2 Nine Major Issues in Soft-Path Land Use Planning

The historical pattern of land development. California's land use pattern is a prime example of automobile-oriented urbanization; this fact needs no elaboration. We raise this point because much of the planning field is based on the proposition that the world is a clean slate, and that problem solving lies in totally new urban patterns, new towns and the like. We assume that California's urban and industrial pattern is largely fixed by the history of its development. While California expects population growth, most of its highways, sewers, water lines, and schools are already in place, and their locations fixed. Many rural counties in California, and some urban ones, have sufficient vacant lots already provided with roads and sewers, for any foreseeable increase in population. The process of "urban infill" is now a matter of state-level policy. Not only are physical facilities in place, but jurisdictions have incurred bonded indebtedness to build these facilities, and look forward to population growth that will help share the burden of these expensive items.

While the emplacement of infrastructural investment is extremely important, the pattern of land ownership may be of equal or perhaps greater import. While land developers can respond in a flexible way to new conditions, land owners are much more constrained. They may be long-time owners not skilled in the buying and selling of land or for other reasons find themselves unable to trade up or out. Or, if they are short-terms owners who have invested in land, they may have paid a high price based on historic zoning, building trends or their own market forecasts based on past experience. Therefore, there is a class of individuals and institutions which are, for one reason or another, reluctant to change, and can be observed to exert their political influence against policies which would decrease the value of their particular holdings. Commonly, these actors are powerful figures in local government, which of course is that level of government expected to play the largest role in implementing a dispersed energy technology.

Our inherited development pattern includes considerable vacant land in and around built-up areas, and outsiders to the land development game commonly assume that these "vacant lots" will be readily available for specific purposes (recycling centers, windmill sites, heat storage areas, etc.). However vacant land is a commodity of considerable value in its undeveloped state. It is a common hedge against inflation and there are numerous tax advantages to holding land as opposed to dollars; a surprising number of parcels are tied up in estates which may take years to resolve; lands owned by corporations may be being held for future corporate expansion or may even be being held off themarket to prevent the location in that spot of a competitor.

All of the above indicate that new energy developments must be woven into an existing fabric of land development, that rearrangement of the land use pattern will take time and considerable trouble, and that the absolute flexibility in rearrangement may be extemely limited.

The Passive and Incremental Nature of Land Use Planning and Land Development. Land use planning is commonly referred to as being holistic, forward looking, comprehensive in area and scope, and heavy with rationality. However, the actual process of planning and evelopment is much the opposite. Communities do seek to be forward looking in their general planning process, true. However the "action" in land development has been not in the adoption of general plans but in the week-to-week amendment and variance process. Now, by design "plans" are really long lists of policies with as few maps as possible and ample provision for flexible case-by-case evaluation. While it is possible to say that these uses are "planned for," it would be more accurate to say that they were fortuitous events, largely outside the control of the planning agency, which were permitted because they are not inconsistent with general plan policies.

The passive nature of planning also contributes to a number of other sub-issues. Desirable land uses (e.g. light industry) are given an excess of land in hope that these uses will arrive. So-called overzoning for industry and commerce is extremely common. In many cases such zoning is exclusive, and residential or other types of development are prohibited in these commercial or industrial zones. Another aspect of this passivity is that communities may have a limited number of options which they may be likely to expect over the life of a plan. For example, a community blessed with geothermal resources might indicate in its plan that certain areas should be reserved for industrial or institutional uses requiring low-quality heat. However, the first solid proposal for a key piece of land might be made by a developer proposing low-density housing (perhaps using some of this energy to heat swimming pools).

Fearing that the ideal developer may never show up and out of a feeling of fairness to the landowner, the jurisdiction might approve the less-than-ideal housing project.

Parochialism. While plans are prepared by technical staffs and they are advised by citizens' committees of all sorts, the final decisions are made by the numerous city councils and county boards of supervisors which act as small legislatures. In California some of these units of government (e.g. so-called charter cities) derive their power from the constitution of the State of California, not from the legislature, and therefore have extremely broad powers over land development. While these jurisdications are charged with carrying out many state-mandated policies, they are elected by and responsible to a local constituency. They cannot be blamed for attempting to strike the best deal possible for their constituents. This has many ramifications for energy planners. A jurisdiction which happens to have abundant or low-cost energy, will find it to its own advantage to, insofar as possible, encourage the use of that energy for uses which will benefit the local, as opposed to the regional or statewide, interests. Typically, the community would seek to attract a tax-generating industry but then use its land use powers to preclude the construction of low-income housing for the workers employed in the facility. These would be forced on to other jurisdictions and, of import for energy planners, at increased cost in terms of transportation-related energy use.

The Sweeping Implications of Land Use Decisions. It is important that energy planners avoid, so far as possible, mistakes made by other mission-oriented planners. Proponents of special purposes such as housing, highways, airports, schools, hospitals, reservoirs or parks have a tendency to think of their projects in physical terms and to think of social, psychological and economic aspects only in the most direct sense. There is a common tendency to equate "difficult to quantify: with "unimportant." These "soft" topics (neighborhood character, lifestyle, congestion, noise, amenity) may nonetheless be of paramount concern. There is a long list of projects important to the welfare of the State of California which are having great difficulty in finding a home. Examples are: reservoirs and canals, minimum security prisons, drug treatment centers, low-income housing, regional solid-waste dumps and executive airports. In the energy field one may note the safety issues surrounding the selection of sites for storage of nuclear waste, for power plants, and for the shipment and storage of LNG. Many special-purpose planners assume that there is a secluded valley somewhere waiting to accept their important land use. In fact, few spaces are so isolated. And if they are, competition for them will be keen. One such valley in the San Francisco Bay area has been targeted by special purpose planners as a motorcycle raceway and off-road vehicle park, a regional waste water treatment facility featuring on-land spraying, a hazardous waste storage facility, and a satellite housing community.

Not only are value-free sites hard to find, but significant changes to existing communities will come hard. If dispersed energy technology requires substantial changes in neighborhood form and character, some difficulties should be expected. Community opposition to change cannot be overstated. The great controversy over freeways is one case in point. In another example the Bay Area Rapid Transit System was built on the assumption that there would be increasing density in those areas immediately adjacent to BART stations. In general, this density increase has not come about due to community resistance to destruction of single-family homes and construction of apartment buildings. In many ways dispersed energy technology is supposed to avoid these very types of problems. Some of the literature of appropriate technology seems to imply that these issues will be solved in convivial town meetings: cooperative neighbors joining forces, discovering new friends, and sharing common interests. One certainly hopes that this would be the case. However, those who have attended public meetings of planning commissions and city councils concerned with the minutia of city development (building a gas station on the corner, erecting an 8-foot fence, violating a setback requirement, erecting a brightly painted sign, seeking permission to open a dog kennel) may have a less optimistic view of the productive nature of such meetings and the likelihood of bringing about constructive community development.

The Multi-Faceted Nature of Land Use Planning. There is a natural tendency on the part of special-purpose planners to believe that their particular topic should provide a primary focus for land use planning around which other topics should be fitted in. Community planners have been faced with a series of waves of interest: housing, transportation, recreation, water quality, air quality, natural beauty, and so on. While some community planners may be expected to roll up their sleeves and plunge into work on the dispersed energy challenge, many planners will likely view this topic as merely the next fad to have come along. In either case, energy will in fact be just one more important variable to be considered by the land use planner. The degree of importance to be accorded energy will be relative. For example, good energy planning might dictate that a certain area be designated as high-density so as to take advantage of an energy source or reduce transportation energy requirements. However, the seismic safety element of the community's general plans might indicate that for reasons of safety the area be limited to low-intensity uses. The resulting compromises will be struck only after difficult and lengthy technical, administrative and political activity. While this fact may seem overly obvious, it bears restating so that in considering the degree of community response to energy problems, the length of time that will be required to achieve certain energy goals will not be underestimated. One planner's rule of thumb is that the time for implementation equals technical feasibility times four. If this were to prove true in the implementation of dispersed energy scenarios, some major adjustments in thinking would be in order.

Transaction Costs. When comparing land use planning decisions to other administrative or corporate acts, land use planning is a cumbersome and time-consuming process. Nowadays the decision to build practically anything will involve the securing of more than a dozen permits, the preparation of an environmental impact statement, the conduct of public hearings, and the possibility of judicial review. This places a burden not only on the developers but on citizens and interest groups who must involve themselves in the process. Some streamlining of the permit process can be expected; however, trends in opening such decisions to public scrutiny make it hard to believe that the decision process on important projects will be greatly simplified. The hard and soft paths may turn out to have quite different transaction costs. One can imagine that major power plant siting decisions might be centralized in a single state commission. If, as opposed to this, soft technology must work its way through a multitude of general plan changes and ordinance amendments in California's 412 cities and 58 counties, the "alternative" technologies are hardly on an equal footing with the hard energy scenario. At this point it is not clear which path might prevail. It may be that if half the cities and counties were to make modest adjustments toward dispersed energy production, more energy might be produced than that forthcoming from superprojects which are delayed or denied.

Horizontal Integration of Plans. Each individual jurisdiction develops and administers its own general plan, sets its own densities and land uses, approves or disapproves the subdivision of land, administers building codes, and evaluates environmental impacts of proposed developments. These important decisions are relegated to the local government level, even though the implications frequently have regional or statewide significance. In general, this system presents great difficulties to state and regional planning for parks and open space, transportation arteries, major industrial facilities, etc. But it may present little or no difficulty to some aspects of dispersed energy technology, e.g. residential solar. However, bio-conversion facilities, district heating plans, and cogeneration possibilities may hinge on cooperation between jurisdictions. In these cases, dispersed energy technologies will suffer the same fate as hard-path counterparts. For example, in the San Francisco Bay area there are 93 cities and 9 counties, plus 25 special districts, regional agencies or other governmental agencies with land use powers. While 85 of these cities and 7 of the counties are members of the Association of Bay Area Governments, membership is essentially voluntary, and except in the case where federal grants must be processed, ABAG exerts relatively little direct influence in the resolution of interjurisdictional problems.

In the past decade there have been proposals for regional governments with "teeth." The State of California's legislative analyst proposed a structure for sub-state regionalization to coordinate state powers in transportation, environmental quality, resource regulation, etc. This proposal was not acted upon and is not now in view. Other proposals have been made to form regional assemblies from the "bottom up." The San Francisco Bay area (the most likely candidate for regionalization) was the subject of a series of bills by Assemblyman John Knox. However, interest has been so low that this year the bills were not even introduced. It would be very risky to try to predict whether or not there will be a resurgence of interest in regionalization. For the time being, energy planners should recognize the problem of bulkanization and realize that boundary problems may be extremely difficult to solve.

Vertical Integration of Plans. While for the most part direct regulations of land use is the province of local government, many other levels of government are often involved. In some special places, two or even three levels of planning and decision-making are superimposed. If a project invovles the shoreline of the San Francisco Bay, the California coast or the watershed of the Lake Tahoe basin, plans and permits must be reviewed and approved by not only the local level of government but by a regional government as well. In the case of BCDC and the Tahoe Regional Planning Agency, vertical integration is provided for by duplication of permit powers. In the case of the coastal commission, however, a new process is being invented called "plan certification" wherein the higher level of government approves not individual projects but the general plans of the lower governments as well. This process is politically attractive and currently acceptable; however, the technical difficulties in plan review have not been worked out, and it may be that true integration and compatibility between levels is not possible in this manner.

In many cases the infrastructure needed to support or direct community growth is out of the hands of the local jurisdictions. State highways are a case in point, but of greater importance at the moment is the planning and design of regional waste water treatment facilities. This involves a complicated combination of federal, state, local and regional government to determine the size, capacity, location and service area of regional facilities. In effect, the population of regions is being set and hence densities and land use types are also being determined. Regional waste water planning (so-called "section 208 planning") is perhaps the most significant form of land use planning taking place today; yet at the moment it does not include energy considerations.

The State of California is not now active in the land use planning field in any direct way. However, it carries on a number of functions with important land use implications. The Governor's Office of Planning and Research is responsible for the development of long-range and comprehensive policy. It has produced one report dealing with urban infill. Other crucial functions include the provision of water through the Department of Water Resources, energy planning through the California Energy Conservation and Evelopment Commission and the state Public Utilities Commission, and transportation planning through CALTRANS. While the land use implications are enormous, there is no coordination or long-range planning per se.

Also of crucial importance are the environmental regulatory agencies. Their activities in setting standards and in approving point source discharges can be pivotal in the growth and development of any portion of the state. Again, although the land use implications of their actions are enormous, they do not consider themselves land planning agencies and do not conduct long-range or comprehensive land use planning as part of their operations. These latter agencies are especially important to energy planning since some aspects of dispersed energy technology can involve air pollution, water pollution and public health. It is important to note that these aspects of development will be out of the hands of community groups and that regional and state approvals must be sought. While considerable compromise and negotiation can take place at the local level (for example, compromising between energy saving and seismic safety), state and regional environmental standards are essentially fixed and inflexible. Even though it might make sense to energy planners to give up a little environmental quality to gain a lot of energy, they should be aware that no such mechanism for striking a balance presently exists.

Institutional Context. Private and governmental organizations involved in land development evolved under conditions of unlimited resources and presumably endless growth; they were not designed for the allocation of scarce resources among competing interests. The technical, administrative and political difficulties of operating as a steady state system, or perhaps "in reverse," have barely been perceived, let alone studied. Thus, it is not a case of merely injecting a little energy consciousness into a smoothly running land use planning machine. This energy consciousness comes at a time when planners and decision-makers will just be learning to think in terms of limited resources. On the one hand, dispersed energy planning is ideally suited to such an ecological approach. On the other hand, energy planning may have to bear the brunt of the stresses, concerns and criticisms which really should be shared by many aspects of society.

11.4 AN OUTLINE FOR SOFT-PATH LAND USE PLANNING AT THE LOCAL LEVEL

11.4.1 Introduction

The individual community embarking on the soft path will face a number of difficult questions:

- o Which technologies are really available, and are they reliable and cost-effective?
- o Which types of land uses in our community are big energy users or wasters?
- o What effects will conservation efforts have, and where should we aim our efforts in conservation: in homes, business or industries?
- o On what parts of our program should we work alone; when is regional cooperation needed?
- o Should we treat energy from the grid as a scarce resource, i.e., disapprove a regional shopping center so that we may approve five thousand homes?
- o If we save, will others waste what we save, or worse, use it to our community's disadvantage?
- o What are our particular strengths and weaknesses in pursuing the soft path, e.g. climate, types of uses, sources of energy?
- o What specific changes should we make in organization, planning and regulation to encourage growth along the soft path?

Answers to these questions lie partly in policy and politics, but in large measure they require simple factual information about land use and energy, information which at the moment is scarcely available.

Some answers, of course, will come through local experience and trial and error, and from sharing information with sister communities. But there are problems. Few jurisdictions amass information in a form amenable to research. They have general plans (which show their hopes) and zoning maps (which do not necessarily comport with the general plan or existing land uses). Census data is cumbersome in urban areas and overly gross in rural areas. Assessor's records though commonly automated are not easily geo-referenced. Few communities have up-to-date maps showing existing land uses in any detail. Fewer still have an accurate count on vacant lots and other commitments to growth. Coefficients linking energy use to land use are based on a few samples and hypothetical cases.

We suggest that a significant investment should be made in research and development. As very general guides we offer the following outline, aimed at the perspective of local government.

11.4.2 An Eleven-Step Process to Energy-Oriented Land Use Planning

1. Draw a sample of areas within a region or entire state representing cross-sections of urban form, densities, traffic characteristics, climate, resource availability, land use mix, age of structures, wealth, etc.
2. Determine and map existing land uses in detail, using classifications that would be energy-sensitive. Possible sources include zoning and land use maps, assessor's records, insurance information, utility information, and actual surveys.
3. Determine and map existing energy use (by land use classifications above) as to gross use, peak and off-peak periods, end-use demand, and quality. Utility information and surveys would be required.
4. Analyze area plans and commitments to growth and estimate future energy requirements, reviewing land use, infrastructure, and development proposals.
5. Analyze the implications of energy supply disruptions. Establish rationing and allocation schemes, energy conservation programs, and potential sources for augmenting supply.
6. Determine the energy conservation potential of existing and planned uses if changes were made in the transportation pattern, housing densities, and the spatial arrangement of shopping, work, recreation, and living areas.
7. Analyze the supply potential of soft energy sources in area noting the locational and area requirements and resultant environmental impacts.
8. Re-evaluate area plans and commitments to growth in light of conservation and soft energy supply possibilities.
9. Evaluate possible economies from regional interties (i.e., wind from Solano County, geothermal from the Geysers, and pumped storage in the Berkeley Hills).

10. Evaluate local program in light of regional and state profiles and targets.
11. Prepare area planning package to ensure full consideration of energy in land use decisions. This might include an element of the General Plan, recommended ordinance changes, an environmental impact assessment guide, and a system for evaluating the energy implications of the capital improvement plan.

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CHAPTER XII

BELIEF, BEHAVIOR AND TECHNOLOGIES AS DRIVING FORCES IN TRANSITIONAL STAGES— THE PEOPLE PROBLEM IN DISPERSED ENERGY FUTURES

12.1 INTRODUCTION

Transitions may be painful, they may be viewed as a challenge, or they may happen unnoticed. They may be public, or they may be private. They may necessitate individual change or societal change or both. Whatever may be their characteristics transitions are an ever present factor in human life, and most of them occur without the aid of any public policy.

One major characteristic of the twentieth century is an increased dependency of individuals and groups on large scale institutions. Over the past 40 years both individual and group self-reliance has dramatically decreased. Wage labor and specialization is the overwhelming pattern. With increased interdependence has come increased government planning, increased reliance on expertise, and an increasingly dis-associated society, with different segments operating as strangers to one another. The phenomenon of strangers in the same land is in no area better exemplified than in the various dialects that are used by different professional expert groups in the United States. Explosions become "energetic disassemblies" and in the process the explosions themselves become part of some abstract reality for the expert. Public planning cannot operate successfully without an understanding of the consequences of the above mentioned variables.

As we mentioned, in twentieth century America public planning requires the use of the expert professional. Experts, by virtue of their training, are taught to think in a certain way. They are taught a language; they are trained to be loyal to the goals of the profession, and to problem solve in terms of these goals. For some problems the narrow range of an expert is productive: we need to know how much energy can be saved by means of certain technical fixes. For other problems narrowness is not only malproductive, but it produces a view of the world that is not adaptive in times of scarcity: as an agro-industrialist of northern California recently remarked to a reporter who asked him about rainfall: "We don't worry about rain; we irrigate here."

The National Academy of Science has in the past few years carried out several massive projects in areas thought to be crucial to the maintenance of world stability: food, climate, energy and to a lesser extent their interdependence. In all of these studies it became clear that we need to include the expert as a part of any national problem we address. We need to understand the experts' professional training and perspective on the world, the structure of their work places, and the unexpressed values by which they judge and select their goals. The problems of our world today have a seamless quality about them that does not recognize the narrow confines of expertise or of professional managers. Disciplines are accustomed to relatively closed systems of a manageable number of components. The energy question, like the question of poverty or health, requires that we deal with a network of dynamically related variables; it is not another quest for the moon.

Public planners must understand the nature of the work force they hire to tackle national problems.

Energy is a social, not a technological issue. A basic flaw in all energy discussions is that the cultural and social context tends to be left implicit. Yet the major choices in energy paths are being made in the context of different and often conflicting social and cultural systems. These different ideologies or belief systems are linked with what experts have termed "the energy problem." For example, one set of beliefs would see the energy problem as one of developing new supplies to meet the expanding energy needs; another might see the problem as one of reducing appetites, and yet another belief system might reflect the energy problem as a choice between hard or centralized systems and decentralized systems that were either hard or soft. The differing ideologies are associated not only with different expert advice, but also with differing organizations of expert knowledge. There is a need to discuss the myths implicit in assumptions about progress, quality of life, and energy use, for even relatively sophisticated scientists (see Cook, 1976) discuss progress as if it were unilineal in development.

Belief systems are also linked with types of technologies, and there are also a number of hypotheses in the literature which link energy forms with particular social and political effects. For example, hard technologists tend to be optimistic as to what hard technologies can accomplish and pessimistic with regards soft technologies such as solar. Soft technologists might share a belief that soft, de-centralized will be associated with democratic principles, while the hard and centralized would encourage further development of the already dominant military trends in the United States. Lovins admits that both paths, hard and soft, will raise difficult social problems although of very different kinds. The problems of hard technologies are visible today - environmental pollution and increasing militarism. The problems of making a transition from an earlier period toward the hard path are part of our history. Our research addresses itself to a discussion of the most relevant social and cultural dimensions relevant to a transition away from hard technologies towards dispersed, soft, increased self-reliance, if that transition is instigated by government.

When public planning enters the scene, particularly since public planning is often accompanied by large public monies, there develops the belief that changes only happen if they are planned by the government. Experience shows, however, that private planning, whether conscious or unconscious, can and has had a tremendous impact on our society. The automobile was a private invention, produced by private industry, a product which revolutionized our way of life and changed the whole fabric of our society, from family relations to land use. And there are other private patterns - those which result from thousands of individual decisions which coalesce, even though there may not be any meeting or conscious planning, a direction is taken. The decision to have fewer children is a private plan which has also and will wring dramatic changes in the economy of this country, from employment patterns to mental health patterns. Public planning runs into difficulties when it does not recognize parallel change in the private sphere. With these general observations in mind we can now report on our progress in relation to research on the California case.

During the summer of 1977 we began to explore the role of belief systems and their accompanying behavior patterns and technology systems as driving forces in relation to a transition from hard to soft energy paths over the next 25-50 years in California (Lovins 1977). An examination of the conscious and unconscious patterns of transition illustrates how technologies and beliefs and the organizations with which they work, act as constraining and/or incentive forces. We looked at barriers and incentives to conscious and unconscious transitions in the public arena, and in the interactive spheres between the public and private domains. We did not interview people who would be impacted (the general public), or who had no direct role in relation to public planning. Our methodological strategies included telephone and face-to-face interviews with over 50 people (see appendix), people with different involvements in the energy question in California. In addition, we explored some of the out-of-state happenings in New York, Michigan, Wisconsin, and Nebraska, and sampled a number of energy concerned bureaucrats outside of California. Our approach was qualitative, with no intention of using survey research techniques. We interviewed with intent to sharpen our understanding of what the relevant variables should be for any analysis of the role of leaders in transition.

During the past 6-7 weeks we focused our attention on learning about two transitional mechanisms, one which was initiated by a California state agency, and the other which is being initiated by actively concerned citizens. The first mechanism was the California Residential Building Code which was mandated by the California Energy Commission to come into effect March, 1978. The second mechanism, and one which has some earlier history of discussion in California and of practice in countries like Denmark, was the use that could be made of dispersed electric generators as connected to the electric grid. In gathering our information it became clear that although the mechanisms were different they had several dimensions in common, and the following discussion will focus on the dimensions that emerged as central to our understanding of transition in reference to the California Residential Building Code and the exploration of the potential of dispersed electric generators. In particular, we would like to focus upon these dimensions for the benefit of technical persons and bureaucrats who may be only too aware of such dimensions, but as yet unable to raise them to the status of crucial variables.

12.2 SOME DIMENSIONS OF THE "PEOPLE PROBLEM"

Those of us who become part of the action force in promoting adaptive behavior in times of scarcity and/or change to new resources need to become more aware of the roles we are playing, and we need to notice these and other variables as they operate to influence our actions. Here we list some dimensions for purposes of beginning to develop a checklist of concerns for people working on transitions to soft paths. Because these dimensions so often appear in binary opposition it appears that we are dealing with parts of two contrasting paradigms, each adaptive under different conditions. We have chosen to isolate these few dimensions for discussion because in listening to people argue, or in listening to people talk past one another, or in hearing cries of impotent agony these often overlapping aspects were most salient:

a. Institutional constraints vs. individual freedom

b. Credible vs. non-credible

c. Tangible vs. abstract

d. Restricted vs. global time perspective

e. Specialist vs. generalist

f. Voluntary vs. involuntary

g. Progress vs. decline or status quo

12.2.1 Institutional Constraints vs Individual Freedom

No matter where we interviewed this summer we ran into direct or indirect commentary on constraints that are organizational in nature.

They were perhaps best summarized in the comments of one activist, concerned citizen. She reflects upon the lack of freedom of operation among wage workers, particularly those who work in large scale institutions, when she notes: "I don't work for anybody, so I can say what I please." She was commenting upon the slowing effect of bureaucratic procedures and the absence of any sense of urgency when she impatiently requested, "Don't talk to me about 1981 or 1982, I want it now..." Her comment on the division of labor in this country which separates those who think about a problem from those who work the problem was "Until you get into the field, you don't know anything." There are important messages here.

A telephone interview with an official of a government foundation in Washington requesting information on the role of agriculture in the solar program received the following response: "Solar energy is not associated with agriculture because solar energy is now associated with other categories at this Foundation...Ten years ago it would have been possible to associate solar energy with agriculture, but now if we used solar in connection with agriculture it would confuse the categories associated with solar." Besides he said, "Trying to change this pattern and associate solar with agriculture would amount to a crusade." Categories in bureaucracies like the NSF or ERDA or any other like organization take on a life of their own that is contradictory to flexible operation in science, and sometimes downright contrary to the goals of science in the public interest. Bureaucrats are there in order to meet the milestones set forth, and if their train is on a successful track as viewed from their expectation of reward they are understandably reluctant to change the direction of the track or the schedules or frequencies of the stops. In short, there seems to be no reward for them to take on any alternative ideas.

In general, bureaucrats are vastly overworked; and without a reward incentive, one can understand their reluctance to undertake any alternative paths. At least by implication, energy bureaucrats are assaulted almost daily by people with ideas that are claimed to be extremely important in the energy business requiring immediate attention. The advancement of a person in a bureaucratic job is defined to exclude the taking of risk. It has been observed that the investment banker makes money only on the basis of taking risks. The bureaucrat does not have this reward structure built in. Soon paperwork and the duplicating machine hides all. When State Energy Commissioners note that the agency has grown from approximately 50 people to 550 people in about two years, and when they note that they feel 'the bureaucrats are taking over,' and when interested citizens can't see what is coming out of a state or federal energy agency that is in direct response to an energy crisis - it may be time to think about new organizations that can function in times of transition and emergency, rather than borrowing a type of organization, for this new era, that has known paralysis diseases.

To return to the freedom of the concerned citizen as contrasted with the constraints of the wage worker (be she/he scientist or other) -

as uncomfortable as it may be to scientists, we must raise questions of what organizations do with deviant scientists, with scientists who do not think like the rest. We know what happened to Gofman and Tamplin, but there are others, not so well-known. More important perhaps is to understand that scientists who do stay are being rewarded for thinking in a certain way, and after some years these ways of thinking become God's Truth, assumptions not to be challenged. In the energy field, energy experts tend to think in terms of the way to satisfy the energy demand as projected, by the way, by energy industries. They do not think in terms of non-commercial sources of energy: firewood, cow dung, agricultural wastes, or in broader terms - solar. It may be the time to call a spade a spade, and to call solar derived goodies just that - solar derived fossil fuels, plants, etc. A return to the original source in labeling, as with the solar example, would be part of a process necessary to educating people in the basics. Then, the agro-executive would know that he should be concerned with rain, because irrigation derives from rain.

12.2.2 Credible vs Non-Credible

Public acceptance is related to a number of variables such as price, status, convenience, and in a more general sense credibility. Credibility is crucial to implementing any policy requiring public cooperation (Hoos 1976). Recent polls have shown that citizen trust in what the government is saying about energy is at a low point. One study reported in Science (Murray et al. 1974) noted that only about 8% of the people surveyed believed what the government was saying about energy.

Credibility is diminished by a number of factors: (1) the gap between what the government says and what government does, particularly in areas observable to the average person (e.g. by visiting government buildings); (2) diversity of opinion among experts, which is seen by the public as lack of agreement among experts; (3) scientific overconfidence ("Often wrong but seldom in doubt," which translates as an oversell of science); (4) industry-invented shortages with the motive of increasing profit; (5) self-serving practice in public and private administration of invoking "expert" advice; (6) single angle analysis rather than a holistic approach, for example, only technical aspects or nuclear or solar energy rather than the socio-cultural context within which they will operate; (7) extension of the role of expert, for example, nuclear scientists talking about the "necessity of nuclear power," which is not a technological question, but rather one requiring social and economic expertise, or creating a technology without consideration of the kinds of expertise needed - "the people problem"; (8) ascribing of credibility to experts who may or may not merit it. An example from the Bay area: people are saving more water than anybody dreamed possible, and using more gasoline than ever before.

Questions of price, status, and convenience are more particular. Expensive or convenient for whom, when? In addition to credibility, then, there is the need to know something about the potential cooperating population: the present variety of lifestyles and energy consumption patterns in the U.S. is wide. We have come to accept a homogeneous perspective of American society, based on the lifestyle ideals of the upwardly mobile middle class. The opportunity of personal choice in lifestyle and the potential for a heterogeneous society must be understood and utilized in our projections and plans for the future.

We can learn from past mistakes. The long-term inadequacy of educational, welfare and urban planning was based on erroneous assumptions regarding family composition. The "ideal" family was thought to be a father who works and supports the other, a mother who keeps house and cares for the children, and children who are totally dependent on their parents for all their needs. However, this description held true for only about half the families in the U.S. Ethnographies on American communities show an amazing diversity of attitudes toward wealth and well-being and of mechanisms for gaining and displaying status (Vidich and Bensman, 1958). When there is diversity in the population the solutions or the pathways might do well to be diverse as well - different paths appealing to different people. Some people are born conservationists, others prefer a solar technical fix, some like the idea of dispersed electricity generation, and some wouldn't want to be bothered. Whatever paths we pursue there needs to be visibility and role modeling.

12.2.3 Tangible vs Abstract

It appears that the public is convinced that there is a water shortage by their first-hand experience of a lack of rainfall and because they believe the evidence shown them that water reservoirs are extremely low. Oil, on the other hand, seems to be in superabundant supply. There is no shortage of gasoline. In fact, the newspapers carry statements that there is a glut of oil. Government on the federal and state level is free to admit the presence of this oil glut, remarking that it is very unfortunate because a genuine shortage of oil is soon to follow. A commonly held opinion within government and among experts is that the public will only respond to a visible crisis. One way they argue to make it visible and to clear up the ambiguity is to raise prices. The public may fall into line if the price goes up high enough, but such behavior will in no way compare to the cooperation that stems from a credible story on water.' There is an important point being made, however, and in conjunction with the credibility problem we might look at the question of tangible/abstract in terms of role modeling.

Large organizations in this state are building new buildings and are continuing to face increasing fuel bills for space heating, hot water, air conditioning, refrigeration, etc. What are these leading institutions doing that would contribute to their becoming more energy efficient? Only a few educational institutions, such as San Jose State University, are actively engaged with their own plants.

At a Bay area university there is a large new building being built. No solar space heating or hot water is planned for this building. Apparently those controlling the investment capital have made a decision that any methods for heating or cooling buildings should pay for themselves within 5 years. If this 5 year pay-off period cannot be met, the old established methods for heating, cooling, and hot water will be used.

The public may well ask, if there is indeed need for energy efficiency, why aren't these leading institutions in the state converting at least one major building to solar space heating, paying special attention to using a combination of passive and active system design? With the university systems there is a reservoir of expertise unmatched in other institutions. Within state government there is money laid aside for retrofit - again few visible products.

Perhaps the most visible example of abstractness of goals is in the state energy commission building. It is a source of embarrassment to the commissioners and their staff at the state of California Energy, Resources and Development Commission that the new building housing their activities at 1111 Howe Avenue in Sacramento has no solar facilities and is a poor example of energy conservation. In short, from an energy use standpoint, this complex of offices is wasteful, poorly conceived, and out-of-step with the purposes of the commission. As far as we know there is no detailed study of their own plight in this regard.

Moral of the story: "do as I say" must be accompanied by a model worthy of "doing as I do." Carter's plan to solarize the White House would be an example of role modeling.

12.2.4 Restricted vs Global Time Perspective

In discussing energy questions time appears in many forms. A restricted time perspective might describe solar as an intermittent energy source, and thus not dependable. Correspondingly, in a more global long time perspective all non-renewable sources of energy are disastrously intermittent. In a restricted sense technology has bought us time; we can now cross the country by jet in a matter of hours. In a broader sense, however, technology has not expanded our time as illustrated by Linder (1970) in The Harried Leisure Class. For urbanites discussing land productivity 50 years of time is a long time, while many farmers in this country would find saturation of land within a span of 50 years to be an unacceptably short term use of land. Flat plate collectors might not be used on the Stanford University campus because the policy of the University was a five year or less pay off time.

Time also enters in relation to the amount of time it takes to get things moving. The public might well ask why the government is not doing things now (not 1980), while the government assumes that because the people do not respond to an announcement of an energy crisis they will be slow to respond to change, e.g. take a long time. Time is also being used as incentive; in Princeton, there are feedback studies being done which inform people how much energy was used in the last day. It is believed by industry to take a long time to make changes in production; the same people believe that the American people only respond to sudden change, that is change that does not occur over a long period of time.

It is important to fit the time perspective to the problem. Restricted time perspectives are not what we need for environmental protection, nor for encouraging conservation in building. On the other hand, short term feed-back in savings for households might appeal to the "piggy bank" that is in us all.

12.2.5 Specialist vs Generalist

In our introduction we have already alluded to the problems of expertise: inability to see the piece in the whole, loyalty to professional goals rather than wider social goals, insecurity generated by the fact that most experts are wage workers, insulation generated by the fact that expert language protects the expert from outside criticism (not everyone knows what an energetic disassembly is), and increasing inability to entertain simple solutions or to deal with mundane problems (how many architects in this country know anything about energy efficiency; how many experts on decommissioning of nuclear plants are there; how many drinking water experts are there?). It is because of such observations that Lovins and others have urged that the non-expert be brought into the dialogue over energy.

It must also be underlined that by the very form of initiation or induction all professionals are ideologically bound. Professional expert ideologies are sometimes referred to as mind-sets. Such mind-sets often indicate what one tends to be optimistic or pessimistic about.

Nuclear experts are generally pessimistic about solar, as are other professionals who do not find solar intellectually challenging. Retrofit, a nice mundane concept, did not have much potential almost all of our energy expert officials agreed. As we moved into the John Q Public level there was genuine interest in retrofit because it was something that people of low skill could learn to do.

A final comment. Professional training teaches one how to stay in business. There is a history in the United States of incompetent professionalism (whether it be in producing cars, curing drug addicts, or practicing law or medicine) breeding an increased need for that profession's services. Again, we need to find ways to encourage professional public service while at the same time restructuring professional fears for self-preservation.

12.2.6 Voluntary vs Involuntary

There are a number of concepts which are related to the voluntary vs. involuntary dimension. The contrast in discussing the building code was drawn between certainty and responsibility on the one hand and freedom and creativity on the other. The further down the totem pole we got the more certainty people wanted, while the further up the more freedom the architects and materials people wanted. It would be interesting to know if this cut would hold with a wider sample.

In discussing this same building code, another set of terms was frequently used: prescriptive and performance. The prescriptive code is specific on the amount of insulation, climate control, orientation, window spacing, lighting, etc. The performance code (which has not yet been written) provides wider parameters within which a certain level of energy is to be used. While architects prefer performance, one building inspector had the following to say: 'Specification is understandable; performance is not understandable.' He also said there would be full compliance with a prescriptive code on the part of builders and inspectors, 'because they can relate to the measure. Performance is that never-never land of architects and engineers.' This inspector is involved in the training of building inspectors. Actually, we were told that the code would permit a person to build within the total energy budget as an alternative to building according to the prescribed standards, so it is doubly interesting that the code was stigmatized as prescriptive.

There is a further note to be made on the voluntary dimension. While in many ways one of the characteristics noted by outsiders about Americans is their cooperativeness and ability to respond voluntarily most of the officials and professionals we spoke to were convinced that change would have to be mandated, that we could not expect voluntary change. All had ways of "explaining" Californian behavior on the drought in the face of price increase with decreased consumption of water. We have a staff at Stanford looking into "social marketing" of conservation measures - their assumption being that Americans can only be educated or seduced into energy efficiency. Again there are untested assumptions, and we need to key into the conditions that are conducive to voluntary change, or change by incentive. When do punitive measures (price increase which is always favored by economists), as versus reward measures (tax incentives which are often proposed by citizens) work best? I believe if we examined the literature in psychology that reward systems would come out ahead in motivating large U.S. population groups.

12.2.7 Progress vs Decline or Status Quo

Much of the hostility towards soft paths stems from a self-serving view of progress which does not fit with a global evolutionary perspective, but which is part of a restricted time perspective. For the most part, in this view, technology is used as a measure of progress, and it is the presence of technology rather than its use or consequence that provides the measure. Progress, for example, is said to have eliminated the drudgery of women's work, yet in terms of hours/housework it takes as much time today as at the turn of the century. More interestingly, however, the cost of progress is swept under the rug by a clever technique invented by economists - externalities or long term costs. Again time perspective is important. Most hard path advocates believe the erroneous thesis presented in Cook (1976) of linear societal evolution in relation to perceived patterns of energy use. It should be remembered that cultural progress is dependent upon factors other than those arising from the use of energy, and that how that energy is used rather than the use of energy _per se_ is related to improved quality of life, or decline in living quality.

With these dimensions roughly in mind we now turn to two contemporary mechanisms for transition: the California Residential Building Code, and the use of dispersed electric generators. When we look at the code and listen to the arguments over prescriptive vs. performance we need to remember that some of those who object to prescription presently abide by prescription. However, the prescriptions builders, for example, abide by originate from their industry and not from an outside source such as the Energy Commission. When we look at the potential use of dispersed electric generators we will recall that institutions have a coherence about them. Changing public utilities relations with consumers will be seen as disruptive to the status quo. More frequently that we might like to admit in this country, major institutions operate from fear and cloak their fear in symbolic representations such as that embodied in the concept of progress.

12.3 THE CALIFORNIA RESIDENTIAL BUILDING STANDARDS (referred to as "The California Building Code"): PROFESSIONAL AND INSTITUTIONAL BARRIERS. THE VIEW FROM THE TOP DOWN.

The California State Energy Commission has adopted new energy standards incorporated into a building code that is to affect all new residential buildings after March 11, 1978. The contents of the code are described as follows:

> The regulations modify existing insulation standards for residential buildings within the State of California and establish additional energy conservation standards for residential structures relating to water heating, climate control systems, glazing, and vapor barriers." (P. 22 of the draft regulations)

The code is specifically designed to reduce the use of electricity for the heating of residential buildings. Natural gas and especially solar energy should be used to be supplemented by insulation and glazing. There is a statement on mathematical formulae to be used in the calculation of the amount of insulation for the walls, ceilings, and floors. There is also a listing of the cities and towns in the state with corresponding climatic data that more exactly defines the amount of insulation to be installed in a given place. The role of a building official is specified in supervising the implementation of the code. Should alternative means for heating be installed, life cycle cost calculations are carried out according to set mathematical formulae which would indicate that they would be cheaper in the long run than the use of natural gas or solar energy. Thus, the building code not only includes building design and construction regulations; it also incorporates an economic justification for its implementation.

An article by Raymond W. Bliss (1976: 32-40), which is well written and easily understood by the layman, describes the principle on which the building code is based. He discusses the concept of the use of passive solar heating in houses in the northeastern U.S. Bliss presents an equation which schematically describes the processes of heat gain and heat loss in a residential building. By appropriate construction and design, primarily in insulation and window space and positioning, Bliss shows that it is possible to reduce up to 38% of the reliance on heating from centralized sources within a house. The logical extension of this argument is that it is possible to build a house that would need hardly any heating arising from such sources as electricity, natural gas or oil. Such a building, using present available technology, would have thick, heavy walls or a large expanse of windows. The solution then is to make increasing use of inexhaustible energy sources, such as the wind and sun, while limiting the amount of heat loss to the outdoors from within the structure of the building.

We have seen so far that the building code treats briefly with architecture and engineering insofar as building construction and design are concerned; with economics from the perspective of cost benefit analysis; and with the environment in terms of the microenvironmental differences in California. We now come to the human component; as Bliss says, " .... houses are designed primarily for living; and man does not live by Btu's alone." (1976: 33). The human component begins with the state government. The implementation of the building code would result in a marked decrease in the consumption of fossil energy. The saving is especially impressive when one realizes that electric heat energy consumed at the point-of-use is only one-third of the thermal energy required at the point-of-origin (Bliss, 1976: 39). In drafting this prescriptive code, the government through the State Energy Commission was drawing on experiences acquired from an earlier code that had been declared faulty by the courts.

In our interviews we found that reaction to the building code could be divided into two opposing groups - those in favour and those against. One individual, representing an activist organization, professed a basically adverse reaction to any code that would limit the person's range of choices within his residence, which is a man's own "castle." He preferred a "performance" code, one that would only stipulate the amount of energy to be consumed within a given amount of square-footage of residential space. Implicit in this objection are two underlying themes. One is a part of the American ethic that there is a perpetual state of conflict between the rights of the individual and the common good of the nation. The other theme is that the private sector is more capable of working out the solution to a problem than the government could through regulations. There is a contempt of bureaucrats, who are seen as the instigators of the present code for the sole purpose of creating more jobs for themselves.

Construction companies, described by one source as being speculative, conservative, and highly fragmented, would be opposed because of the increased costs of installing the insulations and glazing, among other new stipulations. The financing institutions would be opposed because of the increased amount of financing that they would have to provide, especially at the outset of the code implementation when the cost benefit analyses would not have been thoroughly worked out. Some engineers and architects would be opposed because of the need to master a relatively new technology and what they consider to be restraints on their own creativity. When the building code goes into effect it will not go unchallenged.

There were others who were sympathetic, and yet others who were sympathetic but worried about problems of implementing the code. There would seem to be two main reasons that inhibit the formation of a united front in support of the code. The first is the relative novelty in the extensive use of passive solar energy. The architects and solar energy coordinator could more easily pinpoint problems related to the code and the use of passive solar than they could discuss the advantages. The other factor is that there has been no serious attempt to inform the citizens of the code so that they could become actively involved on a mass basis. Given the wide-ranging scope of the code that extends from all aspects of the construction and use of residences to the gross reduction of the use of fossil energy, the public should be made aware of the gains and/or losses to be experienced.

12.3.1 Description of the Residential Building Code (RBL)

The Code was drafted under the responsibility of the Conservation

Division of the State Energy Commission. It provides specifications on the building envelope, climate control system, climate control equipment and water heating.

The following notes are some of the main highlights:

1) The State is divided into geographical locations using the degree day measurement. For any one day, when mean daily temperature is less than 65° F., there are as many degree days as there are degrees difference in temperature between the mean temperature for the day and 65° F. The number of degree days for San Francisco is 3,080 and Los Angeles 2,061.

2) Floor insulation is required for areas with more than 3,000 degree days.

3) All glazing in buildings which are mechanically cooled or located in areas with summer design temperatures in excess of 85° F., will be required to be shaded to protect the building from direct solar exposure in summer.

4) The standards prescribe maximum level of thermal conductivity for doors.

5) Residential heating systems utilizing depletable energy sources must be selected on the basis of lowest life cycle cost of at least three alternative systems - gas, electric resistance, and heat pump.

6) Electric resistance heating will no longer be allowed to heat swimming pools.

7) Electric resistance water heating systems may not be used unless the life cycle cost of all alternate energy systems exceeds the life cycle cost of the electric system. The procedure for determining life cycle cost will be shown in the Residential Energy Conservation Manual.

8) The standards also cover provisions for pipe insulation, ducts, heating equipment sizing, and efficiencies, exhaust fan back-draft dampers and vapor barriers. (Comm. Socioeconomic Impact Study, pp. 3-5).

We examined reactions to the RBC as an example of the legislation of measures that would result in the lowering of energy use. Within the overall Dispersed Technologies Project, it is an example of a particular type of pathway, namely the effecting of transition through legislation. Two processes can be isolated in the ground works for the RBC - the drafting and the preparations for its implementation.

12.3.2 Drafting

The exercises included in the drafting consist of the carrying out of impact studies by the Commission Conservation Division and the holding of public hearings by the Commissioners.

We reviewed two impact studies. The first is "Initial Study - Residential Building Standards" dated Sept. 29, 1976. It is designed to determine whether the implementation of the RBC would result in any significant effect on the environment. Appropriate to our study are the conclusions on the gross energy that would be directly saved by the standards and the energy used in manufacturing the materials needed to fulfill the standards. Table XII-1 is extracted from p. 11 of the report. The calculations assumed 1,600 sq. ft. for houses. The energy savings are the gross savings in the year 1981, resulting from the construction of residences in the 1978 - 81 period, and operating in conformance with the proposed standards. The table takes account of conversion losses at electrical power plants, but not transmission losses.

The energy used in the production of materials is short-term and is "paid back" in energy savings in about a year. Thus, the RBC would result in significant savings in energy statewide.

Table XII-1

Total Energy Savings due to Standards
(Millions of Therms) 1981 Annual*

Energy Savings from Standards	Case A	Case B	Case C
in Electricity	+60.9	274.4	-138.6
in Gas	170.8	-96.1	+412
Net Saving	231.7	178.3	273.4
Energy Used for Materials	194.8	199.2	191.6
Energy Pay-back Period (years)	.84	1.12	.68

*Does not include energy savings from glazing options or other savings due to cooling.

Explanation of Case Assumptions

Case A: Prices of electricity and natural gas as projected by the utilities.

Case B: Prices of electricity 30% higher than projected by the utilities, prices of natural gas projected by the utilities.

Case C: Prices of electricity as projected by the utilities, prices of natural gas 30% higher than projected by the utilities.

The other is Socioeconomic Impact Study, dated November 17, 1976. It assesses the effects the standards would have on employment in industries affected by the specifications, such as the manufacturing of water heaters, electrical heaters, and heat pumps; as well as on the availability of houses based on their increased capital costs. The study concludes that there would be negligible effect on employment opportunities in the industrial sector. Construction would be especially increased through the use of the specifications for the building envelope.

On the effects of the standards on the consumer, the report portrays a bright and a dark picture. The cost of the new house would increase about 2%. There would, however, be net monthly savings over a 30-year period of about $70. for the 1,600 sq. ft. house. On the impact on low income consumers, the report states,

> "People in the low middle income bracket are potentially the most affected by any increase in the new housing market. Since they can only afford to buy new houses under $30,000, they are rapidly being priced out of the new housing market, as few new houses under $30,000 are available." (pp. 24-25)

12.3.3 Hearings

We looked through the extracts of 7 public hearings held by the Commission between June 9, 1976 and January 25, 1977. Large industries, either manufacturing equipment that would be affected by the standards or utility companies, were heavily represented among those who presented briefs. The hearings were dominated by special interest people such as electric resistance heating companies; there was not focus on broader public interest questions.

There were at least two main issues discussed in the hearings - the reliability of forecasts of energy sources in California and the most efficient means of using it. On the question of forecasting, there is concern expressed within the Commission staff that all estimates are uncertain.

> "All forecasts of future gas supplies are filled with uncertainty and therefore it is impossible to quantify impacts with any degree of confidence." (Socioeconomic Impact Study, p. 41)

Despite the doubts on the stock and price of natural gas, the RBC assumes that equipment using it would be the lowest in life cycle costs. The Commission argues that it would be less expensive to pipe natural gas into homes rather than to use it to produce electricity which would be subsequently transmitted to homes. The large industries respond that by singling out equipment that use natural gas, the Commission is discouraging the flexibility of technology.

The Building Code Action, which describes itself as "an incorporated not for profit association, the members of which are builders, contractors, members of the public, and engineers" also participated in the public hearings. They are now presenting lawsuits against the RBC on two grounds - substantive and procedural. The first opposes the prescriptive nature of the RBC, arguing that it contradicts the free enterprise nature of this society. The second opposes the methods used by the Commission in the calculation of energy budgets of houses and life cycle costs of components.

The National Concrete Masonry Association is also suing against the RBC. As the association has its branch offices in Southern California, we could not investigate by interview the nature of its opposition. We are awaiting a response to a letter we wrote them on this matter. We had also requested an interview with Mr. Michael K. Strumwasser, Deputy Attorney General to discuss legalistic problems of the RBC, which would include a review of the issues, such as those brought by the Masonry suit. Unfortunately, he refused on the grounds that he did not want to discuss a case that was pending for the court. We failed in establishing other contacts within the office of the Attorney General, primarily because of time limitations.

12.3.4 Implementation

We found out that the Commission staff would undertake similar preparations for the implementation of the RBC as those for the implementation of a new non-residential building code, which is to become effective on January 1, 1978. Substantially both codes are similar and the same administrative framework would undertake the tasks of implementation. We found it useful to review the implementation preparations of the non-residential code as a prototype of what would most probably be done for the RBC.

Members of the Commission staff told us that a manual had been drafted to facilitate the use of the code by building inspectors and contractors. There was to be a workshop in Sacramento during August based on the manual. The Commission was setting up an appeals machinery in consultation with the Housing and Community Development Department that would deal with conflicts on the definition of energy budgets arising between individual building inspectors and contractors. Besides, there was to be an "educational program" to familiarize the bankers and other lending institutions with the code (Socioeconomic Impact Report, p. 23). There was no mention of similar programs oriented toward the public in whose interests the RBC had originally been presumably designed.

In speaking with one of the persons who had worked on the manual, we got a completely different impression. He felt that the Commission was "naive" to believe that the building inspectors and contractors would be sufficiently informed with the RBC by January 1, when it becomes effective. He foresaw very difficult days ahead between the builders and the Commission on several procedural problems involving the RBC. Thus, it would be safe to conclude that there would be an inadequately prepared administrative infrastructure for the implementation of the RBC and a grossly uninformed building industry.

12.3.5 The California Energy Resources Conservation and Development Commission (Energy Commission)

We were fortunate to speak to three of the five Commissioners and at least six members of the Commission staff. The Commission was set up in 1975 by the State legislature to be a one-stop agency on energy conservation and the development of technology for alternative sources to curtail reliance on fossil energy. For a study of the history of the Commission, its goals and operations, one could refer to the first and summary volumes of the Commission's eight-volume 1977 Biennial Report. One commissioner describes it as a young organization that is extending and growing too fast. Within two years it has grown from a staff of 45 to over 350. Its total budget is now $14.6 M.

There are basic structural problems within the Commission at the level of policy formation. Decisions are arrived at on a majority basis, a process that has resulted in the formation of a noticeable cleavage within the Commission. One member describes it as a split between the "academic" and the "non-academic" factions. It seemed quite possible that the members spent as much time arguing among themselves as they do on Commission problems because of obvious personality conflicts among themselves.

Within the Commission the mandate of the Warren-Alquist Act (1975) seems fraught with ambiguity. Two Commissioners said that there was disagreement on the nature of the mandate which created the Commission: to strive for energy-efficiency and conservation, to make it easier for new power plants to be given licenses, or to stop the exponential growth of nuclear power. As there is no strict division of responsibilities among the members, each one pursues the function that he most prefers. Given such a state of flux, the productivity of the Commission really depends on the staff personnel and the rapport one or more of the Commissioners would have with them. It was therefore not surprising for one of the Commissioners to remark that the bureaucrats are "taking over" the Commission. Because of the bureaucratization of the agency one Commissioner noted that small scale projects, like windmill electric generators, would do better if carried out on the outside.

The operations of the personnel, on the other hand, are hampered by archaic regulations within the State civil service. We were told that because of recruitment stipulations, it was unattractive for young highly trained personnel to join the Commission staff. In a new and fast expanding field such as energy, there would be a need for the civil service to innovate its recruitment policy to attract some of the few trained in energy and related fields.

Thus, the Commission as an institution is itself undergoing formative, growing pains. It is questionable to what extent it could successfully overcome this stress as well as that of the need to introduce transitional pathways aimed at reducing energy use, such as the RBC.

On the RBC itself our discussion with Commissioner Doctor was most productive, especially as he had personally taken great interest in it. He clarified that the RBC is not prescriptive, but that it is based on component performance. Certain components of the building, the building envelope, climate control system, and water heating, had been specified based on their life cycle costs and their lowering of the total energy budget of the house. Besides, there were provisions within the RBC to vary the specifications provided that the total energy budget of the building would be the same (or less) as that had the code specifications been used.

The other Commissioners were ambiguous on the RBC. One said that the "approach toward it was certainly pedestrian and routine from the perspective of engineers within the Commission staff." Two Commissioners saw the standards as being inevitably subjected to continuous refinement through (litigation) tests.

12.3.6 Interest Groups

The most interesting part of our project was interviewing people who represented various interest groups related to housing, building codes, and energy use. The three main questions for which we were seeking answers were - to what extent is the group which the individual represents organized into a "corporate group" status; what is his position on the RBC; and what effect could the position of his group have on the implementation of the RBC. For analytic purposes the groups are placed under two main functions of housing, construction and use.

Under construction are bankers, contractors, architects, and building inspectors; under use is the realtor group. (Given more time interviews should also be held with people who live in their own houses and those who live in rented houses.)

12.3.7 Banker

We spoke to an appraisal officer of a major bank in San Francisco. By education he was both an architect and a cost analyst. He affirmed that the bank does not take into consideration the life cycle costs of building components in appraising loans for housing. This could be bad for buyers in that the life cycle cost effectiveness of their conservation measures would not be figured into their "income" later on and would prevent them from getting the larger loan which would be necessary to buy their more expensive house. This position coincides with the findings of the Commission Socioeconomic Report as well as that of R. Melicher (1976: 187-195). Although the Commission concludes that the RBC would result in the lowering of the operating costs of houses, the bank itself would have to undertake its own independent study before forming its policy.

Thus, the present policy on lending for house purchases is completely contradictory to the RBC. Besides, the conventional assessment the bank normally places on the character of one's neighbourhood and one's credit worthiness would limit the possibility of the universal application of energy efficient methods in housing.

12.3.8 Contractor

Most of our information on contractors was obtained from a member of the State Contractors License Board. He is a recently appointed public member of the board, who, not being a contractor himself, could be somewhat objective in his assessment of the contracting industry. He characterizes it as one of the largest industries in the State. There are presently over 112,000 licensed contractors and 1,000 are admitted monthly. There are 52 divisions within the industry featuring such specialization as plumbers, electrical wiring, and carpenters, etc.; they are held together by interlocking trade unions.

Presently there is a major debate among the contractors on which division should assume the now lucrative market of energy efficient components and on the standards to be met. Should it be the plumbers, electricians, air conditioners, etc.? This disagreement is one of the major obstructions for the universal adaptation of energy-efficient components.

On the energy issue the contractors unite in a front against the Commission for giving mandates on construction as in the case of the RBC. They especially resent not having been consulted by the Commission in the preparation stages of the RBC. Before the days of the Commission, building codes had been drafted by the building industries, which were then adapted by city building inspection units. The contractors also are opposed as a group to the utility companies, which they see as acting in unison with the Commission to preserve their monopoly.

Apart from their crucial role in the building of houses, the authority of the contractors arises from their tremendous lobbying power in the legislature. Thus, the comment of a member of the Commission staff that the standards had been specifically made prescriptive because the builders operate traditionally on specifications is misleading. The builders have operated on their own specifications and they will not easily change to start using those arising from other sources, unless their self-interests are satisfied.

12.3.9 Architects

We spoke to about six architects, both within the government and private industry, and almost all of them were opposed to the RBC. We detected what could be called a pervasive "architect ethic" that is twofold. On the one hand, architects display a non-involvement on social issues. In their training, the orientation is to the visual effects of one's work in the design of a house, and to creativity; any constraints on freedom become problematic. A member of the faculty at Wurster Hall told us that their curriculum is presently being reworked to infuse a greater concern for environmental issues including energy use. However, the results of this effort to be seen in the work of architects is far away.

Secondly, architects normally react critically to codes, primarily because they see them as a hindrance to their productivity. A relatively innovative code such as the RBC lends itself to criticism on procedural grounds, such as the calculation of energy budgets. Thus, in a manuscript (1977: 4-5), Sartor, an architect specializing in solar design, criticizes as absurd the RBC specification "that 1 sq. ft. of properly shaded, double-glazed south-facing window would require 6 sq. ft. of floor slab to be exempt from 16% maximum glazing." Generally, the types of architects' reactions to the RBC are (a) one of acquiescence - with all its defects the code is probably a step in the right direction; and (b) one of complete opposition - the code is basically erroneous and should be withdrawn.

We could not interview a representative of the AIA. We did learn that it is an elitist professional association with some potential for mass action. We are awaiting response to a letter written to the California branch of the AIA.

Few people outside the architecture profession accept the constraint argument as the vast majority of homes are not custom-designed. As to the effects of the code on creativity a veteran architecture professor scoffed at the idea that the code would dampen creativity. He suggested that the real worry was increased paper work and the resultant delays which would be discouraging to the be discouraging to the buyer and architect alike.

12.3.10 Building Inspector

We interviewed two building inspectors, one working with the City of Albany and the other the officer-in-charge of the Sonoma County building inspection unit. In the case of the former there was a complete ignornance of both the non-residential code and the RBC. He is presently already overworked and understaffed, and is aware the new code will require more work.

The latter had been involved in his capacity as Education Director of the California Association of Building Officers in the drafting of the manual based on the non-residential code. He was generally in favour of the RBC, although he was critical of some aspects, notably the mechanical equipment that use natural gas. We found it very surprising that he was not overly concerned about the increased burden on his staff that the RBC would necessitate. Thus, his concern could be characterized as being more directed toward the day to day exercises of building inspection than on the total scope of the RBC. As the former inspector, he was very busy with his duties while he spoke with us.

We learned from the architect who had been associated with building inspectors in the drafting of the manual for the non-residential code that there was great resentment from the larger body of building inspectors based on the Commission's proposed methods of implementation.

12.3.11. Realtor

We spoke to a part-time real estate agent from San Jose who was quite articulate and could afford to be somewhat objective in his assessment of the realtor business, since he did not totally rely on it for his livelihood. He characterized the realtor as primarily a middleman who thrives on speculation on housing by trading, owning houses, or being agents for owners. The RBC would be subsumed into their business transaction in such a way that some profit could be realized. He cited the expertise of the realtors in padding their income tax returns through negligible improvements to houses, mileage deductions and other types of transactions involved with the promotion of sales.

He argued that the applicability of life cycle costs of energy efficient components are not of significant advantage to the individual household for two reasons. Firstly, the average house in San Jose, for example, is lived in by one family for 7 years. Secondly, less than 50% of the houses are owner-occupied. Thus, people are not really concerned about the cost effectiveness of the house energy budgets because of the mobility of the society and the increasing scarcity of houses.

The RBC might lower the energy use in the house. However, it would probably increase the capital costs making it less possible to own a house for the ordinary person and more easy for the realtor. It is when people own their homes over an extended period of the family lifetime that the savings gained through its operations on less energy are realized by its occupants.

The realtors are organized into powerful lobbying groups that could agitate on the RBC, depending on the turnover of business in housing.

12.3.13 Preference: Prescriptive or Performance Codes?

The difference between prescriptive or performance codes was central to the discussions with the broad range of concerned groups and individuals. It was of some interest that the majority of special interest people are against prescriptive codes. However, at the building inspector level, and the concerned citizen, there seemed to be an attitude shift. The building inspector prefers prescriptive because "it's easier to relate to" and performance calculations are far too sophisticated. The concerned citizen, too, is in favor of prescription; it may be that the certainty that accompanies prescription is comforting.

12.3.4 Discussion

There are three main lobbying groups on housing, any of which could muster some power that could adversely affect the implementation of the RBC. These are lenders, builders, and realtors. They determine in corresponding order the money, the building, and the availability of housing. Their self-interests override the energy issue. Building codes could be passed but these groups determine the extent of its effectiveness. They have in the past joined their forces, when it was necessary; and together they were successful. This is seen in the case of the Building Code Action bringing a lawsuit against the Commission for drafting a prescriptive non-residential building code. It was successful and the court ordered the Commission to draft performance standards. Commissioner Doctor was certain that this would not happen in the case of the RBC because of the mandate under which it had been drafted.

There is a great need on community-oriented group action to arouse the interest of the consumer on housing, the RBC, and energy. In our interviews we were informed of two such attempts. One stressed building codes and housing. It was briefly mentioned by the building officer of Sonoma County as an effort of extension services provided by his education division to the public. They held discussions with such groups as parent-teachers' associations to explain the relationship between building codes and housing. The other was the orientation of potential house buyers to the opportunities offered by the FHA by a concerned group in San Jose.

The best example of the stressing of energy and housing was shown by the Farallones Institute of Albany. The Institute is a non-profit group which earns its keep through public participation in donations, subscription, and lecture-demonstration series. It is an attempt at grassroots application of technology for independent living, emphasizing the recycling of the use of energy tapped from renewable sources of wind and sun. Their importance to our research is that they underline the need for a departure from all aspects of the present hard technology for the implementation of a soft technology at basically an ideological commitment. Besides, it demonstrates the effectiveness of citizen-directed approach to the problem of energy primarily in the role of innovation, research, and teaching.

It was suggested to us by a consultant to the Commission that the RBC should be more appropriately introduced on a decentralized basis. The city should provide the major focus for the implementation of the RBC, as has been done successfully in Davis. (We could not go to Davis for interviews.) The degree day concept would be more clearly defined to reflect microenvironments within the community. There is also a possibility that the interests of big hard industries, such as banking, construction, and real estate would be less consolidated making it possible for consumer interests to be better articulated.

From the communications specialists at Stanford we learned about the use of feedback as a means of informing the consumer of how much energy he had used within a specific time. This seems as being more fruitful for energy saving in the short term in contrast to that of life cycle costs of housing components which may or may not be used by the same person over an extended period of time.

A concerned citizen belaboured the need for retrofit as a means of curtailing the energy consumption within one's present residence. She had charted out a method whereby the cost of retrofit could be subsidized through tax deductions. This again seems to be a procedure of the "here and now" to which the consumer could easily relate.

Finally, the assumption of the RBC on energy savings as it relates to the individual is that each household unit (family group, etc.) would live in its own home over an extended period of time so that the initial capital costs of the specified components could be realized. For the universal realization of this assumption far more people should be owning their homes than presently. Thus, there will have to be some effort to accomplish this aim.

The variety of interviews all suggest that there are almost self-contained levels of dealing with this problem. It is difficult for people involved in a level to break out of it, and see the picture as a whole. For a mandate to work proper incentives must be set up. Right now, there is a disincentive for the homeowner, as well as job threats for people who work with specific materials. The 1974 automobile interlock system is an interesting example of disincentive to incentive. The car wouldn't start unless seat belts were buckled. Dealers provided ways around it by disconnecting the belts before the car was sold or later if requested. When the legislature created a $2,000 fine for the dealer who disconnected, and a $200 fine for the owner of the vehicle for cutting the system, then the law was effective. Effectiveness studies (Rogers, 1977) showed that most 1974 car-owning people did have their seat belts buckled, and death rates were down from accidents. Usually draconian measures are unpopular and sometimes are not needed if the total picture is part of the "code writers" purview. Voluntary adoption as exemplified by the response to the water shortage is cheaper and a more preferred way in the United States. Steps have to be taken to present energy as a social issue basic to our survival. Success achieved in this effort would facilitate the acceptability of legislative measures designed to lower energy use.

12.4 RESTRAINTS ON DISPERSED ELECTRIC GENERATION: INSTITUTIONAL AND IDEOLOGICAL BARRIERS, BOTH PUBLIC AND PRIVATE

Information on this question has been collected from a variety of states: Wisconsin, Michigan, New York, and California. What follows is the essence of the California situation as learned from talking to representatives of public utilities, citizen action groups, and a variety of other people listed in Appendix XII-2.

Our questions to the Public Utilities were straightforward. What presently is the attitude of California electric utilities toward small, privately owned installations that would use electric power from the utility and be capable of the delivery of power to the utility, thereby using the utility grid as supply and storage for electric power? Does the public utility welcome small generator-users connected in parallel to their system? Both the Pacific Gas and Electric Company and the Southern California Edison Company for example, state publically that they not only welcome the connection of small privately owned electric generators, but that they are soliciting this type of connection. One representative of the Southern California Edison Company maintains that presently he has contracts being written for about 584 million watts of power from small electric generators, which he maintains will be in operation about the first of the year.

There are, however, some problems: the price the utilities are willing to pay for dispersed power, and their willingness to relinquish control over the source of power that they sell. Southern Cal Edison will pay 11 mils (one mil equals 1/1000 dollar) per kilowatt hour peak, 7 mils for mid peak, and about 3 mils for minimum peak power. (These rates correspond to about 33 mils, 22 mils, and 10 mils in charges respectively.)

These purchase rates are arrived at by Edison by averaging the costs of all the types of existing facilities within Southern California Edison. They have little or nothing to do with the cost of new generating capacity to be constructed for ownership by the Southern Cal Edison Company. Needless to say, the new generating capacity will be coming in at prices greater than $1,000 of investment for each busbar kilowatt (that is, at the electric power plant); and by Southern Cal Edison's own direct admission the price for new generator capacity will rise soon to $1,500 per installed kilowatt. Translated into consumer costs, the cost of electric power would be greater than $0.03 per kilowatt hour rising to $0.045 per kilowatt hour. In fact, if the fuel costs rise after the generators are built, the cost per kilowatt hour could continue on an inflationary spiral soon reaching present prices typical of the Eastern Seaboard of the United States - 5¢, 6¢, and up to 10¢ per kilowatt hour. Detroit Edison in Michigan charges 3.85¢/kilowatt hour. They will pay 11¢/kilowatt hour for power but charge $6.50/month for this service as contrasted to $2.50/m for regular service. New York City presently charges 10¢ per kilowatt hour for peak power, and has been forced by a New York State Supreme Court decision to pay 25 mils per kilowatt hour for power from small generators such as windmills. P. G. & E. charges about 33 mils per kilowatt hour and is offering 14 mils per kilowatt hour peak for power from small generators. As of mid-August, P. G. & E. maintains they have not had any takers of their offer.

It seems safe to assume that if a utility would pay more for power from small generators, there would be more interest from people in constructing generating facilities with their own capital. To be consistent with their own self-interest, the Public Utility must own the means of generating the power. This is because of the attitude expressed by the Public Utility's Commission in California, and incidently, practically everywhere else in the world.

Presently, the Public Utility is allowed to charge for electric power in terms of <u>their</u> capital investment. It does not matter whether the capital investment is actually functioning or what type of fuel the particular generating system uses. The rules of the game are: more capital investment by the utility yields proportionately higher rates to be paid by the consumer. In fact, one interpretation of incentive has it that a Public Utility can therefore make money on facilities that do not work. A Public Utility cannot charge higher rates unless they put in more investment, owning the means of generation is the major investment required. Under these rules established by precedent and present attitude, the Public Utility cannot serve their own self interest by paying more than their average rates for dispersed electric power owned by other than the Utility. It is probable that federal legislation will supercede state legislation on this point in the near future. As a reference point, federal power costs less than 3 mils/ kilowatt hour.

There has been citizen activity in this area, in and out of California. In Wisconsin, Wind Works has been active with the energetic participation of Congressman Reuss (see attached clippings). In New York City similar interests in wind power have sought a court decision that would favor more pay for power from small generating units. In California, a number of organizations, including TURN (Toward Utility Rate Normalization), located in San Francisco, have actively sought to change the rate that Public Utilities will be required to pay from dispersed generators. They would like the rate to be tied to the cost of new generating capacity rather than the system average rates. This would mean that a real incentive would be given to the small private owner for installing small generators.

As more and more small generators come into operation, the role of the Public Utility would alter from primarily that of electric power generation to primarily that of electric power distribution. Some advocates of dispersed electric power generators feel that the Utility should pay one-half the amount for dispersed power that it can sell power for. One suggestion is, that this pattern of payment should follow the Agricultural Share Croppers-Land Owners relationship, where one-half of the crop is given to the land owner, and the other half is kept by the share cropper (private communication by O. J. M. Smith, 1977).

A number of people are alert to the problem of self interest in the electric utilities. While the utilities cannot be expected to want to put themselves out of business, or to reduce their economic return to their investors, it is possible to alter the relation between consumer and producer so that the goals of the utilities and the wider good mesh in a more productive and stable relationship. As it appears now however, the Public Utility is interested in preserving itself as it is. Accordingly, small scale windmill electric power generators are to be tolerated until the number of these generators become so large that their presence would offset generating capability by the Utility. If the Utility felt that its rate base were threatened by the dispersed generators, then it is likely they would try to become the owners of the new generating facilities as happened in Denmark. It is possible that the Public Utility would cooperate and even stimulate dispersed electric generators if it were shown to be in their self interest to do so. Presently electric research institutes like EPRI in Stanford have little interest; they do not have any studies concerned with small scale dispersed generation of electric power whether from total energy concepts within existing buildings or from windmill generators in rural settings. On the other hand research on windmill electric generators is being conducted at Livermore and a number of other national labs and government supported labs.

It would seem then, that by a shift in attitude on the part of the Public Utilities Commission in California, a new relation could be established where many small owners would invest their capital in the erection of small electric generators. For example, based upon the previous installation of windmills there are at least 200,000 rural sites in California (Smith, 1977 private communication) where wind is sufficiently strong and reliable so that each site could carry a new windmill driving an electric generator. Each one of these sites is already supplied with 10 kilowatt service; that is the wires, meter, switch, circuit breaker, etc. are already installed. It has been pointed out (Smith, 1977 private communication) that a pair of wires could be run from each existing electric service to a windmill generator thus minimizing the cost for the new hook-up. Clearly this would provide 2 billion watts of new electric generating capacity without requiring much investment from the existing Public Utility Network. This amount of new electric generating facility could make it unnecessary to build any type of generating central plant in California for some period of years. No nuclear, no new fossil fuel, no new hydro-electric or geo-thermal plants would be needed.

One interview with a State Energy Commissioner reveals both attitudinal and institutional constraints:

> Interviewer: If you can identify 200,000 rural sites, multiply by 10, (kilowatts each) and you have a significant amount of electricity.
>
> Commissioner: It sounds like someone should get into the business.
>
> Interviewer: How about the Energy Commission?
>
> Commissioner: We're not in the manufacturing business.
>
> Interviewer: But the Commission is a stimulator.
>
> Commissioner: We might assist with a demonstrator.

...

Interviewer: . . . The precedent is there so that a bunch of dispersed generators can feed the grid.

Commissioner: As I said, from what you told me, it sounds reasonable. We would in a small way help, but we are involved in more macroscopic projects. (Underlining ours).

This and other interviews silhouette the problem of institutional constraints. In experimental science facilities Russia has demonstrated the pattern that builders of equipment shall be distinct and separate from the scientific users of the equipment. For example, most of their new accelerators for physics research were designed and built by a building group to a set of specifications. The building group was not allowed, let alone encouraged, to have contact with the using group. The building group then delivered the finished machine to the people that were to use it. To date, this has resulted in a level of mediocrity and time wasting effort. It would seem to be axiomatic that the people most interested in the success of a project should be involved in the earliest development of the project. There must be a continuity between initiator, builder and user. Oftentimes innovative projects in the United States have involved a very few individuals in this continuity relationship. Projects have been spark-plugged and brought into fruition -- forced, if you will -- to be successful, simply by the will, skill and guts of, in some cases, one individual. On the other hand, if we look at government entitites such as the State Energy Commission or ERDA, we find that the conception and the charter of these organizations leads to grave problems. There is no mission to demonstrate success in a practical sense. There is no continuity or carry over from the research and development to the actual operation and maintenance of the devices. They are only able to study and illustrate by demonstration projects -- the delivery and maintenance of practical service is left to others.

In the view of some, dispersed generators are not macroscopic in scope. An approximate projection in California would be that the population will double within the next 37 years. By letting people make a dollar from conservation and make use of their own labor and private capital, it should be possible to supply more than adequate electric power to twice the population of California with the same installed capacity we have in California presently. This is based upon the observation (Smith, private communication 1977) that California has twice as much installed generation capacity as we are presently using. Part of this extra capacity is necessary as a safety feature where unforeseen problems, shut downs due to the weather, etc. allow the system to keep on functioning. The addition of 2 billion watts of new capacity dispersed over the state would add a highly reliable component to the existing electric power generating network.

It may be that people in ordinary walks of life are better able to realize the potential of the sun and its offspring wind than are experts in the energy business and officers in public and private institutions. During the 1948 power shortage in California there was an attempt to utilize the electric generating potential of induction motors normally used to pump water. Ralph Parks, an agricultural engineer in extension services at Davis, went around the state demonstrating this on site to farmers in rural California in the spring of 1948. His innovative attempts were cut short because the power shortage in California was over before many people had tried to implement his suggestion.

We have spoken about the constraints on professionals and on government agencies, but the picture was not much different when we turned to an independent, private institution like Stanford University. The question was asked of a Stanford official: "Why aren't windmill generators or co-generation facilities being established on the Stanford campus, or on other lands under control of Stanford University?" The response was that selling electric power from Stanford University to any Public Utility places Stanford in the position of being regulated by the Public Utilities Commission in California. It would seem unacceptable that the Public Utilities Commission should have regulatory control over an institution like Stanford University. When this question was raised with the legal staff of the Public Utilities Commission, the response was that the required regulation did not have the character implied. A parallel was drawn between an institution owning a source of water and their selling this water to the public.

The state of California requires regulation of water sources that are sold to the public. But, below a certain capacity for water delivery, this regulation does not extend into the affairs of the private seller of water. Quality of water is monitored, but the internal affairs of the institution are otherwise left alone. The

PUC legal staff has judged that any institution such as Stanford University, the University of California, etc. could get a simple letter approved delimiting the regulation of their affairs by the Public Utilities Commission. Such a letter of application could be routinely approved. The question is left hanging, why aren't our institutions of higher learning using their own investment capital to demonstrate to the public that conservation is both prudent and a way to make money for the institution? And why are these institutions not demonstrating leadership? It may be that we need a new division of labor in organizations whereby piecework is replaced by the need for whole job responsibility, and we need to do this in the name of efficiency. We have come full circle.

12.5 FUTURE RESEARCH

In studying the residential building code we have looked at the institutional barriers toward transition toward energy efficient use when introduced through legislation. Directions for further study of residences should include:

a. A study of the City of Davis where a residential building code similar to that of the Commission's has already been operational, with particular attention to the method of appeal and to the hypothesis of a variety of people interviewed that legislative mandates should best be implemented on a decentralized plan.

b. Attention to ways of circumventing legislation.

c. Attention to special interest groups such as the National Association of Concrete Masonry, and consumer reactions: house owners, house renters, state house financing agencies, low income groups.

d. Attention to building regulations and mandated change in general.

It would be worthwhile to continue work on the non-technical and technical problems of realizing large numbers of small electric power generators in rural California driven by windmills, sterling solar engines, co-generation, or total generation sources, etc. The present work can be profitably extended along several lines expressed therein focusing on three facets of such technology: cost estimation, vulnerability, and the value of reliability.

In sum, we are saying that building codes and dispersed generation are useful pivot points for raising questions about transitional tactics.

So as to generalize any findings beyond these two particular mechanisms we would suggest expanding the idea of dimensions as a checklist for change inducing personnel. The dimensions explored but superficially in this working paper are crucial to how and if things happen.

In addition, it became clear from our interviews this summer that we need to plan for education. A variety of people commented on what the other guy needs to know but doesn't. A retrofit specialist wants to educate architects and engineers in heating and conservation efficiency; another group thought that we needed to educate builders, another the building inspectors. Another University group was working on educating consumers by "social marketing tactics" and by various kinds of "feedback studies." Do-it-yourself retrofit would be a useful educational technique whatever the cost effectiveness, and if in the process we provide jobs for the low skilled again the educational effort would be important to measure beyond cost effectiveness. Energy extensions have been talked about. The concept must, if our interviewees are correct, reach beyond educating the little people in the value of efficiency or on informing consumers of their rights in efficiency mandates.

APPENDIX XII-1

In carrying out the Residential Building Code (RBC) Ethnographic Project, we interviewed a total of 29 persons. The following is a breakdown of the groups represented.

State Energy Commissioners	3
State Energy Commission Staff	7
Architects	4
Governor's Office Personnel	2
Attorney General Office	1
Stanford Research Group	4
Building Officers	2
Banker	1
Realtor	1
PG&E Solar Coordinator	1
Building Code Action	1
Retrofit Expert	1
Farallones Institute	1

APPENDIX XII-2

In carrying out the dispersed electric generator work, we interviewed 70 persons. The following is a breakdown of the groups represented.

Stanford University, Professor of Engineering	1
U.C. Berkeley Professors	10
State Energy Commissioners	3
State Energy Commission Staff	15
State Architects' Staff	1
Lawyer, Consumer Organization	4
Engineer, Public Utility	6
Official, Energy, U.S. Government	1
Official, Energy, California Government	7
Energy Specialist, Nat. Lab.	6
Engineer, State of Calif. Water Resources	1
Energy Scientist, Non Profit Institute	2
Energy Specialist, U.S. Congressman's Staff	1
Education person, Nat. Lab.	1
Engineer, Wind-Works	1
Newspaper Reporter	1
Lawyer, Public Utilities Commission	2
Staff Planner, a California County	1

Engineer, Agriculture	4
Consumer Activist, Windependance	1
Science Writer	1
Public Information Officer, EBMUD	1
Engineer, Sales	1
Scientific Attaché	1
Scientist, National Resources Council	1
Engineer, U.S. Air Force Base	2
University of Rhode Island, Professor	1
Statistician, Edison Elec. Institute	1
Resident - Owner Solar Home, Rhode Island	1
Builder, Solar Home, Rhode Island	1

APPENDIX XII-3

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CHAPTER XIII
DEVELOPMENT OF AN ENERGY ATTITUDE SURVEY

13.1 INTRODUCTION

Our project this summer has involved the construction of a questionnaire for a public opinion survey in the state of California concerning "soft" and "dispersed" technologies and systems. The development of a sampling frame, choosing the sample, finalizing the questionnaire, and the conduct, analysis and interpretation of the results will be accomplished in the October 1977 - September 1978 period. The data will be collected by use of a self-administered mail questionnaire.

The research will explore the possibilities and the constraints of decentralized energy technologies in terms of public perceptions and attitudes towards energy production, use, and conservation. One of the underlying assumptions of this research is the notion that in a democratic society the adoption and the implementation of any policy requires public consent and cooperation, the broader the better. In other words, we need to find out as accurately as possible how viable the various energy options are in relation to the aspirations and tolerances of the citizenry.

Another assumption of our effort is that the formulation of policy, i.e., decentralized energy technologies in this case, can be significantly aided and improved by the input of public opinion, alerting the policy maker to the fullest possible range of complexities and challenges which he or she must fact if the policy is to succeed. Presumably a more sensitive and widely acceptable policy is more likely to work well.

The validity of the use of survey research techniques to obtain this type of information is worth consideration. As with any measuring tool of science, whether in physics or in the social sciences the manner in which the observation is made, in fact, the observers themselves, can influence the outcome of the research. Depending on the type of survey, i.e., personal interview, mail, telephone, there are serious challenges in developing questions, format, and administration techniques so as to avoid biases which seriously reduce the validity of the research. The only insurance against such an eventuality is in careful design of the sampling and questionnaire. However, no matter how much care is taken a single survey is a unique creation and the interpretation of results must take into account the specific point in time it was administered, question order, and wording. It is, however, the one social science tool from which we can obtain information from a large representative sample of the population in a short time span using a standardized measuring technique.

The work this summer has had as its objective obtaining information from the literature; from interviews with key informants representing varegated sectors of the economy, as well as a group discussion with consumers. From this information we have developed the goals of the questionnaire and a prototype of the questionnaire itself.

The literature study consisted of searching out all the studies we could find in which energy attitudes were obtained on the use, production, and conservation areas. This search resulted in 74 articles and research reports. These reports were read by the investigators to glean information which would help in the selection of areas of study and specific questions within these areas. The bibliography of materials collected is attached.

The interview schedule of key informants was set up to allow us to receive input from a broad groups of interests in the area of energy. They were 30-90 minutes in length and were conducted in the office of the respondent. The interviewer was one or more of the investigators and followed, in general, a protocol which included the following points.

1. Briefly describe total project and spell out specific responsibility. Explain what we will do with their information.
2. Explore their general attitudes toward centralized and decentralized technologies.
3. What are their feelings about the likelihood of a soft technology future?
4. What types of soft technology are most likely to be viable?
5. What are major problems in the way of implementing soft technology?
6. What kind of incentives or constraints would encourage use of soft technology?
7. What do people need to know to increase likelihood of soft energy sources?

8. Should soft energy use be brought about by regulation or by voluntary action? Is it through institutional or individual change?
9. What is the role of conservation in energy policy? How are conservation and soft technology related?
10. Are changes in values and/or norms necessary for soft energy use?
11. What are the demographic, socioeconomic, and psychographic characteristics of the user of soft technology?
12. What kinds of questions would they like answers to in order to make better decisions in their area of responsibility?

The list of key informants is attached. Examination of this list confirms that we, in fact, did obtain information from a wide variation of vested interests in California. As a whole, the informants were quite anxious to share their opinions and knowledge and considerable guidance was obtained to help in questionnaire development.

The group discussion with consumers consisted of a 1 1/2 hour in-depth discussion with 11 consumers from the Sacramento area. They were selected to represent variations in age, income, education, occupation, sex, and two who had installed a solar energy device. This interview was conducted by two of the investigators and the structure followed many of the protocol points listed earlier, but also included some general questions about the energy situation. The entire session was recorded, later transcribed and analyzed, again for clues to appropriate questions to include in the questionnaire.

Two meetings were held with Dorothy Leonard Barton and Gene Rosa of the Stanford-Argonne ERDA project in order to coordinate and share ideas and activities related to surveying public perceptions of soft energy technology.

Based on examination of the literature, the results of the key informants' interviews, and group discussion, we arrived at general areas to include in the questionnaire as well as specific questions. Four areas emerged for our inquiry.

The first is to put to the test of public opinion some of the underlying assumptions of the decentralized-soft technology approach;

we take as a point of departure for such an approach the work of Amory Lovins, at least to the extent that we can identify some central, basic themes in it that seemingly go beyond personal idiosyncrasy and the likely speculations of only one individual.

It is worth noting that Lovins himself seeks validation for the dispersed soft energy approach in popular judgment, rather than in some form of expert opinion or empirical testing with claims to "scientific" (or other) objectivity. He says that:

> Ordinary people are qualified and responsible to make ... energy choices through the democratic political process, and on the social and ethical issues central to such choices the opinion of any technical expert is entitled to no special weight; for although humanity and human institutions are not perfectable, legitimacy and the nearest we can get to wisdom both flow, as Jefferson believed, from the people, whereas pragmatic Hamiltonian concepts of central governance by a cynical elite are unworthy of the people, increase the likelihood and consequences of major errors and are ultimately tyrannical (1977, p. 14).

In fact, Lovins goes on to say that

> The basic issues in energy strategy, far from being too technical for ordinary people to understand, are on the contrary too simple and political for experts to understand (1977, p. 23-24).

Among the views which Lovins puts forward and which we think (a) reflect important principles and (b) deserve a test of public attitudes are, e.g., certain characterizations of the present energy systems and certain values attributed to the alternatives.

Thus, Lovins argues that

> In an electrical world, your lifeline comes not from an understandable neighborhood technology run by people you know who are at your own social level, but rather from an alien, remote and perhaps humiliatingly uncontrollable technology run by a far away, bureaucratized, technical elite who have probably never heard of you. Decisions about who shall have how much energy at what price also become centralized—a politically dangerous trend because it divides those who use energy from those who supply and regulate it. Those who do not like the decisions can simply be disconnected.
>
> The scale and complexity of centralized grids not only make them politically inaccessible to the poor and weak but also increase the chance of malfunctions, mistakes, and deliberate disruptions (1977, p. 88).

It would not be unreasonable to assume that some segments of the public—and perhaps even a majority—view the present energy delivery systems somewhat differently; e.g., given a choice between known (to respondents) dependability and efficiency of what they get from central grids with no more effort than the payment of a monthly bill, they may prefer this to what they perceive as dubious technological experiments and potentially burdensome involvement with one's neighbors and, frequently, with absolute strangers who live next door, or next block. Whether the present energy management situation is quite as intolerable and fraught with as much potential for disaster as Lovins would have it, and whether grass roots participatory democracy is what people want as a remedy, deserves some answers from the public.

Another illustration is provided by the rejection of nuclear technology as an energy alternative for the future. Some of Lovins' basic assumptions include the view that if neclear power development is stopped in this country, it is also likely to be stopped elsewhere, including the USSR. How plausible is this obviously very important premise in the eyes of the electorate? Lovins argues that the development of nuclear technology here or elsewhere is likely to prove incompatible with the maintenance of a democratic society because of the need to "deal with" protestors, disruptors, and saboteurs, who would focus their activities on nuclear plants and facilities. To what extent is this "either-or" perception shared by the public?

A second area of interest for us is information about present patterns of energy-related behavior and attitudes, as well as evidence of change in behavior and attitude, specifically toward: (1) soft technology, (2) conservation, and (3) the organization and management of energy resources, (4) life styles, (5) communication patterns.

In this section we will be concerned with the potential market for soft technologies. Who is most likely to adopt such technologies? What sources of information and products appear most credible and effective in the distribution of such technologies? What are the perceived obstacles and difficulties to the adoption of these technologies? Is it dearth of capital? Information? Availability of the technologies themselves? To what extent is high energy consumption connected by the public with satisfying living standards, creature comforts, and national prosperity? How significant in individual decisions are such factors as reliability, environmental impacts, safety and convenience? Are patterns of energy use changing among different population groups? Here we will be looking for the kind of information which would potentially relate to both paradigm-related and policy-induced change: from greater dependence on hard, centralized technologies to increased dependence on soft, decentralized systems. To what extent is the public adopting or seriously thinking about solar heating or cooking devices in homes, factories, shops and offices? What degree of interest and awareness attach to such "technical fixes" as improved home insulation, the use of bicycles and car pools? What constraints and incentives for such devices are thought to be useful? We realize from the experience of previous studies, of course, that the information collected in a survey such as ours is likely to have its defects; no more than a useful approximation of current trends is likely to be obtained.*

Our third area of interest is to relate the soft-dispersed technology issue not merely to numbers: how many people in what areas of the state—by age, sex, occupation, income, education, ethnic background, etc.—think what; we will seek to delineate different types of energy publics which might be defined in terms of certain attitudinal factors in addition to, or even apart from, obvious demographic characteristics. Is there, e.g., a new frugal, anti-materialistic ethos among various segments of the population which correlates with some significant and consistent attitudes toward energy issues? Are conservation attitudes and behaviors good clues to the choices people might make between the "soft" and "hard" energy paths? Are allienation and social disaffiliation related to such choices, as Lovins and others imply?**

*See, e.g., David B. Montgomery and Dorothy Leonard-Barton, "Toward Strategies for Marketing Home Energy Conservation," June 1977, p. 2 on the discrepancy between attitude to car pools and actual behavior.

**See Paul Craig and Robert Nathans, "Compliant Energy Paths," Draft Paper, July 1977, pp. 72-76, and particularly p. 73. See also A. Groth and H. Schutz, Voter Attitudes on the Nuclear Initiative in California (Davis: Institute of Governmental Affairs, 1976) pp. 41-47.

We will also want to examine whether or not any of the theory and practical information on innovation and diffusion apply to the adoption of soft energy equipment.

Our fourth area of interest may be described briefly as items of service or interest to other participants in this project. For example, we will include questions relating to attitudes on land use, perceptions or expectations concerning civil liberties, and other subjects suggested to us by other participants.

An annotated prototype questionnaire which attempts to reflect our four areas of interest is attached. At this stage of development it is clearly too lengthy for a high response rate mail questionnaire. Our objective during the next phase of the project is to cut and amend questions to provide for a shorter and more meaningful instrument.

After pilot testing the questionnaire will be administered to a probability sample of Californians by mail. The sample size chosen will be large enough to allow for non-responders and still have a meaningful number of respondents in desired segments of the population.

13.2 KEY INFORMANT INTERVIEWS

1. Aero Power Company. Bob Dailey writer. Aero Power is involved with the design, engineering, construction, and testing of wind powered electric generating systems.
2. Alternative Energy Cooperative. Julie Reynolds, member. AEC is a small organization in the Bay Area which does research, builds demonstration projects and collects and distributes information to the public, primarily in the solar area.
3. Pacific Gas and Electric. Bryon Woertz, Solar Representative.
4. Pacific Gas and Electric. Dennis L. Morre, Senior Energy Service Engineer, Energy Conservation and Services Department.
5. San Diego Technical Action Center. Alan Sijolm, Director, Richard Dietz, Energy Group Director. This center serves in an advisory function to the county in technical areas. They serve as unofficial coordinators in the energy area for the county.
6. Southern California Solar Energy Association. John Brand former Chairperson, present Secretary-Treasurer. This organization serves a variety of functions including educational, lobbying, and equipment manufacturing promotion.
7. San Diego Gas and Electric. Don Wissinger, Director of Energy Information Service.
8. San Diego Gas and Electric. Sam Rinaker, Public Relations Director.
9. Urban Integral House. Tom Jovitts, Manager. The UIH is part of the Farollones Institute and is involved with demonstration and testing of alternative technology.

10. Friends of the Earth. Helene Dassler, Resource Person. An organization dedicated to programs in environmental protection and ecology.

11. Berkeley Solar Group. Bruce Wilcox, Partner. The group is primarily engaged in solar energy and conservation consulting.

12. Energy Resources Conservation and Development Commission of California. Cynthia Praul, advisor to Commissioner Varanini, Jim Harding, advisor to Commissioner Doctor, Meir Ceasso, research advisor.

13. Office of Appropriate Technology of California. Judy Michaelowski, Assistant Director, Stephanie Pincett, Research Librarian. This office is involved in education and demonstration projects in alternative technologies.

14. Village Homes of Davis. Mike Corbett, Developer. Village Homes is a development built to utilize solar energy, conservation, and other aspects of interdependent community living.

13.3 ENERGY QUESTIONNAIRE

This questionnaire should be filled out by the person to whom it was mailed. Please respond as fully as possible by checking or entering the appropriate numbers or response in the proper place. There are no right or wrong answers. You do not have to answer any questions you do not wish to answer. All answers will be kept completely confidential.

1. What do you consider as the three most important national issues in the United States today?[1] (Please check three)

   — Middle East tensions
   — drug abuse problem
   — inflation
   — environmental pollution problems
   — organized crime
   — the energy problem
   — corruption in the government
   — poverty
   — unemployment
   — racial tensions
   — moral decay
   — the urban problem

2. How severe do you feel the shortage of energy supplies in this country is?[1A]

   — very severe — moderately severe — not severe at all — there is no shortage __ don't know.

3. Looking at the causes of the energy problem, who do you feel bears the greatest responsibility? (Please check as many as you want.)[2]

   — oil companies/oil industry
   — Arab oil producers
   — Federal Government/Administration
   — Congress
   — the public/consumers
   — utility companies
   — automobile companies
   — labor unions
   — environmentalists/ecologists
   — there is no energy problem
   — no one is responsible
   — other (specify: ______________________________)
   — don't know

4. Of the several possible causes for the lack of energy supplies, which ones do you think are very important, moderately important, or not important at all?[2]

	Very Important	Moderately Important	Not Important At All
a. wasteful use of energy by Americans	___	___	___
b. efforts by ecologists to block energy projects, like nuclear powerplants	___	___	___
c. efforts by oil companies to obtain higher profits	___	___	___
d. increased energy demands resulting from population growth	___	___	___
e. wasteful use of energy by industry	___	___	___
f. government favoritism to oil companies	___	___	___

5. To what degree are the following people and organizations responsible for solving the energy problem.[2]

	Very Responsible	Somewhat Responsible	Not Responsible
oil companies/oil industry	___	___	___
Arab oil producers	___	___	___
Congress	___	___	___
Federal Government/Administration	___	___	___
State Government	___	___	___
Local Government	___	___	___
Neighborhoods	___	___	___
The public/consumers	___	___	___

(question 5 continued)

	Very Responsible	Somewhat Responsible	Not Responsible
Utility companies	___	___	___
Environmentalists/ ecologists	___	___	___
Labor unions	___	___	___
There is no energy problem	___	___	___
No one is responsible	___	___	___
Other (specify: ____________)	___	___	___
Don't know	___	___	___

6. How would you rate the competence of the following people and organizations in handling the energy situation?[3]

	Excellent	Good	Fair	Poor
a. the Federal Administration	___	___	___	___
b. the Congress	___	___	___	___
c. gasoline and oil companies	___	___	___	___
d. utility companies	___	___	___	___
e. labor unions	___	___	___	___
f. the American public	___	___	___	___
g. people in your neighborhood	___	___	___	___
h. experts	___	___	___	___
i. the business community	___	___	___	___
j. State Government	___	___	___	___
k. Local Government	___	___	___	___
l. your friends	___	___	___	___

7. During the next ten years, the following actions should be given the greatest emphasis in our efforts to deal with the energy situation;[3]

	Strongly Agree	Agree	Neither Agree Nor Disagree	Disagree	Strongly Disagree
a. Develop new means of energy production (eg. solar, wind, methane)	___	___	___	___	___
b. Place more governmental controls on energy (oil coal, nuclear, gas) companies	___	___	___	___	___
c. Seek to obtain more energy from other companies	___	___	___	___	___
d. Work to change our style of living in order to reduce energy use	___	___	___	___	___
e. Deregulate fuel supplies	___	___	___	___	___
f. Encourage fuel producers to increase supplies	___	___	___	___	___
g. None of the above	___	___	___	___	___
h. Other (specify: ______________)	___	___	___	___	___

8. Indicate your sources of information on energy matters in general.[4] You may indicate as many sources as you wish. If you checked "yes", please rate the source on a scale from 1 to 5, as to how reliable you think the source is in terms of accurate, useful information.

Received information from this source		Source	Very Unreliable	Unreliable	Neither Reliable Nor Unreliable	Reliable	Very Reliable
Yes	No		1	2	3	4	5
___	___	State newspapers	___	___	___	___	___
___	___	Local newspapers	___	___	___	___	___
___	___	Out-of-state newspapers	___	___	___	___	___
___	___	Magazines	___	___	___	___	___
___	___	Bulletins	___	___	___	___	___
___	___	Billboards	___	___	___	___	___
___	___	Public utilities	___	___	___	___	___
___	___	Television	___	___	___	___	___
___	___	Unions	___	___	___	___	___
___	___	Friends and neighbors	___	___	___	___	___
___	___	Relatives	___	___	___	___	___
___	___	People at your place of work	___	___	___	___	___
___	___	Scientists	___	___	___	___	___
___	___	Elected public officials (Governors, Legislators, mayor, etc.)	___	___	___	___	___
___	___	Clubs and organizations (Farm Bureau, Chamber of Commerce, Sierra Club, PTA, etc.)	___	___	___	___	___
___	___	Community Leaders (Minister etc.)	___	___	___	___	___

(question 8 continued)

Received information from this source: Yes	No	Source	Very Reliable 1	Unreliable 2	Neither Reliable Nor Unreliable 3	Reliable 4	Very Reliable 5
__	__	Professionals (Doctor, Vet., Lawyer.)	__	__	__	__	__
__	__	None of these	__	__	__	__	__
__	__	Other (specify: ________)	__	__	__	__	__
__	__	Don't know	__	__	__	__	__

9. Is the federal government spending too much, about right, or too little money on trying to solve the country's energy problems?[5]

__ Too much __ About right __ Two little __ Don't know.

10. Has the federal government established some type of agency or department to be responsible for energy policy and practices?[6]

__ Yes __ No __ Don't know.

11. Rank order from most (1) to least (6) important the following energy sources which you think should be rapidly developed to try to solve the energy problem in the next ten years.[7]

- __ nuclear
- __ oil
- __ solar
- __ coal
- __ wind
- __ natural gas
- __ biomass(decaying plant material)
- __ geothermal (natural steam sources)
- __ tides
- __ hydroelectric (electricity generated by water flowing over dams)
- __ ocean currents
- __ other (specify: ________________)

12. How many years will it take to solve the energy problem? (please check one)[8]

__ 2 years __ 4 years __ 6 years __ 10 years __ 20 years

__ 30 or more years.

13. Some people say that, within a few years, we may not have enough energy in this country. Given a choice between:

(1) making your personal lifestyle more modest

and (2) contributing some additional tax dollars to the discovery and development of new energy sources,

which would you personally prefer as a course of action to try to solve the energy problem? (please check one)[9,25]

— choice 1
— choice 2
— both 1 and 2
— neither 1 nor 2
— don't know

14. Californians are now experiencing water rationing in many parts of the state. Do you think energy rationing should be initiated in the state if the energy situation worsens?[9,20]

— Yes — No — Don't know.

15. Below are statements regarding the energy situation in this country and around the world. Please indicate how much you agree with or disagree with each statement by checking (X) in the appropriate box.

STATEMENTS	Strongly Agree	Agree	Neither Agree Nor Disagree	Disagree	Strongly Disagree
The energy shortages are not real but are due to oil companies wishing to increase their prices.[10]					
The energy problem has made us all aware that there are severe limitations of non-renewable resources (eg., oil, gas and coal).[8]					
Technological discoveries in the next 10 years will provide for all the energy we could ever want.[11]					

(question 15 continued)

STATEMENTS	Strongly Agree	Agree	Neither Agree Nor Disagree	Disagree	Strongly Disagree
Nuclear power is so dangerous that it ought to be abandoned altogether.[12]					
We should change our whole way of life so that we can live with energy shortages in the long run.[11]					
Regardless of the cause, we are facing a long-term energy shortage (natural gas, gasoline and electricity).[8]					
The increased utilization of coal is a major hope for solving the energy shortage.[11]					
People should be able to buy and use whatever they can afford and like in this country.[13]					
The Alaskan pipeline will produce enough oil to greatly reduce the energy shortage.[11]					
If this country halts the development of its nuclear industry, all other countries in the world (including the Soviet Union) are likely to follow the U.S. example and stop, too.[14]					
Oil and gas companies should be put under national control.[13]					

(question 15 continued)

STATEMENTS	Strongly Agree	Agree	Neither Agree Nor Disagree	Disagree	Strongly Disagree
We should have nation-wide rationing of gasoline.[9,13]					
We will have sufficient energy if we develop more efficient energy devices.[11]					
One of the major problems in dealing with the energy situation is that there is no general agreement among the experts as to what the problem is or what is the best solution.[9,13]					

16. From what you have heard or read, how serious would you say the need is for you to save energy?[15]

— Very serious — Somewhat serious — Not serious at all
— Don't know.

17. Have you or members of your immediate family done any of the following things during the past year in order to save energy?[16]

	Yes	No	Don't know
a. take fewer vacations and travel less	—	—	—
b. kept home cooler in winter	—	—	—
c. kept home warmer in summer	—	—	—
d. use car pool	—	—	—
e. use public transportation	—	—	—
f. use less hot water	—	—	—
g. turn off lights	—	—	—
h. insulate home	—	—	—
i. walked or biked more places	—	—	—

(question 17 continued)

	Yes	No	Don't know
j. drive at 55 m.p.h. or less	___	___	___
k. bought a car that consumes less gas	___	___	___
l. use major appliances less	___	___	___
m. participated in recycling programs	___	___	___
n. other (specify: ________________)	___	___	___

18. Do you believe that you are presently doing everything that you can to conserve energy?[15,16]

___ Yes ___ No ___ Don't know.

19. If the energy situation worsens, how difficult would it be to:[17]

	Very difficult	Somewhat difficult	Not difficult
a. reduce heat in your home	___	___	___
b. cut down on the amount of electricity in your home	___	___	___
c. cut down on the amount of your automobile driving	___	___	___

20. Considering the people in your neighborhood, would you say that most of them are: (please choose one).[18]

___ actively trying to conserve energy
___ conserving a little energy from time to time
___ not concerned with energy conservation
___ other (specify: ________________)

___ don't know

21. What do you think would be the best way of making people conserve more energy? (please choose one)[19]

— provide more public education about it

— give good tax breaks to people who use less energy or who adopt energy-saving devices in homes and businesses

— punish by law people who waste energy

— none of these

— other (specify: ______________________________)

— don't know

22. How much have you reduced your water usage in the last year?[20]

__ 0 percent __ 10 percent __ 20 percent __ 30 percent

__ 40 percent __ 50 percent or more __ don't know.

23. Is your home insulated?[9]

— Yes — No — Not applicable (no need) — Don't know.

If "no", are you planning to insulate in the next year?

— Yes — No — Don't know.

24. Below are statements regarding energy conservation. Please indicate how much you agree with or disagree with each statement by checking (X) in the appropriate box.

STATEMENTS	Strongly Agree	Agree	Neither Agree Nor Disagree	Disagree	Strongly Disagree
Conservation and increased production of coal, oil and gas will supply enough of our energy resources in the years to come.[13]					

(question 24 continued)

STATEMENTS	Strongly Agree	Agree	Neither Agree Nor Disagree	Disagree	Strongly Disagree
We should have a national energy policy in which governmental legislation requires that we practice conservation.[19]					
Effective conservation requires a drastic change in lifestyle from other people.[11]					
I would be better able to conserve energy if I had some way of knowing what I had used each day.[21]					
When energy conservation is a way of life, the poorer people will pay for more than an equal share of discomfort and expense.[22]					
Wearing a sweater in the house during the winter in order to be comfortable when the temperature is kept low for energy saving reasons is a perfectly reasonable thing to do.[13]					
Energy conservation is important in reducing the energy shortage.[9,13,15]					

(question 24 continued)

STATEMENTS	Strongly Agree	Agree	Neither Agree Nor Disagree	Disagree	Strongly Disagree
Public transportation should be developed in California to decrease our reliance on the automobile if we want to conserve energy.[13]					
I would be better able to conserve energy if I had some way of knowing what was appropriate for me to save.[13]					
Conservation ought to be a matter of individual choice.[15]					
Conservation should be encouraged by penalizing those people who use more than their fair share of energy.[19]					
Gasoline prices should be increased to the point where people are found to buy less and thus conserve.[19]					

25. Solar energy is appropriate for which purpose: (please check as many as you wish).[9,13]

— hot water in the home
— electricity for the home
— swimming pool heaters
— cooling the house
— heating industrial buildings
— electricity for industry
— other (specify: ______________________________)
— none
— don't know.

26. If you wanted information on solar heating equipment to install in your house, who or where would you go to?: (please check as many as you wish)[4]

— utility companies
— hardware store
— solar equipment companies
— a consumer research agency
— friends and neighbors
— nowhere
— other (specify: ______________________________)
— don't know

27. Have you ever looked into solar?[9]

— Yes — No — Don't know

If no, why not? ______________________________)

28. Do you have any solar equipment in your house?[9]

__ Yes __ No __ Don't know

(a) If "Yes", what kind?
- — solar hot water heater
- — solar swimming pool heater
- — solar-water storage house heater
- — solar-air storage house heater
- — solar cells
- — other (specify: ________________)
- — don't know

(b) From whom did you receive information about the general use of solar energy? ______________________________________

____.

(c) Who in your household made the decision to install your solar equipment? (please choose one)

- — Yourself
- — Spouse
- — Joint decision between you and your spouse
- __ Other (specify: ______________________)
- — Don't know

(d) Where did you purchase your solar equipment? (please choose one)

- — utility company
- — hardware store
- — solar equipment company
- — friend or neighbor
- — other (specify: ______________________)
- — don't know

(e) How satisfied are you with your solar equipment?

— Very satisfied — Satisfied — Neither satisfied nor disatisfied — Disatisfied — Very disatisfied

(f) If either disatisfied or very disatisfied, why? __________

____

(question 28 continued)

(g) About how long have you had the solar equipment?

— years — months

29. If you are not already using solar energy in your home, what are your reasons for not switching to them? (please check as many as you wish)[9].

- — too expensive
- — waiting for the technology to improve (the technology is too new and unreliable)
- — waiting for greater tax relief
- — other (specify: ________________________________)
- — don't know

30. Would you install a solar heating system in your home for about $4000 if you knew that this amount would be made up in savings in monthly utility bills in 10 years?[23]

— Yes — No — Not applicable — Don't know

31. Would you feel more secure if a utility company installed a solar heating system in your house than if: (please check as many as you wish)[24,25]

- — a small business put one in
- — you installed one yourself
- — a neighbor put one in for you
- — other (specify: ________________________________)
- — don't know

32. How likely is it that you will buy a solar energy system (for heating your home, water, or swimming pool) within the next year?[9]

- — Very likely
- — Fairly likely
- — Not too likely
- — Don't know

33. Is there a solar energy demonstration home located near you?[18]

— Yes — No — Don't know.

34. Do any of your neighbors heat their homes by solar energy?[18]

— Yes — No — Don't know

35. Is there a need for more governmental regulation to encourage the use of solar energy in the country?[19]

— Yes — No — Don't know

36. Many people believe that the potential of solar energy is very great. Below are several reasons suggested as possible causes for solar home heating systems not being very widely distributed in the United States today. Please indicate how much you agree with or disagree with each reason stated here by checking (X) in the appropriate box.[9]

REASONS	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
No industry standards					
Too expensive					
Aesthetics					
Not enough information					
Governmental inertia					
Not reliable					
Inexpensive utility rates					
Building codes					
Increased property tax					
Small income tax credit					
Sales tax					
Storage problems					

(question 36 continued)

REASONS	Strongly Disagree	Disagree	Neither Agree Nor Disagree	Agree	Strongly Agree
Power company opposition					
Inexpensive fuels					
Lack of research and development funding					
Difficult to get loans from banks					
Cloudy weather					

37. Do you use wind as a source of power in your home?[9]

    — Yes — No — Don't know

38. Do any of your neighbors generate their own electricity or pump water by a wind generator or windmill?[18]

    — Yes — No — Don't know

39. Would you be willing to join a small neighborhood association that would be in charge of producing and distributing their own electricity or other utilities?[24,25]

    — Yes — No — Don't know

40. Should there be greater penalities (eg. taxes) on oil, gas and coal to encourage the use of alternative energy systems (eg. solar, wind?)[19]

    — Yes — No — Don't know

41. Is the federal government spending too much, about right, or too little money on alternative energy systems (eg., solar, wind)? [5]

    — Too much — About right — Too little — Don't know

42. Do you grow your own food?[25]

    Yes ___ No ___ Don't know ___

43. Do you recycle food wastes in your garden?[25]

__ Yes __ No __ Not applicable __ Don't know

44. Do you do any composting in your garden?[25]

__ Yes __ No __ Not applicable __ Don't know

45. Would you eat food derived from municipal sewage?[25]

__ Yes __ No __ Don't know

46. Is it more important to spend money on mass transit (eg. bus, trains) or more important to spend money on highways in California?[26]

- __ more mass transit
- __ spend money on both
- __ spend no money
- __ more highways
- __ other (specify: ____________________)
- __ don't know

47. Pick one of the possible incentives for encouraging mass transit that you prefer:[26]

- __ reduced fare
- __ increased comfort
- __ greater convenience (eg. faster trips and larger trip schedule)
- __ other (specify: ____________________)
- __ don't know

48. Is there public transportation available where you live that you (or the chief wage earner) can use to get to work?[26]

__ Yes __ No __ Don't know

49. Suppose that energy costs increased by about $500 per year, and $500 were given to you as a tax rebate by the government; how would you spend this money?[9] ____________________

____

____.

50. Below are statements regarding alternative energy sources (such as solar and wind energy). Please indicate how much you agree with or disagree with each statement by checking (X) in the appropriate box.

STATEMENTS	Strongly Agree	Agree	Neither Agree Nor Disagree	Disagree	Strongly Disagree
We shall develop solar energy as quickly as possible as a solution to energy shortages.[11]					
Home heating by solar energy is economically feasible.[9]					
Home heating by solar energy is reliable.[9]					
Home heating by solar energy is practical.[9]					
Wind generators could be a solution to our energy problem.[11]					
Windmills are a practical source of electrical generation for use by households.[9]					
The use of plant materials to produce methane gas can provide energy for running automobiles.[9]					
I am satisfied with the service provided by the utility company.[9,24]					

(question 50 continued)

STATEMENTS	Strongly Agree	Agree	Neither Agree Nor Disagree	Disagree	Strongly Disagree
Government has an important role to play in the encouragement of the use of solar energy?[19]					
Homes are solar heated by solar cells.[9]					
Retrofitting one's home for solar energy is expensive.[23]					
Energy consumption must be reduced for alternative energy systems (eg. solar, wind) to work.[11]					
In order to encourage energy conservation, there should be a tax rebate for those who install insulation and solar energy.[19]					
It is desirable and practical to change from the present system of big power companies handling all our utilities to having small neighborhood groups supply their own power needs with such devices as solar heating systems, windmills and the like.[24,25]					
Solar energy for heating hot water in one's home would be less expensive to use than gas.[23]					

(question 50 continued)

STATEMENTS	Strongly Agree	Agree	Neither Agree Nor Disagree	Disagree	Strongly Disagree
We should develop hydro-electric (electricity generated by water flowing over dams) power sources as quickly as possible to solve our energy problem.[11]					
If we move in our society to the increased use of solar power, the utility companies should have the major responsibilities.[24,25]					
Communities should be developed in which energy conservation and solar energy or other renewable resources are the normal way of life.[9]					
In order to conserve and efficiently utilize alternative sources of energy (eg. solar, wind and methane), I would be willing to contribute some of my money, time and effort to a local energy-supplying community organization.[24,25]					
If solar heating required more people to live closer together than is the case today, I would find this acceptable.[27]					
The people in one's own neighborhood should control the way energy is produced and used rather than the utility company.[24,25]					

(question 50 continued)

STATEMENTS	Strongly Agree	Agree	Neither Agree Nor Disagree	Disagree	Strongly Disagree
This country is moving towards a more frugal and simple way of life which is consistent with energy conservation and use of renewable energy sources (eg. solar).[25]					
Utilities have tried to suppress the development of the solar energy industry.[9]					
Money and personal possessions are not important to me.[25]					

51. Here are descriptions of 3 possible ways we might live with regard to energy in the long term future (that is, the year 2000). For each description please indicate first how you would like such a set of conditions, and, secondly, how likely you think that this future will occur.[28]

(a) People will live a life characterized by a high standard of living. Automobiles are used for personal and recreational uses which are powered by batteries and by electric power cables buried in the roads. With the development of many labor saving devices for the home, energy is used at a very high rate which is supplied at a reasonable cost through the use of nuclear power plants and sattelite solar energy collectors which distribute power by means of a network linking the entire country.

Like very much	Like	Neither Like Nor Dislike	Dislike	Dislike Very Much
1	2	3	4	5

Very Likely	Likely	Neither Likely Nor Unlikely	Unlikely	Very Unlikely
1	2	3	4	5

(question 51 continued)

(b) People will be living much different lives than they do today. Energy saving equipment and methods required by law are a part of every household. Lowered use of energy is common, encouraged by the high price of energy and penalties for excessive usage. Utility companies supply all the power generated in the main by solar energy collectors located in communities, as well as local hydroelectric and geothermal sources. People will depend on mass transportation for much of their travel.

Like very much	Like	Neither Like Nor Dislike	Dislike	Dislike Very Much
1	2	3	4	5

Very Likely	Likely	Neither Likely Nor Unlikely	Unlikely	Very Unlikely
1	2	3	4	5

(c) People will be living much different lives than today. Much of the power they need for everyday home activities will be supplied by themselves from solar generators or from neighborhood centers. Conservation will be a normal way of life which is done voluntarily because it is what is learned in school and from our parents. Transportation is mainly public, personal cars are primarily powered by methane produced by plant material. Utility companies are important sources of energy only for large cities and industry.

Like very much	Like	Neither Like Nor Dislike	Dislike	Dislike very much
1	2	3	4	5

Very likely	Likely	Neither Likely Nor Unlikely	Unlikely	Very Unlikely
1	2	3	4	5

52. Do you belong to any environmental organization (eg., the Sierra Club, Friends of the Earth, the National Audobon Society)?[29,31]

— Yes — No — Don't know

53. Have you written a letter or sent a telegram to your congressman on any environmental issue during the past year?[29]

— Yes — No — Don't know

54. Is the federal government spending too much, about right, or too little money in cleaning up the environment?[25,29]

— Too much — About right — Too little — Don't know.

55. Have you ever heard of the State Energy Resources Conservation and Development Commission?[6]

— Yes — No — Don't know.

56. Have you ever heard of the State Office of Appropriate Technology?[6]

— Yes — No — Don't know.

57. Have you ever heard of the Public Utilities Commission?[6]

— Yes — No — Don't know.

58. Below are statements concerning the country's environment and economy. Please indicate how much you agree with or disagree with each statement by checking (X) in the appropriate box.

STATEMENT	Strongly Agree	Agree	Neither Agree Nor Disagree	Disagree	Strongly Disagree
We should be prepared to make some sacrifices in environmental quality so as to develop new energy sources.[29,30]					
Cleaning the environment is more important, even if it means closing down some old plants and causing some unemployment.[29]					

59. How satisfied are you with the general conditions in American today (that is, with the overall social, economic, environmental and political situation of the country)? (Please check one)[31]

— Very satisfied — Satisfied — Neither Satisfied nor Disatisfied

— Disatisfied — Very disatisfied

60. How satisfying to you do you expect the general conditions to be 5 years from now? (Please check one)[31]

— Very satisfied — Satisfied — Neither Satisfied nor Disatisfied

— Disatisfied — Very disatisfied

61. How woud you rate your present personal situation and lifestyle? It is generally: (please check one.)[31]

— excellent
— very good
— good
— fair
— poor
— don't know

62. How do you feel your future personal situation and lifestyle in five years will be? Will it be generally: (please check one.)[31]

— excellent
— very good
— good
— fair
— poor
— don't know

63. Looking at the social and political situation in the country today, how would you rate the trustworthiness of the following people and organizations? [3]

	Excellent	Good	Fair	Poor
(a) The Federal Administration	—	—	—	—
(b) The Congress	—	—	—	—
(c) Gasoline oil companies	—	—	—	—
(d) Utility companies	—	—	—	—
(e) Labor unions	—	—	—	—
(f) The American public	—	—	—	—
(g) People in your neighborhood	—	—	—	—
(h) Experts	—	—	—	—
(i) The business community	—	—	—	—
(j) State government	—	—	—	—
(k) Local government	—	—	—	—
(l) Your friends	—	—	—	—

64. Would you say that most people are trustworthy? [3]

— Yes — No — Don't know

65. In general, how would you rate the common sense and competence of ordinary people in this country? [24]

— Excellent

— Very good

— Good

— Fair

— Poor

— Don't know

66. Are you a participant in any civic, labor, religious, political, cultural or social organization or informal groups in your community? [32]

— Yes — No — Don't know.

(question 66 continued)

If "yes", would you say that you attend functions of such group(s):

— once or more a week
— at least twice a month
— once a month
— sometimes but rarely
— never attended
— other (specify: ______________________________).
— don't know

67. Have you taken part in any of these actions during the past year to try to affect energy policies or energy use?[33]

	Yes	No	Don't know
(a) Talked with friends about the energy situation?	—	—	—
(b) Signed a petition dealing with the energy problem?	—	—	—
(c) Formed a group as a result of your energy-related concerns?	—	—	—
(d) Attended any public discussions on energy issues?	—	—	—
(e) Written to a newspaper or other publication about the energy shortage?	—	—	—

68. Below are statements regarding the way people feel about their relationships to local, state, and federal governments. Please indicate how much you agree with or disagree with each statement by checking (X) in the appropriate box

STATEMENTS	Strongly Agree	Agree	Neither Agree Nor Disagree	Disagree	Strongly Disagree
The ordinary citizen doesn't really influence important decisions in this country.[34]					

(question 68 continued)

STATEMENTS	Strongly Agree	Agree	Neither Agree Nor Disagree	Disagree	Strongly Disagree
When I think about politics in Washington, I feel like an outsider.[34]					
People like me aren't well respresented in Washington.[34]					
The State Energy Resources Conservation and Development Commission should be responsible for major policy decisions regarding energy sources, prices and conservation for industry and home.[9]					
There is little the average citizen can do to keep prices from going higher.[34]					
For the most part, our government serves the interest of a few organized groups.[34]					
Persons like myself have little chance of protecting our personal interests when they conflict with those of strong pressure groups.[34]					

Finally, may we ask you to check on a few questions about yourself. Your help in this regard is quite important. In most studies, we know that there are some differences in the way in which people view a situation depending on their background. For that reason, we would appreciate your cooperation greatly.[35]

69. What is your ethnic origin? (Please check one).

— Filipino — American — White-American — Black-American

— Mexican-American — Chinese-American — East-Indian-American

— Polynesian-American — Native-American Indian

— Japanese-American — other (specify: ____________________)

70. Sex: — Male — Female

71. Religious Preference/Affiliation: (Please check one)

— Muslim — Buddhist — Catholic

— Protestant — Jewish — None

— Other (specify: ____________________)

72. In what category does your age fall? (please check one).

— 18-24 — 25-34 — 34-44 — 45-54 — 55-64 — 65-74

— 75 and over

73. How long have you lived in your present residence? __ Years

— Months.

74. Are you employed (earning a wage)? — Yes — No (please check one).

If yes, are you: — a salaried employee (working for someone else)

— self-employed — retired.

75. What is (was)your occupation? (Include housewife, mother, student etc.) ______________________________

76. What is your marital status? (please check one)

— single — widowed — married — divorced — separated

— other (specify: ____________________)

77. How many people live in your house (including yourself)?

— Adults (18 years and older) — Children.

78. In which bracket does your total annual household income fall? (please check one)

— less than $2,000 — $6,000-$7,999 — $15,000-$19,999

— $2,000-$3,999 — $8,000-$9,999 — $20,000-$29,999

— $4,000-$5,999 — $10,000-$14,999 — $30,000-over

79. What is your educational background? (please check highest level)

— Completed elementary school — Commercial college degree

— Some high school — College degree (B.A. & B.S.)

— High school graduate — Advanced graduate work

— Some college — Teaching credential

— Junior college diploma — Ph.D. degree

— Other (specify: ____________)

80. Are you or is anyone in your immediate household a member of a labor union? Yes — No — Don't know. —

81. What political party leanings do you have? (please check one).

— Democrat — Independent

— Republican — Other (specify: ____________________)

— Don't know.

82. Size of area in which your residence is located: (please check one).

— city — suburb — small town — rural area.

83. Name of city closest to you (include the one you are living in):

____

84. Number of vehicles in household: ____________________

85. Type of residence you live in: (please check one).

— Single-family house — Apartment

— Multi-family house — Mobile home

— Townhouse — Condominium

— Other (specify: ____________________)

86. Number of rooms in residence (not counting bathrooms): __________

87. Do you rent or own (buying) your residence?

— Rent — Own (buying) — Other (specify: ______________)

88. If you were asked to place yourself in one of the following categories, what class would you say you are a member of? (please check one).

— Upper class — Lower class

— Middle class — Other (specify: ________________)

— Working class — Don't know.

89. If you rent, are the cost of utilities included in your rent?

— Yes — No — Don't know.

13.4 ANNOTATION

Each of the questions in this questionnaire has been footnoted to this section. Some of the questions have more than one footnote. Several of the footnotes are applicable to several questions in the questionnaire; the reader can refer back to these questions by noting the question numbers in the parentheses next to the footnote number. For example, 2(4,6) states that footnote 2 applies to questions 4 and 6 in the questionnaire.

1(1) This question has been asked in various forms in a number of national surveys(e.g.,Harris Survey, January 1, 1976). By using this question, the importance of the "energy problem" is seen in relation to other natural issues that confront the American public.

1A(2) This is a standard energy question used in many energy surveys (Bultena; Milstein; Opinion Research Corporation ((September 1975))). It is interesting to note that as of May 1977, only one-half of Milstein's sample believed that the energy shortage was real, this fraction has not changed significantly since the end of the Arab oil embargo (October 1974). Moreover, what interests us is how these people who believe in the seriousness of the energy problem relate to attitudes on other facets of the energy problem. For example, some evidence indicates that awareness of the seriousness of the energy problem is positively related to conservation behavior (Milstein; Thompson and MacTavish; Murray et al).

[2](2,3,4,5,7,15) Questions seeking responsibility for the energy shortage have been asked in a number of energy surveys (Bultena; Thompson and MacTavish). Undoubtedly, there is no one individual or organization that is to "blame" for the energy problem in this country. Similarly, there are many individuals and organizations who feel that they have some legal or moral responsibility for trying to solve the energy problem. These questions are useful contextual material for later sections dealing with alternative energy sources, lifestyle changes, and the relative emphasis given to supply and/or demand solutions.

[3](6,63,64) This question and question 63 attempts to measure indirectly the legitimacy of those institutions deemed responsible for solving the energy situation. For example, although oil companies may be perceived by the American public to be responsible for reducing any energy shortage that exists, their programs may not be supported by the public if the oil companies are viewed as incompetent and untrustworthy. La Porte and Methay found trust in governmental and other social institutions to be a significant correlate of more general studies. Groth and Schutz found trust toward government and science to be correlated with support for the nuclear power industry in California. They also discovered trust in people to be positively correlated with support for the nuclear power industry. The Harris Survey (March 22, 1976) showed declines in confidence in virtually all major institutions since 1966.

[4](8,26) This question not only is important in depicting where consumers obtain their information on energy matters but also is relevant for the

possible designation of key arenas for intervention strategies in the diffusion of technological innovations (e.g., solar collectors). Longitudinal analysis is possible by comparing the results of Groth and Schutz.

5 (9,41,54) This type of question is used in many national survey recent analysis of these questions has shown that the respondent is responding towards the substantive area in question (e.g., environmental quality and defense spending) rather than the nature of governmental spending per se. In addition, other questions dealing with the same issue will provide a "check" on the relevance and applicability of this question, a "check" that is frequently missing in national surveys for this type of question.

6 (10,55,56,57) A "visibility" or "communications" question: how successful has a particular organization been in creating an image and/or name in the minds of the American public? This question will be useful as a feedback mechanism for those organizations mentioned or suggested in this questionnaire and who wish to see how effective they are in communicating with the public.

7 (11) Several surveys have asked questions pertaining to the desirability of the development of different sources of energy (Bultena; Executive Office of the President; Harris Survey (February 17, 1977)). This question will be relevant in comparing California with other regions and the rest of the nation in order to determine if the views of the public in California today are more favorable or less favorable to alternative sources of energy.

8(12) This question indicates the extent of optimism and confidence in the American public in solving the energy problem. Comparison with the previous question clarifies the nature of this optimism: for example, do advocates of conventional fuels (e.g., nuclear, coal, natural gas and oil) see the energy problem being resolved in a different time perspective than those people supporting alternative energy sources (e.g., solar and wind)? This question also provides a good "check" on question 2.

9(13, 14, 15, 23, 24, 25, 27, 28, 29, 32, 36, 37, 49, 50, 68) This question developed out of several interviews conducted with "key informants" during the summer of 1977 (Interviews 1 to 14).

10(15) Oil companies have been one of the major actors that have been "blamed" for the energy situation we face today (Bultena; Energy Group Discussion Meeting), (see footnote 2).

11(15, 24, 50) The "technological fix," in contrast to economic, political, and social change outlooks, is one perspective commonly associated with environmental and energy controversies. Several studies have found overwhelming public confidence in the ability of science and technology to come up with energy solutions (e.g. Bultena; Drossler Research Corporation). The need for lifestyle changes presents a different approach to trying to solve our energy problems without solely relying on conventional or new technology (see footnote 25). A 1975 national survey (Harris Survey, December 4, 1975) showed a great apparent willingness to adopt new lifestyles among the public.

[12](15) Attitudes towards conventional sources of energy are important for comparisons with attitudes towards alternative sources of energy. In particular, this question will be useful for (1) longitudinal analysis with Groth and Schutz's results on the Nuclear Initiative of 1976 in California; and for (2) examining Amory Lovins' (1976, 1977) argument that nuclear development should be stopped in this country because it is technically and socially dangerous.

[13](15, 24, 25) This question developed out of a group meeting of Sacramento Area residents (Energy Group Discussion).

[14](15) This question will be used to examine Amory Lovins' (1976, 1977) argument that nuclear development should be stopped in this country because stoppage would promote global non-proliferation of nuclear power.

[15](16, 18, 24) Although the respondent may believe that there is a serious energy shortage (see Question 2), the person may not believe that he or she must save energy since it is not their responsibility. Zuiches reports no relationship between belief about the energy problem and energy conserving behavior.

[16](17, 18) These are standard items used in survey research on energy conservation behavior (Bultena; Opinion Research Corporation (September and October 1975)). The degree of conservation behavior among the California public will be compared against the benchmark of various national surveys. For example, the Harris Survey of November 1975 discovered a substantial

decline, compared to data collected in March 1974, in automobile related conservation behavior and more moderate declines in most other conserving activities.

17 (19) This question was a major focus for quantitative analysis by Curtin and indicates potential problems organizations might encounter in encouraging further energy conservation by the household.

18 (20, 33, 34, 38) Visibility of energy conserving behavior (e.g., small cars and recycling) and application of alternative sources of energy (e.g., solar collectors, wind generators) in the neighborhood were deemed by "key informants" to be very important in expanding a "conservation ethic" and a "soft technology future" (Interviews 1 to 14). See Montgomery and Barton on the great adaptive significance of personal models of behavior and word-of-mouth information (see also Rogers and hoemaker).

19 (21, 24, 35, 40, 50) Behavioral change can occur by use of incentives (e.g., tax credit) and/or constraints (e.g., governmental regulation). The use of influence and/or power is a major field of interest in the discipline of political science and the general area of social change. Montgomery and Barton summarize different incentives for different groups and conclude that tax credits are of greater popularity than punitive devices. See Milstein and Melicher for confirmatory evidence.

20 (14, 22) Although the dissimilarities between conserving water and conserving energy may be great, water conservation attitudes and behavior are important

to compare since most of the California population is being mandated to conserve water at the present time. Hence, water conservation now might indicate the future prospect of energy conservation in California.

21 (24) "Feedback experiments" in energy consuming behavior have led to mixed results (Montgomery and Barton). Nevertheless, some type of feedback, perhaps combined with economic incentives, may be needed to vigorously demonstrate that energy conserving behavior leads to a measurable reduction in energy demand in the household.

22 (24) The problem of equity is a major source of concern in policy analysis (Morrison). Besides the ethical implications, practical problems may be encountered in terms of policy implementation if a sizeable portion of the population feels that a segment of the community is not being treated fairly.

23 (30, 50) "Life cycle costing," it is argued, is one way of making solar heating systems competitive with natural gas heating systems. The general public, it is argued, would be more receptive to solar heating if they knew that they would save money in the long run despite the large initial expenditure (Interviews 1 to 14). There is no evidence on this as yet.

24 (31, 39, 50, 65) One of the major controversies concerning the future of "soft technology" is the issue of centralization/decentralization. For example, will large-scale, heavily-capitalized solar energy projects be constructed

using, with slight modification, the present infrastructure (e.g., electrical grid systems) or will production and consumption of solar energy for heating and electricity occur at the household level? The decentralized nature of alternative energy systems is one of the major tenets in Amory Lovins' work (1977). Whether the average person is willing to be involved in the production of his/her own energy alone, with friends, or in neighborhood associations, is problematic and is the focus of several questions in this survey.

[25](13, 31, 39, 42-25, 50) Duane Elgin and Arnold Mitchell have recently described a lifestyle called "voluntary simplicity" marked by 5 values: (1) material simplicity; (2) human scale; (3) self-determination; (4) ecological awareness; and (5) personal growth. Although this questionnaire does not attempt to cover all the values of this lifestyle, many of the questions directed to the use of energy in this survey are also pertinent to the "world view" of voluntary simplicity. For example, some of the social characteristics of voluntary simplicity are: (1) reduction of material complexity; (2) appropriate technology; and (3) greater local self-determination. Amory Lovins (1976, 1977) also suggests that it is more worthwhile to pursue qualitative improvements in life rather than mere growth and accumulation. A 1975 natural survey (Harris Survey, December 4, 1975) showed a great apparent willingness to adopt new lifestyles.

[26](46, 47) This question has been asked in various forms in a number of national surveys (e.g., Opinion Research Corporation (August 1975)).

[27] (50) An important land use planning consideration when examining the future of "soft technology" in California.

[28] (51) The development of 3 "end-states" occurred as a result of much discussion among members of the "California Group" about what the future of California would be like in 50 years. The descriptions of these "end states" do not reflect a concensus of the future among the participants in the group. The characterizations of the future, however, do highlight some of the main issues developed by Amory Lovins and members of this energy group.

[29] (52, 53, 58) Questions on environmental attitude and activism are useful in interpreting "soft technology" attitudes and behavior with the extensive qualtitative and quantitative literature on environmentalism as well as with the "voluntary simplicity" movement (see footnote 25).

[30] (58) This question replicates a 1977 national survey question (Executive Office of the President) where some 60 percent of the respondents agreed with this proposition.

[31] (59 - 62) The next series of questions (Questions 59-62) are designed to measure satisfaction and optimism with respect to personal and general societal conditions. The assumption is that both or either of these attitudes are likely to vary inversely with preference for a radical departure from present energy patterns. We would like to know, if this is the case, how numerous this component of the electorate is and who

is in it. A greatly disenchanted population might be a precursor to the widespread adoption of "soft technology" (Lovins, 1977; Craig and Nathans).

[32](52, 66) These questions try to measure individual affiliation with, or integration in, on-going institutions. The lack, or relatively low levels, of social integration are likely to correlate with distrust and opposition to current energy delivery systems. This has been confirmed by Groth, Schutz, and Blakely). Furthermore, group participation may facilitate participation in other groups and collectives (e.g., neighborhood associations).

[33](67) These questions aim at the degree of activism of energy-concerned respondents (Bultena). There is no evidence yet on differences between "activists" and "non-activists" in terms of energy conserving behavior or attitude towards soft technology.

[34](68) These questions attempt to measure alienation among the respondents. We hope to determine if alienated people are strong advocates of local control, lifestyle changes, and soft technology.

[35](69-89) Most of the demographic questions have been asked in various forms in many energy surveys (Opinion Research Corporation; Bultena; Thompson and MacTavish; Groth and Schutz; Schutz and Blakely). Lopreato and Meriwether report that, in their review of energy surveys, few significant relationships have been found between energy attitudes, conservation behavior, and such demographic variables as education, income, or region of residence.

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11. Tom Javitts (manager of the Urban Integral House), August 5, 1977, in Berkeley.

12. Mike Corbett (developer of Village Homes), August 5, 1977, in Davis.

13. Helene Kassler (solar energy research for Friends of the Earth), August 17, 1977, in Berkeley.

14. Bruce Wilcox (Berkeley Solar Group; vice-president of Northern California Solar Energy Association), August 22, 1977, in Berkeley.

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CHAPTER XIV

INTERVENTIONS TO INFLUENCE FIRMS TOWARD THE ADOPTION OF "SOFT" ENERGY TECHNOLOGY

14.1 DESIGN OF AN INTERACTIVE MODEL

14.1.1 The Problem of Influencing Energy-Using Firms Toward "Soft" Technology

Firms and households, as energy users, have not in modern times adopted "soft" technologies except in highly unusual, isolated instances. Conventional fuels (oil and natural gas) and electrical energy have been cheap and convenient. In this paper, we will study the problem of influencing typical energy-using firms away from the traditional reliance on conventional energy sources and toward "soft " technologies.

Three possible types of actuating forces could cause energy-using firms to contemplate shifts from conventional energy usage to soft technologies. First, some firms might respond to exhortation --appeals for a change out of a sense of social responsibility and to satisfy philosophical commitments to the community. (This sort of impulse toward change has indeed influenced the behavior of some firms in such other contexts as affirmative action and consumer information, but we shall not focus on it in this study.) Second, a significant change in energy prices --bringing about a situation in which conventional energy became much more expensive relative to energy from soft technologies-- could actuate change. Third, firms could be subjected to regulatory interventions intended to cause them to shift toward soft technologies.

Such interventions by a "control organization", as we will refer to the change-producing agency, need to be viewed in the context of a system of economic activities, as is sketched in Figure XIV-1. To simplify the problem, we will develop a model that connects the control organization with the energy-using firm through control conditions applied, as in Figure XIV-1, only at points B and C. These are, respectively, the conditions of operation of the firm, and the market relations between the energy-using firm and the producers of conventional energy. We will not, in this model examine the latter.

14.1.2 Specifications of the Interactive Model

Thus, our simplified model takes the form shown in Figure XIV-2. The experimenter will have the ability to (1) set certain conditions of operation for the firm; (2) set certain conditions of operation for the control organization; and (3) set certain conditions on the interactions between control organization and firm. The model is then designed so that control organization and firm will interact over a horizon of T periods, where T is determined by the experimenter.

The firm is specified generally in this model as a producer of two products for the market, seeking to maximize its total net revenue, subject to several constraints: a limit on the amount of conventional energy that it may use; a limit on the amount of "soft-source" energy that it may use; a limit on its total machine capacity for production; and a limit on the amount of working capital that may be tied up during the production period. The firm has two alternative energy sources --the

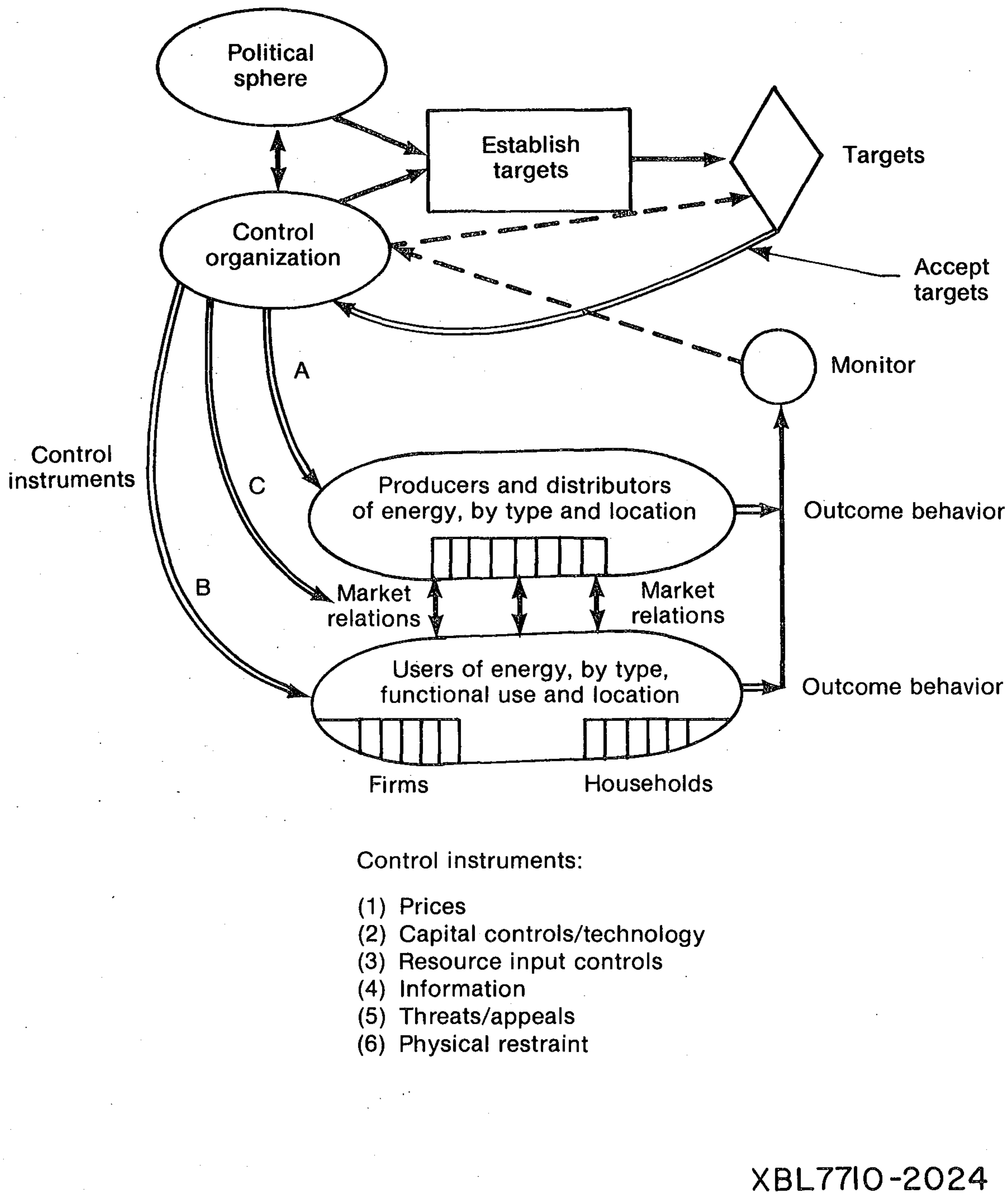

Figure XIV-1. Control Organization: Sketch of System Model for Energy Regulation

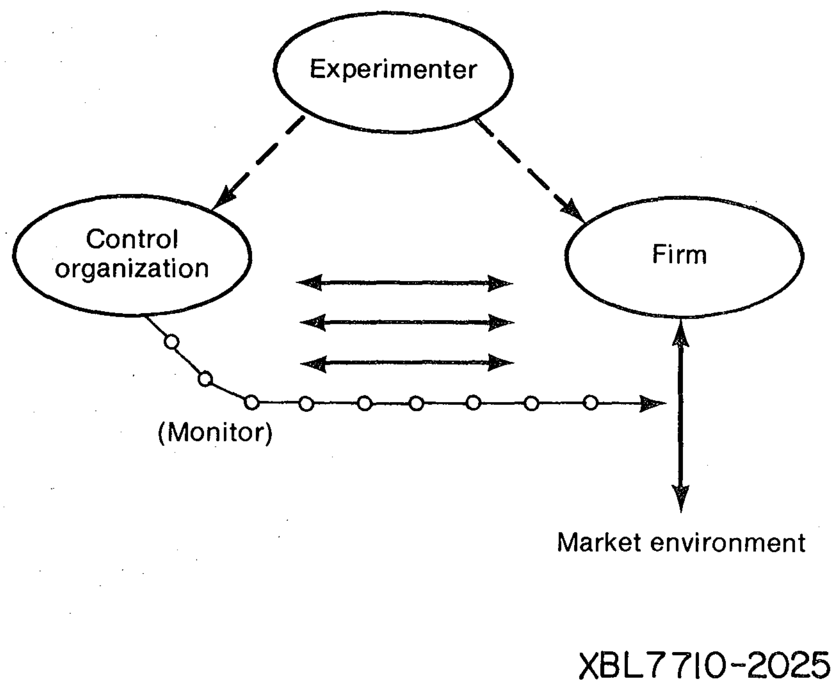

Figure XIV-2. Interactions Between Control Organization and Energy-Using Firm, Arranged for Multi-Terminal Experimentation conventional source and the soft source-- available to it for producing product A, which requires a high input of energy per unit of A produced. The same two alternative types of energy source are available to the firm for producing product B, a less energy-intensive product.

We presume that the base case should reflect contemporary conditions of dominant reliance on conventional energy sources. Thus, the parameters will at first be set so that the firm's optimal production plan will be to produce some of product A and some of product B by relying, for both products, on conventional energy sources.

The firm's decision-maker will be confronted, in the first few time periods, with the problem of choosing production levels for products A and B, and the energy sources, with the intent of maximizing the firm's total net revenue (total dollar sales minus total variable costs). The linear programming model and the base case are summarized in Table XIV-1.

Then the control organization's decision maker will begin communicating with the firm, seeking to influence its usage of conventional energy as against soft-source energy. Any of three different conditions for the interaction will be permitted under the model's design, with the experimenter either pre-specifying what are the regulator's allowable types of interaction or permitting the regulator to choose freely any one or a combination of the three. The firm and the regulator, or control organization, then communicate with each other at the end of each time period for a number of periods, during which the control organization is seeking to induce or compel the firm to modify its pattern of energy usage.

The regulator will be able to affect the firm's behavior by any one of three types of change in circumstances from the base case:

Table XIV-1

Summary of Specifications for the Firm

The firm is to max R, total net revenue, = $b_1X_1 + b_2X_2 + b_3X_3 + b_4X_4$, where the b_i are unit net revenues of the unknown activity variables X_i, and $b_i = p_i - c_i$ (price minus average variable cost, for each activity variable), where i = 1, ..., 4, subject to:

(1) $a_{11}X_1 + a_{12}X_2 + a_{13}X_3 + a_{14}X_4 \leq E_1$, the allowable amount of conventional energy source.

(2) $a_{21}X_1 + a_{22}X_2 + a_{23}X_3 + a_{24}X_4 \leq E_2$, the allowable amount of soft-source energy.

(3) $a_{31}X_1 + a_{32}X_2 + a_{33}X_3 + a_{34}X_4 \leq E_3$, machine capacity.

(4) $a_{41}X_1 + a_{42}X_2 + a_{43}X_3 + a_{44}X_4 \leq E_4$, working capital.

(5) $X_i \geq 0$.

The activity alternatives are defined as follows:

X_1 = number of units of product A produced using conventional energy sources, requiring high energy input/unit output.

X_2 = number of units of product B produced using conventional energy sources, requiring low energy input/unit output.

X_3 = number of units of product A produced using soft energy source; same energy input as X_1.

X_4 = number of units of product B produced using soft energy source; same energy input as X_2.

Base Case

Set the b_i and a_{ij} and E_j so that the solution calls for $X_3 = X_4 = 0$, $X_1 > 0$, $X_2 > 0$. That is, the soft source is not used. Also set the coefficients in row four and the value of E_4 so that there is no working capital effect of the energy mode.

The firm is then represented at a terminal, and a subject gets used to choosing the X_i to maximize R subject to the constraints. The program could provide the subject with the facility to consult a linear programming algorithm for assistance in the optimization.

(I) Absolute or relative price reduction of the soft source energy. This means that the regulator tries increasing b_3 and b_4 while b_1 and b_2 stay the same, or decreasing the latter while leaving b_3 and b_4 the same. In the latter case the firm will suffer net reduction of R_{max} .

(II) Make the soft source easier to finance in working capital terms, by increasing E_4, the working capital constraint or reducing the soft-source coefficients. An approximation would be made to tax credits or other such devices.

(III) Mandate or compel a change. Cut E_1 to reflect a reduced allocation of conventional energy to the firm. This would then force a shift in energy mode to the soft source, or a change in product mix to the less energy-intensive product, or both.

14.1.3 Specifications of the Regulator or Control Organization

The model provides for interaction between the firm and a regulator (or control organization, in our general terminology). The regulator's purpose in the interaction is to influence the behavior of the firm in some specified direction.

The regulator's objective or objectives could be given to it from outside the model (in the real world, by the political authorities, or in the Laboratory world, by the experimenter).

The regulator's objective could, in the first version of the interaction, be to bring about a reduction of K% in the firm's usage of conventional energy.

Secondarily, this objective could be specified without much adjustment time, and without consideration of secondary costs, and without any way for the regulator to provide adjustment help or incentives. Alternatively, the regulator might have the objective of K% energy reduction, subject to the condition that the regulator's actions cause as little disturbance as possible of the product mix and profitability of the firm.

Also, the regulator could be provided with several time periods for accomplishing the adjustment or with very little adjustment time.

Finally, the regulator might be provided with subsidy funds to facilitate the adjustments by the firm, and the regulator would then provide subsidy reimbursements when the firm made the appropriate adjustments.

Ultimately, we would wish to develop a more detailed analytic structure of the objectives and activities of the regulator, perhaps along the lines of a goal programming model. The subsidy could be used to reimburse the firm for the required increase of b_3 and b_4 relative to b_1 and b_2 . The regulator could be evaluated in terms of not wasting subsidy funds, among other criteria of the reasonableness of its controlling actions.

14.1.4 Programming of the Interactive Model

The model described above will be programmed to run in the Management and Behavioral Sciences Laboratory of the Center for Research in Management Science. The Laboratory's computer system is specially designed to support multi-terminal exercises and experiments.

The resident computer language in the Laboratory is APL, augmented by additional features that enable the source program to connect and manage a number of terminals representing different parts of one modelling effort. In this case, the experimenter will have one control terminal available, from which to establish the initial conditions of a session of interaction, monitor what happens, and, if necessary intervene during the course of a multi-period session. The control organization or regulator will be located at another terminal. One or more persons can be assigned to this terminal to perform the regulatory work.

Each firm in a population of firms will be at a separate additional terminal. The Laboratory system will be able conveniently to accommodate up to six or eight firms initially, and we will test the feasibility of sufficiently rapid response with a still larger number of respondent firms represented, up to approximately 20. Each firm will operate independently of the other firms, interacting only with its pre-specified market environment and with the control organization that is seeking to influence its energy-usage pattern.

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CHAPTER XV

THE ENTRY OF SMALL FIRMS INTO DISTRIBUTED TECHNOLOGY ENERGY SUPPLY INDUSTRIES

15.1 INTRODUCTION AND SUMMARY

This paper discusses the intial phase of a research program which addresses certain cultural and institutional factors that may facilitate or inhibit small business firms' exploitation of dispersed energy technologies. This study seeks to identify linkages between those characteristics of individuals, groups, and organizational structures - within the small firm - which may be useful in: 1) differentiating innovative and noninnovative firms within select industries; and, 2) identifying those firms which may more readily adapt to a new distributed technology based energy industry. Of major concern here are problems of transition from existing energy sources and use patterns to new patterns consistent with adoption of distributed solar technologies and reduced energy consumption.

The results of this study should provide useful information to policy makers who may wish to encourage movement of firms into a distributed technology based energy industry by identifying economic, social, and psychological elements associated with successful organizational innovation. This research may also be instrumental in the identification of areas where educational effort may help bring about desired innovation through the dissemination of relevant information. Finally, the results may aid small firms, which may be contemplating entry into the distributed energy technologies arena, in their self-assessment of the probable success of innovations which they may undertake.

The remainder of this paper is divided into three major sections. In the first section the meaningfulness of this particular research effort within the larger context of the "Distributed Technologies" project is discussed along with some basic underlying assumptions. In the second section selected literature relevant to the concept of innovation is reviewed and a series of issues to be investigated is derived. In the final section the research design for a pilot survey will be presented. Included will be a discussion of the conceptual model of relationships between characteristics of firms and factors that might affect organizational innovativeness, a statement of propositions to be tested, and a description of methods of data collection analysis.

15.2 RATIONALE AND ASSUMPTIONS

This multidisciplinary project (i.e., Distributed Technologies in the Energy Future), which projects a plausible future for the year 2025, rests upon three basic premises: 1) the world will have undergone a major shift in its sources of energy; 2) there exist alternatives to dependence upon coal and nuclear materials as primary sources of energy; and 3) future rates of energy consumption must not necessarily exceed the current rate. Although numerous and divergent causes may be offered, including depletion of oil reserves, effects of pollutants upon the environment, the emergence of new energy technologies, etc., most authorities do agree that the net effects will be a shift in the mix of basic energy sources.

However, no consensus exists with respect to the second and third premises. Experts and laymen alike choose sides and passionately join debate over the feasibility of various alternative energy technologies and the societal consequences that may follow. The continuing debates over nuclear waste disposal, the possibility of subversive and covert manufacture of nuclear weapons, an induced "green house" effect and climatic change, the interplay between environmental protection and full employment, and calls for "zero population growth" and "zero economic growth" are symptomatic of this basic lack of consensus.

Another fertile area of speculation and controversy centers upon temporal concerns and includes questions about the phasing and rate of movement toward replacement energy sources. Some suggest that within the next five to twenty years a severe imbalance between the supply and demand for petroleum will force the accelerated development of alternate energy sources and related supply technologies. This supply-demand imbalance will place tremendous stress upon the international economic and political order. A crisis situation characterized by the rapid onset of an energy transition phase followed by a high rate of change in energy supply technology suggests that many societies, including that of the United States, may resort to authoritarianism in order to maintain political and economic control.

Others argue it is unnecessary to postulate that we will be driven into an energy future on the heels of crisis. Rather, as a result of concern for the preservation of the physical environment and widespread adoption of a lifestyle which favors greater simplicity, society will make rational choices: 1) to adopt energy sources and supply technologies which are environmentally benigh and 2) to reduce the rate of energy consumption. This line of argument suggests that planning based on popular, deliberated and reasoned choice will dictate enactment of the energy transition phase,and that movement toward a new energy future will be characterized by a moderate and steady rate of change.

So far care has been taken not to associate any particular mix of energy sources with energy futures molded by either crisis or reason. Within the context of the above discussion it is easy enough to suggest that the crisis driven future will rely mainly upon a coal-nuclear fuel energy sources mix,while the future driven by reason and deliberation will rely mainly upon a solar and solar derivative energy sources mix.

However, as Table XV-1 shows either energy sources mix may be associated with either "crisis" or "reason" driven futures.

Mix of Energies	Nature of the Progression Toward the Future: crisis driven	deliberated and reasoned
coal and nuclear	I	II
solar and solar derivatives	III	IV

Table XV-1

States of the Future and Energy Sources

Connections between energy sources and the nature of future states of society must be established through the specification of alternative energy supply technologies. At this point the simplicity of Table XV-1 lost. Within each cell of Table I there exists a number of alternative supply technologies that may be applied to a seemingly infinite number of energy source combinations. Each energy sources mix and its associated supply technologies will produce a unique set of implications for the nature of the institutions that will permeate the future society and the formal organizations through which these institutions will find expression.

The extent to which the social institutions of a future society may be expected to differ from those of contemporary society can be examined in terms of relations between energy source mixes and supply technologies; however, such an examination will not be attempted here. For the purpose of this discussion a more relevant exercise is the identification of appropriate institutional structures given the choice of solar-solar derivative energy sources and distributed supply technologies as vehicles for movement into the future. An "appropriate institutional structure" includes those values, belief systems and organizational forms which 1) facilitate the establishment of new primary energy sources and associated supply technologies and 2) simultaneously require minimal deviation from existing societal patterns.

Much of the discussion concerning appropriate social institutions for development and maintenance of distributed solar technologies revolves around questions of size, type, and source of organizations which will disseminate information about new technologies and utilize them to provide solar energy to consumers. Are large, geographically dispersed, well-financed corporations presently involved in energy production and distribution, or an aggregation of small, localized, and independent firms better equipped to move toward a distributed solar energy future? Under our definition of appropriate institutional structures, it might be reasonably argued that existing public utilities, energy suppliers, and relevant governmental agencies should guide the transition to distributed solar technologies. Some would suggest that this is especially true if we enter a crisis driven energy future. However, strong arguments may also be advanced in favor of small business as the standard bearer.

15.2.1 Small Business and the Political Economy

An implicit assumption generally seems to exist that regardless of the nature of any other changes which society may undergo between now and 2025, the type of "guided capitalism" which now characterizes the American political economy will remain relatively unchanged. Thus, the production and distribution of goods and services, including energy, will continue to be governed by the operation of a constrained market mechanism. Continuation of the present political economy may be considered axiomatic for big and small business alike if the future is driven by reason and deliberation.

Economists and business historians have noted that within the context of the American economy a duel market system has developed in which a few very large firms and millions of small firms constitute the "center" and "periphery" of the national economy, respectively. Heilbroner (1972:121), drawing upon the work of Averitt (1968), observes that of approximately 12 million small business in America, including 2.9 million farms, roughly 12.5% are corporations. While these small corporations do five times as much business as all small proprietorships and partnerships, they account for only 2% of total corporate sales. At the other end of the spectrum a small core of approximately 500 giant corporations account for more than 35% of all industrial sales. However, all small business employs approximately 40% of the national labor force while big business and nonprofit organizations employ 25% and 35% of the labor force, respectively.

This information suggests that even though a disproportionate capacity for the production of wealth, and the political and social powers that follow, rests in the hands of a few large corporations, the characteristic small business perspective which pervades much of American political and social life has its origin in the large number of people who have direct links to small business. The large number of small firms, their geographical and industrial dispersion, and the relative low capital requirements thought to be associated with distributed solar energy technologies suggest that small business, as a social institution, may provide a viable means for the widespread dissemination of distributed solar technology.

If the future is crisis driven and our political economy moves in the direction of the "mixed" systems of Western Europe or perhaps Eastern Europe, the small enterprise may continue to be a viable device for the operation of distributed solar technologies. If a large number of small firms becomes actively engaged in the distribution of solar energy through distributed technologies in a manner analogous to the production of food by small farmers, then even radical shifts in the political economy may leave small energy producing units intact. Experience has shown that in European mixed economies heavy industry engaged in the production of capital goods and vital public services, including the transportation and communication sectors, are most frequently subject to centralized operation through command mechanisms. In these same national economies the agricultural sectors frequently may operate under a minimally constrained market mechanism. A similar situation could exist for small enterprises which utilize distributed solar energy technologies.

15.2.2 Small Business and Changes in Lifestyle

The Affluent Society (Galbraith, 1958), The Hidden Persuaders (Packard, 1957), The Other America (Harrington, 1962), Silent Spring (Carson, 1962), The Population Bomb (Ehrlich, 1968), The New Industrial State (Galbraith, 1967), Future Shock (Toffler, 1970), and The Greening of America (Reich, 1970) are representative of publications which have been widely read over the past two decades and considered by many to contain prophetic indictments against certain elements of mid-twentieth century American society. Some would suggest that the seeds of the message have taken root and are presently transforming some basic values generally held by members of this society. Unlike earlier attempts by religious sects and other groups on the periphery to establish utopian societies through experiments in communal living, the current movement seems to be emerging within the middle-class mainstream of American society.

The mood is not necessarily one of hostility or resentment toward the existing order but rather is characterized by the conscious exercise of choice in the use of time, effort, and money in pursuit of an improved quality of life and personal self-sufficiency. Reduction in the national birth rate, decisions by some municipalities to limit their growth, increased participation in jogging, hiking, and other non-spectator outdoor activities, and increased concern over the intrinsic value of work for employees may be manifestations of the movement toward a life style of "voluntary simplicity."

One consequence of such a life style may be the development of preferences for interaction with smaller organizations rather than larger ones. Given the displeasure voiced by many over the activities of large public utilities and the large oil companies, small firms which become involved in dispensed solar energy technologies may attract a body of loyal supporters. Such support from a growing segment of the middle class acquires additional significance when it is realized that, with the exception of the last two years, there has been a continuing trend toward a more even distribution of income among all levels of the total population. This trend is reflected in Table XV-2.

Table XV-2

Percent Increase in Pre-Tax Average Income
(1950 Dollars)

Population Rank	1935-36 to 1962
Lowest fifth	120%
Second fifth	136%
Third fifth	131%
Fourth fifth	115%
Highest fifth	74%
All Groups	98%

Source: Statistical Abstracts 1965, p. 340

The trend toward a more uniform income distribution effectively increases the ranks of the middle class or, alternatively, increases the proportion of aggregate income available to the middle class for expenditure. This infusion of income coupled with a value system which favors dealings with small firms may increase the likelihood that small firms will be able to successfully supply solar energy through the distributed technologies.

15.2.3 Small Business and System Responsiveness

Ashby (1957), in his discussion of the regulation of cybernetic systems, introduced the concept of "requisite variety." The concept suggests, among other things, that a system's survival potential is increased if the system contains a variety of responses which approximately mathces the variety of inputs to the system from its environment. One method by which the response repertoire of a system may be increased is through decentralization. The implication for energy distribution systems is apparent. Upon transition to a new energy future the extant large centralized distribution systems may be subject to additional unknown shocks from the environment. Examples of such shocks include sabotage of electrical transmission towers and abrupt discontinuation of fuel supplies. Distributed energy technologies operated by small firms should dramatically increase the variety of the energy supply system and thus increase its ability to respond to shocks from the social environment.

As noted in the main body of this report, a major criterion for the designation of a distributed technology is the extent to which the end user is able to exert control over the entire fuel cycle of a particular energy supply system. This, and other criteria, imply that the consumer should possess the ability to install and maintain a localized, low technology energy supply system. Even though there may be a movement under way toward ideals of voluntary simplicity and personal self-sufficiency, and individuals may possess sufficient technical competency to fully control the operation for an energy system, it is highly unlikely that large numbers of end users (including individuals, households, business firms or other organizational entities) will install and maintain their own energy systems. It is more likely that society will continue to seek efficiency of operation through the division of labor. Thus, an attempt will be made to strike a balance between the need for requisite variety in the energy system's response capability and the need for efficient system operation. Again, it appears reasonable that small firms will be instrumental in meeting these societal needs.

If the arguments stated above are accepted and it is agreed that small business is a firmly established institution within American society whose potential usefulness as an efficient and reliable supplier of solar energy through distributed technologies may be increased by a shift in social values, a major problem continues to exist. How are small firms that presently may be only marginally involved in the supply of energy, to be encouraged to enter an emerging energy supply industry based on the use of distributed technologies? The observation has been made that:

> ...barriers to far more efficient use of energy are not technical nor in any fundamental sense economic. So why do we stand here confronted, as Pogo said, by insurmountable opportunities?
>
> The answer - apart from poor information and ideological antipathy and rigidity - is a wide array of institutional barriers...
> (Lovins 1976:74)

Lovins argues correctly that institutional forces will represent major deterrents to the transition by small firms from their present industrial technologies to a new energy industry. Many believe that simple economic determinism is the driving force behind most social changes. Once small businessmen perceive that there is economic advantage in shifting to a new or different industry the transfer will be made. Policy makers, operating upon this assumption, then will devise incentives in the form of tax rebates or subsidies to encourage the desired industrial movement. Under crisis conditions movement is accomplished with greater ease through the exercise of direct command.

However, ample evidence exists that economic considerations are only a portion of the complex situation surrounding a decision to innovate. Particularly when movement into the future rests upon deliberation and reason , the perceptions, values, and beliefs held by the small businessmen, who must make the decision concerning innovation, are of major importance. These perceptions, values, and beliefs are influenced by the quantity and quality of information available to decision makers as well as the decision makers' awareness of and openness to information. Availability of information also affects the rate and levels at which innovation will occur. This research seeks to identify more clearly those institutional mechanisms which may inhibit or facilitate the movement of small firms into a solar energy industry based on distributed technology utilization.

15.3 LITERATURE REVIEW

In this section the concept of organizational innovation is considered in detail. Rogers and Agarwala-Rogers (1976) have made some useful distinctions between innovation and some closely related concepts. In the passive sense, innovation is defined as "as idea, practice, or object perceived as new by the relevant unit of adoption" (Rogers and Agarwala-Rogers 1976:150), where the relevant unit of adoption may be an individual or a larger social unit. When organizations constitute the relevant units of adoption, two general types of innovation may be discerned. Innovations _of_ the organization are those innovations, adopted through organizational decision, which do not require substantially different individual behavior of people within the organization. An example would be the addition of a new product line by a manufacturing firm. Innovations _in_ organizations, however, do require changes in the behavior of individual members. An example would be the conversion of military academies to coeducational institutions.

Most interest in innovation as expressed in the literature is in the process through which innovations are adopted and diffused. In this active sense innovation is a special case of a larger process of social change. "Whereas innovation implies adoption of an idea perceived as new, change may also involve the replacement of an already existing idea by another idea. The idea being adopted may be perceived as new (and thus be an innovation), or it may be a familar, accustomed idea. So some changes are innovations, but not all" (Rogers and Agarwala-Rogers 1976:153).

The definition of innovation as "...the generation, acceptance, and implementation of new ideas, processes, products, or services" (Thompson, 1965:1) is representative of broader definitions which include the element of creativity in the innovation process. March and Simon (1958) approach the concept of organizational innovation from a psychological perspective and note that the innovative process is closely related to such cognitive processes as problem solving, productive thinking, creative thinking, and invention. Steiner (1965:16) has identified parallel characteristics between the creative individual and the creative organization.

However, Khandwalla (1977:551) seeks a clear distinction between creative and innovative activity by noting that "invention" is the act of creating something novel and useful, while "innovation" is the process of developing the invention so that it can be put to practical use. The distinction between creativity and innovation is important for purposes of this research. Here creativity is considered to be primarily a cognitive process and thus a psychological characteristic of individuals. In this sense, there are no creative organizations per se, only creative individuals. Since our main interest is in organizational processes, no attention will be given to creativity as a psychological property of the individual. Obviously there are within organizations creative individuals who may be innovators. The role of innovators within the organization is of relevance to this research.

15.3.1 The Process of Innovation

Based upon the synthesis of research into the diffusion of innovations which has been conducted in numerous and diverse academic fields, Rogers (1962) has developed a model of innovation adoption which includes the following five states: 1) awareness - the individual is exposed to an innovation but lacks complete information; 2) interest - additional information about the innovation is sought; 3) evaluation - a decision is made to either try or not try the innovation; 4) trial - the innovation is implemented on a small scale for test purposes; and 5) adoption - the innovation is employed for continued use. Duncan (1976) has employed a model of the innovative process which consists of two main stages. The first state is initiation which consists of three substages, including 1) knowledge awareness, 2) attitude formation and 3) decision. The second stage is implementation which consists of two substages - initial implementation and continued-sustained implementation, respectively. The five

The five substages of Duncan's model closely resemble the five stages of Roger's model.

Clark (1968) has identified four models through which the adoption of innovation occurs in universities. The organic growth model, which consists of a series of stages and processes for the analysis of an innovation, is thought to be most applicable to innovations that develop outside of established institutional structures. The differentiation model, based on the concept of task specialization, treats the development of innovations with organizations through creation of specialized structures. The diffusion model, which is basically that of Rogers, is considered to be applicable for situations where innovations are developed outside of formal organizational structures and then diffused into them. Several features of the other models are selected to produce the combined-process model which views innovation as occurring both internal and external to the organization with frequent diffusion of ideas back and forth across the organization's boundaries.

While the models proposed by Clark provide additional perspectives for the study of organizational innovation, the diffusion model of Roger's and variations thereof, have found widest application in contemporary studies of organizational innovation.

15.3.2 Characteristics of Innovative Organizations

Thompson (1965) has observed that bureaucratic, production-oriented organizations typically are not well suited for innovative activity. Organizational innovation is thought to be facilitated when the following conditions exist with respect to the formal organization and individuals and groups within the organization. 1) The organization is the recipient of diverse inputs of information and knowledge necessary for the generation of new ideas. 2) Slack resources not committed to production operations are available to support innovative activities, and 3) the atmosphere is free of external pressure. 4) Individuals involved in innovative activities are motivated by challenge and intrinsic rewards; they possess a richness of experience and self-confidence. 5) These individuals exhibit neither strong commitment to, nor alienation from the organization but view the organization as a means of professional advancement. 6) Work groups within innovative organizations are subject to the diffusion of uncertainty throughout the organization which provides stimulation to innovate. 7) Status striving within groups is reduced and power is dispersed among group members. 8) Work groups will consist of individuals who perform diverse tasks and who possess professional orientations. 9) Groups may be organized as project teams with individuals holding multigroup memberships. 10) High interorganizational mobility is to be expected.

Wilson (1966) has advanced a number of hypotheses concerning innovation and crisis conditions, the effects of decentralization, the usefulness of participative management techniques, the value of uncertainty, and the importance of professional orientation among members that are consistent with Thompson's observations. O'Keefe, Kernaghan, and Rubenstein (1975) found in their study of scientific work groups that adoption of an innovation by a supervisor who also serves as an information source facilitates the adoption of the innovation by highly cohesive work groups.

In a study of product variation and reorientation in manufacturing firms, Normann (1971) emphasized the importance of goals, values, and power within the organization upon the phases and types of innovations. Political processes which result in consensus formation and cognitive processes through which people in organizations acquire information about the external environment are seen as crucial elements in the innovation process.

Shepard (1967), in his discussion of innovation and innovation resistance in organizations, describes what is basically a political model of innovation. He notes that frequently innovations and innovating units are concealed from the organization's control system during the initiation stage. These concealed efforts take the form of local conspiracies among the innovating unit and its supporters. The innovator and innovating unit must be willing to take risks since failure, which could damage career advancement, may occur. In order to maintain continuing support, the innovator must exercise personal influence upon key individuals. Walton (1975) identified loss of support from higher levels of management as a contributing cause of the ultimate failure of some initially successful innovation efforts.

One area of interest that has generated some controversy concerns the extent to which organizations are encouraged to innovate under conditions of crisis. Shepard (1967) has stated that radical innovations are most readily adopted and implemented in times of organizational crisis and that innovators may induce crisis in order to create conditions favorable to adoption of their innovation. Utterback (1971) concluded that the primary limitations upon organizational innovation within the firm are not costs or technical knowledge, but the firm's ability and aggressiveness in recognizing the needs and demands of its external environment. However, Normann (1971) states that in his study few innovations were emergency actions to protect the company from an immediately threatening situation.

In many cases there was no threat at all and no dissatisfaction, yet some companies introduced significant changes.

Cyert and March (1963) provide a possible explanation for the inconsistent findings by noting that organizations which possess slack resources are inclined to allocate such resources to strong organizational subunits which will seek technological innovations. The results of such innovations may provide increased professional status and prestige for the innovative subunit. Thus, Cyert and March predict that firms may innovate when either successful or unsuccessful. Innovation under unsuccessful circumstances will be problem oriented and aimed at short term difficulties. Innovation under successful circumstances will utilize slack resources and will be only remotely related to any major organizational problem. Therefore, innovation may be proactive as well as reactive in its relationship to the organization's environment.

Rosner (1968), in a study of innovation in hospitals, found that innovation tended to vary directly with the amount of slack resources and inversely with the economic orientation of the hospitals.

Slevin (1971, 1973), through a series of laboratory tests, has investigated conditions under which individuals will innovate. Slevin has concluded that, under experimental conditions, an individual's innovative behavior is related to his current level of successful performance, desired level of performance, the cost associated with innovation, and rewards for successful performance.

Relations between innovation and structural characteristics of organizations constitute a final area of interest to this literature survey. In their study of Scottish and English firms which were attempting to enter the field of electronics, Burns and Stalker (1961) found that those firms which placed less reliance upon formal procedures, encouraged horizontal as well as vertical communication, flexible roles, and active involvement in decision making were more likely to successfully enter the electronics industry than were those firms which were characterized by conventional bureaucratic structures. Thompson (1965) reflects the findings of Burns and Stalker by noting that innovative organizations are characterized by a structure of loosely defined duties and responsibilities, fewer levels of hierarchy, greater use of group processes, multiple group memberships for individuals within the organization, and a high degree of technological interdependence among work units.

Lynton (1969) has considered various ways in which innovative subsystems may be linked to the total organization when the organization exists in a highly uncertain environment and organizational decision makers perceive the need for change to be negligible, temporary, frequent and specific, or continuous and major. Aiken and Hage (1968) found that organizations with many joint programs tend to be more complex, more innovative, have more active internal communication channels and a somewhat more decentralized decision-making structure. Aiken and Hage then hypothesize that organizations characterized by increased division of labor will be more innovative and that the need for resources to support such innovations will encourage the development of interorganizational relations.

Sapolsky (1967) examined three organizational structural variables within the context of a two stage diffusion model. The effects of <u>complexity</u>, as measured by the number of occupational specialties, level of professionalism, and diversity of task structure; <u>formalization</u>, the emphasis on adherence to rules and procedures in job performance; and centralization, the concentration of authority and decision making within the organization's hierarchy, were investigated during the initiation and implementation stages of the innovation process. Complexity was found to be directly related to innovation during the initiation stage, but inversely related to innovation during the implementation stage. Formalization and centralization were both found to be directly and inversely related to the implementation and initiation stages of innovation, respectively. The implication of these findings is that structural characteristics that facilitate the initial stages of the innovation process may inhibit the final stages. Duncan (1976) has developed a contingency model for appropriate structural differentiation in response to various stages of innovation.

A number of implications for this research effort may be drawn from the potpourri of studies described above. It should be noted that the findings discussed above were collected under a diverse set of circumstances through diverse methodologies. Even though the "weight of the evidence" suggests universal applicability of certain hypothesized relationships, such hypotheses should not be taken as axiomatic but corroboration should be sought among appropriate small California firms.

15.4 RESEARCH AND DESIGN METHODOLOGY

The literature suggests that the concept of innovation is complicated and will most likely yield to greater understanding when examined at several social levels simultaneously. Accordingly Table XV-3 identifies four levels of social organization and constructs within each level which may be relevant to the innovativeness of small firms.

Table XV-3

Levels of Social Organization
and Research Constructs

Social Environment
- environmental complexity
- rate of change of environment
- size of organization's domain
- degrees of interaction between organization and environment

Formal Organization
- size
- span of control
- communication volume
- levels of hierarchy
- ratio of administrative-to-operative workers
- specialization/departmentalization
- formalization
- locus of authority
- centralization
- extensiveness of files
- technology complexity
- turnover rate-absenteeism
- financial
- organization culture-history, legal form, goal specification
- environmental complexity-environmental relations

Formal - Informal Group
- task specialization
- role specification
- locus of influence
- cohesiveness
- status
- conflict inter-intra group
- participation
- coalition and clique formation
- organizational climate
- interaction network
- existence of innovative unit

Table XV-3 (continued)

Individual
sentiments toward coworkers
attitudes toward work
job satisfaction
time orientation
physical space
uncertainty perception
attitude toward work group
risk aversion
commitment
personality assessment
anxiety
creativity
task specialization
job content
external contact
quality of life
standard demographics
existence of innovative individual

The specific objective of this study is to identify conditions and relationships among psychosociological constructs that will consistently distinguish innovative and noninnovative small business firms which are presently engaged in energy supply related activities. These firms are the most likely candidates for entry into an emerging distributed technology based energy supply industry since they possess the requisite experience and general operating capabilities to successfully make the transition. If the relations among key conceptual variables that facilitate or inhibit organizational innovation can be better understood, then it may be possible to encourage sufficient infusion of small firms into the new industry more intelligently. Table XV-4 shows a generalized research design.

Table XV-4

Generalized Research Design

Conceptual variables by level of analysis	Small firms presently in conventional energy supply related industry		Small firms in solar-solar derivative energy supply industry
	innovative firms	noninnovative firms	———
Organization constructs			
Group constructs			
Individual constructs			

As indicated in Table XV-4 two broad categories of firms will be studied. These include 1) businesses, such as heating and air conditioning contractors and sheet metal contractors, which are involved in the maintenance and installation of conventional energy supply to end users, and 2) newly established firms or previously existing firms which have made the transition to solar energy supply systems. The concept of innovation may be thought of as the dependent variable.

The independent variables will be distributed among three conceptual levels of analysis including the individual, group and organization. Characteristics of the social environment in which the organization exists are believed to be important determinants of organizational performance. However, a thorough analysis of these environmental characteristics of organizations is beyond the scope of this study. The specific conceptual variables to be included will be selected from the lists of suggested areas of interest shown in Table XV-3.

The decision to conduct a cross-level analysis of factors which might effect organizational innovation rests upon a belief that the concept of innovation is of such complexity that a satisfactory explanation must consider the nature of interaction among the individual, the group, and the organization. Many organizational theorists consider the group to be of fundamental importance in the explanation of organizational phenomenon since the group is the nexus of individual-organization interaction and mediates the relationship between the individual and the organization as shown in Figure XV-1.

Individual ⟷ { Task Group: social aspects, formal aspects } ⟷ Formal Organization

Figure XV-1
Social Linkage within the Formal Organization

One relationship that will be of particular interest is that of successful innovation and successful organizational performance. As Webber (1975) has pointed out, innovation is not always desirable or useful. Success in reaching organizational goals is not necessarily related to successful innovative action. Thus, attention will be given to characteristics of firms which fall into each cell of Table XV-5.

	Successful Innovation	Unsuccessful Innovation
Successful goal attainment		
Unsuccessful goal attainment		

Table XV-5
Innovaltion and Organizational Success

It should be clearly understood that even though the process of innovation has been addressed at length, this research is not a longitudinal study of that process. This is a single-point cross-sectional study of characteristics which differentiate degrees of organizational innovativeness. Thus, correlation techniques, including regression analysis, will be used to investigate strength and direction of relationships among variables and factor analysis will be employed to identify groups of predictor variables.

In order to reduce the conceptual variables to forms that lend themselves to measurement, operational definitions will be developed for all relevant concepts. Three primary methods of data collection will used: 1) mail questionnaires; 2) semi-structured interviews; and 3) records analysis. Wherever practicable, multiple measures will be obtained for a variable through the use of both perceptual and archival data. Questionnaires will rely heavily upon forced-choice Likert-type scales. Wherever possible, existing psychometric scales, for which reliability and validity information is available, will be used in order to minimize the necessity for the development of new scales.

Presently, a pilot study is about to be initiated among approximately twenty Bay Area small businesses in the sheet metal industry in order to pretest the data collection instruments and procedures. Hopefully, the sample of organizations can be expanded to exceed 100 in the second phase of this research in order to facilitate the development of reliable and valid predictors of organizational innovativeness.

Postscript

> ...certain phenomena are "artificial" in a very specific sense: They are as they are only because of a system's being molded, by goals or purposes, to the environment in which it lives. If natural phenomena have an air of "necessity" about them in their subservience to natural law, artificial phenomena have an air of "contingency" in their malleability by environment.
>
> The contingency of artificial phenomena has always created doubts as to whether they fall properly within the compass of science. Sometimes these doubts are directed at the teleological character of artificial systems and the consequent difficulty of disentangling prescription from description. This seems to me not to be the real difficulty. The genuine problem is to show how empirical propositions can be made at all about systems that, given different circumstances, might be quite other than they are.
>
> (Simon 1969:ix)

And so it is with the study of those artificial systems call organizations.

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CHAPTER XVI

SHORT TERM MATCHING OF SUPPLY AND DEMAND IN ELECTRICAL SYSTEMS WITH RENEWABLE SOURCES

The short term matching of supply and demand is a feature of the economic system that is largely taken for granted. For example, wheat is harvested once a year in one region and bread is eaten daily in far away urban areas. This short term matching in time and space relies on a complex network of storage and transportation facilities. Longer term matching is accomplished, with varying degrees of efficiency depending on lag times and other factors, by the feedback mechanism of the market. In some countries, the imperfections of the market feedback mechanism (which is supposed to encourage production and discourage consumption by means of high prices in times of scarcity), has allegedly been improved upon by central governmental planning. For example, in the U.S., natural gas prices are controlled substantially below market clearing prices in the interest of some larger public good. But we are interested in examining how the short term matching over time and space is accomplished in existing electric utility systems and in trying to discover what the problems would be if the sources of electrical energy were all renewable, i.e., solar, wind, and hydro.

Electrical utilities also solve the space and time supplying demand matching problem by a combination of transportation (which they call transmission) and storage. However, electrical energy is unique among commodities in that it is transmitted instantaneously but it is never stored as such. Even battery storage converts electrical to chemical energy and back, and each transformation involves some loss.

The demand for electrical energy is highly variable over time, but a large fraction of this variability is quite predictable because it is periodic, that is peaks recur at fixed intervals daily, weekly, and seasonally. In addition to the predictable periodic component of demand variability, there is superimposed a random and hence unpredictable component. A large part of this random component is driven by weather and takes the form of air conditioning load and cloudy winter afternoon lighting load. Becuase of the time varying nature of electricity demand, investment in generating facilities is usually partitioned into three categories: base load plants are large, energy efficient, capital intensive facilities which the utility would like to operate at least 80 percent of the time; intermediate or cycling facilities which are often older, smaller and less efficient base load plants; and peaking plants (gas turbines are commonly used) which are less energy efficient (30% as compared with 40% for the best base load plants), small, can be rapidly started and brought on line, and have low capital investment per unit of capacity. Hydro electric plants are somewhat different, being capital intensive, extremely efficient, have zero "fuel" cost, but are quick starting. When plenty of water is available, these are operated as base load or intermediate load facilities, but in drought years they are reserved for peak load operation to the extent that diurnal flow fluctuations can be tolerated downstream. The minimum cost operating strategy for such a system is to supply as much of the instantaneous load as possible with low marginal fuel cost plants. The important point is that the instantaneous power production rate must equal the instantaneous demand rate.

The consequence of this requirement for instantaneous match is that the utility must have sufficient generating capacity to meet the peak demand. Because conventional plants are quite reliable (less than 10% forced outage rate) the dominant source of uncertainy is the random nature of the demand and not uncertainty about the available capacity. The storage in the system is predominantly in the form of fuel at the generating plants and water behind the dams.

Because high peak to average demand ratio means that a large fraction of generation capacity is unused a large fraction of the time, the investment in excess capacity can be reduced by load smoothing. One way to do this is to store thermal energy at the site of end use. Such thermal storage is particularly attractive for central air conditioning systems. Presumably, as more electrical energy pricing schemes, such as time varying rates that increase during the peak hours, become more common, load smoothing practices will become economically attractive and hence more widespread.

Another load smoothing strategy is the interconnection of service areas by a transmission grid. This geographic averaging strategy tends to reduce the random component peaks, but it does not do much to reduce the diurnal cycle unless the connected area spans several time zones.

When an electrical energy system relies primarily of solar, wind and hydro sources, however, a significant new dimension enters the problem, namely the large variability in the available instantaneous supply. Both sun and wind sources are highly variable in the short run, being subject to large diurnal and seasonal periodic variations. In addition, both are subject to random interruption by cloudy and calm weather. The random variations are probably more significant for wind than for solar, in comparison with the predictable variations.

There is another kind of variability in weather dependent sources, particularly hydro power. There is considerable evidence that weather patterns undergo pronounced shifts that last for years. Anecdotes in historical traditions (the seven fat and seven lean years, and the little ice age of the late middle ages) as well as records of the Nile River floods and tree ring analysis, support the notion that the world climate may shift among quasi stable states which are characterized by rather different values of average annual rainfall and average annual solar energy received, and that these shifts may occur on a time scale of centuries or decades.

Clearly a mixture of supply sources is one way to smooth out the variations in supply. To the extent that cloudy weather and high winds are positively correlated, wind and solar sources are complementary. Furthermore, long periods of cloudy weather may be accompanied by larger than usual rainfall. At least it is likely that the variations in availability of energy from these three sources may tend to average each other out at least as much as if they were independent random variables.

Still it is clear that even a mixture of weather dependent sources is variable over time in ways that do not match demand variability. The obvious strategy to consider is storage. However, sun and wind cannot be stored as can fuels. To illustrate the magnitude of the storage problem, consider a simple analysis of pumped water storage in comparison with storing fuel. A cubic meter of fuel oil at 6.2×10^6 BTU per bbl. represents 390×10^6 BTU or 34.29 kwh at 30 percent conversion efficiency. This is equal to 12.6×10^9 kg-m of potential energy. To store this energy in a pumped storage with a 100 meter head requires pumping 1.26×10^4 cubic meters of water. Thus the pumped water storage of energy requires 12,600 times as much volume as fuel storage, and that does not account for the energy loss in conversion of electrical energy to potential energy and back. The conclusion is that, while fuel storage facilities represent a very small fraction of the capital cost of fossil fuel generating stations, energy storage will represent a significant investment in a solar and wind based system. Furthermore, the variability in the solar and wind energy flux implies that the capacity utilization ratio of these facilities will necessarily be low; in other words the ratio of installed capacity to average demand will probably be higher than is the case for existing conventional generating systems.

CHAPTER XVII

VULNERABILITY OF RENEWABLE ENERGY SYSTEMS

17.1 INTRODUCTION

In this section we review the types of energy sources that are emphasized in the California distributed energy futures in terms of the types of interruption to which they may be vulnerable.

Vulnerability refers to the degree to which an energy supply and distribution system is unable to meet end-use demand as a result of an unanticipated event which disables components of the system. The kinds of events referred to are sudden shocks, rare, and of large magnitude. It is not possible (at least not easy) to compute the probability of occurrence of such events from statistical analysis of data. The events of interest in the theory of reliability, by contrast, are random failures of individual components, the probabilities of which may be estimated from life testing experiments.

Given the configuration of the energy system, its supply and demand points, the links in the distribution network, and the capacities of all the components, it is possible in principal to compute the severity of the impact of any particular catastrophe, provided one can specify the duration of the outage of each component. However, because the probabilities of all possible catastrophes cannot be determined, it is not possible to compute a general measure of system vulnerability as defined here.

It is not even possible to compare the vulnerability, in general, of different systems. The nature of the difficulty is, of course, that the relative vulnerability of different systems is dependent on the nature of the catastrophe. Consider, for example, the comparison between pipelines and tank trucks using highways to distribute petroleum. The pipeline network contains fewer parallel links than the highway net in California, and has less excess capacity for carrying fuel. Therefore, it is more vulnerable to disruption by earthquake. However, it is less vulnerable to a teamsters union strike. BART is more vulnerable to strikes and failures of electrical supply than private autos, but less vulnerable to smog emergencies and oil embargos. Roof top solar collectors to provide building heat are less vulnerable to most catastrophes than, say, a system of gas-fired heaters, but are more vulnerable to a major shift in climate in the cold, cloudy direction. These examples suggest that centralized systems are not necessarily more vulnerable to all kinds of catastrophes than decentralized systems.

17.2 THE CHARACTER OF RISK

The character of risk associated with renewable energy forms differs qualitatively from risk associated with traditional non-renewable energy forms. These differences are of such a fundamental nature, and affect energy system design so profoundly, that traditional ways of thinking about risk and reliability require refinement.

The essential features of this difference are easily stated. Traditional energy forms derived from oil, gas, coal, or uranium can be made arbitrarily reliable by sufficient attention to technical characteristics of the systems. Because the basic energy sources are present in known locations (at least until depletion sets in), technology can be used to provide a continuing stream of energy in the form of electricity, gas, oil, etc.

Renewable energy forms are flux sources. They are present only so long as the flux of energy is not interrupted. Because there will always be events which interrupt the energy flux for greater or less periods, reliability is achievable only through introduction of energy storage. In contrast to the traditional energy forms, storage is an intrinsic rather than a derivative component of the energy system. This fact also means that energy system reliability is intrinsically linked to fluctuations in a far more fundamental sense than is the case with conventional systems.

There are certain types of vulnerability that apply to solar-based renewable energy forms as a class. These are interruptions in the solar flux reaching the collector. Long term changes in the opacity of the earth's atmosphere of the sort discussed by Kenneth Watt* are examples of this sort of interruption. The problems of weather-dependent renewable resources are discussed in more detail in Chapter XVI.

The time constant for such interruptions can be quite variable. A solar system for a building might be sized to provide energy storage for a few days or weeks. Some systems, such as ACES (Annual Cycle Energy Storage) could withstand longer interruptions. (Such a system would, however, be thrown out of equilibrium by an interruption of solar flux for a period comparable to its storage time, and might take a considerable period to get restarted, because the heat capacity used for thermal storage would have to be recharged.)

Energy systems relying on certain types of biomass have fairly long intrinsic time constants. Forests, for example, are relatively immune to variations which last a few years, because the growing time is measured in number of years.

Solar and wind heating systems can be designed for fluctuations in weather which we can predict. They are virtually impossible to design for the unforeseen; and some low likelihood events are in fact foreseeable. Kenneth Watt* has described the collapse of the grain market in England in 1815 for several years following a major volcanic explosion, Tambora, in the Dutch East Indies. This led to darkening of the skies throughout the world. A solar system is vulnerable to such disruption, despite our inability to perform calculations relating to the probability.

At issue here is the importance of designing our total energy system to allow for contingencies. Because it is clearly impossible to maintain reliability under every conceivable situation, one must rather recognize that disruptions will occur, and arrange that the resulting

*Kenneth E.F. Watt, <u>The Titanic Effect</u>, Stanford, Conn.: Sinauer Associates, 1974.

dislocations are not excessive. This is of course what we normally do in many areas. We expect (in snow country) a few storms each winter which will shut our schools down. A few extra days are often allowed at the end of the year as snow make-up days.

A similar philosophy appears eminently suitable for an energy system. A city (or other unit) might establish its own criteria for reliability. A calculation would present information on the cost of various levels of reliability for a district solar heating system. At modest cost, climate conditioning could be provided on, say, 95 percent of all days. At slightly higher cost it could be provided on 99 percent of all days. And at very high cost it could be provided on 99.9 percent of all days. Associated with the supply reliability data would be data on the inconvenience associated with loss of climate conditioning. Well-insulated buildings do not become very uncomfortable when energy supply fails. After public discussion of costs and benefits, a design decision would be made.

None of these would provide complete reliability. For each choice, there would be some probability that the system would, at some time and for some period, fail. The consequences to the user of such failure are, of course, critically dependent on the exact details of the system. One example is illustrative. A well-insulated home might be relatively comfortable even in the total absence of heat, while a poorly insulated home would exhibit large temperature swings, drafts, etc.

17.3 CLASSIFICATION

We identify several ways of classifying the types of external events which can disable energy systems:

Natural: earthquake, flood, storm, fire

Hostile and violent acts of humans: riot, war, sabotage

Human error: loss of coolant accident, plane crash

Government: injunction, pollution control emergency, revocation of permit

Economic motives: strike, lock-out, embargo, monopolistic supply hold-back.

Within these catastrophes we discuss a number of different types of events and event interaction.

Traditionally, energy supply systems have been designed so as to meet the most stringent needs. All inferior needs are automatically satisfied when the most stringent need is met, though at a cost. We have found it convenient to categorize reliability requirements on a logarithmic time scale. In the following table are listed some illustrative examples of reliability requirements for electrical energy:

Table XVII-1

Time Scale of Failure	Example of Problem Area
$<10^{-2}$ hours	Computer, clock, operating room lights
10^{-2} - 10^{0} hours	Television (during prime viewing time), elevator, electric stove, iron lung
10^{0} - 10^{1} hours	Refrigerator, freezer, lights
$>10^{2}$ hours	Heating system

These examples are among the simplest. They are dependent upon climate, personal taste, time of year, time of day, etc. A clock that fails for a few minutes may not matter much, unless one has to catch a train or airplane. A heating system could be out for days with no inconvenience in a moderate climate, but could lead to trouble in a fraction of a day in a cold winter with a badly insulated house. Failure of a heating system during the weekend in a commercial building might produce no inconvenience, but during the week could be a problem. An elevator failure of a few minutes' duration is likely to produce only emotional stress, whereas a failure for a few hours might lead to real hardship. On a time scale of days, presumably everyone trapped in an elevator will have been rescued, so past a certain time of outage, longer delay does not have proportionally increased consequences.

Industrial processes require reliability covering the full scope of times, from reliability of a few seconds for computers, to minutes for certain types of crystal growing furnaces, to fractions of a day for heat treating systems with long time constants.

In critical applications it is already routine to provide back-up systems. A few examples illustrate present practice. Computer power supplies use capacitors to provide smoothing over periods of seconds. For critical applications batteries can cover hours. Hospitals have motor-generator sets to cover outages, and these often use dynamic energy storage (flywheels) to provide coverage during the period between failure of an external source and start-up of the back-up generator.

In many instances ingenuity comes into play, and short term failure does not cause serious inconveneince. Today transistor radios and television are widely available, and can be used to follow new events in the event of a power failure. This occurred during the New York City blackout, for example. Cooking can be done on camp stoves if failures are thought to be of long duration. Other systems cannot readily be backed up, and shut-down is the only route open. This is generally the case in commercial buildings and with industrial processes.

If the time variation of an energy system is known (statistically), then a storage system can be built which will provide any specified level of reliability. Overall reliability can be increased by coupling together sources separated geographically. This will work best if geographically separated systems are not correlated in their energy output. In fact, however, such correlations are likely. Thus, consistent, calm weather over much of California often occurs, which would inactivate all wind systems. Similarly, long periods of foggy weather could affect even widely separated solar collectors.

This type of effect can be analyzed quantitatively, but only if one is convinced that the data on which analysis is based are sufficiently reliable. For long term system design this situation may very well not obtain.

An interesting example is water flow data used in the analyses upon which the Colorado River Compact of 1927 was based. It was recognized that river flow varies substantially from year to year. Thus the compact was written to allow for averaging over a number of years. What was not realized was that the decade prior to the compact had shown abnormally high water flows, by as much as a million acre feet per year. The fact that flows have been below the values used in the compact for most of the years since it was written has given rise to some of the most difficult and complex water battles ever waged.

Another classification scheme deals with which components of the system feel the effects of a particular type of interruption: individuals, those in a geographic area, or a class of components. For example, a teamsters strike will disable truck transportation links, while an air pollution emergency will shut down fuel burning plants in a particular air basin.

The catastrophic event may result in destruction of components or their temporary disablement for a time depending on the severity and nature of the event. The immediate consequence of the catastrophe is that some components suddenly quit operating, which may trigger further failures. As a result, the system may fail to supply all of the end use energy demand that it otherwise would. The seriousness of the impact of a particular catastrophe may be measured by the amount of unsatisfied energy demand. By this measure, a 10 kw customer is 10 times as important as a 1 kw customer, and a 10 kw shortage that lasts for an hour is equivalent to a 1 kw shortage for 10 hours. This measure is not egalitarian, but it does suggest that the consequences of a failure to supply a large industrial user that employs many people is more serious than a supply failure in a small retail store.

"Common mode" failures are much discussed in analyses of technical systems, especially reactor systems. These are failures in which a defect in one component affects several chains. Thus, for example, two independently operated emergency valve systems do not provide redundance if both are operated from the same electrical supply system.

Renewable energy systems are vulnerable also to common mode failures. In a sense, the example discussed above of decreases in solar insulation due to volcanic ash is a common mode failure. Other examples are:

- Crop disease	Affects monocultures.
- Seasonal variation of wind	Affects wind machines, even if they are built into a grid. Magnitude of the effect depends on the size and scope of the grid and the associated storage system.
-Drought	Affects hydro systems, availability of cooling water. Time constant likely to be one year or more.

Sabotage of renewable energy forms appears not to have been extensively discussed. Large, centralized solar systems are likely to be susceptable to roughly the same sort of organized attack as are other energy systems. Some of the more exotic systems (e.g., outer space arrays) are probably intrinsically subject to total destruction by a single attack by a group with the technical wherewithal to reach the target.

Small-scale solar systems are, like all systems, vulnerable to interruption. Because there is no possibility of affecting large groups of people by a single attack, the total societal disruption of a single event is small. Biological systems relying on monoculture are, perhaps, subject to concerted biological attack in much the same way as are oily water systems. In all situations we can identify that there are long intrinsic delays between the time of the attack and the response of the biological systems. This absence of immediate publicity may deter all but the most intrepid attackers. (Although, it must be noted, computers have been subject to delayed action attack. The New Yorker of August 1977 reported an instance of a disgruntled computer company employee who instructed a computer to erase records two years after the employee had left the firm.)

17.4 CONCLUSIONS

While comparisons of vulnerability cannot be readily made among systems of widely differing character, there are some valid general statements about alternative configurations of a particular system. For example, it seems clear that we can reduce the vulnerability of a system if we can increase the fraction of its capacity that survives a catastrophe. A number of strategies suggest themselves for accomplishing this goal:

1. Redundancy or provision of extra capacity, in the form of larger units, extra units, or additional links in the distribution network.
2. Replacement of large units with more and smaller ones, without increasing total system capacity.
3. Geographic dispersion of supply points within the net.
4. Fuel diversity of energy sources.
5. Technological diversity to reduce dependence on a single critical material or labor union.
6. Storage of energy, fuel, critical materials, spare parts, etc. If energy storage is provided near demand points, it not only protects against supply point failures but also against network link outages.

Because the relative vulnerability of different systems is strongly dependent upon the type of catastrophe, and because there are formidable difficulties in the way of assigning relative importance weights to different types of catastrophes, it does not seem that a general systems vulnerability measure is easily computed. What can be done is to compute the vulnerability reduction, in the face of a specified set of catastrophes, of proposed modifications of a particular system. (Estimating the benefits from this reduction of vulnerability and the associated costs of attaining it is another matter.) Furthermore, it appears that the vulnerability of a particular system to a particular, well-specified catastrophic event can be calculated, and the relative vulnerability of different systems to the same type of catastrophe can be estimated, at least qualitatively. These directions appear promising for further research.

CHAPTER XVIII
DISTRICT HEATING FOR CALIFORNIA*

18.1 INTRODUCTION

Densely populated urban areas present special problems for the use of "soft" technology to meet energy requirements. Some form of centralization, capturing potential economies of scale, seems necessary to distribute energy under high density conditions. In this paper we examine two potential solutions to this problem for California conditions. We will look at centralized district heating which uses waste heat from power generation and neighborhood solar sub-grids. The former approach is more strongly centralized, more rigid and less resilient with respect to exogenous disturbance. The latter concept, the solar sub-grid, decentralizes the district heating idea and substitutes an income energy source for an energy capital resource. In both cases, the energy supplied for residential and commercial space and water heating is thermodynamically matched to the load. It is relatively low in temperature (∿100°C). Neither scheme matches supply of energy with demand in a strict geographic sense. This kind of matching is very difficult in high population density regions since the pressures on land are severe.

The capital requirements for each scheme are large. It is unlikely that full blown district heating or even the neighborhood solar sub-grid could ever come about through private sector initiative. There must be full connection of all customers, a mandate for raising the funds and access to capital markets for either scheme to occur. These problems suggest that either solution to high density energy supply needs will come through public initiative and with public finance. The decision to opt for one alternative as opposed to another requires analysis of the costs, risks and uncertainties. In any case, the land use pattern required by either supply plan

*The author is grateful to Melvin K. Simmons for help with solar resources estimates and David Goldstein for advice concerning passive solar performance.

permits only limited flexibility once the investment has been made. Amortization of the capital involved will require many years. Because many costs are fixed the choice of one system or another will tend to foreclose the possibility of change further down the road. As we shall see this problem is somewhat more severe for centralized district heating than for the solar sub-grid.

To assess the flexibility of district heating and solar sub-grids, we will analyze changes in the unit heat charge as a function of various crucial parameters. The unit heat charge is the cost per million Btu (MMBtu) of useful energy. Today's cost of natural gas is about $1.70 per MMBtu. Used for space heat with a furnace efficiency of 65 percent, the unit heat charge is actually $2.62/MMBtu of useful energy. Electricity at four cents per kilowatt-hour is equal to $11.70 per MMBtu.

It is instructive to divide the unit heat charge into fixed and variable costs. Fixed costs are associated with investments which must be made regardless of the demand level. Variable costs fluctuate with the level of energy required. An example of a fixed cost is the distribution system for energy. Capital invested in gas mains, electricity distribution lines and substations, or district heating hot water mains must be amortized regardless of the utilization rate of the facility involved. Fuel costs are an example of a variable cost. In conventional thermal power plants the cost of electricity produced is a function of the fuel required per kilowatt-hour; that is variable.

Our analysis will show that centralized district heating costs are dominated by fixed charges, primarily for hot water mains. The solar sub-grids with variable storage and collector requirements are more flexible to changes in demand levels. It is not realistic to consider the demand for low temperature heat an exogenous invariant quantity. Demand for space heat is a function of both building envelope characteristics and "passive" storage capability. Water heating requirements are sensitive to water conservation policy. Yet energy systems with long lifetimes must be built with an expected level of demand in mind. Especially in cases where a large portion of the capital investment is in fixed costs, demand projections have a crucial impact on the planned unit energy costs of the project. If demand fails to meet projections, then unit energy costs must be increased to satisfy the revenue requirements associated with capital amortization. Analysis of such phenomena has been done for the electric utility industry (Kahn 76). We will see similar results in our study of district heating.

Two other variables are critical in the analysis of high-density, low-temperature heat requirements. These are climate and population concentration. As a rule of thumb, it is intuitively clear that district heating will be more economically attractive where heating loads are high and population density is high. The simple reason for this is again that the fixed costs are divided over a broader base. Thus our analysis shows that centralized district heating looks more economic for San Francisco than for Los Angeles because the former is both denser and colder than the latter.

18.2 ENERGY REQUIREMENTS

We calculate the annual low-temperature energy requirement for residential and commercial floorspace in San Francisco and Los Angeles in three cases. Our base case is a strong conservation scenario in which all buildings are heavily insulated and double-glazed. Next we estimate the impact of passive solar design on external energy requirements. Finally, the impact of a 25 percent reduction in hot water use is calculated.

Our analysis of space heating energy requirements is based on results presented in Table XVIII-1. They are taken from LBL (1976). This table shows annual kilowatt-hour requirements in four climates for various levels of insulation and glazing. It is straightforward to convert these data into unit heat requirements. For example, consider the Los Angeles Airport area and a single family (1450 ft^2) dwelling with double-glazing, R-18 walls and an R-30 ceiling. Table XVIII-1 says the annual energy requirement for this house is 2500 kWh. We convert this to Btu/ft^2/degree day using 2015 degree days for Los Angeles. The result is 2.92 Btu/ft^2/dd (=(2500 kWh x 3413 Btu/kWh)÷(1450 ft^2 x 2015 dd)). We will assume that half the housing in each area is single family type and half is multi-family units. Within each cate-

Table XVIII-1

Our Estimates of Heating Energy Requirements

Single Family Detached House, 1450 ft^2, Resistance Heat 70° Thermostat

Insulation	Travis	Oakland	Burbank (kwhr/yr)	Los Angeles (Airport)
None	27,750	31,200	19,300	15,700
R-19 Ceiling Only	18,750	20,550	12,350	10,000
∿R-7 Ceiling and Walls	∿12,000	∿12,500	∿7,000	∿6,000
Current State Code: R-11 Walls, R-19 Ceiling	10,400	10,200	5,800	4,900
Current Code Plus Double or Storm Windows	7,200	6,400	3,500	3,100
Double Glaze, R-11 Walls, R-30 Ceiling	6,700	5,900	3,100	2,800
Double Glaze, R-18 Walls, R-30 Ceiling	6,100	5,100	2,700	2,500

Multi-Family House or Townhouse, 1100 ft^2, Two-Story Building, Interior Unit; 70° Thermostat, Resistance Heat

Insulation	Travis	Oakland	Burbank (kwhr/yr)	Los Angeles (Airport)
None	15,100	14,250	8,500	7,100
R-19 Ceiling Only	11,500	10,250	5,800	4,800
Current State Code: R-11 Walls, R-19 Ceiling	6,500	4,750	2,300	2,150
Current Code Plus Double or Storm Windows	4,700	2,800	1,150	1,300
Double Glaze, R-11 Walls, R-30 Ceiling	4,500	2,600	1,100	1,150
Double Glaze, R-18 Walls, R-30 Ceiling	4,150	2,250	900	1,050

gory we assume double-glazing, R-30 ceiling and half R-11 walls, half R-18 walls. In Table XVIII-2 we show the average energy required for space heat on a Btu/ft^2/degree day basis. For our analysis of the Los Angeles region, we rely on an assessment of district heating made by Brookhaven National Laboratory (Karkheck, 76). This study found that a region of Los Angeles covering about 71 square miles and containing 933,000 people was feasible for district heating. We will analyze this study in greater detail, as well as a version of it which appeared in Science (Karkcheck, 77).

Table XVIII-2 also contains estimates of energy requirements for space heating in commercial buildings and hot water heating requirements in both the commercial and residential sectors. For commercial space heat, we use the average residential unit requirement (in Btu/ft^2/dd) and our basic allocation of 143 ft^2 per capita for commercial floorspace. Thus the commercial requirement is 36 percent of the residential requirement (.36 = 143/400). Our estimate of water heating is based on 20 gallons per day per capita of 140°F water in the residential sector. For commercial hot water use, we scale again by floorspace. It is interesting to note that hot water requirements in the base case dominate space heat requirements in Los Angeles (73% of total low-temperature energy). In San Francisco the two are nearly equal in the base case.

Finally, Table XVIII-2 contains estimates of annual energy requirements with passive solar design for space heat and moderate water conservation. Although the performance of passive design is not widely understood nor the detailed performance of such houses well documented, there is evidence which suggests that a substantial part of the heating load could be supplied by heat storage in the thermal mass of a passive building. For our analysis we argue that this can be modeled by reducing the balance point for degree day calculations to 55°F from 65°F. This will reduce the heating degree days by about 80 percent for each climate. Our hot water conservation estimate is based on a 25 percent reduction from the 20 gallon/day/capita estimate in the base case. The lowest total demand for low-temperature heat comes in the passive solar plus water conservation case. For Los Angeles this is 60 percent of base case demand; for San Francisco it is 48 percent of base case demand.

Table XVIII-2

Annual Energy Requirements for Low-Temperature Heat
Base Case

	San Francisco	Los Angeles
Average Unit Requirement for Space Heat	3.64 $Btu/ft^2/dd$	2.19 $Btu/ft^2/dd$
Degree Days/Year	3,080	2,015
Population Considered	677,000	933,000
Total Residential Space Heat Requirement	3.04 x 10^{12} Btu	1.65 x 10^{12} Btu
Commercial Space Heat Requirement (=36% of residential)	1.09 x 10^{12} Btu	.59 x 10^{12} Btu
Water Heat - Residential 20 gallons/day/capita heating water from 60°F to 140°F	4.67 x 10^{12} Btu/ capita/year	
Total Residential	3.16 x 10^{12} Btu	4.36 x 10^{12} Btu
Commercial Hot Water Requirement (=36% of residential)	1.14 x 10^{12} Btu	1.57 x 10^{12} Btu
TOTALS (Base Case)	8.43 x 10^{12}	8.17 x 10^{12} Btu
Passive Solar	5.13 x 10^{12} Btu	6.38 x 10^{12} Btu
Passive and Water Conservation	4.06 x 10^{12} Btu	4.90 x 10^{12} Btu

18.3 CENTRALIZED DISTRICT HEATING

In this section we rely upon the methodology used in the two BNL studies cited above (Karkheck 76, 77). These studies develop estimates of the sizing, length and cost of hot water distribution mains for district heating. In Figure XVIII-1 we reproduce the BNL map of population density by census tract in Los Angeles. Figure XVIII-2 shows the proposed hot water transmission plan. Table XVIII-3 summarizes cost and sizing data for the proposed Los Angeles system. Using this data BNL calculates the revenue required to amortize the capital investment in the district heating system. They use a 50-year lifetime and 10-percent interest rate which is reasonable for public finance. The unit heat charge then is simply the annual revenue required divided by the total heat load.

There are several limitations to the BNL approach. We have already touched on one of these, the annual heat load. Table XVIII-3 shows 10.6×10^{12} Btu/yr required for space heat and 17.8×10^{12} Btu/yr for both space and water. Our estimate of space heating requirements is about 20 percent of the BNL estimate. The discrepancy is due to two factors. First, BNL used national average heat loads which include many cold climates. Second, we factor in significant conservation over the time frame of our study while BNL assumed existing levels of thermal integrity. Our assumptions will raise the unit heat charge considerably above the $1.73-$1.82/MMBtu derived by BNL.

There are other costs for district heating systems which were not considered by Karheck. First, there is the problem of the single heat source. In the 1976 report this is considered to be a fusion reactor. The Science article considers light water reactors. In either case BNL has neglected the basic fact that power generators experience considerable periods of shutdown for maintenance, repairs or re-fueling. A typical estimate of LWR capacity factors is 65 percent, while experience to date puts the figure closer to 55 percent. The problem with a single heat source for district heating is that the demand for hot water is continuous. There must be an alternate supply source to handle the load during outages of the power generator.

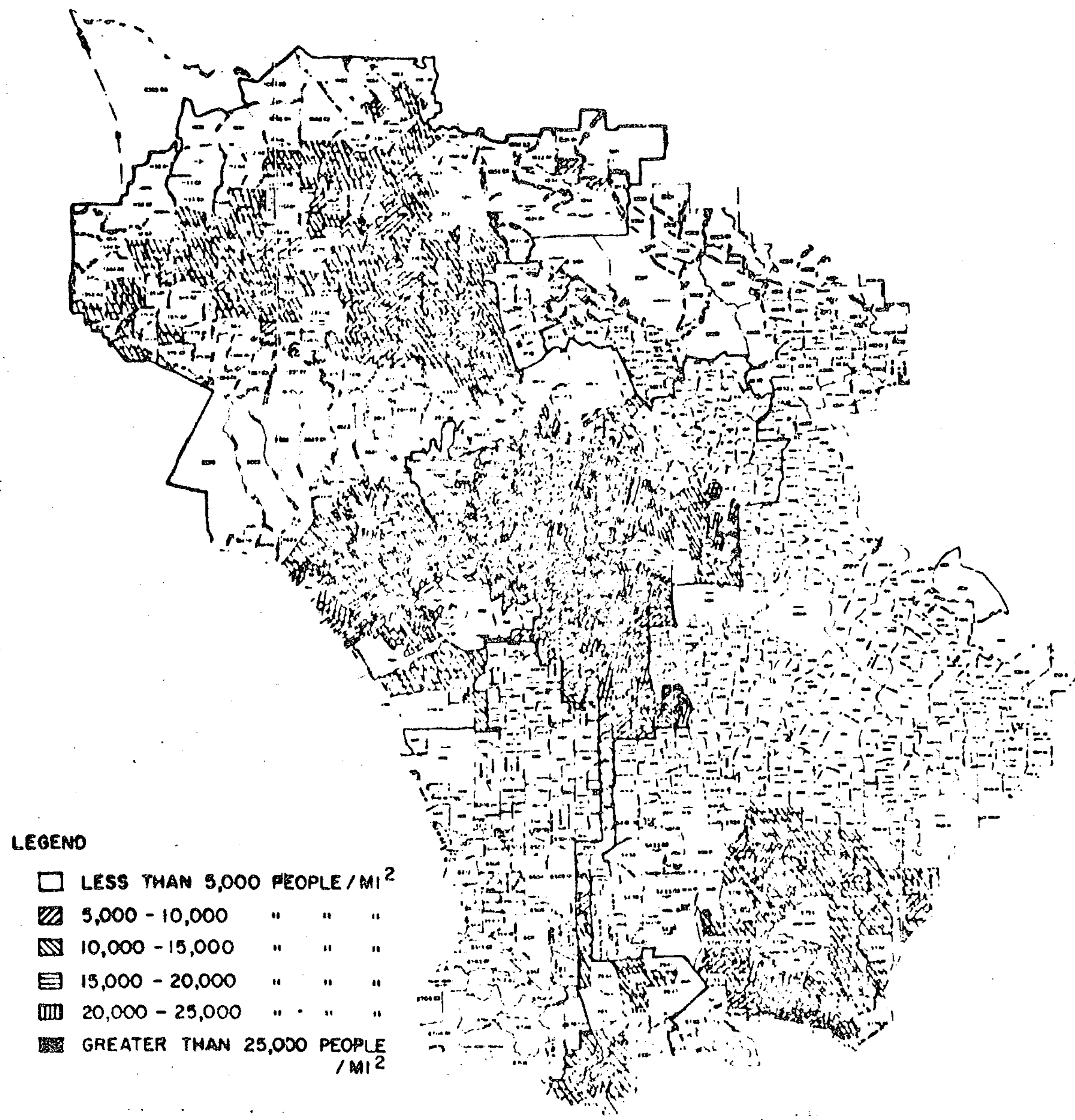
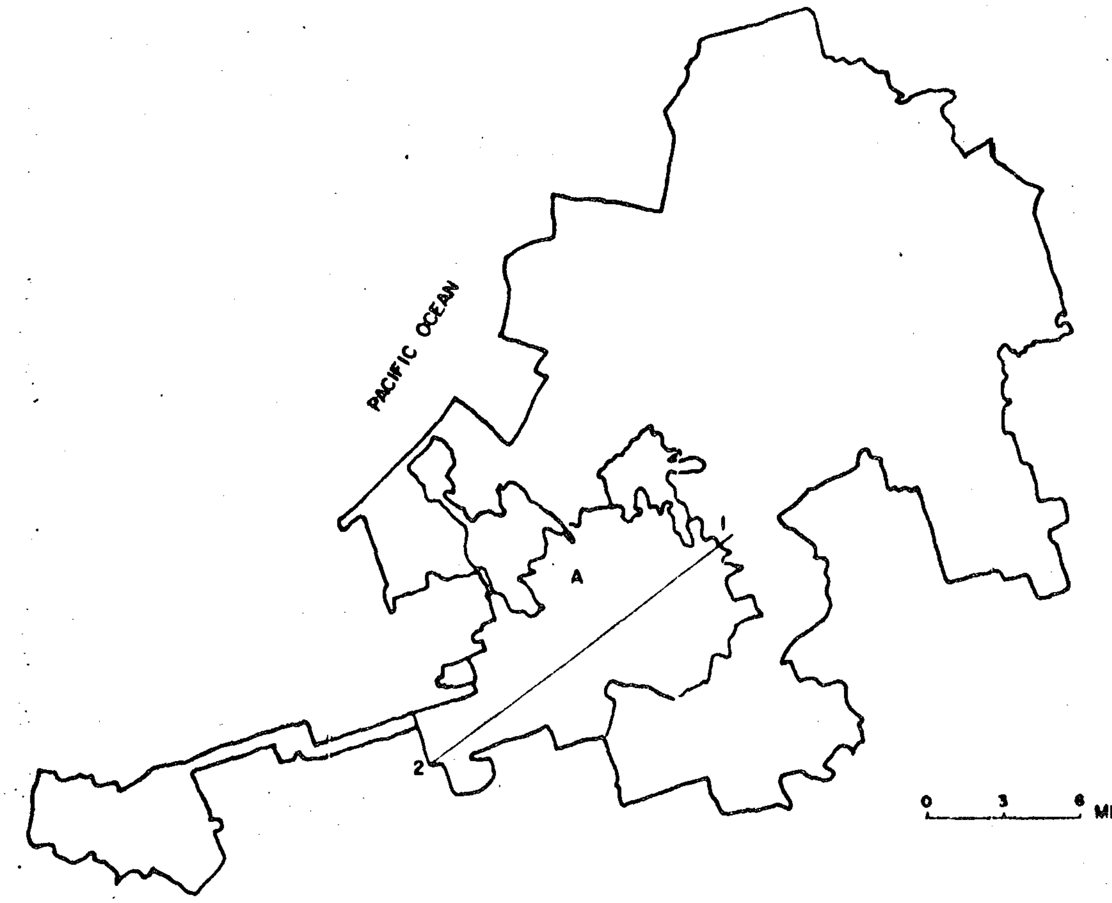


Figure XVIII-1. Census Tracts of Los Angeles



LINE	LENGTH
1-2	14 MI

SECTION	AREA MI^2	POPULATION	POP. DENSITY PEOPLE/MI^2	HOUSING (APT)
A	70.7	932,900	13,200	50 %

Figure XVIII-2. Los Angeles Transmission Plan, Population and Housing Profile

Table XVIII-3

Los Angeles Regional Summary

1.	POPULATION SERVED, THOUSANDS	932.9	
2.	AVERAGE DENSITY, PEOPLE/SQ. MILE	13200	
3.	CLIMATE	12°F	
4.	DURATION OF HEATING SEASON	168 days	
5.	HEAT LOAD, Btu x 10^{12}		
	SPACE HEAT	10.6	
	SPACE & WATER HEAT	17.8	
6.	DESIGN CAPACITY, GAL/HR x 10^6		
	SPACE HEAT	4.2	
	SPACE & WATER HEAT	6.3	
7.	NUMBER OF BLOCKS HEATED		
	HOUSE - POPULATION, THOUSANDS	9725 - 466.45	
	APT - POPULATION, THOUSANDS	6200 - 466.45	
	COMML	1050	
8.	RURAL TRANSMISSION LINE @ 4 PSI/MI. PRESSURE DROP		
	INSIDE DIA., IN.	58	
	UNIT COST, \$/MI. x 10^6	1.75	
	LENGTH, MI. (SITE)	22 (Malibu)	
9.	CITY TRANSMISSION SYSTEM @ 4 PSI/MI. PRESSURE DROP		
	SEGMENT	1-2	
	INSIDE DIA., IN.	58	
	UNIT COST, \$/MI. x 10^6	2.5	
	LENGTH, MI.	14	
10.	DISTRIBUTION SYSTEM @ 1.5 PSI/MI. PRESSURE DROP	Ordered	Random
	I.D. (IN.)/UNIT COST (\$ /MI. x 10^6)/LENGTH (MI.)	12/.265/52.5 8/.185/310 6/.155/972.5	6/.155/1697.5
11.	TOTAL SYSTEM COST, \$ x 10^6	296	337
12.	PUMPING POWER, % OF POWER SUPPLIED		
	COMBINED SUPPLY	1.8%	
13.	CONDUCTION LOSS, % OF POWER FLOW/TEMP. DROP		
	COMBINED SUPPLY	8.8%/7.5°F	

There are several possibilities for dealing with this problem: standby boilers, additional transmission to other power generators or transmission to sources of industrial waste heat or storage. To quantify this additional cost we choose to double the proposed length of city transmission lines on the assumption that additional supplementary waste heat will be available in relatively close proximity to the district heating system.

The second neglected cost factor is the value of heat supplied to the district. The BNL 1976 study assumes this is a free good. The 1977 version considers the penalty in reduced electric output incurred by raising the steam outlet temperature to the level necessary for district heat (about 100°C). They estimate this penalty at about 10 percent. It is not clear, however, that this cost is fully allocated to the unit heat charge. Because LWR's are the assumed power generator, BNL argues that the incremental fuel charge is small (about 14¢/MMBtu). Yet such an approach neglects the capital charge associated with decreased LWR electrical output. If we were to assume that 10 percent of the price of electricity should be allocated to district heat, then at current costs of 4.5¢/kWh, the heat charge would be $1.32/MMBtu. This is a conservative assumption in light of Swedish experience which shows that 1/7 of the kilowatt-hour costs are attributable to district heat (Larsson, 77). The Swedish figure might be too high for California conditions since the amount of heat supplied is more substantial in the Swedish case. Therefore we will use the $1.32/MMBtu as a charge for heat.

Finally, BNL makes no allowance for maintenance expenditures. In seismically-active regions hot water pipes can be expected to require repair. Indeed, centralized district heating is vulnerable to disruption on a massive scale in a major earthquake. The reason for this is, of course, the exposure of the transmission lines to breakage. With only one or two possible heat sources, the risk is significant. We will see that decentralized solar sub-grids are less vulnerable in this respect because of the multiplicity of heat sources. For the purposes of our cost estimates, we will use the Swedish estimate of maintenance charges which is two percent of capital investment per annum (Larsson, 77).

Table XVIII-4 presents capital cost estimates and unit heat charges for centralized district heating in Los Angeles and San Francisco. The capital costs for Los Angeles follow the BNL data in Table XVIII-3 corrected for additional transmission. For San Francisco we scale the number of miles of transmission and distribution to the Los Angeles ratio of miles of line per square mile of district heating. Table XVIII-4 shows that unit heat charge increases with conservation as we would expect. In both systems the base case is about $3.60/MMBtu cheaper than the most severe conservation case. The percentage increase is greater for San Francisco because the base case is about one-third cheaper than for Los Angeles.

18.4 NEIGHBORHOOD SOLAR SUB-GRIDS

Lovins argues for a decentralized approach to district heating using solar energy (Lovins, 77). There is considerable latitude in the definition of what constitutes a neighborhood; the range is from 10 to 1000 people. For our purposes we will assume the higher figure. The basis for this assumption is that there are economies of scale associated with the backup systems required in solar sub-grids. Storage and/or garbage incinerators as a backup to solar collectors are cheaper in larger sizes. We will quantify this in our analysis of the unit heat charge associated with various demand levels. It is clear that there are several complicated tradeoffs involved in designing decentralized district heating. Among the variables are the size of the neighborhood to be served, collector-to-storage ratio, and the degree of reliance on alternate backup. We will analyze one combination that represents only a single possible solution to the problem of optimizing such systems. We will show that our approach is cheaper than some alternatives, but we do not claim that ours is the optimal design. Indeed, it is typical of "soft" energy systems that subtle and complex design problems must be solved for efficient utilization of resources. Hopefully an attempt to grapple with concrete data will illuminate some of the subtleties involved.

Table XVIII-4

Centralized District Heating Capital Requirements and Unit Heat Charge

		Los Angeles	San Francisco
1.	Rural Transmission	$ 38.5 x 10^6	$ 22.00 x 10^6
	City Transmission	70.0 x 10^6	45.00 x 10^6
	Distribution	263.0 x 10^6	167.00 x 10^6
		$371.5 x 10^6	$234.00 x 10^6
	Annual Revenue Required	$ 37.47 x 10^6	$ 23.60 x 10^6
	Maintenance Cost	7.43 x 10^6	4.68 x 10^6
2.		$ 44.90 x 10^6	$ 28.28 x 10^6
3.	Base Case Energy	8.17 x 10^{12} Btu	8.43 x 10^{12} Btu
4	(= 2/3)	$5.50/MMBtu	$3.35/MMBtu
5.	Waste Heat Charge	$1.32/MMBtu	$1.32/MMBtu
6.	Total Unit Heat Charge	$6.82/MMBtu	$4.67/MMBtu
7.	Passive Solar Case Energy	6.38 x 10^{12} Btu	5.13 x 10^{12} Btu
8.	(= 2/7)	$7.04/MMBtu	$5.51/MMBtu
9.	Unit Heat Charge (= 8 + 5)	$8.36/MMBtu	$6.83/MMBtu
10.	Passive & Water Conservation Energy	4.90 x 10^{12} Btu	4.06 x 10^{12} Btu
11.	(= 2/10)	$9.16/MMBtu	$6.97/MMBtu
12.	Unit Heat Charge	$10.48/MMBtu	$8.29/MMBtu

The basic design approach we take is to use active solar systems (collectors plus storage) to meet the neighborhood heat load and distribute energy via hot water mains. Each neighborhood will be independent of others, so investment in a fully interconnected distribution and transmission system will be unnecessary. There is a risk aversion benefit to lack of interconnection, namely, protection from massive common mode failure. We have already observed that centralized district heating systems are exposed to seismic interruption. The decentralized approach with its diversity of heat sources does not bear the risk of universal supply disruption. Because of decentralization all investment in transmission is unnecessary. The savings in distribution mains will be modest—we estimate 15 percent. For smaller neighborhoods, the distribution savings will be greater, but this economy is limited.

The design philosophy of the storage and collector system is not based on the 100 percent load concept. Although Lovins has argued for 100 percent solar buildings, it is easy to show that garbage incineration for peaking loads is less expensive. Of course, this kind of argument is critically dependent on the cost data used. We look at installed costs for steel water storage tanks which are higher than some other approaches using poured concrete. The latter are much harder to adopt to a retrofit mode. Since our estimates of collector costs are somewhat optimistic, conservatism on storage costs is a reasonable balance. In Table XVIII-5 we calculate collector and storage requirements for our various cases. Roughly speaking, in the base case, four or five days storage for hot water needs requires as much energy (and volume of water) as one day storage for space heat. Therefore we size our storage systems to handle all of the hot water load for the longest period of consecutive cloudy days (4 or 5 days), but only one day of storage for space heating. The remaining space heat backup will be provided by garbage incinerators. Roughly speaking, the cost of using storage for all backup would be double the cost of our limited design, while the incinerator cost is only about 15 percent of our storage investment. Swedish experience with district heating shows that peaking requirements are best met with standby units, rather than other methods.

Table XVIII-5

Collector and Storage Requirements for Solar Sub-Grids

Solar Resource

Los Angeles: .19 MMBtu useful heat/ft^2 of collector

San Francisco: .16 MMBtu useful heat/ft^2 of collector

Collector Requirements (= Annual Energy/Solar Resource)

	Los Angeles	San Francisco
Base Case	$43.0 \times 10^6\ ft^2$	$52.7 \times 10^6\ ft^2$
Passive Case	$35.6 \times 10^6\ ft^2$	$32.1 \times 10^6\ ft^2$
Passive & Water Conservation Case	$25.8 \times 10^6\ ft^2$	$25.4 \times 10^6\ ft^2$

Storage Requirements (Base Case)

Los Angeles: 4 days consecutive cloudiness

San Francisco: 5 days consecutive cloudiness

Annual Hot Water Load:

Residential	4.67×10^6 Btu/capita/yr
Neighborhood	4.67×10^9 Btu/yr
Commercial	1.68×10^9 Btu/NGBD/yr
TOTAL	6.35×10^9 Btu/NGBD/yr

Storage Size:

Los Angeles	$(4/365)(6.35 \times 10^9$ Btu$)$ = 69.6 MMBtu/NGBD
San Francisco	$(5/365)(6.35 \times 10^9$ Btu$)$ = 86.9 MMBtu/NGBD

Space Heat Load:

Peak Load Losses	6.5 Btu/ft^2/degree day
Los Angeles	cold, cloudy temperature = 40°F 1 day requirement/NGBD = 6.5 x 400 x 1000 x 25 = 65 MMBtu
San Francisco	cold, cloudy temperature = 35°F 1 day requirement/NGBD = 6.5 x 400 x 1000 x 30 = 78 MMBtu

Table XVIII-5

Collector and Storage Requirements for Solar Sub-Grids (continued)

Storage Requirements (Base Case) - continued

Los Angeles	4 days of water at 20 gallons/capita/day - residential
	4 days of water at 7.2 gallons/capita/day - commercial
	= 108,8000 gallons/NGBD
	Space heat, storage at 180°F for delivery at 120°F means 480 Btu stored/gallon = 135,000 gallons/NGBD
	Total = 244,000 gallons/NGBD
San Francisco	Hot Water = 108,800 gallons
	Space Heat = 162,000 gallons
	Total = 271,000 gallons/NGBD

Losses are negligible

Storage Requirements (Passive Case)

Reduce degree day balance point to 55°F so heat load requirement drops.

Los Angeles

= (15/25) 65 MMBtu

= 39 MMBtu

= 81,000 gallons

Total Storage = 190,000 gallons/NGBD

San Francisco

= (20/30) 79 MMBtu

= 52 MMBtu

= 108,000 gallons

Total Storage = 217,000 gallons/NGBD

Storage Requirements (Passive & Water Conservation)

Reduce storage for hot water by 25 percent.

Total Storage:

Los Angeles = 163,000 gallons/NGBD

San Francisco = 190,000 gallons/NGBD

In Table XVIII-6 we calculate costs. Our assumed price of solar collectors is \$5/ft^2. This has been documented by JPL, 76, and other studies, though it is less than the cost associated with government-funded demonstration projects. For storage costs we rely on data from Rosenfeld and Dubin, 77, and Tamblyn, 77. In the range of interest the cost per gallon declines expenentially from 60¢/gallon at 125,000 gallons to 51¢/gallon at 250,000 gallons. These costs include peripherals such as extra plumbing. For capital amortization we use a 10-percent interest rate, 50-year lifetime for hot water mains and storage and a 20-year lifetime for collector and incinerator. Cost of incinerators was taken from Saylor, 76.

The results of the analysis follow the pattern we have seen in the centralized case. Table 7 XVIII-7 summarizes the cost data in all cases. Unit heat charges for the solar sub-grid are less in San Francisco than in Los Angeles, but the gap between the two regions is less in the decentralized case than in the centralized one. With increasing conservation, the cost of energy from solar sub-grids goes up, though not quite so fast as in the centralized case. Although we have not analyzed the sensitivity of our results to changes in assumptions, it seems clear that the major uncertainty lies in the cost and performance data on solar collectors. Capital requirements for collectors might be significantly greater than assumed, and they already are the largest cost factor. Economies of storage are unlikely to offset this. The tradeoffs, however, are different for the two regions. Collector is more of an expense in San Francisco because the solar resource is less and the per capita load is higher. Even these conclusions are relative to the level of demand, because storage requirements do not decrease with energy, while collectors do.

18.5 CONCLUSIONS

There is no simple moral to our story except to say that decentralized systems for district heating involve a planning effort that is considerably more complex than what we see with the centralized version. The latter is dominated by fixed costs. Either investment is justified or not.

Table XVIII-6

Capital Requirements and Unit Heat Charge for Solar Sub-Grids

	Los Angeles	San Francisco
Base Case		
1. Distribution	$\$223.00 \times 10^6$	$\$142.00 \times 10^6$
Collector	215.00×10^6	264.00×10^6
Storage	116.00×10^6	90.00×10^6
Incinerator	19.00×10^6	17.00×10^6
	$\$573.00 \times 10^6$	$\$513.00 \times 10^6$
Revenue Required	$\$ 61.68 \times 10^6$	$\$ 56.41 \times 10^6$
Maintenance	9.14×10^6	8.46×10^6
2. Annual Expense	$\$ 70.82 \times 10^6$	$\$ 64.87 \times 10^6$
3. Annual Energy	8.17×10^{12} Btu	8.43×10^6 Btu
4. Unit Heat Charge	\$8.67/MMBtu	\$7.70/MMBtu
Passive Case		
1. Distribution	$\$223.00 \times 10^6$	$\$142.00 \times 10^6$
Collector	178.00×10^6	161.00×10^6
Storage	97.00×10^6	77.00×10^6
Incinerator	19.00×10^6	17.00×10^6
	$\$517.00 \times 10^6$	$\$397.00 \times 10^6$
Revenue Required	$\$ 55.41 \times 10^6$	$\$ 43.00 \times 10^6$
Maintenance	8.40×10^6	6.40×10^6
2. Annual Expense	$\$ 63.81 \times 10^6$	$\$ 49.40 \times 10^6$
3. Annual Energy	6.38×10^{12} Btu	5.13×10^{12} Btu
4. Unit Heat Charge	\$10.00/MMBtu	\$9.63/MMBtu
Passive & Water Conservation Case		
1. Distribution	$\$223.00 \times 10^6$	$\$142.00 \times 10^6$
Collector	129.00×10^6	127.00×10^6
Storage	90.00×10^6	70.00×10^6
Incinerator	19.00×10^6	17.00×10^6
	$\$461.00 \times 10^6$	$\$356.00 \times 10^6$
Revenue Required	$\$ 48.95 \times 10^6$	$\$ 38.30 \times 10^6$
Maintenance	7.42×10^6	5.72×10^6
2. Annual Expense	$\$ 56.37 \times 10^6$	$\$ 44.02 \times 10^6$
3. Annual Energy	4.90×10^{12} Btu	4.06×10^{12} Btu
4. Unit Heat Charge	\$11.50/MMBtu	\$10.84/MMBtu

Table XVIII-7

Unit Heat Charge Summary (per MMBtu)

	Los Angeles		San Francisco	
	Central	Sub-Grid	Central	Sub-Grid
Base Case	$ 6.82	$ 8.67	$ 4.67	$ 7.70
Passive Case	8.36	10.00	6.83	9.63
Passive & Water Conservation Case	10.48	11.50	8.29	10.84

Once the investment is made, the consumer has no incentive to conserve; there is, in fact, a disincentive. Solar sub-grids offer the prospect of complicated optimization. This can be seen as a challenge or a burden, depending upon one's values. There is little doubt, however, that the solar sub-grid requires a level of local community involvement that is substantially greater than centralized district heating. Some of the social requirements of the solar sub-grid have economic benefit. Garbage incineration for backup ought to be given a credit against the unit heat charge because it displaces a waste disposal burden borne by municipalities otherwise. This should be traded off against the cost of local maintenance. Both are difficult to quantify.

Studying the comparative costs in Table XVIII-7, one might interpret the extra burden of decentralized systems as an insurance premium. We have argued that solar sub-grids provide protection against common mode failure; the cost premium buys this insurance. It is interesting to observe that the premium is less for Los Angeles than for San Francisco. What this says about policy is not clear.

We do not claim that our comparison is definitive. It raises as many questions as it answers. We do claim to show, however, that conservation policy is not decoupled from supply strategy. The type of low-quality heat one supplies is indeed a function of projected demand. Soft path supply approaches, because they are more flexible than the hard path alternative, offer wider scope for optimizing the supply and demand balance. This makes the soft path an attractive problem and holds out the hope that a social and economic optimum can be found.

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