Small Towns Institute
POST OFFICE BOX 517, ELLENSBURG, WASHINGTON, 98926

VOLUME 7, NUMBER 5, NOVEMBER, 1976

Small Town

Energy Conservation for Small Towns

by BILL KOPPER and DAVID BAINBRIDGE

Both authors are associated with Living Systems in Winters, California, the environmental planning group which has produced many of the studies referred to in this article. Living Systems arose out of the Ecology Graduate Group at the University of California at Davis, where Jon Hammond, Marshall Hunt, Bill Kopper, and David Bainbridge became involved in planning and environmental issues. Hammond and Hunt went on to intensive work with the Davis Energy Code, while Bainbridge founded his own environmental planning firm and travelled widely, working on bikeway planning and design, environmental impact, and wilderness management, before returning in 1975 to Living Systems to work on planning aspects of the Davis code. Bill Kopper worked with Consumer Action Groups, a small farm project, and was elected to the Davis City Council in 1976.

Living Systems is now doing similar codes and planning in Sacramento and Indio, California, and has designed or begun several solar houses and buildings, including a 250,000 square foot office building for the State of California. This building will be 100% naturally cooled, ninety percent naturally lighted. Life cycle cost is expected to be about half that of a normal office building.

The company is interested in working with other small towns in California, Oregon, or Washington, and will work on funding proposals with towns seriously concerned with energy conservation issues. They would particularly like to do a major retrofit study for a town interested in striving for energy self-sufficiency.

Living Systems is currently preparing an up-to-date publications list. Except as indicated in the footnotes, publications by Living Systems are available from them at: Route 1, Box 170, Winters, California, 95694. –ASD

INTRODUCTION

This year, for the first time in our nation's history, we are importing more oil than we are producing. Rather than inaugurating a new era of energy dependency this bicentennial year, it would be more fitting if we set a national goal of 50 percent reduction in overall energy consumption in the next ten years. While 50 percent may sound like an unrealistic goal, it is clearly attainable.

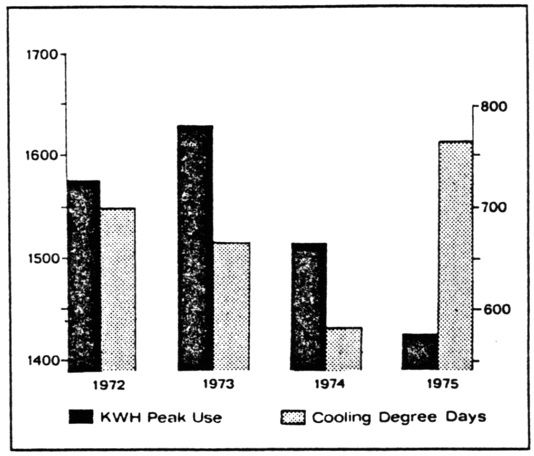
Sweden and West Germany, with much more severe climatic conditions and with standards of living equal to our own, use less than half the energy per capita that we consume. These and other western European countries have managed to save energy by increasing the efficiency of energy use in all sectors of society including transportation networks, home appliances, industrial machinery, lighting, heating and cooling of buildings, and electrical generation. Energy conservation does not necessarily require changes in lifestyle, but it does require greatly improved efficiency of energy use.[1]

Apart from our need to conserve precious reserves of fossil fuels for future generations, the case for energy conservation may rest on economics alone. The U.S. General Services Administration predicts a doubling in energy costs in five years and a five percent per year increase thereafter, a fifteen percent per year rise is estimated by NASA, and a not so modest ten percent per year hike is projected by Pacific Telephone. Frequently, the cost effectiveness of energy conservation measures is staggering.

For example, if a typical house is built in the Central Valley climate of California, every 55 square feet of unshaded west-facing window in the house will increase the peak air conditioning demand in the house by approximately one ton.[2] Since the peak load for electrical demand in this area corresponds to the peak demand for residential air conditioning, one extra ton of air conditioning will increase the peak hour demand on the electrical utility system by approximately 2 KW.

We have a choice: we can buy an additional ton of air conditioning for the house at a cost of about $250 and spend around $2000 to increase our generating capacity by 2 KW, or we can eliminate the solar radiation coming through the windows by shading them. A quality metal shade screen runs $1.50 per square foot installed or $82.50 for 55 square feet.

In Davis, a town of 30,000 near Sacramento, California, the citizens have become aware of methods of energy conservation and have reduced their per capita consumption of electricity by about ten percent over the past three years. This reduction in electrical use may be attributable in part to an educational program on how to save energy in the household as well as the development of an energy conserving building code which has made many citizens aware of how their houses function with the climate.[3]



The above graph demonstrates that Davis residents have cut their peak load electrical use dramatically even though the number of cooling degree days increased over the past three years.

The Davis Energy Conservation Building Code is based upon the principles of "design with climate" developed by Olgyay,[4] Givoni,[5] and Neubauer.[6] While the concepts of design with climate have been known for several decades, their application was precluded by the advent of low cost air conditioners and cheap electricity. The Davis Code has digested these principles into an easily understandable form for architects and builders. New houses constructed under the guidelines of the Davis Energy Conservation Code save about fifty percent of the energy needed for heating and cooling compared to a typical California home.

Following adoption of the Code, the City of Davis further pursued ideas and methods of conserving energy and commissioned the development of new planning and design policies. The policies include narrowing and shading streets, shading parking lots, protecting solar rights of residences, and developing additional bicycle and pedestrian facilities.

As the City of Davis has demonstrated, a town may have a substantial impact on energy use. While Davis has been fortunate to be able to set an example in this area, many municipalities have been prevented from dealing with energy conservation because of the pressing problems of providing services and the lack of information. This article is intended to help meet the need for information by providing ideas on how small towns can conserve energy by requiring the construction of energy conserving buildings and developing energy conserving design and planning standards.

Wide streets typical of the 50's and 60's are not built to human scale. This 80 foot wide street has severe microclimatic impact and adverse effects on energy use.

AN ENERGY CONSERVING BUILDING CODE

The Davis City Council decided to develop an energy conserving building code after reviewing research by a local conservation group which demonstrated that California State standards do not take into account local microclimates, and consequently permit extremely inefficient buildings to be constructed even though insulation is upgraded. The Council hired Living Systems to prepare the code and implement the program.

Like many California communities, Davis is located in a favorable climate for natural heating and cooling. The winter days are predominantly sunny allowing substantial solar heating of dwellings, and the hot summer days are accompanied by a cooling night sea breeze which provides comfortable sleeping temperatures and pleasant summer mornings.

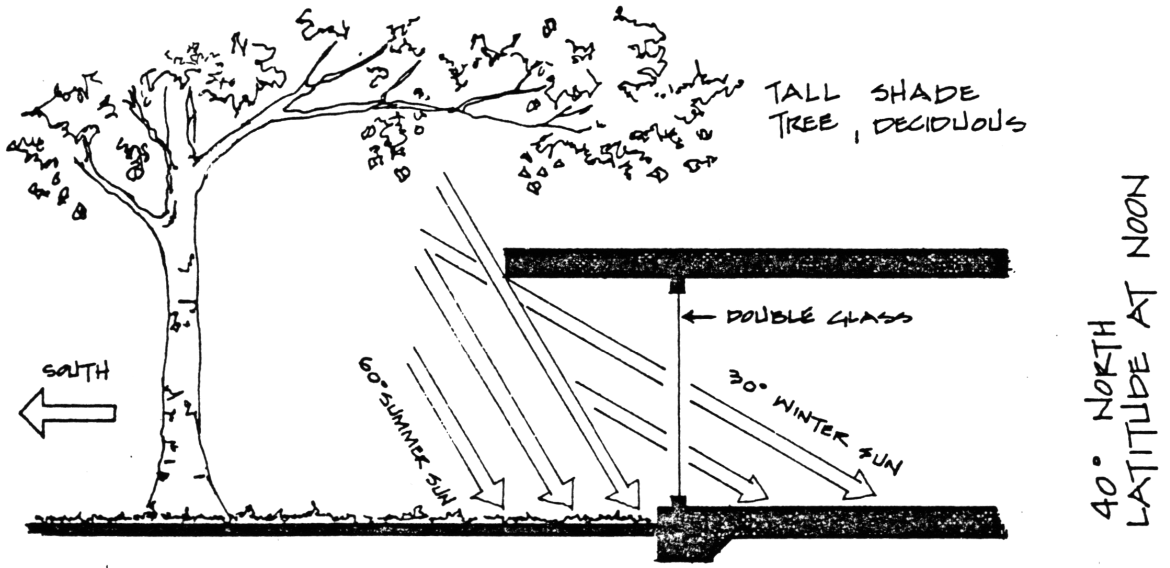
Dwellings built in the Davis climate should have large expanses of south-facing glass backed by sufficient thermal mass to store the winter sunlight penetrating the windows. As shown in the accompanying drawing, an overhang should be constructed above south facing windows to shade out the summer sun while permitting penetration of the low winter sun. Windows on the east, west, and north sides should be kept to a minimum and should be shaded in the summer to prevent radiant heat gain. Roofing materials should be light colored to prevent absorption of the summer sun.

Although the Davis Code does not specifically require any of these design features, it encourages their implementation because it is the simplest way for architects and builders to meet the performance standards of the Code. The Code sets a maximum allowable heat loss per square foot on a *winter design day* and a maximum allowable heat gain on a *summer design day.*[7] Conformance with the Code is demonstrated through standard ASHRAE[8] methods of calculating heat loss and heat gain.

Detailed climatic data should be collected on maximum and minimum temperatures, humidity, precipitation, cloudiness, wind, radiation, cold snaps, dust, heat waves, and calm heat. This information should be compiled into a building climate map.

Before setting performance standards, a decision must be made as to the desired comfort level within dwellings. Comfort levels usually include temperature, humidity, radiation, and wind speed and are based upon indices developed by Olgyay and Givoni.

The building performance standards are set so that the dwelling will mitigate the external climatic conditions and achieve the desired comfort levels with the lowest possible use of energy for heating and cooling. Once building performance standards are decided upon, it is necessary to develop design guidelines which will allow architects and builders to meet the standards.



Almost any design is possible under the guidelines of the Davis Code as long as the performance standards are met. Windows may be added until they assume a substantial amount of the wall area of the dwelling, but they must be thermopane glass or shuttered or both. Glass may also be added if sufficient thermal mass is placed within the shell to make use of the increased radiant gains.

The Code provides two methods of compliance: a Path I prescriptive approach and a Path II approach which allows greater design flexibility but requires more calculations.

Elements of an Energy Conservation Building Code

While the Davis Code provides exceptional performance for houses built in the Davis climate, it is inadequate or inappropriate for the many other climates in the State and country. The first step in development of an energy conserving building code for a community is to conduct a climate analysis.

These guidelines may include elements such as limiting the amount of window area, shading windows, or requiring exposed slab construction or other thermal mass, increased insulation, light colored roofs, thermopane glass and cool pools.

Political Considerations in Implementation

Development of an energy conserving building code is contingent upon the attitude of the community and the willingness of local elected officials to weather the skepticism of builders and developers, and perhaps some of the less enlightened architects. In some cases where the City Council is willing to act on a modification of the building code, the staff expertise still may not be available to conduct the climate analysis and develop the appropriate performance standards and guidelines. State and Federal energy agencies could help alleviate this problem by providing grants to municipalities to develop energy conserving building standards or by developing building climate maps with appropriate performance standards and design guidelines for each building climate zone.

Even if the preceding steps are taken it will still be necessary to persuade the communities of the need for an energy conservation program. This may best be achieved by encouraging local groups such as environmentalists, the League of Women Voters, or service clubs, as well as public utilities, to cooperate in an educational program. It may be appropriate for State or Federal energy agencies to conduct seminars for these select groups on the opportunities for energy conservation in building design and the methods of implementing energy conserving building codes.

In steering an energy conservation building code through the City Planning Commission and the City Council, it is essential to defuse the opposition. This is best done with logical arguments which respond with hard facts to the positions of builders and developers, resulting in educational benefits to all involved. The most persuasive argument used in Davis was proof that the cost of housing would go up no more than $200 per unit and that this added cost would be recouped within one or two years in utility bill savings. Since no substantial increases in construction costs were projected, the building trade unions did not oppose the new Code; and the public-at-large supported the Code because of the potential savings in utility costs. The builders and developers were isolated in their criticism which was eventually focused on the design problems of meeting the requirements of the Code.

Parking lots should be well shaded.

Once the Energy Conservation Building Code is adopted by the city, it is necessary to initiate a program which will teach builders, architects, developers, and building inspectors how to use the Code. We found that it was best to develop a set of forms similar to those previously in use by the City of Davis to show compliance with the State insulation and glazing standards, and then to teach builders how to use these forms through seminars.

Above: New developments in Davis, California will have narrow streets without street parking. Below: A narrow, tree-shaded street in Davis is one way with two bike lanes and parking.

During each of the seminars those in attendance were taken through the step-by-step procedures of filling out the forms and testing their designs for conformance with the Code. Some of the programs dealt with the principles of design with climate while others simply discussed structural modifications which would allow builders to meet the code with their standard subdivision plans. The most difficult concept for builders to grasp was shading, and thus three methods were developed to show compliance with shading requirements: 1) the use of profile angles to cast shadows on windows on the design days, 2) construction of a model and testing of shading with the City's solar simulator,[9] and 3) a math model which provides the correct length of shading overhangs for different size windows on different elevations.

After adoption of the Code and completion of the seminar series the Davis Building Inspection Department was able to assume full responsibility for implementation and enforcement of the new Energy Conservation Building Code.

A RETROFIT PROGRAM

While energy conserving building codes can save substantial amounts of energy in new construction, they have only a spin-off impact on the existing dwellings which will

comprise the vast majority of the housing pool for many years. A comprehensive retrofit program is needed to upgrade the thermal performance of existing units in order to meet a goal of a 50 percent reduction in overall energy use in ten years.

Most retrofit programs include insulating attics and weatherstripping windows and doors. These two steps are generally the easiest and cheapest for homeowners to accomplish and have been promoted extensively by utility companies and insulation firms. Nevertheless, our research in Davis has shown that the retrofit measures which will result in the greatest savings of energy for heating and cooling will vary widely depending upon the individual dwelling.[10]

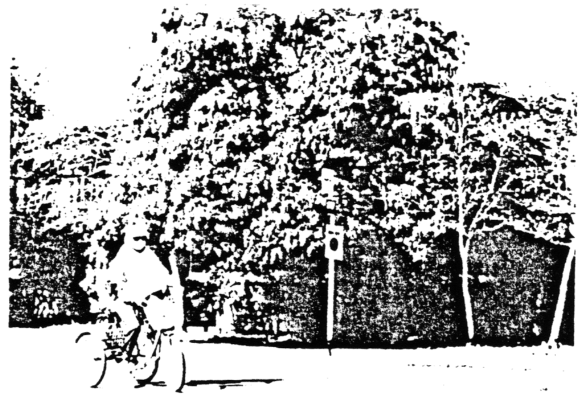
Almost all the Davis houses built with joists and wood floors on a concrete foundation have some insulation in the attic and thus lose the greatest amount of heat through the floor. In many cases it makes good economic sense to insulate with fiberglass batts underneath the floors. In the summer, many houses in Davis gain the greatest amount of heat through the windows. The largest portion of this heat gain is radiant heat which may be blocked out with landscaping or shade screens. There are no cases in Davis where an investment in shading devices does not pay for itself within two or three cooling seasons.

An Energy Conservation Service

In order to achieve optimum retrofit activity we feel that two programs are needed: 1) tax incentives should be provided for insulating, weatherstripping, and other energy conservation remodeling; and 2) an Energy Conservation Service should be initiated to provide people with free assistance on how to retrofit their homes for energy efficiency.

We have initiated an experimental Energy Conservation Service in Davis and have evaluated about seven houses. In each case we have developed a report on how the homeowner may bring the dwelling up to the standards of the Davis Code. Several houses could not be brought up to the performance standards without blowing insulation into the walls which is a costly procedure and not recommended at this time. Others had large expanses of glass whose effects we were able to mitigate by developing shading and thermal drapery systems. In the case of one dwelling, we placed an arbor over the entire north wall and also designed two alternative thermal drapery systems.

The general approach of the experimental Energy Conservation Service is to conduct an audit to identify the sources of greatest energy wastage in the dwelling. In order to accomplish this goal, the shell of the structure is evaluated for energy use for heating and cooling. In addition, appliances and lights are monitored for their electrical usage. The detective work in the audit shows where the energy is wasted in the dwelling, and subsequently recommendations are made which will reduce the use of gas and electricity. Each recommendation is subject to a cost-benefit analysis which reports the price of the improvement and the savings per year in



Above: Twenty-five percent of all trips in Davis are made by bicycle, a factor which adds immensely to the pleasant qualities of the community. Below: City of Davis has used small cars and trucks with great success. Honda Civic CVCC's will be ordered for 1977.

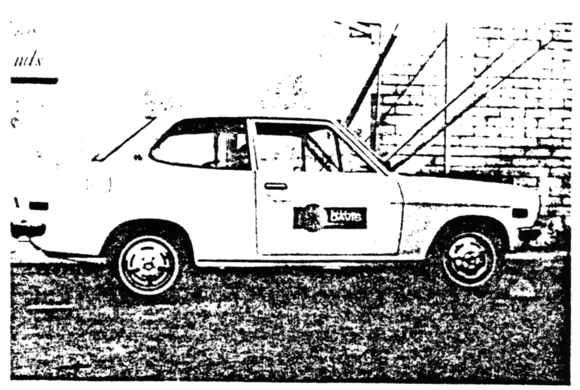
utility bills.

Appliances and Energy Use

It makes little sense to develop energy efficient dwellings if they are filled with inefficient appliances. Running through the gamut of appliances—electrical knives, water pics, electric can openers, crock pots, electric tooth brushes, electric combs, stereos, TV's—electric dryers and dishwashers stand out as two very wasteful conveniences. The use of both appliances can be minimized by the use of a solar clothes dryer and hand washing of dishes. However, the worst offender is the home refrigerator; and in general older models—from the 1930's and 40's—have much lower electrical consumption than recent ones.

PLANNING FOR ENERGY CONSERVATION

Among the most significant and long lasting decisions a City or County makes are in the areas of land use and transportation planning. Planning affects the environmental quality of the community, noise levels, transportation patterns, air pollution levels, the conversion of prime agricultural or other valuable land to urban use, and the consumption of energy in all sectors of society. In order to facilitate planning for energy conservation, an energy conservation planning package was developed for the City of Davis.[11] Some of these policies are summarized below:



1. *Increasing Setback Flexibility and Reducing Minimum Lot Size*

Existing design and planning practices encourage larger than needed side yards and ornamental front yards. Neighborhood planning policies which encourage large lots serve to promote sprawl and increase the area covered with pavement-increasing summer heat problems. Sprawled development increases travel time, distance, and energy use.

Setback flexibility allows orientation of houses for natural heating and cooling and for solar water heating. In order to attain proper orientation it may be necessary in some cases to set houses on the extreme edges of lots. This may be done through removing restrictions in the Planned Unit Development zoning.

2. *Solar Rights*

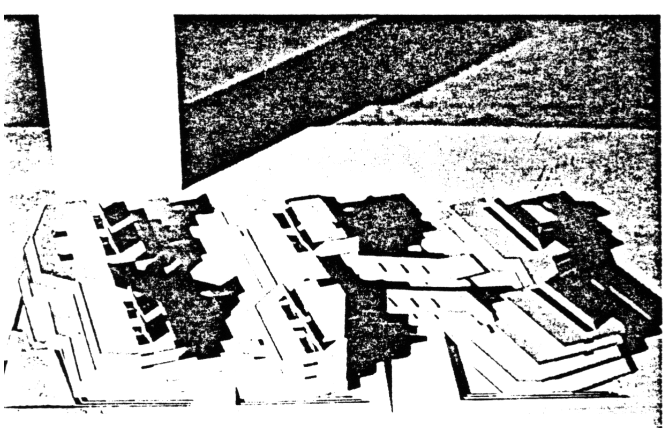
It is of little use to orient buildings to make use of the sun's energy for space heating or water heating, if there is no system to ensure that the solar system will not be shaded by neighboring landscaping or structures in future years.

Solar heating systems will not work if they do not receive sufficient sun. Large investments are involved. Therefore a guarantee of "solar rights" in new residential developments is necessary. The states of Colorado and Oregon[12] have already adopted solar rights laws.

3. *New Street Width Standards*

Besides saving valuable land, narrow streets have many benefits. Research has shown that neighborhoods with narrow shaded streets are ten degrees cooler in the summer than neighborhoods with wide unshaded streets.[13] On a typical summer day a ten degree warmer outdoor temperature would require fifty percent more electricity for cooling in the household. Narrow streets are also safer for bicyclists, pedestrians, and motorists because the higher the impedance, the lower the traffic speed.

An early model of the new state office building in Davis designed by Living Systems. The structure has 100% natural cooling and 90% natural heating and lighting.



Bikes are used at night, in the rain, and even during Davis' rare snowfalls. At present, bicycle racks are woefully inadequate.

In the transportation section of the energy conservation planning package Living Systems has developed a group of resolutions and ordinances which will facilitate the use of pedestrian and bicycle systems as a means of moving people around the city. For intercity transportation, Davis has joined the Sacramento Regional Transit District and bus service is provided to Sacramento and Woodland.

4. *Landscaping*

The environmental quality and beauty of a community is largely a function of its architecture, street layout and grid system, parks, and landscaping. These latter three elements of design are all within the purview of municipal control and operation. Requiring narrower streets to reap microclimatic and financial benefits must also be accompanied by the selection of appropriate landscaping. Large deciduous trees such as oaks, hackberries, sycamores, and ashes provide cooling shade and transpiration and a quiet beauty which gives older Sacramento Valley towns so much of their character and livability. These trees shed their leaves in the winter and allow the warm sun to enter residences.

Shading and landscaping may often be the determining factors when an individual makes a decision to walk or bicycle in the summer or ride in an air-conditioned car. The glaring, hot unshaded asphalt makes streets and parking lots a desert micro-climate in the summer months—an extremely uncomfortable environment for cyclists and pedestrians. In the landscaping program Davis has developed several resolutions, code amendments and ordinances which will encourage the shading of streets and parking areas.

The project also encourages the widest possible use of home gardens to realize energy savings in the food sector. For each calorie of food produced by commercial agriculture ten calories are invested; a home gardener can do much better.

5. *Transportation Systems*

Approximately 45 percent of the energy consumed in California is used to move automobiles, airplanes, trains, buses, trucks, motor scooters, and motorcycles from one place to another. Much of our use of motor vehicles is governed by our values and the physical and social organization of society. With our increasing national reliance upon foreign supplies of oil and the dwindling worldwide supplies of fossil fuel energy, many citizens have come to realize that we should re-orient our society to forms of transportation other than the automobile.

In 1968 Davis became the first city in California to develop a comprehensive network of bike routes and bike lanes throughout the city. Although it will be a number of years before the automobile is very likely supplanted by other more appropriate systems as the dominant means of urban transportation, we should make every effort to design a city where a smooth transition is possible. Bicycles, pedestrian facilities, mini-buses, tricycles, and other small, non-polluting vehicles should be increasingly emphasized.[14]

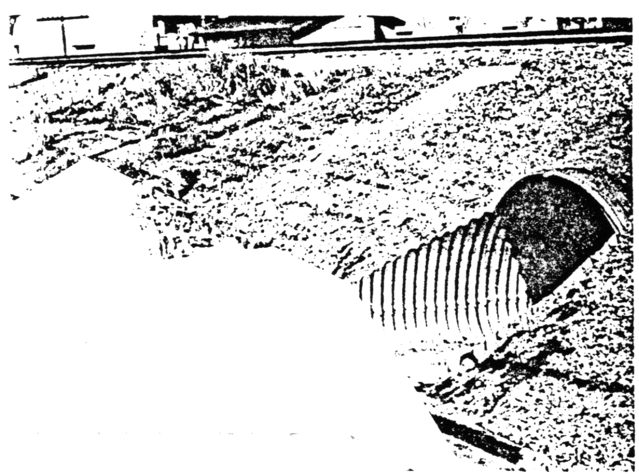
In addition to the planning policies discussed above, the City of Davis contracted with a consulting firm for an evaluation of the city vehicle fleet. The study indicated that substantial energy and financial savings would be realized by using Chevrolet Novas instead of intermediate size Plymouths as police cars. In addition, Honda's CVCCs were selected for most city uses because of their low maintenance and fuel consumption.

6. *Utilities*

It is also very important for a town to design water, sewer, and solid waste systems for maximum energy efficiency. Investments in these services are often long term and high energy cost could cripple towns with inefficient systems. The use of composting toilets (eliminating 40 percent of water use) should be encouraged rather than pursuing centralized secondary treatment at very high energy cost. Water systems should include cisterns for storing rain water and "grey water" should be used for irrigation where it is possible to do so. Solid waste disposal should maximize separation and recycling at the home level and not at large, highly mechanized sites.[15]

If the utilities and services are well designed and efficiently utilized, then revenues will stay closer to expenses rather than falling increasingly far behind as energy costs spiral upward.

Culverts make inexpensive bicycle under-crossings and are used in several places in Davis. Good facilities such as these encourage riders!



---

[1] Hayes, Denis, *Energy: The Case for Conservation*, Washington, D. C.: Worldwatch Institute, 1976; $2.

[2] 12,000 B.T.U. per hour. Hammond, Jon, "Proposal for an Energy Conservation Service," Winters, California: Living Systems, 1976 (out of stock as of this writing). out of print

[3] Hammond, Jon, *et al.*, *A Strategy for Energy Conservation*, Winters, California: Living Systems, 1974; $5.30, 51 pp. (still avail.)

[4] Olgyay, V., *Design with Climate*, New Jersey: Princeton University Press, 1963.

[5] Givoni, B., *Man, Climate and Architecture*, London: Elsevier, 1969.

[6] Neubauer, L. W., "Optimum Alleviation of Solar Stress on Model Buildings," in *Transactions of the American Society of Agricultural Engineers*, 15 (1), 1972.

[7] The concept of winter and summer design days is drawn from research in Israel and England, verified in a study in Twin Rivers, Pennsylvania. Basically it is an average worst typical day for summer and winter. In Indio, California, three design days were found to be more representative–winter, summer, and a fall/spring combination. The analysis of weather records enables us to establish a temperature profile for the day which can be used for thermal performance calculations. In analysis of existing homes, and their energy use, it is remarkably accurate. Hammond, Jon, *et al.*, *The Davis Energy Conservation Building Code*, Winters, California: Living Systems, 1975; $2.50, 36 pp.

[8] American Society of Heating, Refrigeration, and Air Conditioning Engineers publishes a *Handbook of Fundamentals* which includes accurate methods of calculating heat gain and heat loss in a building.

[9] A solar simulator is a device used for testing shading effectiveness. It can be any number of different devices that mimic the sun's path through the day and through the year. The Building Inspection Department in Davis uses one built for them by Living Systems. It has a series of flood lamps on a pole to represent the various design hours and days and a model mount on a swivel to check various sides of the house. It is used to check shading in the summer and solar credit in the winter.

[10] Kopper, Bill, *Energy Conservation Advisory Program*, Winters, California: Living Systems, 1976; $6.36, 68 pp. (out of stock at this writing). OUT OF PRINT

[11] Bainbridge, Dave, *et al.*, *Planning for Energy Conservation*, Winters, California: Living Systems, 1976; $6.36, 83 pp.

[12] Colorado Acts of 1976, Chapter 326, (formerly Senate Bill 95), and Oregon Acts of 1975, Chapter 153, (formerly House Bill 2036).

[13] Myrup, L. O., *Numerical Model of the Urban Atmosphere*, Vol. 1, Davis: University of California, 1972.

[14] Illich, Ivan, *Energy and Equity*, New York: Perennial Library, Harper & Row Co., 1974; Bainbridge, David, *Bikeway Design and Planning: A Primer*, Winters, California: Living Systems, 1974; 18 pp., $1. OUT OF PRINT

[15] Bainbridge, David, *Water Conservation*, Winters, California: Living Systems, 1976; 10 pp., $1. OUT OF PRINT

See instead Hammond, Kopper, Bainbridge THE DAVIS ENERGY CONSERVATION REPORT April 1977 $5.30 City of Davis