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PLANNING FOR AN ENERGY CONSERVING SOCIETY:
THE DAVIS EXPERIENCE

Edward L. Vine

February 1979

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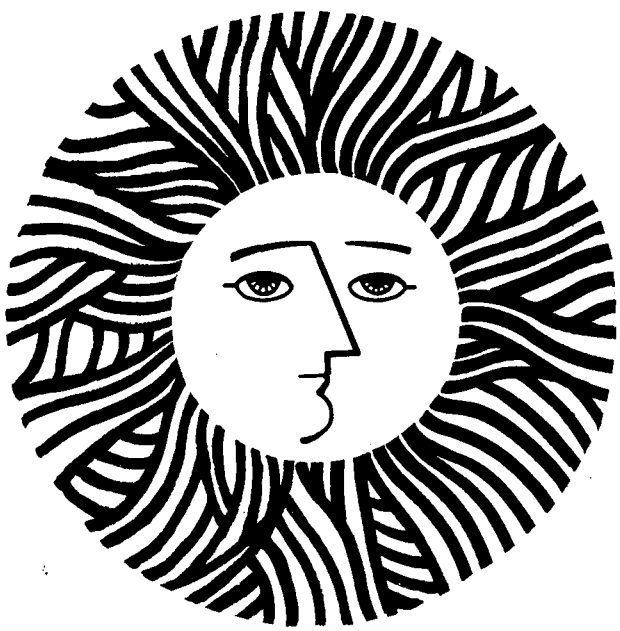

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PLANNING FOR AN ENERGY CONSERVING SOCIETY:

THE DAVIS EXPERIENCE

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PREFACE

The Distributed Energy Systems Study Group is currently conducting a study on the opportunities and obstacles in planning for an energy conserving society in California. One of the Group's tasks is to analyze the influence of local planning policies on the use of energy conservation measures and renewable energy sources in local communities. After comparative evaluation of findings from five different localities in California--the cities of Davis, Palm Springs, and Los Angeles, and the counties of San Diego and Santa Clara--recommendations will be suggested for possible methods local governments can adopt to successfully reduce the amount of energy consumed in their jurisdictions. This report concerns the Davis planning system, and the work was funded by the U.S. Department of Energy under Contract W-7405-ENG-48.

INTRODUCTION

"Local governments are ideally suited to assume an important role in the implementation of energy conservation measures." (Rancer, 1977).

"Davis has done more for energy conservation than any other city in the nation." (Wall Street Journal, 1978).

Many cities and counties in the United States have the potential of reducing the amount of energy consumed in their jurisdictions by means of voluntary and mandatory methods. Local governments can become involved in energy matters in three basic ways (Greenberg, 1977):

1. In-house efforts. Attempts are made to improve the efficiency of current and future energy use within the city or county administration. Local government programs might include building management, vehicle policies and equipment purchase criteria.

2. Direct influence on the community. Local government's regulatory and permitting powers (e.g., ordinances and building code changes) are utilized to make residential and non-residential structures more energy efficient.

3. Indirect influence on the community. Public outreach and education programs are conducted to disseminate information on the energy situation and on energy technologies as a means of increasing popular support for governmental programs and for voluntary energy conserving behavior.

However, it has been found in California, for example, that only a few communities have taken advantage of the significant opportunities for energy savings (Greenberg, 1977). Most local government activities have focused on "in-house efforts", public education programs and long-term sutides (e.g., describing the present energy picture and anticipating future energy needs, costs and sources of supplies). Some communities have established "energy committees" to study the possible roles and

actions available to their government, while a few localities have lobbied at the state and fedearl levels to procure needed funds and/ or to support various energy conservation legislation. All but a handful of local governments have avoided the use of mandatory energy conservation programs, and, not coincidentally, only a few communities have been able to reduce their consumption of energy.

The City of Davis, California, has conducted energy programs in the three areas mentioned above since the early 1970's. In addition to an extensive public education program, the City adopted an energy conservation building ordinance (one of the first in the country) and key planning policies to try to reduce energy consumption in new residential and non-residential structures as well as in the City's circulation system. The energy conservation building code was based on climate analysis and utilized a minimum building performance standard which could be met by following certain passive solar design guidelines. The planning policies contained selected design standards to make planned unit developments and the City's circulation systems more energy efficient. After initial opposition from the building community, both the code and the planning policies have achieved wide popular support in the community. As a result of a combination of public policies and private initiative, household energy consumption has been dramatically reduced. Specifically, household gas consumption in the residential sector decreased 21 percent from 1973 to 1977 while household electrical consumption in the residential sector decreased 13 percent over the same time period (Table 1). The City of Davis hopes to reduce its overall energy use by 50 percent in a ten year period (1976-1986) by implementing its policies (including a proposed retrofit ordinance for upgrading the thermal performance of existing houses) and by encouraging greater voluntary energy conserving behavior in the community.

This report examines the development and implementation of the energy conservation building code and selected energy planning policies of the City of Davis. The historical analysis focuses on the problems that occurred as these energy issues were raised and studies how they were resolved by members of the Davis community during the policy formulation and policy implementation stages. This report does not attempt to describe all the

planning policies that the City of Davis has enacted which deal either directly or indirectly with energy conservation. Only those policies which generated criticism and/or opposition within the community are examined in detail. Those policies which were adopted and implemented without much "noise" are briefly mentioned and may be examined in greater depth in a later paper.

It is important to emphasize that this investigation is primarily concerned with policy implementation, not policy impact, as described in the following definition: "...policy implementation encompasses those actions by public and private individuals (or groups) that affect the achievement of objectives set forth in prior policy decisions" (Van Meter and Van Horn, 1975). In this study, the implementation phase took place after the energy conservation building code was adopted and after the energy planning policies were included in the Design Review process of planned unit developments. This study examines "proximate effects" (e.g., the builders' acceptance of the energy code) whereas an impact study examines "ultimate effects" (e.g., the observed consequences of the energy code on the community's energy consumption or on the rate of building development in Davis)(Van Meter and Van Horn, 1975). Policy impact analysis is intimately related to policy implementation, but, except for a few brief passages in this paper, it is not the focus of this study.

The methodology utilized in this study consisted of collecting data from the following sources: popular and academic journals, books, newspapers, administrative documents (e.g., general plan and zoning regulations) and reports published by private consultants. In addition, interviews were conducted among 27 individuals who participated, directly or indirectly, in the City's energy planning system. These people included energy consultants, members of the City Council and Planning Commission, staff and officials of the Public Works Department, the Planning Division and the Building Inspection Division, the City Attorney, the City Manager, bankers, builders, architects, developers, and academians (Appendix D). An earlier version of this report was reviewed by 15 of the 27 interviewees and by two energy consultants, and many of their comments have been incorporated in this

revision. In most cases the comments were very helpful in clarifying specific statements and correcting errors in the report. The opinions, findings, and conclusions in this report, however, are those of the author and do not necessarily reflect the views of any of the interviewees or reviewers.

The construction of the Davis experience relies heavily on the information collected during these interviews. The following notation is utilized in this report to refer to these interviews (I: Reese). "I" refers to an interview and "Reese" is the person who was interviewed. Appendix D contains the list of persons interviewed in this project, their occupation, and the location and date of the interview. It is important to note that reference to an interview does not necessarily mean that the interviewee supports the referenced statement. The notation merely indicates that the source for that statement is from that interview.

I. THE DAVIS COMMUNITY

A. Location

The City of Davis is located in the Northern Central Valley of California, approximately 15 miles west of Sacramento and about 70 miles east of San Francisco. Its latitude is 38 minutes and 32 degrees north and its longitude is 46 minutes and 121 degrees west. The City is about six and three-quarter square miles in size and its elevation is 60 feet. It is primarily built on, and surrounded by, prime farm land (Class 1 Yolo sandy loam soils), one of California's most valuable resources that is currently being subjected to urban encroachment and environmental degradation (Reganold and Singer, 1978).

B. Climate

Davis' climate is characterized as temperate Mediterranean (Figure 1) (Hammond et al., 1977). Winter days are cool: average temperatures are around 45°F (2,819 heating Degree Days) and seldom colder than 25°F. The usual winter pattern is 3 days of clouds and rain followed by 3 days of sunny skies. Sun shines 44% of the daylight hours in the winter. Rainfall averages 18 inches per year, most of this occuring during the winter; the range in precipitation from dry years to wet years is 4.7 inches to 36 inches.

Summer days are hot and dry; daily maximums are commonly around 90°F (1,063 cooling Degree Days), sometimes reaching 105°F and over. Rainfall during the summer months is almost zero. During the summer, sea breezes from the south (via the Carquinez Straits) reach Davis, typically, in the late afternoon or early evening, cooling the area to an average summer nighttime low of 53°F. Dry northerly winds and wet southerly winds alternate during the months between fall and spring. Mean average daily solar radiation during the year is 431 langleys per day with considerable variation between summer and winter months (Table 4). In sum, Davis' climate presents both a heating and cooling problem for energy planners, designers and builders.

C. Socio-Economic Profile

Davis is a predominately white middle class community of 36,500 people with few extremes at either end of the ecnomic scale. The median income for the entire planning area in 1975 was $11,382, with medians in individual planning areas ranging from $19,552 to $6,362 (City of Davis, 1973). The occupational structure of Davis has the following composition: 53 percent are professionals (especially in the educational field), 10 percent are in managerial occupations, 20 percent in clerical positions and sales work, 8 percent are craftspersons or operatives, and 9 percent are service workers or laborers (City of Davis, 1973). The median age in the City is 23 years.

Davis is primarily a residential community with a small, centralized commercial downtown area and a few light industries located in its periphery. New residential construction is largely conducted by 7-8 building companies and a number of smaller contractors. The University of California is the largest source of employment in the City. More than half of the city's adult residents are involved with the U.C.D. campus as students, faculty or staff. As of September 1978, U.C. Davis enrollment was 17,511 (U.C. Davis, Registrars Office, personal communication). As of June 1978, total U.C. Davis staff was 12,994: 3,690 academic, 9,304 other (U.C. Davis, Personnel Office, personal communication). A large proportion of residents also work for the State of California or related employment in the Sacramento area.

D. Energy Profile

Most of the primary energy use in Davis is accounted for in the residential sector (56 percent) while the industrial (21 percent) and commercial (22 percent) sectors account for most of the remaining energy (Table 2). It is not surprising that one half of the energy used in the residential sector is natural gas since 99 percent of existing Davis homes use gas heat (Sedway/Cooke, 1978a). Electrical energy in the residential sector is primarily used for air conditioning (31 percent) and refrigeration (14 percent)(Table 6). Residential consumption

of natural gas and electricity has declined during the last seven years of record (1970-1977) in an uneven direction (Figures 2 and 3; Table 1). Use of natural gas and electricity in the commercial and industrial sectors has decreased, too (Table 1). Although Davis' energy consumption is relatively small compared to California and the rest of the country (Table 3), an explanation of the dramatic reductions in energy use is of significant interest for communities throughout the nation.

E. Community Concerns

During the early 1960's, the University of California expanded its Davis campus, resulting in rapid population growth in the Davis area. A projected population of 90,000 people by 1990 (as projected in the old Davis General Plan) caused many citizens to become very concerned about the future of their community. Increasing population was leading to rapid growth of residential construction on prime agricultural land: land valuable for local consumption, the State economy, visual aesthetics and open space (Reganold and Singer, 1978). (See Table 5 for the rate of construction in the Davis area over the last eight years). As environmental concern increased during the late 1960's and early 1970's, interested residents and students, as well as a concerned city government, began to take positive steps toward solving the problems that were confronting the area.

II. DEVELOPMENT OF THE DAVIS ENERGY CONSERVATION BUILDING CODE

A. Student Groups and the Energy Conservation Ordinance Project

During the early 1970's, concerned students at the University of California at Davis formed small research groups to share their ideas with people of similar environmental interests and to try to take positive action against the environmental deterioration that was afflicting their community. In 1971 about a dozen students formed the Greater Davis Research Group (also known as the Davis Planning Research Group) to discuss planning and environmental issues in general and specific issues such as energy, population growth and land use and growth controls (I: Bainbridge, Hammond).

The major concern of this research group was the growth of Davis. The problems of growth were seen in the gradual loss of Davis' small town character (an amenity that had attracted many people to move to this community) and in the rapid disappearance of valuable agricultural lands to development. The group's desire to prevent the loss of prime agricultural soils was shown in their halting a proposed subdivision for two months while debate was carried on within the city government on the appropriateness of unlimited growth. The research group made presentations around the city on the problems of growth and tried to explain to people the "larger scheme of things" with respect to environmental concerns and planning. Their actions were primarily responsible for forcing the City of Davis to extensively review the General Plan (I: Black, Hammond).

The Greater Davis Research Group was very interested in implementing their ideas and concerns in the real world. In the Spring of 1972, Bob Black (former President of the student body at U.C. Davis and member of the research group) formed a coalition and ran for City Council on a platform that was based on the positions posited by the Greater Davis Research Group. The coalition's victory in the March election enabled them to take majority positions on key issues in the five member City Council, thus drastically changing the development-oriented perspective that had been a dominant force in city government for most of Davis' history. Thus, the two major objectives of the Greater Davis Research Group--to get Bob Black's coalition elected to the City Council and to get the City Council to review the old General Plan--were achieved. As a result, the research group disbanded shortly after the city election, and its members turned to other activities.

During its brief lifetime, the Greater Davis Research Group investigated what energy research had been conducted in the local area and discovered the following: (1) Professors Richard Cramer (an architect) and Loren Neubauer (an engineer) of the U.C. Davis campus had conducted a number of experiments in the late 1950's and early 1960's in Davis and in other parts of California on the effects of microclimatic factors on

housing design and performance. Their research was aimed at determining the best design for the envelope of buildings with a minimal use of energy while providing reasonable temperatures during the year. Their results were published in a number of academic journals (e.g., Neubauer and Cramer, 1956 and 1968; Cramer and Neubauer, 1959 and 1961) but were not used by builders, designers or planners. (2) Energy use in the Davis area was found to be very high; consumption of electrical energy per household in Davis was 150 percent above the state average (Hammond et. al., 1974). And (3) the City of Davis had the potential for taking constructive action to reduce the consumption of energy in the community, but had not done so. Based on these concerns, several former members of the Greater Davis Research Group decided to continue their involvement in energy issues and formed, with other concerned individuals, the Low Energy Research Group in January 1973 (I: Hammond).

Shortly after the formation of the Low Energy Research Group, Jon Hammond (previous founder of the Greater Davis Research Group, member of the Low Energy Research Group and graduate student at U.C. Davis) decided that an energy conservation building code for the City of Davis might reduce the amount of energy consumed in the area's buildings. Hammond wanted to use the municipal building code as the mechanism for mandating energy conservation in the community in order to work within an existing and publicly accepted process. Under state law, each local government could adopt its own provisions (usually involving minimal alterations) in the Uniform Building Code as adopted by California according to local conditions (e.g., climate and topography)(I: Owen). These provisions would then be submitted to the State for approval, and the State may accept the local government's changes if it can be documented that they are related to unique local conditions.

With the strong encouragement of Bob Black (who was now a member of the City Council), Hammond wrote a grant proposal which was submitted by the Low Energy Research Group to the Council for the Advanced Study of the Environment (CASE,a U.C. Davis research institute funded by the Rockefeller Foundation) and to the Davis City Council (as part of a general plan action program) in the Spring of 1973. The proposal,

drafted by Bill Kopper (a member of the Low Energy Use Group) and Hammond, was entitled the "Energy Conservation Ordinance Project" and included the idea of a proposed building ordinance. The principal investigators for this proposed study were Hammond, Marshall Hunt (member of the Low Energy Research Group and a graduate student at U.C. Davis), and Professors Cramer and Neubauer.

The proposed research was not intended to be merely an "academic exercise" in examining how buildings use energy (I: Hammond). Hammond was interested in determining how Davis buildings could be improved to use energy more efficiently. Moreover, he wanted "the philosophy of community and political action" to be integrated into the project (I: Hammond). Research results were to be sensible and understandable to the general public, as well as to community leaders, so that they would comprehend the work and support the ideas and policies developed in the project.

The City Council, with Black's strong encouragement, agreed to fund the proposal only if Hammond received additional funds from the CASE Institute. In May 1973, CASE funded the project for $15,000. Shortly thereafter, the City of Davis contributed an additional $5,000. During the next 18 months, Hammond and Hunt used the $20,000 to support themselves, conduct research and pay for the services of Cramer and Neubauer.

B. Research Investigations

During the Summer of 1973 and the Winter of 1973-74, Marshall Hunt, with the assistance of Professor Neubauer, conducted research on existing homes and apartment complexes in Davis to determine how orientation and architectural design features of dwellings (e.g., shading of windows) affected gas and electric consumption. They were able to demonstrate in apartments that:

"In the summer, the second floor rooms averaged 12°C (52°F)

warmer than those on the ground floor, and north-south exposures were much cooler than east-west. The coolest units were north-south facing on the ground floor, reaching a maximum of 24°C (75°F), perfectly comfortable in hot summer weather. The hottest apartments were those facing east-west on the top floor. The results of the temperature tests were perfectly paralleled by the actual electrical use of the apartments.

"In the winter, the south facing apartments performed significantly better than those facing north, east, and west. On several occasions, south facing apartments had high temperatures in the 80's F on sunny winter days, with a maximum of 87°F. During several days the high temperatures were 24°F above ambient, and 17°F above apartments with north, east or west exposure. These high temperatures occurred in selected vacant apartments with solar exposures that were far from ideal. By comparison, a specially constructed research room with nearly ideal south window exposure registered an interior maximum temperature 48°F above the maximum ambient." (Hammond et. al., 1977).

Less clear results were found for single family detached houses than for apartments. However, it was demonstrated that houses with lots of shade trees in the area used less electricity for cooling per square foot than other dwellings. In addition, houses with the best insulation were clearly more energy efficient in both summer and winter. In sum, this research demonstrated that there were vast discrepancies in the thermal performance of buildings constructed in Davis and that good thermal performance in buildings could be provided by proper orientation and shading of windows.

During this time period, Bill Kopper was hired by the consultants to conduct research on household management practices and appliance usage which would reduce energy consumption. Analysis of data collected from 78 household interviews and from gas and electric bills showed that electric consumption was positively correlated with the number of children in the household, the hours of television watched, and the number of washloads per week (Hammond et. al., 1974). Electric consumption in the household was also highly related to the ownership of appliances. Data collected from the survey was used to compile a profile of electrical energy use in the average Davis household (Table 6), which was later updated to show the composite energy use in Davis households (Table 7). The findings clearly demonstrated that the largest energy uses

could be eliminated without great inconvenience if these specific actions were implemented. The Strategy examined six subject areas: (1) household energy consumption in Davis; (2) building performance in Davis; (3) ways to improve existing buildings; (4) proposed building standards; (5) neighborhood planning for energy conservation; and (6) solar heating and cooling in Davis. All of these areas were aimed primarily at the individual or personal level, although the neighborhood planning section could best be handled by city government.

The sections on household energy consumption and on building performance were based on Kopper's survey of Davis households and Hunt and Newbauer's research on existing apartments and houses in Davis, respectively. The first section also contained telephone survey data on people's willingness to give up certain household appliances. It was found that those appliances which used the most electricity (e.g., air conditioners, refrigerators, freezers and clothes dryers) were least likely to be sacrificed. Accordingly, the Strategy included suggestions for selecting and using major home appliances that would result in saving energy.

The section on the improvement of existing homes featured standard energy conservation measures (e.g., insulation, shading and use of light colors on exterior surfaces) which the homeowner could install in his dwelling. The consultants also suggested ways the homeowner could adopt to conserve energy in the daily operation of his or her structure.

The section on solar heating and cooling was aimed at both existing and new residences. The Strategy showed how a conventional house could evolve into a solar-heated house simply by incorporating passive solar features (e.g., large south-facing windows) and later installing active solar collectors. When compared with the average Davis house being built at that time, calculations showed that these houses would use approximately 90 percent less energy for heating and no energy for cooling, while maintaining the room temperature between $60^{o}F$ to $80^{o}F$ during the year.

for the household occurred in heating and cooling residences and in transportation. Hence, these results supported the proposed building code's basic direction--making residential structures more energy efficent--and the planning policies that were being developed by Hammond and other individuals--making the City's circulation systems more energy efficient.

In January 1974, Hammond, Hunt, Cramer and Neubauer published a preliminary report on the status of their efforts and submitted the report to the Davis Planning Commission. The progress report psychologically and politically benefitted their research program, as they were able to show convincing data on energy use in buildings that had never been seen before (I: Hammond, Hunt). During the Spring of 1974, Hammond and Hunt visited Steve Baer and Zomeworks in Albuquerque, New Mexico. Baer was one of the few people with practical experience in designing and constructing passive solar homes at that time. After obtaining some "real world" experience in the Southwest, Hammond and Hunt returned to Davis to prepare the final research report.

C. Strategy for Energy Conservation and the Proposed Building Code.

In August 1974, Hammond, Hunt, Cramer and Neubauer published A Strategy for Energy Conservation: Proposed Energy Conservation and Utilization Ordinance for the City of Davis, California (hereafter referred to as the Strategy). The purpose of this report was:

> "...to examine some aspects of how houses and neighborhoods in Davis operate, how they consume energy, how they can be made to consume less, and how they can be made more self-sufficient so that they can serve their inhabitants better." (Hammond et. al., 1974).

The report encouraged people to make very simple and specific improvements in their homes to save energy without relying on any new technological breakthroughs and without incurring any significant expenses (and possible leading to some savings for the consumer). The consultants predicted that 50 percent of the energy consumed by space heating and cooling and 50 percent of that used by household appliances

Various solar water heating systems and solar-heated swimming pool systems were also examined in this section.

The section on neighborhood planning for energy conservation contained planning policies aimed at facilitating the implementation of the proposed ordinance, improving the energy efficiency of the City's circulation systems, and encouraging the use of alternative modes of transportation. An analysis of these policies is presented later in this report.

The section on proposed building standards contained the basic framework for the future energy conservation building code, the keystone of the energy planning process in Davis. In designing the standards, the consultants considered the following criteria to make sure that the code would be practical, complement the existing building code, and encourage innovation (Hammond et. al., 1977):

1. The code would be flexible and easily understood.
2. Performance standards rather than prescriptive regulations would be used as a basis for the code.
3. Compliance must be possible using standard building technologies.
4. The code must reduce energy use significantly.

The research team also wanted to avoid raising construction costs significantly. Although there was no mandate in the code that its provisions had to be cost-effective, the consultants realized that cost was a sensitive issue and might be used against the proposed code if compliance with the code were to result in large financial outlays (I: Cramer, Maeda).

The proposed ordinance was a "performance code". It was based on the thermal performance of a house in the Davis climate on specific "design days" (August 21 for summer and December 21 for winter) when heat gain and heat loss calculations were to be made by the designer.

These design day calculations examined the total heat balance of a building over a 24-hour period to determine the energy needs of a building. Since these calculations focused only on the direct use of solar energy (i.e., radiant energy), the numbers served only as approximations to the building's actual thermal performance. Other microclimatic factors (e.g., infiltration and internal heat gain), which were excluded in the proposed standards, would have to be included in accurately sizing proposed solar heating and cooling systems (Hammond et. al., 1974).

In accordance with the concept of designing a building with climate, the proposed standards emphasized the following passive solar design features:

1. Orientation of building in a north-south direction (south was defined as 165° - 195°).
2. Control of the amount and orientation of glazing:
   a. overall window area was to be limited to 12.5% of the floor area for single-pane glass; but window area could be greatly increased by using double-pane glass, thermal drapes, shutters or by using properly shaded south facing windows, all under the general concept of earned glazing;
   b. shading of glazing was required (e.g., overhangs, awnings, arbors or deciduous trees);
   c. encouragement of windows and overhangs on south side of building.
3. Use of thermal mass for heat storage.
4. Use of light colors on exterior surfaces (i.e., roofs and walls).
5. Insulation (R-11 insulation for wood frame walls and R-19 for roofs).
6. Provision for natural cross-ventilation and requirements for the shading, location and energy efficiency of air conditioners.

These passive features were aimed at attacking both the winter heating and summer cooling problems in the Davis area for new residential construction.

Two alternative pathways were developed to insure maximum design flexibility in complying with the thermal performance standards of the proposed code. Path I, the prescriptive approach, delineated a set of rules and allowable tradeoffs which, if followed, would result in compliance with the permissible heat loss per square foot on the winter design day, and heat gain per square foot on the summer design day. Designers and builders were required only to show that their windows met the minimum shading requirement and that they had complied with the rules and minimum criteria. They did not have to make detailed calculations on heat gain nor on heat loss. Path I, the "cookbook recipe method", was expected to cover 90 percent of future residential construction, especially tract homes (i.e., houses that were mass-designed and mass-produced).

Path II, the performance approach, was more complicated than the first approach and was developed especially for builders of custom homes in order to encourage innovative solutions in adapting buildings to the local climate. Designers and builders were required to present their heat loss and heat gain calculations to establish that the proposed building met the minimum performance requirements of the code. Heat loss and heat gain standards could be violated if the designer could show that the proposed design used less energy than a design in conformance to the standards.

Both approaches could be used as design tools for those builders who wanted to go beyond the code's standards (see below). The performance standards would be enforced by the City Building Inspection Division of the Community Development Department and would also be important in the deliberations of the Design Review Commission and other municipal departments which had discretionary powers over the external appearance and building shell of buildings.

As mentioned previously, the proposed standards covered only new residential construction and emphasized only passive solar design features. The consultants had decided earlier that the proposed ordinance

would not include non-residential (e.g., commercial and industrial) buildings, existing residences and municipal buildings and would not emphasize active solar systems for the following technical, economic, social and political reasons:

1. Non-residential buildings: Davis is primarily a residential community with very little industrial and commercial activity. Accordingly, the proposed standards were aimed at one of the largest energy uses in the area, residential use. Furthermore, since there was a wide variety of types of non-residential buildings as well as a diversity of uses performed in such buildings, each building would have to be treated as unique. The complex calculations required for each building were too time consuming and expensive to do, and they necessitated a certain amount of technical expertise that was not available to the consultants at that time (I: Bainbridge, Kopper, Maeda, McGregor).

   In addition, economic analysis for non-residential buildings would be very difficult to conduct in comparison with the simple cost calculations performed on new residential buildings (which were based primarily on initial costs rather than life-cycle costs) (I: Hunt). Finally, although dramatic energy savings could be made in the non-residential sector and be visible to a large number of people, it would be very difficult for owners of non-residential buildings to support energy conservation measures when energy represented only a small fraction of the total costs involved in constructing, operating and maintaining these buildings (I: Bainbridge, Maeda).

2. Existing buildings: There was an urgent need to work on new residenital construction, rather than existing homes, since new houses and apartments usually involved the installation of large air conditioning systems, the highest users of electricity (Table 6), while many of the older homes in Davis worked well enough without air conditioning (I: Bainbridge, Hunt). Retrofitting was also perceived to be a more difficult process than building a home

properly in the first place (I: McGregor). In addition, it would be very difficult to calculate the cost-effectiveness of retrofitting existing homes due to their immense variety (I: Maeda). In fact, for some homes, certain elements of retrofitting would not be cost-effective (I: Maeda).

Another problem with existing residences was the issue of "equal treatment": were existing buildings with different energy efficiencies to be treated differently or similarly? (I: Hunt). In addition, too many people would be affected by a policy aimed at existing homes (I: Hammond, Streng). It was assumed that the greater number of people affected by a policy, the less chance that the policy would be adopted. Hence, by limiting the proposed ordinance to new residential developments, the group of citizens most likely to participate in the City Council hearings on the code would be future home owners. However, due to the high costs of participation (e.g., travelling from other parts of California and the U.S. to attend the meetings), their involvement in the development of the code would be very limited (Olson, 1968).

Also, a mechanism already existed for enforcing new construction to comply with the code's requirements: the building permit process. A different mechanism would have to be established for enforcing the code for existing homes. Finally, it was hoped that by concentrating first on new residential construction, the right atmosphere would be created for applying the code to existing homes at a later time (i.e., the "incremental approach") (I: Hammond, McGregor). (The City of Davis is currently developing a retrofit ordinance for existing dwellings. See below.)

3. Municipal Buildings: The proposed standards did not include City of Davis buildings because few City buildings were being built in the area, and City buildings would be costly to retrofit (I: Hammond, McGregor). However, City buildings were not immune to energy conservation critiques. The design for a proposed new Civic Center was attacked for its neglect of energy conservation features. The proposal was subseqently defeated by the Davis electorate on a bond measure as a result of this critique and its cost (I: Bainbridge, Cramer, Hunt, Streng).

4. Active Solar Systems: Passive solar energy systems were simple, low cost uses of solar energy which could be tailor-made to Davis' microclimate. At the time of the development of the code, only a few active solar systems were available on the market and these required technical expertise, skill, and capital to install and operate (I: Hunt). Also, active systems were not expected to be cost effective (except possibly for hot water heating), while large energy savings were associated with passive solar systems (I: Hammond, Kopper). Finally, conventional building practices and uses were permitted by the passive approach so that local builders and designers could easily construct such systems without extra cost (I: Hammond).

Thus, the proposed building standards were aimed at new residential construction, using the building as a passive solar collector, because this was the most technically, economically, socially and politically feasible strategy to pursue.

D. The Building Community's Response

In the Fall of 1974, the Strategy was presented to the City Planning Commission, the Design Review Commission, and the City Council. These governmental bodies approved the concept of the work, and the City Council encouraged the consultants to work with the Building Board of Appeals, a group of lay and professional people who served as a forum for builders to appeal Building Inspection Division decisions on building code enforcement, and also to review changes in the Uniform Building Code as adopted. Its members were appointed by the City Council and usually included engineers, architects, developers, builders and the Fire Chief. The City Council deferred review to the Board because it had the necessary expertise to analyze the proposed ordinance: the members of the Board were technically oriented and were familiar with the existing building code (I: Black, Whitcombe).

The Building Board of Appeals conducted hearings and meetings over a six month period (1974-1975) to make recommendations for changes in the proposed ordinance and to design an actual ordinance. The Board was the first forum for the building industry and other individuals to express their skepticism and/or opposition to the proposed ordinance. It appeared that most Davis builders were unhappy with the ordinance for some of the following reasons:

1. The proposed code represented another layer of controls and regulations on an interest group that already perceived itself as being overregulated by environmental and growth control regulations (I: Streng). Impending legislation exacerbated the situation. In February 1975, the State of California's energy conservation regulations for new residential construction went into effect, and in July 1975, the City of Davis adopted the Housing Development Priority Program which attempted to control the number and type of residential developments constructed in the area (Appendix A). In addition, builders were already hard pressed due to the fact that the building boom in the area had occurred a few years earlier (Table 3) (I: Hunt). In sum, most builders did not want to have any more governmental infringement on their livelihood (I: Black, Corbett, Cramer, Figueroa, Kopper, Lumbrazo, Maxwell, Neubauer).

2. The builders expected that the changes made to comply with the code would be costly, both in time and money (I: Black, Broward, Corbett, Figueroa, Hunt, Leber, Lumbrazo, Maxwell, Neubauer). Consequently, it was feared that the price of housing would increase, further dampening the housing market and driving builders out of Davis (I: Leber).

3. The mandated requirements would restrict the design freedom of the builder and architect, thereby leading to unattractive housing, both internally and externally (I: Broward, Corbett, Hunt). It

was argued that custom housing, in particular, with its vast window area for scenic views, would be hurt the most by the proposed ordinance (I: Neubauer).

4. The proposed energy conserving measures would not be as effective as the consultants expected, especially for those measures that were "behavior dependent" (e.g., manually operated shade screens) (I: Black, Broward, Hunt).

5. There was no real need for an energy conservation building code because there was no serious energy problem and because State legislation on state energy conservation standards appeared imminent, thereby obviating the need for a local code (I: Corbett, Cramer, Lumbrazo).

Moreover, many builders were afraid of change and were unsure of what was going to happen to them if the code were to be passed (I: Bertero, Hornbeek, Maeda, Maxwell, Neubauer). Most of the builders had little knowledge of passive solar design, nor did they know the actual content of the code when the hearings were first conducted in front of the Building Board of Appeals (I: Hunt).

Builders' involvement and knowledge of the code gradually increased as it became evident that State energy conservation regulations appeared to be close at hand and some type of energy conservation code was going to be adopted by the Davis City Council. Accordingly, their interest peaked near the time of adoption of the code (I: Figueroa, Hammond, Madea). At the same time, their frustration and anger increased as they felt slighted for the perceived lack of input into the development of the code (I: Roe, Streng, Whitcombe). Several builders repeatedly tried to get together with the consultants to negotiate on the proposed ordinance and speed up the process of getting an energy code adopted, but the builders were unsuccessful in their attempts (I: Streng). As a result, several builders felt the code was "crammed down their throats" (I: Whitcombe).

Additionally, a sense of distrust developed between some members of the building community and the consultants who had prepared the ordinance (I: Streng). Several builders did not trust Hammond and Hunt because of their youth, lack of experience in building conventional homes, and their different value systems and lifestyles (I: Maxwell). Consequently, a number of builders felt the consultants to be relatively insensitive to the demands of others as evidenced in the consultants' persistent refusal to modify the proposed standards (I: Roe, Streng).

The consultants were wary of the builders and other individuals who wanted to weaken the proposed ordinance. Hammond and Hunt were willing to make some compromises on the code, but they were determined that the intent and effectiveness of the code should not be substantially reduced (I: Black, Hammond, Owen). Hence, the consultants did not agree to any compromises until the City Council's public hearings on the proposed ordinance.

As the debates continued, the builders began to examine the code more closely and offered specific changes on the design aspects of the code as a basis for compromise (I: Black, Hammond, Hunt, Kopper, Leber, Maeda, McGregor, Whitcombe):

1. Roof color standards were too restrictive; darker colors should be permitted.
2. Unshaded glazing was too small.
3. Easier calculations were needed for determining the amount of earned and unearned glazing.
4. Since the code would be difficult to implement:
   a. it should not go into effect immediately; a phasing in of the code over a period of four years would be preferable;
   b. there should be a waiting period from the time of adoption to the time of implementation of the code so that builders could adjust their designs accordingly;
   c. already approved lots should be exempted from the code (i.e., there was a need for a "grandfather clause" for old lots);
   d. the code should be implemented on a voluntary basis rather than on a mandatory basis.

The builders also felt that the code was too complex and confusing and would be very difficult to implement (I: Roe, Streng). They wanted to start with a simple code which, if necessary, could be amended and made more restrictive during annual reviews of the code (I: Streng). They also believed that they would be better able to comply with a more restrictive code in the future when certain energy conservation products (e.g., double-glazing and better window shades) were more available and less expensive (I: Streng).

The builders yearned for both simplicity and flexibility, two mutually contradictory objectives (I: Hammond, Hunt, Maeda). Attempts to make the code simpler (e.g., by offering general categories or rules to follow) would inevitably result in a more standardized and rigid code. On the other hand, providing concessions to individuals on specific building items (i.e., making the code more flexible to the wishes of the builders) would eventually result in a more complicated and confusing code. In sum, tradeoffs had to be made between simplicity and flexibility, thereby leading to continual dissension and discussion between builders and consultants.

All but one builder in the Davis area opposed the code for the reasons mentioned previously. The lone builder strongly supporting the proposed standards was Mike Corbett, former member of the Greater Davis Research Group, who had built conventional homes in the Sacramento and Davis areas. At the time the code was being developed, Corbett was constructing seven houses in Davis that incorporated the same features as proposed in the code, without any extra cost and using standard building technologies. Corbett, working independently of, but parallel with the consultants, gave credibility to the conceptual framework of the code (I: Black, Hunt). Of equal importance, Corbett's support prevented the formation of a united front among the local builders whose influence had been diminished by the elections of 1972 when development-oriented interests lost the majority voice of the City Council (I: Black, Hunt).

E. Opponents and Supporters of Code

Builders were not alone in their opposition to the proposed code. There were a few citizens who were concerned about additional government regulation.

Also, several architects questioned the policy of encouraging all new residences to be oriented in one direction (I: Hornbeek). They feared that all the homes would appear the same, and, therefore, be aesthetically displeasing. The City's Building Inspection Division (of the Community Development Department), staffed by 6 full-time employees (some with engineering backgrounds), voiced concern over the extra effort and trouble that would be involved in their implementation of the proposed code, especially with no expected increase in staff (I: Kopper, Maxwell). Furthermore, building officials were dismayed by some technical errors discovered in a review of the proposed standards and, therefore, were reluctant in supporting such a code (I: Maxwell).

Among the supporters of the code were many citizens and local environmental groups whose existence and general support were known but who did not do any actual lobbying for the code (I: Black, Kopper, Maeda). Their political support was not activated because the City Council had already shown that they were in favor of an energy conservation ordinance (I: Black, Hunt). While some members of the City Council were concerned about too much governmental infringement on private rights, all the members were philosophically behind the idea of energy conservation (I: Hammond, Hunt, Kopper, Leber, Lumbrazo, Maeda, Maxwell). Bob Black, the chief proponent of the code on the Council, was seen by the other members as the "energy expert" whose advice was to be seriously heeded (I: Black, Neubauer). After he was elected to the City Council, Black had invited John Hammond and Mike Corbett to appear before the Design Review Commission to offer suggestions on how builders could make their buildings more energy efficient. Later, Black told the building community that the City Council was going to support some type of energy conservation ordinance, and any compromises on the proposed standards would have to be negotiated with the consultants rather than with the City Council (I: Black). He was determined not to make any political tradeoffs that would seriously weaken the code, and this attitude was shared by at least two other members of the Council.

The City Planning Commission, the City Attorney, and the Design Review Commission also expressed their support for the proposed ordinance (I: Corbett, Hunt). The City Planning Division (of the Community Development Department), on the other hand, was somewhat supportive of the code, but most of the staff

remained primarily uncertain and neutral to the proposed ordinance (I: Corbett, Figueroa, Hunt, Kopper). This department was concerned about the development of a practical and easily utilized ordinance and, therefore, were very sensitive to the objections of those individuals opposed to the code (I: McGregor). In addition, the staff was not experienced in the use of building codes except as they related to traditional public health and safety aspects of structures (I: Hunt, McGregor).

F. The Consultants' Educational Strategy and the Search for Funds

After the Stategy for Energy Conservation was published, Hunt and Hammond received more money from the CASE Institute and $11,000 from the City of Davis (via the Janis Foundation) to continue their work on the energy conservation ordinance. Realizing that social factors were as equally important as physical design features in promoting energy efficient housing, the research team made a concerted effort to educate the members of the Davis community (I: Hammond, Hunt). In addition to making presentations before the City Planning Commission, the Design Review Commission, the Building Board of Appeals and the City Council, Hunt and Hammond spoke at service clubs, classes and various community groups and organizations (e.g., the Chamber of Commerce and the League of Women Voters) which they perceived as having political influence in the community. They explained their research findings and the purpose and content of the proposed code. Not coincidentally, Hunt became a member of the City Planning Commission in November 1974. His appointment was encouraged by Bob Black and other members of the City Council for his expertise in energy matters (I: Black).

During late 1974 and early 1975, Hammond and Black made several trips to Washington, D.C. in an attempt to secure grants from federal agencies such as the Energy Research and Development Administration, the Federal Energy Administration, the National Science Foundation, and the House Committee on Science and Technology. After being turned down by these agencies, Hunt and Hammond, with the assistance of the City Manager, submitted a grant from the City of Davis to the U.S. Housing and Urban Development Department

(H.U.D.). H.U.D. had recently created an Innovative Projects Program for local governments under Title I of the Housing and Community Development Act of 1974 (P.L. 93-383). In early Fall 1975, the City of Davis received an H.U.D. grant of $86,000, one of 17 approvals out of 400 applicants (I: Black). The funds were allocated to the research team who, with the assistance of City staff and officials, used the money for completing, adopting and implementing the energy ordinance and energy planning policies, and for designing two homes which utilized passive solar designs.

G. The City Council Hearings

During the Summer and Fall of 1975, intense negotiating and bargaining on the provisions of the proposed ordinance and resolution were conducted among the consultants, builders, the City Attorney, the Building Board of Appeals, the Building Inspection Division and the Planning Division of the Community Development Department. The Building Board of Appeals had issued a set of recommendations on the proposed ordinance that the builders could live with: e.g., the Board had recommended that the amount of unshaded glazing in a house be the equivalent of 5% of the floor area, and that a glazing constant of 40 square feet in single-pane glazing be added for homes (I: Streng). When the City Council's hearings on the proposed ordinance started, debate became more acrimonious as proponents of the recommendations of the Building Board of Appeals argued with supporters of the recommendations of the consultants (I: Streng).

Partly on the basis of the objections of builders and partly on the need to make the code more practical, changes were made in the consultants' original proposal by the City Council, as described below (I: Black, Hammond, Hunt, Kopper, Leber, Maeda, McGregor, Owen, Streng, Whitcombe):

1. "Grandfathering". Homes which were to be built on lots already approved in a tentiative subdivision map prior to September 1, 1974 were to be exempt from the code. This provision was included for those individuals who had complained the loudest during the public meetings.

2. Delay Period. The ordinance was to become effective 90 days after the time of adoption in order to (a) conduct workshops on the code, (b) develop forms and a workbook on implementing the code, and (c) give builders time to change the orientation of lots that had been previously approved by the City. As a result of this compromise, there was a rush to get plans approved before January 1 when the code became effective.

3. South Orientation. The definition of south was expanded to include 157.5° to 202.5°, thereby giving more flexibility to the placement of residence.

4. Exterior Color. Darker colors could be permitted on outside walls and on roofs for some types of buildings if additional insulation was provided. No wall colors were required for apartments. These changes were made for aesthetic purposes.

5. Amount of Glazing. A glazing constant of 20 square feet in single-pane glazing and 28 square feet in double-pane glazing was added for homes. This increase in allowable window area primarily benefitted smaller homes (e.g., 900 square feet) which had small amounts of unearned glazing when based on percentage of floor area (which was 12.5% for single-pane and 17.5% for double-pane) and, therefore, had a difficult time placing windows in the correct areas.

6. Unshaded Glazing. The amount of unshaded glazing was increased for apartments from 0.5% to 1.5% of the floor area, and for homes from 0.5% to 3% of the floor area. This was true for south facing glass as well as east and west facing glass.

The first two changes were incorporated in Ordinances 784 and 787, which contained (1) a statement of the energy problem, (2) description of local

climate conditions (in order to escape state preemption), (3) summary of research findings, (4) minimum performance standards for summer and winter, (5) partial exemptions and variances, and (6) an appeal process (see Appendix B). The next four modifications were included in Resolution 1833 which implemented the ordinances and contained methods for calculating building performance: the Path I and Path II approaches, similar to the paths described in the Strategy, but with several changes and exceptions (see Appendix B). Thus, despite being left out in the early development of the proposed standards, the building community played an integral part in designing the final ordinance and resolution.

Many participants felt that the changes made the code more lenient by weakening the performance characteristics of the original proposal (I: Black, Hammond, Hunt, Kopper, Maeda). Others saw the compromises as necessary "political tradeoffs" that "rewarded" the building community for their extensive participation in the political process (I: Black, Maeda). The builders believed that the weakening of the code made it possible to build better homes with the existing technology at that time (I: Streng). After obtaining the building community's support through the bargaining process, the City Council unanimously adopted the code on October 15, 1975.

III. IMPLEMENTATION OF THE DAVIS ENERGY CONSERVATION BUILDING CODE

A. The Workshops and the Workbook

In the Fall of 1975, Jon Hammond, who had recently formed a consulting firm called Living Systems, started to use the H.U.D. grant money to implement the Davis energy conservation ordinance. These funds were used for starting up Living Systems (e.g., hiring staff, developing forms, and consulting with individuals). The money also played an important role in getting the code adopted: prior to adoption of the ordinance, the consultants declared to the opposition that they had the funds for implementing the code so that the City of Davis would not have to incur any financial burden in the implementation process (e.g., permit fees) (I: Hunt).

After the energy conservation ordinance was adopted in October, there was no written material available on the code other than the code itself. Hence, the first need was for an "outreach program" to educate the building community and City staff about the meaning and content of the ordinance and resolution. During the 90 day period following adoption of the code, Living Systems and the City of Davis conducted several workshops, funded by the H.U.D. grant, in which participants were provided information about design with climate and the basic principles behind the code, led through the code step-by-step, explained the "rules of thumb", and taught how to fill out the appropriate forms. The workshops were "manageable" (approximately 50 people), and the participants included builders, designers, architects, real estate people, City building and planning officials, students, press, interested citizens, and vendors of energy conservation devices.

There were varied interpretations of the value of these workshops. As a training tool, several individuals felt them to be "worthless" as, in many cases, the people who actually filled out building forms did not attend the workshops (I: Bainbridge). Instead, the owners of building companies attended and turned some of the meetings into "political forums", once again testing the performance and expertise of the consultants (I: Hunt). Thus, the meetings were considered to be less effective than anticipated, since the information was not getting out to the people who really needed it (I: Bainbridge, Maeda). On the other hand, it was argued that it was very important that the owners of the building firms came to the workshops since the people who filled out the forms were not likely to remain in those positions as long and had less influence over others (I: Hammond). Moreover, the owners felt that it was their duty to attend these meetings to try to reduce the practical problems of complying with the code (I: Streng).

Many other people felt the workshops to be very helpful because they: (1) pinpointed specific problem areas in the ordinance and resolution that had to be clarified (e.g., the shading of glazing); (2) aided in refining implementation techniques for both the builidng inspector and the building community (e.g., developing forms that were similar to those previously in

use and were understandable, generating a format for a workbook, and testing builders' designs for conformance with the code); (3) further educated the building officials who were in charge of implementing and enforcing the code; and (4) facilitated communication among all the participants in Davis' energy planning system.

The Energy Conservation Building Code Workbook, prepared jointly by Living Systems and the City of Davis, and provided for in the H.U.D. grant proposal, was completed after many revisions in July 1976, six months after the code had been in effect. The Workbook contained examples of houses and how the Path I and Path II methods could be handled with different design constraints. It also included examples of completed forms, tables of R values of different materials, a list of roofing materials and their color value and other information designed to help builders, architects, developers and future homeowners. The Workbook was unquestionably of immense value for these people as well as for the staff of the building inspection and planning divisions (I: Leber, Maxwell, McGregor). Prior to the publishing of the Workbook, the mechanics of complying with the code were hammered out among building officials, consultants and builders. If a workbook had not been prepared, a continuing seminar series would have been necessary (I: Leber).

B. The Costs of Implementation

During the first six months after the energy conservation code became effective (January 1976 to July 1976), there was some confusion over the "complexity" of the performance calculations, over which lots were to be exempted under the code, and over what was generally required of builders and designers (I: Hornbeek). During this transition period, there was a delay in processing building plans because of the additional duties placed on the Building Inspection Division without a concomitant increase in building inspection staff or budget. While a residential plan checker was added to the Division (whose cost was paid by plan check fees), time was needed to educate the building inspector on the code as well as to train field people in the enforcement of the code suring construction periods (e.g., to make sure that double-pane glass was being installed instead of single-pane glass)(I: Leber, Lumbrazo).

The plan check for energy conservation features was fully integrated into the total plan check process, thereby simplifying the administration of the code. Initially, the Building Inspection Division spent a great deal of time and effort on checking plans, including the crush of permits which had been hastily submitted just prior to the effective date of the code in order to be exempted from the code. Once the plan check process stabilized, time spent on reviewing a plan ranged from an average of 30 minutes (for the less complex designs) to 2 hours (for the more complex designs) with most plans falling on the low end of the range (Rancer, 1977). In sum, the entire process of developing the ordinance and resolution, the implementation tools and the public education program took about one year and cost the City $20,000 in consultant's fees (via H.U.D. money) and considerable staff time (Rancer, 1972)(I: Hunt).

There have been a variety of costs (e.g., direct and indirect, monetary and non-monetary) to the builder and designer associated with the implementation of the code. This most frequent complaint mentioned by those interviewed in this project was that an applicant for a building permit needed to spend more time on paperwork (I: Broward, Hornbeek, Lumbrazo, Maxwell, Roe). It was stated that the applicant needed to acquire more information to comply with the code than previously, especially for performing calculations, building scale models and completing forms (I: Hornbeek, Maxwell). One builder mentioned that he spent approximately 40 minutes per house on calculations and paperwork (I: Bertero). Another builder stated that one-half of his time was spent on "unproductive paperwork" (I: Streng). And a third builder declared that one-third of his company's "principal time" was spent on paperwork (i.e., one partner spent all his time on paperwork)(I: Roe). It is important to note that "paperwork" involved compliance with other City, State and Federal regulations, in addition to the energy conservation code. The amount of paperwork directly attributed to the energy conservation code decreased as the builders became more experienced in building under the code (I: Broward).

Initially, plan check fees varied accordingly, from no charge for the prescriptive path (Path I) without exceptions to $25 for the performance

path (Path II). As a result of the passage of Proposition 13 in June 1978, the City of Davis decided to raise plan check fees for both residential and nonresidential buildings: Path I plan check fee was raised to $30.00, Path II plan check fee was raised by $50.00, and nonresidential plan checks were charged $30.00 per hour.

One of the central arguments used by the builders against the code was that the proposed ordinance would result in a significant increase in the cost of housing. This objection was proven invalid, as evidenced by recent construction in the Davis area. Average cost in new residential construction as a result of the code was approximately $250 per house (not including the cost of insulation, a major expense which was also required by the State) with a range from $50 to $1,000 per house, depending on its orientation, the type of house, the number and type of energy conservation features installed in the building and the competence of the developer (Davis Energy Conservation Report, p. 114; I: Bainbridge, Broward, Kopper, Lumbrazo, Maeda, Maxwell). Houses oriented east-west required considerable shade screening while those buildings oriented north-south met the code's performance criteria with little or no modifications and, therefore, minor costs (I: Maxwell).

The most substantial cost increases occurred for custom housing rather than tract housing: custom homes could be built with extensive glazing if double-pane glass was used and provisions were made for shading (e.g., overhangs, shade screens, and trellises), thus, increasing the cost of compliance with the code. In addition, custom builders felt the reduced amount of glass needed to comply with the code negatively affected the "liveability" of the house--a nonmonetary cost (I: Streng). Nevertheless, the added monetary costs due to the code were relatively minor when compared to the total expense of custom housing (I: Hornbeek).

While many builders in Davis have constructed homes based primarily on passive solar design features, resulting in minor costs, a few builders have installed active solar systems for space heating, cooling and hot water systems and have increased the amount of insulation in walls and ceilings. Accordingly, this variation in building design has led to a greater increase in housing costs. These direct costs do not take into account the expected

savings in energy costs over the lifetime of the building. The extra initial costs could be recouped in one to two years if, for example, utility costs are reduced $5-$10 per month.

The cost of compliance with the energy conservation code was not a major factor in Davis because many of the features of the ordinance were easily implemented with existing construction technology and because many builders had already incorporated these features in their buildings prior to the code's adoption (I: Bertero, Broward, Hammond, Roe). For example, insulation had already been required by the State, slab floors had been used by some builders since January 1975 and earlier as part of Federal Housing Authority requirements, overhangs had been used by some builders as early as 1964, and several builders had already reduced window area to minimize heat loss (for small homes and custom housing)(I: Broward, Streng). The glazing requirement was burdensome at first. Proper housing orientation and shade screening were the most common design changes affecting the building industry, and both "innovations" were easily met by builders and designers early in the planning process (I: Bertero, Broward).

All but two builders have followed the prescriptive approach (I: Hunt). Most builders felt that using fixed standards on materials and design resulted in quick compliance with the code and, therefore, avoided the relatively more laborious and difficult performance path (I: Streng). This was especially true for builders of tract housing. The few individuals who chose the performance method were custom builders with complicated designs.

C. The Effectiveness of the Code

It is very difficult to measure the true effectiveness of the Davis energy conservation code, since many variables other than the code itself affect energy consumption. Household natural gas and electrical consumption in Davis' residential sector have decreased dramatically; a 21% reduction for natural gas from 1973 to 1977 and a 13% reduction for electricity over the same time period (Table 1; Figures 2 and 3). Two factors possibly accounting for this reduction are: (1) the code itself and (2) the energy conserving behavior of Davis residents. While there is no data available

on the amount of energy saved in Davis as a result of the code, there is an abundant supply of personal opinions from homeowners and builders. One builder in Davis, who had been originally opposed to the code, experimented with different housing orientations and monitored the temperatures of his buildings. He recorded substantial differences between indoor and outdoor temperatures when using the passive features of the code and orientating his houses correctly. In addition to confirming the consultants'expectations, this builder has become an ardent supporter of the code. Several builders have stated that they expect a 50%-60% savings on heating and cooling costs compared to the typical Davis home (I: Broward, Corbett, Hammond).

It is important to note that the expected energy savings could also occur to a large degree as a result of other programs in Davis--for example, the application of State energy conservation regulations (especially insulation standards), and the City's own energy planning policies (especially proper lot orientation)(see Section IV)--which are independent of the code. Furthermore, houses built under the code represent a small percentage of the total housing stock: 1,294 single family homes and 655 multiple housing units have been built as of October 31, 1978. These 1,949 housing units represent only 14% of the total housing stock in Davis (13,633 units)(Davis Building Inspection Division, personal communication). Hence, one must seach for other variables to account for the significant reduction of energy use in the Davis community.

The energy conserving behavior of Davis residents was mentioned by several individuals as being an important factor in reducing energy use in Davis (I: Cramer, Hammond, Kopper, Reese and Streng). The Davis community is generally young and well-educated, two demographic variables reportedly related to conservation behavior (Curtin, 1976; Olsen, 1977). Perhaps of greater importance was the extensive public education program developed by the City of Davis to teach residents how their homes operated and to urge them to initiate conservation measures in the household (Hammond, et. al., 1977). The program emphasized more efficient use of household appliances, and encouraged homeowners to retrofit their homes with insulation, weatherstripping, and shading devices (Kopper, et. al., 1976a, 1976b). In addition

to the publishing of a retrofit manual, several Davis homes were evaluated by the City for their heat gain and heat loss and the cost-benefits of different retrofit techniques.

The City also disseminated information about energy conservation to the public through three editions of an eight page tabloid newspaper called the Energy Conservation News. The paper included topics on energy conservation in the home, stories on bicycling and low energy transportation, information on how to retrofit a home, gardening and water conservation, and other related stories. In sum, an extensive public education program attempted to influence energy consumption in all Davis households, and the program's effectiveness was undoubtedly reflected in the energy figures cited previously.

It is possible that the reduction in energy use in the Davis area was more a result of favorable weather conditions than of the factors described above. Although there is no published data available, the number of heating and cooling degree days has not significantly changed since 1970 (Bruce Maeda, Davis Alternative Technology Associates, personal communication). Moreover, household electrical use in Vacaville and Woodland--nearby communities experiencing similar weather conditions--have increased 5% and 3.9% overall, respectively, between 1973-1976 while Davis' household electrical use declined by 8% during the same time period (Hammond, et. al., 1977). Hence, it appears that weather conditions were not a significant variable affecting energy consumption in the Davis community.

It is clear that a systematic and comprehensive evaluation of the Davis energy conservation building code is needed to determine the code's contribution to the Davis energy situation. The City of Davis has recently received a grant of $4,000 from the California Energy Commission to conduct a study of the code's performance; this study will begin in early 1979. It is also important to determine how Davis residents are conserving energy in the household as a result of the public education efforts over the last several years because their behavior may be the most significant variable affecting the reduction of energy consumption in Davis.

D. The Building Community's Response

Although some builders and architects are still opposed to the code for socio-political reasons (e.g., governmental infringement on private rights),

During the implementation period, the consultants conducted research on various components of buildings to determine if theprinciples of the code were correct in practice as well as theory (Hammond, et. al., 1977). Studies on heat transferance from windows and walls to the interior of a house demonstrated the effectiveness of south-facing glazing in heating homes. Experiments on roof color and roof material proved that almost all roofing materials had similar thermal properties except for cedar shakes which performed substantially better. And experiments on the thermal properties of cement blocks and water storage concrete slabs confirmed the validity of allowing additional glazing on the south side of a dwelling to capture and store winter sunlight. The results from these experiments confirmed many of the passive solar features recommended by the consultants and further destroyed any remaining technical objections by those opposed to the code.

E. The Future of the Davis Code

Since the energy conservation building code is being implemented without too much trouble, there were few suggestions for changing the content of the ordinance and resolution. Although some people felt that the code could be simpler (i.e., easier to apply while maintaining its effectiveness) and/or tougher, most individuals felt that the code should be left alone for a while, since any future thermal improvements in the code may not be politically viable (I: Corbett, Maeda). However, there were several recommendations for improving the educational process (I: Hunt, Maeda): (1) hiring of an ongoing energy worker and establishing a local energy center as a source of information (particularly for new builders and prospective property owners), (2) revision of the Workbook, and (3) higher standards for building inspectors who must deal with new State and local energy regulations.

The future of the Davis energy conservation building code is in doubt because of recently enacted State energy conservation standards for new residential and nonresidential buildings (effective July 1, 1978; California Energy Commission, 1978). The Davis code is considered by many builders in the Davis area to be cheaper and more flexible than the State regulations, but just as energy efficient because the local ordinance does not require

double-pane glass (which is expensive and is required in new residential construction by the State in regions over 3500 heating degree days) but does require proper site orientation and shading (which are not required by the State)(California Energy Commission, 1978b)(I: Bainbridge, Hunt, Maeda). A double-pane glazing requirement had been proposed by the consultants prior to the development of the proposed Davis ordinance but had been withdrawn because the glazing was too expensive, not readily available and would be politically unfeasible as a mandatory requirement (I: Cramer). The adopted ordinance did give credit to those people who used double-pane glazing (e.g., 17.5% of the floor area of units could be used for glazing if it was double-pane in contrast to 12.5% for single-pane). It is uncertain whether the Davis code is a "stronger" or "better" (i.e., save more energy with less cost) ordinance than the new State regulations. One local energy consultant asserts, based on a preliminary analysis, that the Davis code is stronger, primarily due to its low unearned glazing base (Bruce Maeda, Davis Alternative Technology Associates, personal communication). Presently, the City Attorney is advising the City to continue enforcing its own code for new residential buildings until the State can prove that their regulations are more cost-effective and energy-effective than Davis' ordinance (I: Owen).

The City of Davis is currently in the process of reviewing a retrofit ordinance for making existing homes more energy efficient by requiring some level of energy efficiency to be demonstrated by the seller at resale. In May 1977, the City received a grant of $10,000 from the California Energy Commission which was matched with $10,000 from the City in order to hire a Bay Area consulting firm to analyze proposed energy conservation technologies (e.g., shading, screening, landscaping, and insulation) that would be incorporated into a retrofit ordinance. As of late 1978 the consultants had completed their report (Sedway/Cooke, 1978a, 1978b) and had drafted a proposed ordinance. The City is currently reviewing the proposed ordinance and will be conducting public hearings on the ordinance in early 1979.

Prior to July 1, 1978 (when the new State energy conservation regulations became effective), the City had gone beyond its formal mandate and had applied many of the features of the energy conservation code and the planning policies to nonresidential buildings (e.g., commercial and industrial buildings) through

the Design Review process (I: Lumbrazo, McGregor). For example, new car dealerships were required to change the amount of glazing, asphalt, and landscaping in and around their buildings. Also, owners of a national "fast food" franchise were forced to modify their outdoor seating arrangements, landscaping, parking lot shading and the amount and orientation of glazing. Since July 1, 1978, the City has tried to enforce the new State regulations for nonresidential buildings. However, due to a lack of technical expertise in the Building Inspection Division, the complexity and ambiguity of the regulations, and a poor State educational program on explaining the standards to local building officials, the City has decided to submit nonresidential applications to the State Housing and Community Development Department for plan review (I: Maxwell).

IV. DEVELOPMENT OF THE DAVIS ENERGY CONSERVATION PLANNING POLICIES

The history of the energy conservation planning policies in Davis closely paralleled the history of the energy conservation building ordinance. Although the energy code was perceived by the consultants to be the center of all energy issues in the Davis area, the energy planning policies were considered by both consultants and City staff and officials to be very important in facilitating the implementation of the new building code, encouraging the use of energy conservation features in the nonresidential sector and in the City's circulation system, and in supporting the use of alternative modes of transportation (e.g., walking and bicycling)(I: Bainbridge, Hammond). After briefly examining the history of energy planning in the City of Davis, several energy planning policies are analyzed in detail in this section, and problems of implementing these policies are discussed in the next section.

In 1971, the Greater Davis Research Group, which had received strong public support for their positions on the protection of agricultural lands and other environmental issues, requested the Davis City Council to revise the old Davis General Plan (I: Black, Hammond). The Plan was written in 1958, slightly revised in 1961 and 1969, and was in need of complete overhaul (I: Bainbridge, Black). In the Fall of 1971, the City initiated the process of revision, which evolved into the writing of a completely new General Plan. The City Council appointed a 110 member Citizens Review Committee which was

then divided into ten subcommittees to research the various topics to be covered in the Plan (e.g., open space, conservation, community design, development and redevelopment, housing, circulation, land use, recreation, parks and street trees). Each citizen subcommittee had eleven citizens and one technical staff person. In addition to their research, all the subcommittee members and a random sample of Davis residents were surveyed to obtain their attitudes on various subjects, including the issue of whether Davis' future population should be 45,000 to 50,000 people (instead of 90,000) by 1990. The subcommittees, the Planning Commission, the Planning Division (of the Community Development Department) and the City Council extensively reviewed several drafts of the new General Plan over a period of approximately thirty months. The new General Plan was adopted by the City Council in 1973 and has undergone annual review and updating since that time, with additional plan elements being incorporated as they were adopted.

None of the ten subcommittees were directly concerned with energy issues per se. A high energy consciousness did not appear in the City of Davis until after the Arab oil embargo of 1973; by this time. all the citizen subcommittees had been selected. The Public Services, Facilities and Conservation Subcommittee did look at certain general environmental issues, some of which had significant implications for energy use (e.g., increased use of bike paths, public transit, and water conservation). Most importantly, as the General Plan has been reviewed over the years, it has incorporated several energy policies as a result of the extensive discussion over the energy conservation code and the energy conservation policies. Hence, the revised General Plan presently contains a Conservation Element which deals with the conservation of water, soil, climate, biological, mineral and cultural resources, nonrenewable materials and energy (City of Davis, 1973). The energy conservation policies encourage energy efficient buildings, tree shading, the use of less pavement and the use of modes of transportation other than automobiles and trucks. Similarly, the Circulation-Transportation Element encourages the use of bicycles and public transit (City of Davis, 1973).

Several energy conservation planning policies first appeared in the Strategy for Energy Conservation (1974) and were later refined and integrated with other policies in Planning for Energy Conservation (1976). The consultants developed many of these policies at the same time the proposed building code was being developed so that the code and policies could be integrated with one another to effectively reduce energy consumption in the Davis area. Staff and officals of various city departments have taken a very active role in influencing the form and effectiveness of these policies (both positively and negatively) and have developed policies on their own initiative.

The City of Davis enforces its planning policies principally through the review of planned unit developments rather than through conventional zoning regulations (I: McGregor). The governmental bodies involved in the review process include the City Planning Division, the City Planning Commission, the Design Review Commission, the City Council, and representatives of other city departments. Consequently, proposed planning policies can be adopted either through an ordinance or through formal, or informally agreed upon, policies used in the development review process. This distinction will be noted in the following discussion on the proposed energy planning policies which utilizes the framework developed in the Davis Energy Conservation Report (1977)(hereafter referred to as the Davis Report):

A. Land Use Policies
   1. Lot orientation and size
   2. Building setback margins
   3. Fence setbacks
   4. Street width
   5. Solar rights
   6. Landscaping commercial areas
   7. Shading parking lots
   8. Use of alternative parking lot materials
   9. Clotheslines
   10. Swimming pools
   11. Home occupations

B. Reduction of Energy Used for Transportation

1. Pedestrian circulation
2. Further support for bicycling facilities
3. Energy conservation and the City vehicle fleet

A. Land Use Policies

1. Lot Orientation and Size

Proper lot orientation (i.e., lots oriented to face south) is designed to facilitate the implementation of the energy conservation building code. By requiring lots to face south (i.e., requiring streets to run generally east-west), heating loads are met and cooling loads are reduced at no extra cost (Davis Report, 1977). Although not an ordinance, this policy was used in the review of planned unit developments prior to the code's eventual adoption: developers were not able to receive tentative map approval for their proposed developments unless the Planning Commission approved the lot orientation (I: Lumbrazo, Streng). Consequently, more than 90% of all new lots in Davis are oriented north-south; the remaining east-west lots are made wider so that homes can be oriented properly, although smaller lots are allowed in planned unit developments (Davis Report, 1977)(I: Bainbridge).

Although no formal policy has been adopted, the City has tried to reduce the minimum size of lots in order to take advantage of the following benefits: (1) discouragement of sprawled development so that travel time, distance and energy use are reduced; and (2) protection of prime agricultural land and open spece resulting in better use of land and better landscape maintenance (e.g., less maintenance for the property owner)(Davis Report, 1977). The City has allowed as little as 3,000 square feet for lots for attached dwelling units and 4,500 square feet for lots for single family detached units (I: McGregor).

2. Building Setback Margins

The City has allowed greater flexibility in house placement so that property owners can take advantage of solar energy. By minimizing side yards on one side (e.g., 3 foot interior and 15 foot street side years), front

aesthetic reasons, or because they do not believe there is an energy problem, there is no longer any strong opposition by the building community to the code (I: Bainbridge, Hunt, McGregor, Reese). Reasons for the generally supportive atmosphere by builders and designers include the following (I: Broward, Hunt, Lumbrazo, Maeda, McGregor, Owen, Reese): (1) the code resulted in energy savings and lower utility bills while maintaining comfortable room temperatures; (2) energy conservation can be used as a marketing tool to sell homes; (3) the procedures for complying with the code presented no major problems; (4) the builder's principal objections (e.g., the expected increase in the cost of housing and the ineffectiveness of the code) were proven false; (5) the code generated a great deal of favorable publicity and it would have been foolhardy to continue opposing the code; and (6) the builders had other concerns to contend with (e.g., the Housing Development Priority Program, Appendix A). Consequently, although there are provisions in the code for applicants to appeal adverse decisions, no appeals have been made, nor have any changes been made in the ordinance or resolution.

In a related issue on a proposed energy ordinance in Sacramento County, Sacramento builders requested an opinion from the Office of the Attorney General concerning the issue of State preemption over local governments in mandating energy conservation standards. The Attorney General's opinion (61 OPS Cal. Atty. Gen. 118) stated that local government energy codes were required to be reviewed by the California Energy Commission to make sure that the local code saved at least as much energy as the State energy conservation regulations. The Davis energy code was submitted to the California Energy Commission to determine if this requirement was fulfilled, but the State has not responded at the time of this writing.

The members of the building community have made positive contributions to the energy conservation field in Davis and in nearby communities. During the period when Sacramento County conducted hearings on a proposed energy ordinance (designed by Living Systems), several Davis builders travelled to Sacramento to advocate the adoption of the proposed building code, emphasizing both its energy saving and commercial advantages. Moreover, in Davis, some builders have "gone far beyond the code" by installing more sophisticated passive solar systems, active solar systems and additional energy conservation

features for a variety of reasons (I: Hammond, Hunt, Kopper, Lumbrazo, Roe, Streng, Whitcombe):

1. A State tax credit for solar energy systems provides an incentive for builders to install active and passive solar systems (for space heating and/or cooling and heating hot water). (Recent State energy legislation--AB3623--allows builders to claim the credit themselves or to pass the credit to the homeowners).

2. Energy conservation features are very economical and can be marketed for their practicality, status and economy (e.g., reduced utility costs) especially when the State tax credit is taken into account in conjunction with solar systems.

3. Solar homes have good publicity value, and they bring people out to a subdivision so that other homes can be sold. (However, one builder noted that this reason may be advantageous only for less competitive builders because he doesn't have enough houses to meet current demand.)

4. There is a consumer demand for solar homes and for energy conservation in general. (In fact, some people move to Davis for energy conservation reasons alone.)

5. By installing solar systems and more energy conservation features, builders receive "brownie points" in their attempts to obtain housing allocations through the City's Housing Development Priority Program (Appendix A).

6. Some builders sincerely believe that energy conservation is essential and see the code as one step on the path to an energy conserving society.

7. Many builders take pride in building quality homes, and quality now includes how much energy is required by the home.

yards (e.g., 15 feet), back yards (e.g., 5 feet), and the distance of garages from sidewalks (e.g., 20 feet), the City also expects to save more open space outside the City, encourage better lot utilization (e.g., by creating more usable land in front or back yards and eliminating or reducing side yards which are seldom utilized), stimulate more housing variety, and reduce development costs (Davis Report, 1977). In addition, zero yard setbacks are allowed in planned unit developments to encourage commonwall construction which reduces heat load and heat loss. These concepts are used by the City in planned unit development designs (I: McGregor).

3. Fence Setbacks

Similar to the preceding ideas, the deregulation of fence setbacks is aimed at encouraging the full use of south facing windows. Fences, walls and hedges are permitted to be as high as six feet in rear yard, interior side yard and front yard (within a fifteen foot setback) and can be located closer to the street in order to prevent shading of south glass while maintaining privacy at the same time in some instances. The City Council is now considering further deregulation of fences (I: Lumbrazo).

4. Street Width

In the Strategy for Energy Conservation, the consultants recommended lower minimum standards for the following types of Davis streets:

1. cul-de-sacs (the least travelled residential streets)
   --existing Davis standard: 28 foot minimum curb to curb
   --proposed standard: 25 foot maximum curb to curb or 20 foot wide with "parking bays" (i.e., no street parking)

2. "local streets"
   --existing Davis standard: 34 foot minimum curb to curb
   --proposed standard: 28 foot maximum curb to curb or 20 foot wide with "parking bays"

3. "neighborhood collectors"
   --existing Davis standard: 52 foot minimum
   --proposed standard: 38 foot maximum

The benefits of narrower streets are (Davis Report, 1977): (1) lower development costs (e.g., perhaps as much as $1,000 per lot); (2) higher value for lots due to reduced flow of automobile traffic; (3) better utilization of land (e.g., the space that is saved could be used for parks, greenbelts, and paths for pedestrians and bikes); (4) the encouragement of energy conserving transportation practices while discouraging unnecessary automobile use; and (5) the saving of energy. Research has shown that neighborhoods with narrow shaded streets can be 10 degrees cooler in the summer than neighborhoods with wide unshaded streets so that less electricity is needed for cooling in the household (Myrup, 1972).

The City has reduced the widths of minor arterials, local streets and cul-de-sacs through the review process of planned unit developments, although not to the extent recommended by the consultants. The City implements their policy by using the General Plan's street width standards as guidelines for developers of subdivisions and planned unit developments (I: Pelz). For example, one developer has built 20 foot private streets (curb to curb) with no on-street parking (but with neighborhood parking bays), while the standard in the General Plan for cul-de-sacs is 28 feet (curb to curb) with parking on both sides of the street (I: Corbett, Pelz).

5. Solar Rights

The consultants developed a guarantee of "solar rights" in new residential developments in order to provide protection for solar home owners (Hammond, et. al., 1974). The proposed ordinance required every developer to include a deed restriction describing the allowable height and shape of an "envelope zone" for structures and evergreen vegetation. It was designed to minimize the shading of adjacent properties during winter. The shading patterns cast by the envelope on December 21 from 10:00 a.m. to 2:00 p.m. as well as those of surrounding properties were to be written in an easement or covenant to be included with the property deeds.

The City did not adopt this policy, either formally or informally, because the use of an "envelope zone" was not perceived to be necessary. The City hopes to stay away from this complicated and controversial area by allowing existing mechanisms to solve the problems (I: Leber, Lumbrazo, McGregor). The City anticipates that private parties will be able to resolve any solar access problems for existing homes through private contracts, easements or covenants. It is possible that solar obstructions on existing homes could be prevented through the Housing Resale Inspection Ordinance (No. 820) which is designed to prohibit unauthorized construction and is enforced by pre-sale inspections (I: Leber). Shading problems for new residential developments can be prevented during the Design Review process and the Environmental Impact Review process where shading impacts of planned unit developments are evaluated (I: Bainbridge, Figueroa, Lumbrazo). It is also possible that by using building height regulations, either lot by lot or street by street, many of the shading problems can be avoided (I: Maeda).

Recently enacted State solar legislation in the solar rights field has affirmed some of Davis' current policies, but will force Davis to become more actively involved in the protection of an individual's solar access. A.B. 3250 prohibits local governments from passing ordinances which restrict or prohibit solar use. The bill allows localities to require solar easements as a condition of approval for tentative subdivision maps. The maps shall also provide, to the extent feasible, for lots which will enhance the use of passive design features in buildings. Codes, covenants and restrictions in subdivisions which prohibit or restrict solar are prohibited. For the individual, it permits agreements between neighbors for receiving sunlight, with any costs applied to the State solar tax credit.

A.B. 2321 prohibits, after January 1, 1979, any tree or shrub to be placed or grown after the installation of a solar collector on another's property so as to cast a shadow over 10% of that collector between 10:00 a.m. and 2:00 p.m. Vegetation planted prior to the installation of the system would be exempt. The Act does allow any city council or county Board of Supervisors to vote themselves out of the provisions of this legislation.

6. Landscaping Commercial Areas

The City of Davis has adopted landscaping regulations for commercial areas to try to reduce the energy used for space heating and cooling of buildings and to improve the comfort of pedestrian and bicyclists outdoors (Ordinance No. 920). The developer of a commercial area must submit a landscape plan and elevation for review by the Design Review Commission that would show expected growth and shading patterns of proposed trees (particularly,long-lived, deciduous trees) as they would appear in ten years after the completion of the project. The landscape plan and elevation are to be used in determining whether the landscaping will cover a minimum of ten percent of the site. In addition, the inclusion of drought-resistant plantings is encouraged wherever feasible.

7. Shading Parking Lots

Similar to the above policy, the City requires that 50% of paved parking lots (e.g., shopping areas or school yards) must be shaded with tree canopies within 15 years of the issuance of a building permit (Ordinance No. 920). It is hoped that this policy will reduce the urban heat effect, thereby encouraging the use of walking and bicycling and the reduction of automobile use and auto air conditioners.

8. Use of Alternative Parking Lot Materials

Asphaltic and cement surfaces increase heat loads, runoff, flood peak and speed of peak. Although no formal policy has been adopted, the City is examining the uses of alternative materials (e.g., turf block, brick, cobbles, gravel and decomposed granite) which can reduce runoff and microclimate impact of off-street parking areas. These ideas are looked at in the Design Review process (I: Bainbridge, Lumbrazo).

9. Clotheslines

Since clothes drying is a large user of electricity in the household (Table 4), the City has adopted an ordinance encouraging the use of clotheslines (Ordinance No. 876). The ordinance makes it unlawful to establish any private covenant or restriction that prohibits the use of clotheslines

in residential zones. In addition, all new multi-family developments (e.g., apartment houses) are required to provide clotheslines, clothes racks or similar facilities to dry clothes using the sun.

10. Swimming Pools

Swimming pool heaters are the largest energy consuming appliance which may be installed in a household. Since swimming pool heaters use great amounts of natural gas or electricity, and since solar heating systems for swimming pools are proven and life-cycle costs are lower than for other systems, the consultants and planning staff proposed that all swimming pool heating systems be prohibited unless they used solar energy as the only heat source (Bainbridge and Hammond, 1976). The City of Davis backed away from this proposal for lack of support, and the City's Planning Director called this policy arena "our biggest disaster" (I: McGregor). The City deferred a decision on this policy to the State Public Utilities Commission which, in the face of strong opposition by pool users and pool builders, backed down from requiring the mandatory use of solar energy for heating swimming pools (I: McGregor). The Public Utilities Commission has established higher rates for large gas users, thereby hoping to create a large enough disincentive for pool owners to switch from natural gas to solar energy (California Public Utilities Commission, 1977).

The City of Davis is currently proposing a retrofit ordinance for existing homes, and it is possible that credit would be given for solar heating of swimming pools in this proposed ordinance. It is interesting to note that the consultants preparing the retrofit ordinance evaluated swimming pool covers to be more cost-effective than active solar systems for maintaining temperatures in swimming pools. However, the use of pool covers is dependent on the behavior of pool owners so that their effectiveness might be diminished (Sedway/Cooke, 1978a).

11. Home Occupations

To reduce the amount of energy used in commuting, the City encourages the widest use of homes for working and small businesses. Ordinance No. 875

permits the conduct of business in residential districts subject to several criteria (e.g., only one non-familial employee can be employed and no more than 25% of the area of one floor of the residence could be used for the business). Hence, this policy not only encourages people not to drive to work, but also allows neighborhood customers to bike to the place of business and allows the property owner to save on heating costs (e.g., only one structure has to heated instead of two).

B. Reduction of Energy Used for Transportation

1. Pedestrian Circulation

Since over half of the energy used in Davis is used for transportation (Table 5), and since automobiles are very energy inefficient, Davis' transportation policies are designed to encourage the use of alternative modes--particularly, bicycling, walking and public transit (e.g., Unitrans). By providing better pedestrian facilities such as fountains, sidewalk shading, restrooms, maps and better signs, the City has favored and continues to encourage walking in its downtown area and in the rest of the community. This policy is encouraged on an informal basis by review committees such as the Design Review Commission and the Planning Commission.

2. Further Support for Bicycling Facilities

The City has been concerned with bicycle policies since 1965-1966 when bikes became a very important issue in the City election. Davis was the first city in California to develop a network of bike routes and bike lanes throughout the City. There are about 50,000 bicycles in Davis and an estimated 10,000 are ridden most days; a recent survey has found that there is an average of two bicycles per adult in Davis (U.C. Davis, 1978). More than 50% of Davis residents use bicycles as the preferred mode of local transportation. Accordingly, consultants and City staff and officials have put a lot of effort into developing a comprehensive bicycle policy aimed at improving the safety, convenience and comfort of bicycling.

The consultants had proposed the following bicycle policies (Davis Report, 1977): (1) restricting trash placement in the street to the day of trash pick-up; (2) construction of an improved bicycle route from Davis to Sacramento; (3) City maintenance of bikeways; (4) provision and better placement of more bicycle paths and racks; and (5) the shading and protection of bike paths. The proposed bikeway to Sacramento has not been built, but is being studied by the California Department of Transportation (I: McGregor). The City has pushed for more bike racks and for the location of more bike lanes on collector streets to encourage people to use bikes, to make bicycling safer and to reduce travelling time for bicyclists. The City has also denied drive-around service for a national restaurant and for banks since they tend to encourage automobile use which is contrary to the City's goals. In sum, with wide popular support for bicycling, the City is continuing to encourage the policies outlined above.

3. Energy Conservation and the City Vehicle Fleet

Policies were proposed by the consultants to reduce the life-cycle energy costs of City vehicles, (Bainbridge and Hammond, 1976). By informal policy, the City has switched to smaller, more energy efficient vehicles for police, administrative and utility functions (I: Bainbridge, Pelz, Reese). This transportation policy supplements the City's support for energy efficient public transportation as evidenced in the Unitrans and the Regional Transit bus system.

It is of interest to note that the City has been trying to change the amount and type of lighting used along its streets (I: Pelz). High pressure sodium vapor lighting is being installed by developers and the local utility company (Pacific Gas and Electric Company) although financial constraints on the City has limited the number of conversions that can be made. Davis is also replacing fixtures with sodium vapor lighting when they burn out (I: McGregor).

V. Implementation of the Davis Energy Conservation Planning Policies

Many of the energy conservation planning policies adopted by the City of Davis, either as an ordinance or as an informal policy, have been implemented without much controversy or opposition. There are several reasons for the almost unanimous acceptance of the planning policies: (1) most of the policies can be implemented with existing construction technology and/or with existing building practices; (2) none of the problems that did arise appeared to be insurmountable; (3) in many cases, the policies reduced development costs; (4) many of the individuals affected by these policies felt the City was motivated by good design and was not making an unnecessary intrusion into one's private life; and (5) the struggle over the energy conservation building code resulted in a more aware citizenry, thereby creating an atmosphere conducive to further energy conservation efforts (I: Hornbeek, Pelz, Streng). Consequently, this section will only examine those planning policies which have been the subject of criticism during their implementation.

It is important to note that banking institutions did not play a significant role in the Davis energy planning system. Banks have not changed their lending policies for energy conservation and solar improvements as a result of the energy conservation building code and energy planning policies (I: Armstrong, Hardy). Some banks have offered or are offering loans at reduced interest rates (e.g., 1/4 of 1%) for home improvements for solar and energy conservation systems. When approving these loans there is little concern over the marketability or function of the improvements (I: Armstrong). However, appraisal of homes may be reduced if a particular active solar system has a poor reputation (I: Armstrong). Furthermore, a guarantee is needed for those active solar systems without backup heating systems (I: Hardy). There has been little demand for these loans, and no great demand is anticipated. Most requests for loans have been for new construction rather than for existing homes (I: Armstrong). However, with the slowing down of growth in the community, there has been less demand for new houses, resulting in an abundance of empty houses, the most in thirty years (I: Hardy).

The banking institutions are beginning to re-examine their traditional lending practices to recognize that lowered utility costs per month can allow a higher percentage of income to be diverted to mortgage payments. Thus, more persons may be able to purchase homes if such homes can be built to have lower energy costs (I: McGregor).

1. Lot Orientation and Size

There was no opposition to maximizing the use of north-south oriented lots. Developers discovered that if a lot was oriented properly, it was very easy to comply with the provisions of the energy conservation building ordinance (I: Broward, Corbett, Hammond, Streng). The trend towards minimizing lot size was seen as an effective way in reducing the cost of housing so there was no firm opposition to this policy, too. However, some people had reservations about the continued implementation of this policy. Some custom house builders and owners disliked this policy because they wanted more open space around their houses (I: Broward). Some other builders felt that this policy, as well as some other "small scale" policies, would affect the "liveability" of the residential neighborhoods (I: Hornbeek). For example, areas might become too crowded, too noisy, and affect one's privacy (I: Hornbeek, Roe). In effect, these individuals were concerned about the "quality of life" and questioned whether energy concerns should receive higher priority than other concerns (I: Hornbeek, Maeda). The City's Planning Director was concerned about the future problems of this policy as it related to families wishing to expand the size of their house (I: McGregor). Before 1945, most households expanded their house by "adding-on" (e.g., building another room). During the next thirty years, households expanded by buying larger homes when interest rates and housing costs were low. Since 1975, households have expanded by returning to the earlier method of expansion--"adding on"--as construction costs have skyrocketed. Hence, with a policy of reducing the minimum size of lots, the Planning Director expects that it will be very difficult for households to "add-on". The only other feasible alternative would be to convert existing spaces (e.g., garages and sheds) to living spaces or to construct more two-story houses (I: McGregor, Roe).

The Planning Director fears that in three to five years, when most conversions will have been built, the real impacts of the minimum lot size policy will be felt.

2. Building and Fence Setbacks

The setback policies affecting buildings and fences received favorable support from builders and the Planning Division staff. Some builders, however, have expressed concern about very narrow side yards (e.g., 3 feet) being non-functional (i.e., yards are too small to use), and one builder has decided to discontinue the construction of commonwalls due to noise problems (I: Hornbeek, Corbett). Also, some individuals felt that long rows of fences along the street would be aesthetically displeasing (I: Streng). The Public Works Director noted that houses located on the back of property lines from the street resulted in extra costs for the provision of utilities and for the construction of long driveways to attached garages (I: Pelz). On the other hand, those houses located closer to the street reduced costs for the provision of utilities and for the construction of driveways. Also, minimizing the lengths of driveways reduced the amount of heat reflected from the surface (I: Streng). A final issue concerned visibility at intersections (e.g., the safety of bike riders when entering streets from bike paths when fences along the edge of streets hide the paths from automobile drivers). However, the Public Works Director noted that none of these problems were insurmountable, just different ones (I: Pelz).

3. Street Width

Perhaps the most controversial planning policy was the one concerning narrower streets. Although the City Council and the City Planning Commission supported this policy, the directors of the Public Works Department and the Planning Division of the Community Development Department as well as the Fire Chief and Police Chief were firmly opposed to this policy, especially "very narrow" streets (e.g., 20 foot wide streets without on-street parking). Their objections to this policy were that it was hazardous for children walking and playing in the streets as cars passed by

(since there were no sidewalks), and it would make it difficult to manuever emergency equipment (e.g., fire trucks)(I: Bertero, Broward, Hammond, Hunt, Kopper, Maeda, McGregor, Pelz, Roe). It was argued that there was a need for more off-street parking when very narrow streets were used in conjunction with the elimination of on-street parking. The construction of this additional parking area would, therefore, offset any energy and monetary benefits of reduced street width. The perceived advantages of this policy remain a source of contention among the parties involved and continues to affect the relationships between innovative developers and city government (I: Corbett, McGregor).

4. Landscaping

Policies affecting the landscaping of commercial areas and parking lots were favored by most people, although there was some concern over increased maintenance costs and some confusion over which trees were to be used (I: Broward, Maeda). Although the developer was to pay for the planting and maintenance of the landscape, it was felt the drought tolerant plantings would result in lower maintenance costs (I: Lumbrazo).

VI. THE IMPACT OF PROPOSITION 13

Although the City of Davis, in general, has not experienced any significant problems in implementing these energy planning policies, the City will have a much more difficult time in initiating new pioneering efforts in the energy sector as a result of a measure recently voted upon by the California electorate. In June 1978, California voters passed Proposition 13, the State Tax Reform Initiative, which was aimed at reducing the local property tax. Consequently, local governments, who depend on the property tax for providing key services (e.g., fire and police protection, child care, park and street maintenance and administrative functions), were severely affected by this public measure.

Proposition 13 has had a significant impact on the City of Davis, where voters opposed the measure, 4,391 supporting and 9,491 opposing Proposition 13 (City Manager's Office, personal communication). The Planning Division lost 10% of their work force when one-half of one Associate Planner

position was eliminated (I: Lumbrazo). The Division also lost their funding for public education programs on energy issues ($20,000 per year), and they no longer have money to travel or to purchase documents and supplies (I: Lumbrazo, McGregor). Furthermore, the reduced planning staff is faced with a rising number of programs resulting in a "tremendous workload". As a result, there are no more energy information programs, and it now takes longer to complete studies (I: Reese). Most of the energy work (including the proposed retrofit ordinance for existing houses) had already been accomplished by the time Proposition 13 had passed (I: McGregor).

Other City programs were also affected by Proposition 13. Although there were no positions eliminated in the Building Inspection Division, fees for plan review increased by approximately $1,000 (I: Reese). This increase occurred because the City could no longer subsidize the plan fees (including processing and overhead costs and a building tax)(I: Hunt, Reese). The Public Works Department lost 8 people out of 64 staff people for a 12% reduction (I: Pelz). These people were primarily involved in street maintenance (e.g., weed control and patching of streets). Moreover, 7-8 additional individuals left the Department voluntarily on account of the negative views of "public service" that surrounded the passage of Proposition 13 (I: Pelz). In addition to the 30 positions eliminated in all of the city administration, the City of Davis no longer has the ability to issue general obligation bonds (I: Reese). Consequently, the City's construction tax was increased to recover costs for projects, and capital improvement programs were severely reduced (I: McGregor, Reese). Housing costs have increased approximately $2,000 to $3,000 in the wake of Proposition 13's impact on City services (e.g., this includes increases in utility fees, building permit, rezoning fee, and construction tax)(I: Reese).

It is still too early to tell the real impact of Proposition 13 on the City of Davis and on the housing industry in general. The City is expecting $600,000 from the State surplus this year, but has no idea how much the City will be able to receive in the coming years (I: Reese). The City does know that it will have to "do more with less". The impact of Proposition 13 on

other California communities may be more severe than it was for the City of Davis because the City had begun reducing positions, programs and costs of programs approximately two years before the passage of the Proposition (I: Lumbrazo).

CONCLUSION

"...the people of Davis have broken the myth that the energy problem is far beyond our control and can be handled only by far-away men of great power and expertise." (Hunt and Bainbridge, 1978).

A. Significant Factors in the Davis Experience

The City of Davis has successfully adopted and implemented an energy conservation building code and several significant energy planning policies whose principles can be applied to other communities in the United States. This report has examined those factors that played an important role in the success of Davis' programs (emphasizing the development and implementation of the building code), and their significance is briefly summarized below.

The institutional setting of the Davis community helped determine the outcome of policies and their implementation. The general citizenry of the Davis community was liberal and highly educated, and they took pride in supporting environmental issues, innovation and experimentation (I: Figueroa, Johnston, Hopper, McGregor, Whitcombe). Many Davis residents were tolerant of unorthodox behavior and were used to change (I: Cramer). They often felt themselves to be "pioneers" who favored public action, and, once committed to good ideas, would participate in community activities (e.g., revising the old General Plan) (I: Leber, Roe). When Davis residents were confronted with the impacts of the "energy crisis" and were shown a possible solution to ameliorating these impacts, they strongly supported governmental programs (e.g., the energy code and planning policies).

The University of California at Davis played an instrumental role in helping develop this "community ethos" which placed great value in experimentation and innovation (I: Black, Cramer, Roe). Also, the University was a source of technical expertise and creative research and was a meeting place for several individuals who later became deeply involved in Davis' energy activities (I: Figueroa, Reese).

The leadership of the City of Davis, particularly the City Council, played a very important role in affecting the City's energy planning policies (I: Figueroa, Hammond, Hunt, Kopper, Leber, Maeda, McGregor, Reese, Whitcombe). During the late 1960's, the City Council adopted planning policies on bicycling, street landscaping and recycling which reflected the growing conservation consciousness of the City. During the early 1970's, the City Council reinforced their commitment to the protection of the environment and to greater public participation in governmental affairs by appointing a citizen's committee to rewrite the old General Plan. And during the mid-1970's, the City Council again demonstrated this commitment by supporting an energy conservation building code, energy planning policies and a public education program on energy. Although other local governmental agencies (e.g., the Planning Commision, the Design Review Commission, and the Community Development Department) supported these programs, final approval rested with the City Council.

The City's Community Development Department played an active and important role in working with the consultants and the building community on developing and implementing the energy code and planning policies. As implementors of these energy measures, the Building and Planning Divisions had the resources and skills to work out the technical and administrative problems inherent in the planning process.

There are other factors in Davis' institutional environment whose influence on Davis' energy planning system is more difficult to measure: the City's extensive regulatory programs and the building community. During the early 1970's, the City of Davis was involved in attempts to control growth through land use and building controls. This gave the City limited but effective control over the new housing market and provided a "regulated environment" in which one more regulation, such as the energy building code, would only result in an "incremental" effect compared to a community with few regulations over community development. Furthermore, real estate interests in Davis were relatively few and not very powerful, while environmental interests were relatively influential (I: Black, Leber). The building community's influence was limited, and builders had less political power than in other communities (I: Reese, Streng).

The perserverence of John Hammond and Marshall Hunt was fundamental in ensuring the passage of the energy conservation code and energy planning policies (I: Bainbridge, Black, Cramer, Johnston, Kopper, Leber, Maeda). In collaboration with City staff, they developed a building code that was based on logical principles and hard facts, practical, cost-effective and implementable. With the aid of a strong public education effort which increased public awareness and helped persuade the community to support an energy conservation program, Hammond and Hunt were able to get the code and policies adopted. Finally, their strategy of integrating the planning policies with the building code facilitated the implementation of these programs without much trouble.

Professors Cramer and Neubauer also played a vital part as members of the consulting team. Their research in the late 1950's and early 1960's was very helpful in convincing the City that there was an energy problem in Davis. Their data base also helped direct the research on existing buildings in Davis which was conducted in the 1970's (I: Hammond, Hunt). Equally important was the stamp of legitimacy they gave to Hammond and Hunt who were both young and inexperienced (I: Black, Figueroa, Hunt, Kopper, Reese). Professor Cramer, as Head of the U.C. Davis Academic Senate and Professor Neubauer, as Professor Emeritus of Agricultural Engineering, were respected members of the community, and their reputation and skill made the entire research project more credible.

The use of technical information by the consultants played an important role in affecting the adoption of the energy ordinance. The consultants' research on existing buildings in Davis provided evidence that the proposed code would be effective and was not a "pie-in-the-sky" scheme, so that builders and governmental officials became less suspicious and less antagonistic (I: Black, Hammond, Lumbrazo). In addition, the proposed passive solar technology was simple, understandable, economical and implementable, so that the consultant's demands were not seen as "unreasonable" (I: Cramer, Hunt, Maeda). In sum, the use of "low technology" and the research on existing houses and apartments made the whole process "very believeable" to the Building Inspection

Division, the City Council and the building community, and they also gave greater support to the proponents of the code (I: Cramer, Maxwell).

Factors outside the Davis community significantly affected the fate of the proposed code and planning policies: namely, new State regulations, Federal financial assistance, and the national energy situation. At the time of adoption of the energy ordinance, Davis builders were faced with the following situation. If the City did not pass a local energy conservation building ordinance, then the building community would have to make sure that their plans were in conformance with the new State energy conservation standards of February 1975. Hence, builders would have to negotiate for any changes in building design at the State level rather than at the local level where building officials personally knew the builders and were perceived to be more amenable to bargaining. Furthermore, the new State regulations required the same amount of insulation (the only absolute cost increase item) as required by the proposed Davis code. Consequently, the Davis code would not lead to any significant cost increases compared to the State standards, thereby negating a potentially effective economic argument against the code. Thus, with the threat of State intervention and with similar insulation requirements, the State regulations helped force Davis builders to support a local code.

Financial assistance from the Federal government played a vital role in helping the consultants continue their work on the energy code and planning policies. The grant from the Housing and Urban Development Agency enabled Hammond and Hunt to continue work on the project for a few more years and to do more research (I: Hunt). Also, the possession of these funds demonstrated to the Davis community that money was available for implementing the building code and planning policies, thereby relieving the City from paying the costs of implementation (I: Hunt).

Finally, the national energy situation affected the outcome of the building code and planning policies. The Arab oil embargo of 1973, followed by the gasoline crisis and higher energy costs, forced everyone in Davis to become more concerned about energy in general and higher utility bills in particular (I: Black, Maeda). The high energy consciousness that

developed in Davis during the early 1970's provided a receptive environment for city government to take public action as state and national governments remained paralyzed in their attempts to correct the situation. In sum, the "timing was right" for the City of Davis to take the initiative and adopt important energy planning measures.

B. Innovation in Davis

Most empirical research on innovation has focused on the patterns of diffusion or the spread of innovations among individuals, public and private organizations, and cultural communities (Bingham, 1977; Crain, 1966; Gray, 1973; Katz, Hamilton and Levin, 1963; Mendez, 1968; Rosenbaum, 1977; and Walker, 1969). This investigation, on the other hand, has focused on one community in order to examine more closely those independent variables associated with the adoption of innovation. Moreover, this research has placed particular emphasis on the social structure of the community and on the attitudes and values of the key participants in the Davis energy planning system as well as of the community itself. The findings from this study clearly confirm one of the central ideas reported in the literature on innovation: the importance of the "compatibility" or "fit" between the culture of a group and the elements of a proposed innovation (Katz, Hamilton, and Levin, 1963; Mendez, 1968).

The energy conservation building code and the energy planning policies in Davis developed out of the environmental concerns of the late 1960's and early 1970's. Promoting the use of renewable sources of energy and greater efficiency in the use of nonrenewable sources of energy was a "natural" strategy for attempting to balance the energy supply-demand equation while minimizing the impact on the environment. Hammond and Hunt, proponents of the "environmental ethic", received political support for their activities from the majority of the City Council and from the general public who shared their ideology. This support was necessary in overcoming the objections of the building community and the reluctance and inertia of local government so that an energy code and energy planning policies could be adopted.

The selction of an "action-oriented" energy strategy aimed at reducing energy consumption in the short-term future was very important in getting energy innovations adopted by the community. The consultants and local government could have developed an energy plan, prepared an energy element for the General Plan, or established an energy committee to evalute the energy problems of Davis. The adoption of an energy conservation building code and energy planning policies, combined with a strong public education program, were measures that would ensure immediate action on the energy problems confronting the City of Davis. Political support of key decision makers and the community, early recognition of a local energy problem, availability of technical expertise, and the provision of an adequate data base, were sufficient conditions for the selection of this strategy.

The adoption of energy innovations in the Davis community entailed both structural and behavioral changes in local government. Structural change was reflected in the adoption of the energy code and energy planning ordinances. In particular, the energy code was a piece of legislation that had clear and consistent policy standards, necessary to enforce the intent of the code. Aside from this legislation, there was very little structural change in local government in adopting the innovations: no new organizations created, no significant budgetary changes, nor major personnel transfers. In sum, the provisions of the code and policies were principally implemented within existing governmental structure.

Behavioral change was the major type of change that occurred as a result of the adoption of the energy conservation building code and energy planning policies. Members of the building and planning professions were required to include energy concerns with their traditional concerns (e.g., public safety, cost, aesthetics) in designing, constructing and developing residential and non-residential buildings and streets. Values and attitudes were re-examined to determine the priority of energy concerns in relationship to the individual's and community's value structure. While most people in government and in the building community have accepted the importance of energy conerns in the shaping of the Davis community, there are several individuals who still question the importance of energy over other lifestyle concerns.

In summary, the Davis experience has shown that energy conservation and alternative energy technologies can be adopted and implemented by local governments without significant expense and difficulty. Strong political support of these innovative technologies was essential for overcoming the active opposition and inertia of members of the community. Thus, if local governments wish to develop and implement their own energy policies, existing resources should be devoted towards obtaining support for these policies from key decision makers (e.g., City Councils, Boards of Supervisors) and from the general public (e.g., through a strong public education program). Without this support, energy studies and policies of local governments will not have any effect on the reduction of energy consumption in their communities.

C. Advantages and Disadvantages of Local Development of Energy Policies

The "Davis Experience" has demonstrated that local communities which are aware of the energy situation, willing to support innovative ideas and public measures to carry them out, and which have the leadership and technical expertise (both inside and outside local government) to adopt and implement those measures, are able to take the necessary steps to try to reduce local energy consumption. However, Davis' efforts occurred at a time when both state and federal governments lacked comprehensive energy policies for solving the "energy crisis". Presently, both governmental levels have established a multitude of energy policies for increasing conventional and alternative sources of energy and for decreasing the consumption of energy. Consequently, communities that have not developed any energy policies must ask whether they should attempt to develop their own energy conservation building ordinance and energy planning policies, or instead, rely solely on enforcing those policies developed at the state and federal levels.

There are many reasons why local governments should seek to develop their own policies. First, by adopting their own policies, local governments are able to maintain their local autonomy and local control in the

face of increasing state and federal intervention at the local level. Second, since it is usually easier to obtain the close interaction and involvement of people at the local level (including the individuals who wrote and who are in charge of implementing policies), local governments may have an easier time in enforcing their locally developed policies. Accordingly, local ordinances are seen as being more responsive to the needs of the community, in contrast to State policies that are commonly developed without local involvement. Third, since State energy conservation standards are applied to broad geographic regions in the State based on the number of heating degree days (California Energy Commission, 1978a), there is a need for local governments to formulate energy conservation codes and policies that reflect local topography, local microclimate and local values in order to achieve good housing design that saves energy and which may be more restrictive than the State's general standards. Hence, local ordinances provide the flexibility that can meet the different heating and cooling needs of different geographical areas (e.g., the desert or the mountains) as well as the diverse community needs which affect the quality of the code. Finally, by adopting an energy conservation building code and energy planning policies, local governments can use these efforts as a foundation for continuing their involvement in the development of local energy sources (e.g., biomass and wind energy) to further reduce their dependence on outside sources of energy and save money in the long run.

On the other hand, there are certain disadvantages in the development of local codes and ordinances. There is a need for a significant amount of technical expertise (by local staff or outside consultants) to develop a sound energy conservation building ordinance and energy planning policies. Also, local governments must possess an educated building inspector as well as other city personnel such as planners, engineers and technicians who are willing to learn and implement new technologies. The development and implementation process may also require a significant amount of funding which local governments presently lack. Federal or state governments could assume an important role in the local energy arena by providing funds to local communities for the development of their own codes and policies or by tailoring State and

Federal regulations to regional differences. Dependence on the Federal government, however, may lead to a different set of problems for local governments. Consequently, despite the advantages mentioned previously, local governments in California may wish to rely on enforcing State regulations and policies rather than generating their own programs.

In Davis' experience, the community received State and national renown for the development of their energy measures but no monetary rewards for reducing residential, commercial and industrial energy consumption. However, local governments can receive both symbolic and monetary rewards for their efforts in reducing energy consumption and promoting the use of renewable sources of energy by establishing their own municipal utility company. This strategy not only leads to greater local autonomy but also provides an incentive for local governments to increase their efforts in the energy conservation field. These incentives could also be provided by independent utility companies (e.g., Pacific Gas and Electric, and San Diego Gas and Electric) which could adjust utility rates for communities which conserve energy and/or utilize renewable sources of energy. However, this option may not be practical for utility companies if the reduced rates lead to a decrease in net revenues, so that the creation of municipal utility companies may be a more likely option.

D. Future Areas of Investigation

The Distributed Energy Systems Study Group is planning to conduct its next investigation of the influence of local planning policies on the use of energy conservation measures and renewable energy sources in San Diego County. This region offers a more complex governmental system in respect to the greater number of key decision makers and interest groups. The County has been involved in the energy field for a number of years. The Board of Supervisors has recently voted to require solar water heating systems for new homes built in unincorporated areas as of October 1, 1979, and this policy would be extended to all new residential constuction in 1980.

The study of the "Davis Experience" has generated several research issues which should be investigated to achieve a better understanding of the

opportunities and obstacles in planning for an energy conserving society in California:

1. Davis Issues

   A. Retrofit Ordinance: the City of Davis will be conducting public hearings this year on a proposed retrofit ordinance to improve the thermal performance of existing dwelling units. An analysis of the development and implementation of this proposed ordinance would complement the findings of this report.

   B. Impact Analysis of Davis Energy Code: a comprehensive quantitative evaluation of homes built under the energy code is needed to determine how much energy is saved compared to: (a) Davis homes built prior to the code, and (b) homes built in nearby communities under the new State energy conservation regulations. In addition to quantitative measurement of dwelling units, a behavioral study is needed to examine the energy conserving behavior of Davis residents compared to residents of other communities.

2. Building Code Case Studies

   A. County of Sacramento: the Sacramento County Board of Supervisors defeated a proposed energy conservation building code that was developed by the same consultants who developed Davis' code. An analysis of the resistance to proposed innovation will be very helpful in understanding the diffusion of innovation in different cultural contexts.

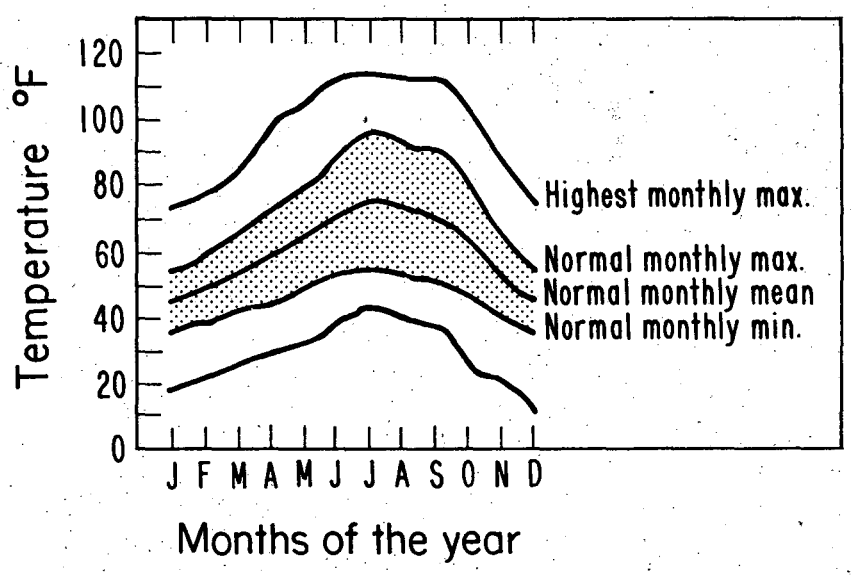
   B. The City of Indio: Indio adopted an energy conservation building code that was very similar to Davis' code. An analysis of the development and implementation of this code would be an excellent comparison to this report.

3. State Issues

A. State Energy Conservation Standards: the California Energy Commission's energy conservation regulations became effective July 1, 1978. An analysis of the development and implementation of these regulations, with an emphasis on the mechanisms used to resolve local-State differences, will provide a better understanding of the advantages and disadvantages of the development of energy policies by local government.

B. Solar Access Legislation: the State of California has recently passed two pieces of legislation (AB 2321 and AB 3250) which encourage local governments to protect an individual's solar rights. A survey of local governments is needed to determine to what extent they are complying with the new legislation and what problems remain for protecting solar access.

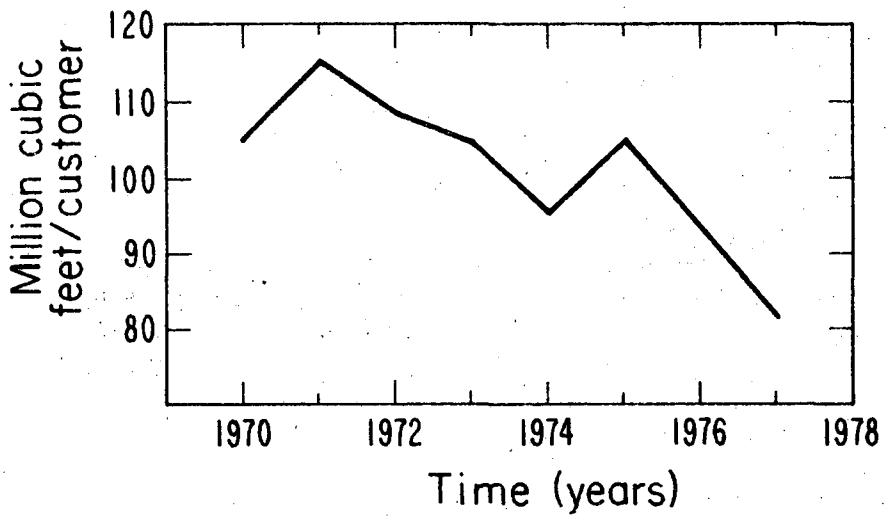
C. Role of Utility Companies: utility companies have been increasing their involvement in the energy conservation and solar energy fields during the last several years. Specific issues that need to be investigated include: (i) an analysis of incentive programs utility companies are conducting for encouraging local governments to save energy; (ii) an examination of the problems utility companies have encountered in leasing energy conservation equipment; and (iii) an evaluation of municipal utility companies' efforts to save energy to determine if they are saving more energy than local governments that do not own utilities.



Source: Davis Energy Conservation Report, p.6

Figure I. DAVIS MONTHLY TEMPERATURES AVERAGES AND MEANS

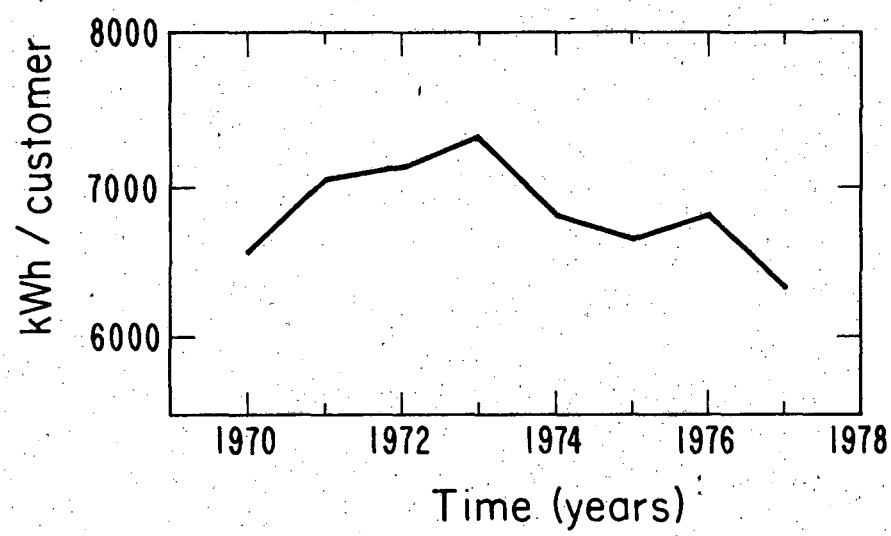
XBL 792-434



Source: Economics and Statistics Department, Pacific, Gas & Electric Company, San Francisco, CA

Figure 2. ANNUAL PER CUSTOMER GAS CONSUMPTION IN THE RESIDENTIAL SECTOR (million standard cubic feet/customer)

XBL 792-432



Source: Economics and Statistics Department, Pacific, Gas & Electric Company, San Francisco, CA

Figure 3. ANNUAL PER CUSTOMER ELECTRICAL CONSUMPTION IN THE RESIDENTIAL SECTOR (kWh/customer)

XBL 792-433

TABLE 1

Energy Consumption in the City of Davis[1]

I. NATURAL GAS CONSUMPTION

A. Annual Gas Sales (in thousands of cubic feet (Mcf))

YEAR	RESIDENTIAL[2]	COMMERCIAL	INDUSTRIAL	TOTAL[3]
1970	668,142	181,781	306,756	1,172,035
1971	788,125	208,929	403,671	1,419,044
1972	843,724	227,049	340,552	1,426,998
1973	876,693	229,943	366,823	1,488,871
1974	883,418	230,685	535,015	1,662,274
1975	1,017,941	246,813	625,628	1,904,953
1976	934,608	189,539	439,409	1,576,114
1977	870,328	159,670	437,489	1,477,578

B. Annual Number of Gas Customers

YEAR	RESIDENTIAL[2]	COMMERCIAL	INDUSTRIAL	TOTAL[3]
1970	6,339	368	5	6,712
1971	6,832	376	5	7,212
1972	7,716	383	3	8,102
1973	8,361	383	3	8,747
1974	9,165	378	3	9,546
1975	9,652	383	3	10,038
1976	10,069	387	3	10,459
1977	10,559	380	3	10,942

TABLE 1 (continued)

C. Annual Customer Gas Consumption (Mcf/customer)

YEAR	RESIDENTIAL[2]	COMMERCIAL	INDUSTRIAL	TOTAL[3]
1970	105	494	61,352	175
1971	115	556	80,734	197
1972	109	592	113,517	176
1973	105	600	122,274	170
1974	96	611	178,338	174
1975	105	645	208,543	190
1976	93	489	146,470	151
1977	82	420	145,830	135

TABLE 1 (continued)

II. ELECTRICAL CONSUMPTION

A. Annual Electric Sales (in kilowatthours (kwh))

YEAR	RESIDENTIAL[2]	LIGHT AND POWER[4]	TOTAL[5]
1970	47,660,967	38,513,281	88,873,419
1971	55,105,204	41,511,231	99,454,844
1972	62,947,528	45,980,310	111,878,098
1973	70,213,751	47,660,043	120,718,827
1974	72,270,871	46,660,043	121,637,322
1975	75,841,868	50,136,337	129,228,894
1976	79,727,622	49,606,192	132,964,416
1977	78,869,361	47,354,213	129,917,328

B. Annual Number of Electrical Customers

YEAR	RESIDENTIAL[2]	LIGHT AND POWER[4]	TOTAL[5]
1970	7,228	506	7,772
1971	7,797	511	8,349
1972	8,792	533	9,370
1973	9,619	550	10,216
1974	10,630	553	11,232
1975	11,247	567	11,862
1976	11,689	640	12,391
1977	12,480	645	13,185

TABLE 1 (continued)

C. Annual Customer Electrical Consumption (Kwh/customer)

YEAR	RESIDENTIAL[2]	LIGHT AND POWER[4]	TOTAL[5]
1970	6,594	76,164	11,435
1971	7,067	81,275	11,913
1972	7,160	86,308	11,940
1973	7,300	86,669	11,817
1974	6,799	84,071	10,830
1975	6,744	88,360	10,894
1976	6,821	77,540	10,731
1977	6,320	73,399	9,853

SOURCE: Economics and Statistics Dept., Pacific Gas & Electric Company, San Francisco, CA

[1]This data is for the incorporated area of the City of Davis.

[2]This sector includes individual metered and master metered dwelling units. Some large apartment buildings are not included in this sector but are included in the industrial sector since they are charged industrial rates.

[3]Natural gas totals include residential, commercial, industrial sectors as well as other sectors not listed in this table.

[4]Light and power is an approximation for industrial and consumer sectors, however, other sectors are included in this column.

[5]Electrical totals include residential and light and power sectors as well as other sectors not listed in this table (e.g., agricultural power and street lighting).

TABLE 2

Primary Energy Use in Davis

(Per Cent Primary Usage*)

	Gas	Electrical	Gas & Electrical
Residential	29.92	25.88	55.80
Industrial	18.49	2.16	20.65
Commercial	7.25	15.14	22.39
Street Lighting		.65	.65
Agricultural Power		.17	.17
Subtotal	55.66	44.00	99.66

SOURCE: Davis Energy Conservation Report, by Jon Hammond, Bill Kopper, Gloria McGregor, Living Systems and the City of Davis (1977), p. 3.

*Does not include losses incurred in electrical generation.

TABLE 3

Residential Energy Consumption: Local, State and National (1975)

	NATURAL GAS (Billions of Cubic Feet)	ELECTRICITY* (Billions of Kilowatt hours)
Davis	1.02	.076
California	631.40	43.38
United States	4824.12	586.15

SOURCE: For California and United States: Federal Energy Data System: Statistical Summary February, 1978 (U.S. Department of Energy, Energy Information Administration, Division of Consumption Data Studies, Washington, D.C.)

For Davis Data: Economics and Statistics Department, Pacific and Gas Electric Company, San Francisco, Calif.

*Electricity purchased.

TABLE 4

Mean Average Daily Solar Radiation for Davis (By Month)[1]
(in langleys per day)

JANUARY	173
FEBRUARY	243
MARCH	386
APRIL	524
MAY	629
JUNE	685
JULY	688
AUGUST	616
SEPTEMBER	501
OCTOBER	347
NOVEMBER	220
DECEMBER	155
ANNUAL	431

SOURCE: California Department of Water Resources, California Sunshine--Solar Radiation Data (Bulletin 187, August 1978; Sacramento, California).

[1]These mean figures represent data collected from 1957 to 1976.

TABLE 5

Building Permits Issued In Davis[1]

(in dwelling units)

CALENDAR YEAR	SINGLE-FAMILY[2] DETACHED	SINGLE-FAMILY ATTACHED	DUPLEX	MULTIPLE FAMILY	COMMERCIAL BUILDINGS	TOTALS	TOTAL DWELLING UNIT VALUATION
1970	176		42	402		620	
1971	369		76	726		1171	
1972	472		52	397		921	
1973	395	110	32	662		1199	$17,591,340
1974	170	33	14	89		306	5,837,000
1975	167	97	44	52		360	9,812,000
1976	237	135	18	513		903	18,190,900
1977	366	209	18	120	(20)	713	20,889,000

SOURCE: City of Davis, Building Inspection Division.

[1]These numbers represent the number of dwelling units that have received a permit to build; they approximate the number of dwelling units actually built.

[2]From 1970 to 1972, no records were kept for the separation of types of single-family homes. Hence, these numbers include attached as well as detached single-family homes.

TABLE 6

Electrical Energy Use in the Average Davis Household

CATEGORY	PERCENTAGE OF ELECTRICAL ENERGY USED IN HOUSEHOLD
Air conditioning	31%
Refrigerator	14%
Freezer	7%
Lights	7%
Clothes dryer	6%
Television	6%
Range	6%
Dishwasher	4%
Miscellaneous	19%
TOTAL	100%

SOURCE: A Strategy for Energy Conservation, by Jon Hammond, Marshall Hunt, Richard Cramer and Loren Neubauer (1974), p. 3.

TABLE 7

Energy Use in the Average Davis Household

CATEGORY	PERCENTAGE OF ENERGY USE IN HOUSEHOLD
Automobile	50%
Space heating and cooling	25%
Lights, clothes dryer, television and other appliances	12%
Refrigerator, freezer	8%
Hot water	5%
TOTAL	100%

SOURCE: Davis Energy Conservation Report, by Jon Hammond, Bill Kopper, Gloria McGregor, Living Systems and the City of Davis (1977), p. 12.

APPENDIX A

The Housing Development Priority Program

The implementation of the energy conservation building code and the energy planning policies were components of an extensive regulatory program that was being enforced by the City of Davis. Perhaps the most important regulatory program affecting the building community during the mid-1970's was the Housing Development Priority Program (Ordinance No. 765) that had been adopted on July 9, 1975 and became effective August 9, 1975. The objectives of this program were to provide: (1) orderly residential development to meet the needs of the community; (2) protection of adjacent prime agricultural land; (3) housing and services for the student body, faculty and employees of the University of California at Davis; (4) adequate housing for persons of low, moderate or fixed incomes; and (5) environmentally sound development patterns. The members of the City Planning Commission served as members of a Housing Development Review Board which implemented this growth management plan affecting both single-family homes and multiple-family developments.

An Annual Needs Survey was developed to determine the need for housing in Davis. The Survey compared the existing housing stock in the planning areas of the City with the need for new housing stock, and set an annual needs number, encompassed within an overall three year needs number. The first year needs number was definite and definite approval to build followed. The second and third year needs numbers were tentative and tentative approval followed. The Needs Surveys identified the numbers of low, moderate and high income single and multiple-family housing units needed in each of the planning areas of Davis. This identification was necessary for achieving the goal of a similar mix in types of housing available across the city so that property values and social interactions would be maintained wherever one lived in the City.

Upon the completion of the Annual Needs Survey, all of the proposed planned unit developments were rated by the Housing Development Review Board on the basis of ten criteria, in order of their importance: internal growth needs, economic mix, low and moderate income housing, environmental impact, availability of public services and facilities, compactness, design diversity, economic impact, feasibility and competition (Resolution No. 1604, Amplification of Housing Development Priority Criteria). It should be noted that energy conservation was worth 25% of the points given in the environmental impact category. On the basis of these ratings, the Board determined which projects were eligible for approval based upon the number and types of residential units allowed. The number of approvals are determined on the basis of (1) the General Plan, (2) the number of units approved and actually constructed in prior years, (3) availability of utilities and public services, (4) the goals, purposes and objectives of the Housing Development Priority Program, and (5) the Annual Needs Survey.

The significance of this program is that the Housing Development Priority Program gives the City a great deal of control over the type and design of construction which occurs in Davis, thereby strengthening the City's power over the building community. Furthermore, the Planning Commission and the City Council give points to developers who utilize innovative energy conservation features in rating their projects (I: Hunt, Streng). Consequently, builders who go beyond the provisions of the energy code have a better chance of receiving housing allocations than those builders who are not as innovative (I: Corbett). Also, builders who do not comply with the energy code do not have any chance of obtaining housing allocations.

The building community has been very upset about this program for a number of reasons (I: Kopper, Roe, Streng, Whitcombe). Builders argue that regulating the supply of housing has led to an artifical housing shortage

in the Davis area, thereby raising the price of housing (I: Streng). Since the City also requires builders to provide some homes in their planned unit developments for low income people, their margin of profit is reduced, and builders are forced to build more expensive custom homes rather than inexpensive tract homes in order to maintain a profitable business. Consequently, several builders have been forced to leave the Davis community to develop in other areas where they can make more money (I: Whitcombe).

Some individuals have pointed out some weaknesses in the builders' complaints about the Housing Allocation Program. There are 600 to 800 houses that have been allocated but have not been built in Davis, and there is an abundance of empty homes in the Davis area, the most in thirty years; thus, there is no housing shortage (I: Hardy). Also, the dramatic increase in housing costs is more probably due to rising costs in energy, materials and labor rather than due to regulatory programs per se.

ORDINANCE NO. 784

AN ORDINANCE ESTABLISHING ENERGY CONSERVATION PERFORMANCE STANDARDS FOR RESIDENTIAL CONSTRUCTION WITHIN THE CITY OF DAVIS

THE CITY COUNCIL OF THE CITY OF DAVIS DOES HEREBY ORDAIN AS FOLLOWS:

/Section 1. Findings.

A. The people of the State of California face the likelihood of a major energy shortfall and the certainty of rapidly rising energy costs due to uncertainties about present and future supplies of natural gas, and the inability of powerplant construction to keep pace with the rising demand for electricity. Energy demand for the heating and cooling of residential structures has been rising faster than demand in other sectors and rising household energy bills are becoming an increasing economic burden for lower and middle income families.

B. The State of California has adopted an energy and noise insulation standard under the provisions of the California Administrative Code, Title 25, Chapter I, Subchapter 1, Article 5. This standard will make an important contribution to improving housing in the State, but due to the unique characteristics of the Davis climate, the State regulations are deemed to be inadequate for use in the City of Davis.

C. Many years of research 1/ at the University of California at Davis have established the following facts:

(1) An experimental room with large windows facing west regularly achieved temperatures in excess of 140°F during the summer in Davis. 2/ The problem of unshaded windows is inadequately dealt with in the State code. Consequently, dwellings which will overheat to such an extent that they are unfit for human habitation may be built under the State standard.

1/ See Research Bibliography.

2/ R. D. Cramer and L. W. Neubauer, "Solar Radiant Gains Through Directional Glass Exposure", American Society of Heating, Refrigeration and Air Conditioning Engineers, 1958; presented at Lake Placid, New York, June 22-29, 1959; ASHRAE Transactions (1959), Vol. 65, No. 59, p. 499.

(2) It has been found in experimental structures in Davis that solar heat gains from properly oriented windows can significantly reduce the need for heating in the winter. 3/ This factor is not credited in the State code.

(3) It has been found that the thermal capacity or heat storage ability of the building itself can help to ameliorate daily temperature extremes of both summer and winter. 4/ This factor is not accounted for in the State code.

D. From 1973 to 1975 the City of Davis commissioned a study which corroborated the experimental results described above by extensively studying the performance of actual buildings in Davis. Both the thermal performance and actual energy use were examined. 5/ It was found that:

(1) Some dwellings became dangerously hot (100-110°F) in the summer due to direct solar heat gains through large east or west facing windows, while identical dwellings with north or south facing windows remained comfortably cool (75-80°F) and, therefore, used substantially less energy for cooling.

(2) Dwelling units with south windows exposed to winter sun were significantly warmer during the winter (over 10°F warmer on cold, sunny days) and used significantly less energy for heating than dwelling units with windows facing other directions.

(3) Some dwelling units with windows on only one side had no through ventilation and would not cool at night even on cool, windy, summer evenings, thereby requiring expensive cooling system operation.

E. As part of the above mentioned study, the Davis climate was examined in light of the needs for energy conservation and the following findings were made:

(1) The daytime maximum temperature during July, the hottest month of the year, averages 95°F; however, the nighttime minimum averages 55.3°F. These nighttime lows are caused by thermally induced sea breezes originating over the Pacific Ocean which flow into portions of the Central Valley through the Carquinez Straits. 6/ These local

3/ L. W. Neubauer, "Shapes and Orientations of Houses for Natural Cooling", Transactions of the American Society of Agricultural Engineers, Vol. 15, No. 1, pp. 125, 127, 128 (1972).

4/ R. D. Cramer and Loren W. Neubauer, "Thermal Effects of Floor Construction", ASHRAE Journal (January, 1961), six pages.

5/ Jonathan Hammond, Marshall Hunt, Richard Cramer and Loren Neubauer, A Strategy for Energy Conservation (1974).

6/ University of California Agriculture Extension Service, The Climate of Yolo County (1971).

climatic factors were found to all but eliminate need for summertime air conditioning in residential buildings if the following conditions are met:

(a) The windows are protected from direct solar radiation;

(b) The walls, floors and ceilings are adequately insulated;

(c) Adequate thermal storage capacity is provided within the structure; and

(d) Cross-ventilation for summer nighttime cooling is provided.

(2) During January, the coldest winter month, the average 24-hour outside temperature is 45.3°F. 7/ On the average, Davis receives sun for fifty-six percent (56%) of the time possible during the five winter months. The frequency and duration of winter sunshine is such that the need to heat residential buildings is substantially reduced if the following conditions are met:

(a) The walls, floors and ceilings are adequately insulated;

(b) Adequate south-facing glass exposed to the winter sun is provided; and

(c) Adequate thermal storage capacity is provided within the insulated shell of the structure.

F. Due to the above stated factors, it has been found that:

(1) Considerably better minimum performance levels can be required in Davis than provided for by the State code without unduly restricting designs and raising costs, or requiring new technologies.

(2) The present State code allows the construction of buildings that will be unfit for human habitation in the event of the interruption in gas or electrical service during one of the frequently occurring hot or cold weather events. Therefore, the present State code, by its failure to adequately address the heat loss and heat gain considerations of glazing and glazing orientation, does not adequately deal with the Davis climatic conditions.

(3) Considerable reduction in the real cost of housing can be achieved in buildings with good thermal performance by lowering utility bills. In addition, the initial costs of improving the structure's thermal performance is usually offset by the resultant savings due to the smaller capacity heating and/or cooling equipment required for a thermally efficient structure.

7/ Ibid.

Section 2. Definitions.

The following words and phrases shall have the meanings respectively ascribed to them by this section:

A. "Winter Design Day" shall refer to a day upon which it shall be assumed, for purposes of structural heat loss calculations, that all of the following climatological conditions exist:

(1) The sun's path and resultant angles of direct sunlight shall be those which occur on December 21 of each year at latitude 38° 32' North. These angles can be approximated by using latitude 40° North data. (See Table 1.)

(2) The sun's intensity through glazing shall be calculated for December 21 of each year at latitude 38° 32' North; this can be approximated by using latitude 40° North data. (See Table 1.)

(3) The 24-hour average outside temperature is 45°F.

(4) For the sake of determining the external air film coefficient, the wind speed shall be assumed to be 15.0 m.p.h. in accordance with ASHRAE procedures.

B. "Summer Design Day", as used in this ordinance, shall refer to a day upon which it shall be assumed, for purposes of structural heat gain calculations, that all of the following climatological conditions exist:

(1) The sun's path and resultant angles of direct sunlight shall be those which occur on August 21 of each year at latitude 38° 32' North. These angles can be approximated by using latitude 40° North. (See Table 1.)

(2) The sun's intensity through glazing shall be calculated for August 21 of each year at latitude 38° 32' North; this can be approximated by using latitude 40° North data. (See Table 1.)

(3) The outside temperatures on August 21 shall be assumed to be, at each hour, Pacific Standard Time, as follows:

Time A. M.	Temp. °F	Time P. M.	Temp. °F
1:00	66	1:00	95
2:00	64	2:00	99
3:00	61	3:00	100
4:00	60	4:00	99
5:00	59	5:00	98
6:00	59	6:00	95
7:00	67	7:00	91
8:00	72	8:00	87
9:00	78	9:00	81
10:00	82	10:00	77
11:00	87	11:00	73
12:00	91	12:00	68

(4) For the sake of determining the exterior air film coefficient, the wind speed shall be 15 m.p.h. in accordance with ASHRAE procedures.

C. "Floor Area" shall refer to the total habitable area of a dwelling unit (expressed in square feet) which is within the exterior face of the insulated shell of the structure and which is heated or cooled.

Section 3. Minimum Performance Standards Adopted.

The City of Davis hereby adopts minimum standards for the thermal performance of buildings to be constructed within the City of Davis. In order to achieve maximum thermal performance, the performance standards have been carefully adjusted to the special problems and opportunities of the Davis climate. These standards shall apply to all residential structures designated Group H and Group I in the Uniform Building Code.

A. Winter Performance Standard. For a winter performance standard the Total Days Heat Loss per square foot of floor area during the winter design day shall be as follows: For single-family, detached structures designated U.B.C. Group I, see Table 2; for multiple dwellings, U.B.C. Group H, the Total Days Heat Loss shall not exceed one hundred twenty (120) BTU's per square foot of floor area. Commonwall Group I structures shall meet Group H standards. The resolution establishing methods of compliance with the performance standards will allow for numerically increasing the permissible standard on the basis of surface areas in common in order to equitably deal with the variability which occurs in this class of dwelling units.

B. Summer Performance Standard. For a summer performance standard, the Total Days Heat Gain per square foot of floor area during the Summer Design Day shall be as follows: For single-family, detached structures, U.B.C. Group I, see Table 2; for multiple dwellings U.B.C. Group H, the Total Days Heat Gain shall not exceed forty (40) BTU's per square foot of floor area. Commonwall Group I structures shall meet Group H standards. The resolution establishing methods of compliance with the performance standards will allow for numerically increasing the permissible standard on the basis of surface areas in common in order to equitably deal with the variability which occurs in this class of dwelling units.

Section 4. Methods of Compliance with Performance Standards to be Established by Resolution.

Standard methods for calculating the performance of a proposed structure to determine compliance with the standards of this ordinance shall be adopted by resolution of the City Council.

Section 5. Administration and Enforcement.

A. The provisions of this ordinance and the resolution establishing the methods of compliance shall be administered by the Building Official of the City of Davis.

B. No building permit shall be issued by the Building Official for any new structure subject to this ordinance unless such structure is found to be in compliance with the winter and summer performance standards hereby established.

Section 6. Partial Exemption.

Structures designated U.B.C. Group I to be built on lots which are unimproved with structures and for which a tentative subdivision map has been approved prior to September 1, 1974, shall be exempt from glazing shading requirements adopted by resolution pursuant to Section 4 of this ordinance. To the extent that the exemption from glazing shading requirements causes a structure to exceed the performance standards established by Section 3 of this ordinance, such incremental excess shall be permitted.

Section 7. Partial Exemption.

Structures designated U.B.C. Group I to be built on lots which are unimproved with structures and for which a tentative subdivision map has been approved prior to January 1, 1976, but after September 1, 1974, and which lots front upon a portion of street having an axis between 292.5° and 067.5° true (N67.5°W and N67.5°E) and 247.5° and 112.5° true (S67.5°W and S67.5°E), shall be exempt from glazing shading requirements adopted by resolution pursuant to Section 4 of this ordinance. To the extent that the exemption from glazing shading requirements causes a structure to exceed the performance standards established by Section 3 of this ordinance, such incremental excess shall be permitted.

Section 8. Variances.

A. Purpose. The purpose of a variance is to allow variation from the strict application of the requirements of this ordinance and implementing resolutions where, by reason of the exceptional narrowness, shallowness or unusual shape of a specific piece of property, or other extraordinary situation or condition of such piece of property, or of the use or the development of property immediately adjoining the property in question, the literal enforcement of the requirements of this ordinance would involve practical difficulties or would cause undue hardship unnecessary to carry out the spirit and purpose of this ordinance. In most cases, the variance shall only relate to the allowable area of unshaded glazing permissible under the resolutions implementing this ordinance.

B. Application. Application for a variance shall be made by the property owner or the Board of Building Appeals or the Community Development Director on a form prescribed by the City, and shall be accompanied by a fee as prescribed by resolution adopted pursuant to City Code Section 29-12.1, no part of which shall be refundable. No fee shall be charged if the variance is initiated by the Board of Building Appeals or the Community Development Director.

C. Maps and Drawings. Maps and drawings required to demonstrate that the conditions set forth in this ordinance apply to the subject property, together with precise and accurate legal descriptions and scale drawings of the property and existing buildings, and other data required, shall be submitted with the application for a variance.

D. Grounds for Granting. The Board of Building Appeals may grant a variance only when all of the following conditions are found:

(1) That any variance granted shall be subject to such conditions as will assure that the adjustment thereby authorized shall not constitute a grant of special privilege inconsistent with the limitations upon other similarly situated properties which were developed under the limitations of this ordinance.

(2) That because of special circumstances applicable to the subject property, the strict application of this ordinance is found to deprive subject property of privileges enjoyed by other similar properties which were developed under the limitations of this ordinance.

(3) That the authorizing of such variance will not be of substantial detriment to adjacent property, and will not materially impair the purposes of this ordinance or the public interest.

(4) That the condition or situation of the subject property or the intended use of the property for which the variance is sought is not so general or recurrent in nature as to make reasonable or practicable the formulation of a general regulation for such conditions or situations.

(5) That there are not available reasonable alternative construction methods which will bring the proposed structure into compliance with the performance standards of this ordinance.

E. Grounds for Granting--Examples. The following types of physical or topographical factors are examples of conditions which may justify the grant of a variance from the glazing shading requirements to be established by resolution as provided by Section 4 of this ordinance:

(1) Overriding off-site view considerations which are determined to add appreciable incremental value to the subject property.

(2) Minimum size lots with fixed and adverse orientation problems.

(3) Adverse lot orientation dictated by street or utility improvements or similar physical limitations where such limitations are in existence prior to the adoption of this ordinance.

F. State Standards. No variance shall be granted under this section which will result in a structure [illegible] the then existing State of California residential energy conservation standards.

G. [illegible] the Building Official shall provide written notice of the filing of an appeal to all persons interested in the matter and shall cause notice of public hearing to be published in a newspaper of general circulation.

H. Review of the Decision. The decision of the Board of Building Appeals to grant or deny the application shall be subject to appeal in accordance with the resolution establishing the Board of Building Appeals.

Section 9. Appeals.

Any person aggrieved by a determination of the Building Official in the application of this ordinance may appeal such determination to the City of Davis Board of Building Appeals. Such appeal shall be in writing and shall be filed with the Building Official within fifteen (15) days of the determination appealed. All appeals shall be accompanied by payment of a fee in the amount set forth in the City's Community Development fee schedule.

Upon the filing of an appeal, the Building Official shall provide written notice of the filing of the appeal to all persons interested in the matter and shall cause notice of public hearing to be published in a newspaper of general circulation.

In consideration of an appeal, the Board of Building Appeals shall have authority to determine the suitability of alternate materials and methods of construction and to provide for reasonable interpretation of the provisions of this ordinance and implementing resolutions, provided, however, that no alternate material nor method of construction shall be approved which results in a reduction in the performance standards established by this ordinance for both summer and winter conditions.

The decision of the Board of Building Appeals shall be subject to appeal in accordance with the resolution establishing the Board of Building Appeals.

Section 10. Tables.

TABLE 1

Table 4 .... Solar Position and Intensity; Solar Heat Gain Factors[a] for 40 Deg North Latitude

	Date	Solar Time A.M.	Solar Position Alt.	Solar Position Azimuth	Direct Normal Irradiation, Btuh/sq ft	Solar Heat Gain Factors, Btuh/sq ft N	NE	E	SE	S	SW	W	NW	Hor.	Solar Time P.M.
summer	Aug 21	6	7.9	99.5	80	12	67	82	48	5	5	5	5	11	6
		7	19.3	90.0	191	17	135	191	135	17	15	15	15	62	5
		8	30.7	79.9	236	23	126	216	180	40	22	22	22	122	4
		9	41.8	67.9	250	28	82	197	196	79	28	28	28	174	3
		10	51.7	52.1	271	32	40	149	187	116	34	32	32	213	2
		11	59.3	29.7	277	34	35	81	156	140	52	34	34	238	1
		12	62.3	0.0	279	35	35	38	105	149	105	38	35	247	12
				Half Day Totals		161	503	936	981	471	202	154	155	945	
winter	Dec 21	8	5.5	53.0	88	2	7	67	83	49	3	2	2	6	4
		9	14.0	41.9	217	9	10	135	205	151	12	9	9	39	3
		10	20.7	29.4	281	14	14	113	232	210	85	14	14	77	2
		11	25.0	15.2	279	16	16	56	217	242	120	16	16	103	1
		12	26.6	0.0	284	17	17	18	177	253	177	18	17	113	12
				Half Day Totals		49	54	385	831	761	273	50	49	292	
						N	NW	W	SW	S	SE	E	NE	HOR.	←P.M.

[a] Total solar heat gains for DS (⅛ in.) sheet glass. Based on a ground reflectance of 0.20 and values in Tables 1 and 9.

From Handbook of Fundamentals, 1972, American Society of Heating, Refrigeration and Air Conditioning Engineers.

TABLE 2 7/

DETACHED GROUP I DWELLING UNIT
THERMAL STANDARDS

Floor Area (sq.ft.)	Winter Heat Loss (BTUs/[sq.ft.][day])	Summer Heat Gain (BTUs/[sq.ft.][day])
500	363	118
1000	239	103
1500	208	98
2000	192	95
2500	182	93
3000	176	91

NOTE: Direct interpolation shall be used for floor areas not shown.

7/ Infiltration and internal heat production are not considered under the requirements of these standards. These are very important considerations in the real performance of a building and must be estimated when sizing heating and cooling devices whether conventional or solar. However, for the present purpose they are too variable to be standardized.

Section 11. Conflicting Ordinances Repealed.

All ordinances or portions of ordinances which conflict with the provisions of this ordinance are, to the extent of such conflict, hereby repealed.

Section 12. Effective Date.

This ordinance shall become effective on and after the ninetieth (90th) day following its adoption.

PASSED AND ADOPTED by the City Council of the City of Davis on this 15th day of October, 1975, by the following vote:

AYES : Councilmen Black, Holdstock, Stevens, Tomasi, Mayor Poulos.

NOES : None.

ABSENT: None.

Joan G. Poulos
JOAN G. POULOS
Mayor

ATTEST:

Howard L. Reese
HOWARD L. REESE
City Clerk

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ORDINANCE NO. 737

ORDINANCE AMENDING SECTION 6 OF
ORDINANCE NO. 784 (ORDINANCE ESTABLISHING ENERGY
CONSERVATION PERFORMANCE STANDARDS FOR RESIDENTIAL
CONSTRUCTION WITHIN THE CITY OF DAVIS) RELATING TO
ENERGY CONSERVATION PERFORMANCE STANDARDS FOR RESIDENTIAL
CONSTRUCTION ON LOTS CREATED PRIOR TO
SEPTEMBER 1, 1974

THE CITY COUNCIL OF THE CITY OF DAVIS DOES HEREBY ORDAIN AS FOLLOWS:

SECTION 1. Section 6 of Ordinance No. 784 is hereby amended to provide as follows:

Section 6. Partial Exemption.

Structures designated U.B.C. Group I to be built on lots which are unimproved with structures and for which a tentative subdivision map has been approved prior to September 1, 1974, shall be exempt from requirements adopted by resolution pursuant to Section 4 of this ordinance. To the extent that the exemption from requirements causes a structure to exceed the performance standards established by Section 3 of this ordinance, such incremental excess shall be permitted.

SECTION 2. This ordinance shall become effective concurrently with Ordinance No. 784.

PASSED AND ADOPTED by the City Council of the City of Davis on this 5th day of November, 1975, by the following vote:

AYES : Councilmen Black, Holdstock, Stevens, Tomasi, Mayor Poulos.

NOES : None.

ABSENT: None.

JOAN G. POULOS
Mayor

ATTEST:

HOWARD L. REESE
City Clerk

RESOLUTION NO. 1833, SERIES 1975

RESOLUTION ADOPTING PROCEDURES FOR COMPLIANCE WITH THE ENERGY CONSERVATION PERFORMANCE STANDARDS FOR RESIDENTIAL CONSTRUCTION WITHIN THE CITY OF DAVIS

WHEREAS, the City of Davis has, by ordinance, established certain energy conservation performance standards for new residential construction within the City of Davis; and

WHEREAS, the ordinance which establishes energy conservation performance standards provides that standard methods for determining compliance of proposed buildings shall be established by resolution;

NOW, THEREFORE, BE IT RESOLVED by the City Council of the City of Davis as follows:

Section 1. Application.

Compliance with the energy conservation performance standards established by the City of Davis shall be determined by reference to the provisions of this resolution and any amendments thereto.

Section 2. Definitions.

For purposes of this resolution and the energy conservation performance standards ordinance of the City, the following words and phrases shall have the meanings respectively ascribed to them by this section:

A. R Values. (1/U = R) Thermal Resistance (R) is the measure of the resistance of a material or building component to the passage of heat. The units of measurement are: (Hours) (Degrees Fahrenheit) (Square Feet)/BTU. The resistance value (R) of mass-type insulations shall not include any value for reflective facing. (NOTE: For reflective foil insulation, use ASHRAE procedures only. Calculate both the winter and summer composite resistance value and use whichever is less.)

B. Composite Thermal Resistance (R_t) is the sum of each of the resistance values of the parts of an assembly of materials which together form an external skin element of the structure. For example, a commonly used wall is one which has an interior air film, one-half (1/2) inch thick plaster board, three and one-half (3-1/2) inches batt insulation, stucco, and finally, an exterior air film, all of which have R values which are added together to derive the R_t value for the wall element.

C. Orientation. The compass directions are designated as follows when the attached tables are used:

North	337.5° - 022.5°
Northeast	022.5° - 067.5°

East	067.5° - 112.5°
Southeast	112.5° - 157.5°
South	157.5° - 202.5°
Southwest	202.5° - 247.5°
West	247.5° - 292.5°
Northwest	292.5° - 337.5°

D. Exterior Surface Area. The area for each dwelling unit of walls, ceilings, suspended floors, glazing, doors, etc. enclosing conditioned spaces and exposed to ambient climatic conditions.

E. Heavy Exterior Building Elements. The walls, suspended floors and/or ceilings which contain a heat storage capacity of 30 BTU's/Day for each square foot of surface area are considered to be heavy (see definition K). Only those materials located on the interior side of insulation materials may be counted. (An eight (8) inch thick light-weight concrete block wall with exterior insulation slightly exceeds these requirements.)

F. Color. Surfaces with a Munsell lightness value of 6.0 to 10.0 are to be considered light in color. Surfaces with a Munsell lightness value of 9.0 to 10.0 are to be considered very light in color. Unpainted wood surfaces are to be considered light in color. The Building Inspector shall prepare two (2) representative collections of materials and surface covering materials, one with Munsell lightness values greater than 6 and one of materials with Munsell lightness values greater than 9. These collections shall be available for inspection by the public.

G. Glazing. All vertical, horizontal, and tilted translucent or transparent exterior building elements shall be considered glazing with a thermal resistance and daylight transmittance as specified by the manufacturer or as calculated by ASHRAE methods or other reliable references or procedures.

H. Shading Coefficient. The ratio of the solar heat gain through a shading-glazing system to that of an unshaded single-pane of double strength window glass under the same set conditions.

I. Hour's Solar Heat Gain. The amount of energy transmitted through an area of glazing oriented to a particular direction in one (1) hour. The following formula is used for calculation:

HSHG = (SC) (SHGF) (A)

Where:

HSHG = Solar Heat Gain through the glazing for one (1) hour (BTU's/hour)

SC = Shading Coefficient

SHGF = Solar Heat Gain Factor for the hour from attached Table 1 (BTU's/square foot of glazing) using December 21 for winter and August 21 for summer.

A = Area in square feet of glazing exposed to the sun (square feet).

J. Solar Heat Gain Factor. The number of BTU's of solar energy transmitted through one (1) square foot of clear 1/8-inch glass in one (1) hour. This is determined by using the attached Table 1 which applies to 40° North latitude and the eight (8) compass orientations (see definition C).

K. Heat Storage Capacity. The mass located inside the insulated shell of the structure that fluxes through a temperature cycle each day in summer and winter, absorbing heat during overheated periods and storing it for release during underheated periods. Heat storage capacity shall be estimated by the following procedure:

$$HS = (WM)\ (SH)\ (\Delta T)$$

Where:

HS = Heat Storage Capacity (BTU's/Day)

WM = The weight of the materials (lbs.) inside the insulated shell of the building to a depth yielding a resistance of R-1, except in the case of slab floors where only the slab itself is credited.

SH = Specific Heat of those materials (BTU's/[lb.] [degree F])

ΔT = Temperature flux; 5°F will be the maximum allowable for calculation purposes, except that light weight frame construction will be allowed to flux 10°F. (In order to determine the heat or cold available for storage, see Path II, Section 5.)

This total stored heat may be subtracted from the day's heat loss or gain to yield the adjusted Total Day's Heat Loss or Total Day's Heat Gain. Mass located in exterior elements to which the Equivalent Temperature Differential Method (E.T.D.) is applied to calculate summer heat gain shall not be included in the summer heat storage capacity credit.

L. Floor Area. Total habitable area of a dwelling unit (expressed in square feet) which is within the exterior face of the insulated shell of the structure and which is heated or cooled.

M. Accepted References. The following are useful and acceptable references:

Handbook of Fundamentals 1972, American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc. (ASHRAE), N. Y., N. Y., 1972.

Architectural Graphic Standards, Charles G. Ramsey and Harold R. Sleeper, John Wiley & Sons, Inc., N. Y., N. Y., Sixth Edition, 1970.

Design with Climate, Victor Olgyay, Princeton University Press, Princeton, New Jersey, 1963.

Concepts in Thermal Comfort, David Egan, Tulane University, School of Architecture, New Orleans, Louisiana, 1972.

Thermal Design of Buildings, Tyler Stuart Rogers, John Wiley & Sons, Inc., N. Y., N. Y., 1964.

Sun Angle Calculator, Libbey-Owens-Ford Company, Toledo, Ohio, 1975.

Energy Design Manual for Residential Buildings, State of California, Department of Housing and Community Development, Division of Codes and Standards, Sacramento, California, 1975.

Section 3. Standard Methods of Building Performance Calculation.

A. There are hereby adopted two (2) alternative standard methods of determining compliance with the City of Davis energy conservation performance standards. The two (2) alternative standard methods shall be referred to as Path I and Path II approaches.

B. Structures utilizing either Path I or Path II shall comply with the following:

(1) Infiltration. All swinging doors and windows opening to the exterior or to unconditioned areas such as garages shall be fully weatherstripped, gasketed or otherwise treated to limit infiltration. All manufactured windows and sliding glass doors shall meet the air infiltration standards of the 1972 American National Standards Institute (A134.2, A134.3 and A134.4), when tested in accordance with ASTM E 283-73 with a pressure differential of 1.57 lbs./ft.^{2} and shall be certified and labeled.

(2) Loose Fill Insulation. When blown or poured type loose fill insulation is used in attic spaces, the slope of the roof shall be not less than 2-1/2 feet in 12 feet and there shall be at least 30 inches of clear headroom at the roof ridge. ("Clear headroom" is defined as the distance from the top of the bottom chord of the truss

or ceiling joists to the underside of the roof sheathing.) When eave vents are installed, adequate baffling of the vent opening shall be provided to deflect the incoming air above the surface of the material and shall be installed at the soffit on a 45-degree angle. Baffles shall be in place at the time of framing inspection. When loose fill insulation is proposed, the R value of the material required to meet these regulations shall be shown on the building plans or calculation sheet.

(3) Pipe Insulation. All steam and steam condensate return piping and all continuously circulating domestic or heating hot water piping which is located in attics, garages, crawl spaces, underground or unheated spaces other than between floors or in interior walls shall be insulated to provide a maximum heat loss of 50 BTU/hr. per linear foot for piping up to and including 2-inch and 100 BTU/hr. per linear foot for larger sizes. Piping installed at depth of 30 inches or more complies with these standards.

✓ Section 4. Path I (Prescriptive Method).

Buildings meeting all of the following criteria will fulfill the required energy conservation aspects of this code with no overall performance calculations required.

Calculations using the applicable methods outlined in Path II may be employed to demonstrate compliance of alternatives to any particular section of Path I. Thermal trade-offs between sections of Path I must be done by using Path II or by referring to approved thermal trade-offs table developed by the Building Inspector.

— A. Walls. All exterior walls (excluding windows and doors) shall use R-11 batt insulation between studs. Group H structures must have light colored walls or shaded walls. Fifteen percent (15%) of the wall area may be dark colored to allow for trim and color accents. (Group I structures have no wall color requirement.)

Exceptions:

(1) All exterior walls shall achieve a composite resistance value (Rt) of 10.52 if the insulation is not penetrated by framing, and Rt of 12.50 if the insulation is penetrated by the framing or furring. (California Administrative Code, Title 25, Chapter 1, Subchapter 1, Article 5, Section 1094[a].)

(2) Heavy walls with exterior insulation not penetrated by furring or framing shall have an Rt of 7.36, and Rt of 8.75 if the insulation is penetrated by furring or framing.

(3) Group H structures with dark colored walls shall increase their applicable Rt requirements by twenty percent (20%).

— B. Roof/Ceilings; Ceiling/Attics. All roof/ceilings and ceiling/attics must use insulation achieving a minimum resistance of R-19 for the insulation itself. Group H occupancies having roof surfaces unshaded on August 21, at 8:00 a. m., 12:00 noon, or 4:00 p. m., shall be no darker than No. 6 on the Munsell color chart. Unshaded roof areas on Group I occupancies shall be no darker than No. 4 on the Munsell color chart. Roofs having unshaded areas and color darker than No. 6 or No. 4 respectively must increase the total insulation to yield R25 for the insulation itself.

Exceptions:

(1) All roof/ceilings and/or ceiling/attics sections shall achieve a composite resistance value (Rt) of 16.67 if the insulation is not penetrated by framing or furring and Rt of 20.0 if the insulation is penetrated by the framing or furring. (California Administrative Code, Title 25, Chapter 1, Subchapter 1, Article 5, Section 1094[c].) Blown insulation (loose fill type) shall be considered to be penetrated by the framing.

(2) The roof/ceiling and/or ceiling/attic sections of the dwelling unit as a whole may be insulated to values greater and/or less than required in (1) above if the resulting heat loss equals or is less than that which would occur if the values required in (1) above were met, or if the thermal resistance values of the ceiling areas satisfy the following equation:

$$1/Rt \text{ required} = (\text{Area A/Total Area})(1/Rt \text{ achieved}) + (\text{Area B/Total Area})(1/Rt \text{ achieved}) + \ldots + (\text{Area N/Total Area})(1/Rt \text{ achieved})$$

(3) In Group H occupancies, roof/ceilings or ceiling/attics located beneath dark colored roofs shall achieve composite resistance values (Rt) 30% greater than the values in (1) and (2) above, i. e., Rt = 21.67 and Rt = 26.00 respectively. In Group I occupancies, roof/ceilings or ceiling/attics located beneath roofs that are darker than Munsell Color No. 4 shall achieve composite resistance values (Rt) 30% greater than the values in (1) and (2) above, i. e., Rt = 21.67 and Rt = 26.00 respectively.

— C. Floors. Suspended floors over a ventilated crawl space or other unheated space shall have insulation with a minimum resistance of R-11. Concrete slabs on grade require no insulation.

Exceptions:

(1) Suspended floors over an unheated space shall achieve a composite resistance value (Rt) of 10.52 if the insulation is not penetrated by framing, and Rt of 12.50 if the insulation is penetrated by framing.

(2) Heavy suspended floors with exterior insulation shall achieve a composite resistance value (Rt) of 7.36 for insulation not

penetrated by framing members, and Rt of 8.75 for insulation penetrated by framing members.

D. Glazing Area. In Group H occupancies, exterior single-pane glazing (windows, skylights, etc.) may not exceed 12-1/2% of the floor area. Exterior double-pane glazing may not exceed 17-1/2% of the dwelling unit's floor area. In Group I occupancies, a glazing constant of 20 square feet in single-pane glazing and 28 square feet in double-pane glazing may be added to the percentage figures allowed above.

Exceptions:

(1) A combination of single and double-pane glazing may be used so long as the area of the single plus the area of the double glazing divided by 1.4 is not greater than 12-1/2% (plus 20 square feet for Group I occupancies) of the dwelling unit's floor area.

(2) A combination of single and/or double-pane glazing with interior shutters may be used to increase the allowed glazing provided that:

(i) The interior shutters are of a permanent construction and installed so that they are operable, and tight fitting or weatherstripped so that a seal is created.

(ii) The areas in each treatment do not exceed those allowed by the following procedure.

$$GC + (FA)(.125) = Area_s + (Area_D)(.64) + (Area_{shut})/Rt$$

Where:

GC = Glazing constant (square feet) taken at 20 square feet in Group I and zero in Group H occupancies.

FA = Floor Area (square feet).

$Area_s$ = Area in single-pane glazing (square feet).

$Area_D$ = Area in double-pane glazing (square feet).

$Area_{shut}$ = Area in interior shuttered glazing (square feet).

Rt = The composite resistance of the shutter-glazing systems.

(3) When the area of glazing allowed by application of (1) or (2) is exceeded, the excess area will be considered justified if all the following conditions are met:

(i) Glazing must be south facing. If it is mounted other than vertically, it must be tilted at least 30° up from the horizontal to face south.

(ii) It must be clear. (Shading coefficient numerically greater than or equal to .80 for the glazing itself.)

(iii) It must record a full direct sun from 10:00 a. m. to 2:00 p. m. (P. S. T.) on December 21.

(iv) For each square foot of glazing being justified, the building must contain a heat storage capacity (hs) equivalent to 750 BTU's/Day, located inside the insulated shell of the structure, and not covered with insulation materials such as carpet yielding an Rt of 1.0 or greater. The following will allow a quick method for calculation of mass needed for each square foot of exempted glazing:

59 Square feet of interior stud partition wall (2" x 4"s - 16" o.c. with 1/2" gypsum two sides).

117 Square feet of exterior stud wall or ceiling (2" x 4"s - 16" o.c. with 1/2" gypsum inside, insulation, and various external treatments).

21 Square feet of 8-inch lightweight concrete block masonry exterior wall insulated externally, cores filled for structural support only.

15 Square feet of concrete slab floor provided with a steel trowel finish, exposed aggregate, tile (vinyl, asbestos, or ceramic), terrazo, or hardwood parque not greater than 1/2-inch thick.

(NOTE: Lightweight stud frame walls are assumed to flux 10°F; heavy walls are assumed to flux 5°F. See Definitions E and K.)

E. Glazing Shading.

(1) All glazing which is not oriented to the north must be shaded to protect it from direct solar radiation for the hours of 8:00 a. m., 12:00 noon, and 4:00 p. m. (P.S.T.). August 21. Glazing facing SE or SW must also be checked for shading at 10:00 a. m. for SE and 2:00 p. m. for SW in addition to the standard three hours. For each check hour the area of glazing not shaded is calculated and accumulated. In Group H occupancies the total accumulated amount of unshaded glazing may not exceed 1.5% of the dwelling unit's floor area. In Group I occupancies the total accumulated amount of unshaded glass may not exceed 3% of the dwelling unit's floor area. Shading shall be demonstrated to the satisfaction of the Building Inspection Division of the Community Development Department. Drawings showing shadows cast by shading systems, or scale models suitable for use in the solar-ranger setup by the Building Inspection Division, or the use of approved shade screen systems may be employed to demonstrate compliance. Tinted, metalized, or frosted glass shall not be considered self-shading.

(2) Interior mounted shutters meeting the following specifications may be utilized to meet the shading requirements:

(i) The exterior oriented side must be very light in color (Munsell of 9.0 or greater) and flat.

(ii) The shutters must be tight fitting or all cracks or edges in the system must be weather stripped to create a seal.

(iii) The shutters must be opaque.

(iv) A composite resistance value of Rt = 1.0 for the shutters must be achieved.

(3) Exterior mounted shading systems meeting the following specifications may be utilized to meet the shading requirements:

(i) They shall be of permanent materials and construction. A permanent frame with sheathing having a life expectance of five years minimum must be provided and guaranteed by the builder.

(ii) For the required design hour, the shading device must be capable of intercepting 100% of the direct beam solar radiation, or provide a minimum shading coefficient of 0.2 or less. If the shading system at a design hour does not perform to these standards, then the portion of the glazing which is left exposed is to be calculated and added to the accumulated unshaded glazing total.

(4) Other types of shading systems are allowed if they comply with either of the following:

(i) All on-site and off-site obstructions to the sun, providing 80% attenuation of the direct solar beam, may be considered as external shading devices and may be accounted for in the summer shading calculations. (NOTE: If during the life of the structure the off-site obstructions to the sun used to achieve shading standards compliance are modified or removed, then the structure may be found to be in violation of the Code if other compensating obstructions to the sun or shading devices have not been deployed.)

(ii) A shading system may be temporary, provided that it is designed and constructed to function to the standards above and built to last until its function is replaced by plantings. Plan and elevation drawings must show expected plant configuration and accurately state the number of years required for the projected plant growth. Final occupancy permits shall not be issued until the specified plants are in place.

F. Ventilation for Summer Night Time Cooling. Where design of the dwelling unit is such that openable windows may only be provided along one elevation, mechanical cross ventilation must be installed to provide 15 air changes per hour ducted to the exterior.

✓ Section 5. Path II (Performance Method).

Buildings regulated by the Residential Energy Conservation Code that do not meet the criteria of Path I must be calculated by a registered architect, engineer, building designer, or other qualified person to show that the proposed building will not exceed the standards set forth in Section 3 of Ordinance No. . The required calculation schedule is outlined below. (NOTE: More precise calculations may be submitted using ASHRAE or other comprehensive methods provided that the same design days are used.)

Commonwall U.B.C. Group I dwelling units may increase the permissible thermal standards for Heat Loss or Heat Gain using the following equation:

$$TS = TS_H + (TS_I - TS_H)\ (1 - SAC/[1.5][FA])$$

Where:

TS = The Thermal Standard which is applicable to the dwelling unit (BTU's/[sq. ft.][Day])

TS_H = The Thermal Standard for Group H structures (BTU's/[sq. ft.] [Day])

TS_I = The Thermal Standard for a detached Group I dwelling unit of the same floor area (BTU's/[sq. ft.][Day])

SAC = The Surface Area in Common with other dwelling units such as ceilings, walls, and floor (square feet)

FA = The dwelling unit's Floor Area (square feet)

A. Winter Calculations.

(1) The Total Day's Heat Loss shall not exceed the standards set in the Residential Energy Conservation Ordinance, Section 3.

(2) Winter heat loss calculations shall be based on the following formula:

TDHL = (DHL - SHGC)/(FA)

Where:

TDHL = Total Day's Heat Loss (BTU's/[sq. ft.][Day])

DHL = Day's Heat Loss (BTU's/Day)

SHGC = Solar Heat Gain Credit (BTU's/Day)

FA = Floor Area of dwelling unit (sq. ft.)

(3) The Design Day for sun angle considerations is December 21 at latitude 40°N or 38° 32' N. The outside daily temperature average for December and January is 45°F, yielding a 23°F difference between the inside (68°F) and the outside (45°F) average daily temperatures. The number of degree hours in the design day is the temperature difference times 24 hours or 552 for Davis. This figure is used as described in Paragraph (4)(i) below. (NOTE: This design, outdoor condition, is not intended to be for equipment sizing, but rather is meant to serve the purpose of performance design for energy conservation by more closely predicting the long term average conditions and energy use of the structure. Equipment sizing will require additional standard peak load calculations.)

(4) Calculation of Day's Heat Loss (DHL): Winter heat loss is determined by the composite resistance (Rt) of the exterior building surface to heat transfer to the outside air from the heated interior spaces.

DHL = HL + SHL

Where:

DHL = Day's Heat Loss (BTU's/Day)

HL = Heat Loss from outside surface elements (except slab) (BTU's/Day)

SHL = Slab on grade Heat Loss (BTU's/Day)

(i) The heat loss for all surfaces (except slabs on grade) facing the outside air or unheated spaces may be determined by the following formula:

$$HL = (A_1/Rt_1)\ (552) + (A_2/Rt_2)\ (552) + \ldots + (A_n/Rt_n)\ (552)$$

Where:

HL = Heat Loss from exterior surface element except a slab on grade (BTU's/Day)

A = Area of the exterior surface element (sq. ft.)

Rt = The element's composite thermal resistance ([hours] [Deg. F] [sq. ft.]/BTU)

552 = Davis Design Day Degree Hours ([Deg. F] [hours]/Day)

All exterior elements (walls, ceilings, doors and suspended floors) which are exposed to unheated enclosed or partially enclosed spaces shall be calculated as if they are exposed to outside conditions, or the temperature difference may be altered according to accepted ASHRAE procedures for surfaces adjacent to unheated spaces.

(ii) Concrete slab floors on grade lose heat in direct relation to the perimeter dimension in linear feet. The following formula applies:

SHL = (F) (P) (552)

Where:

SHL = Heat Loss from Slab (BTU's/Day)

F = The thermal conductivity of the edge of the slab with F = 0.81 (BTU/[foot] [hour] [Deg. F]) where no insulation is used and F = 0.55 where slab is insulated with edge insulation of R = 4.5 minimum. The insulation shall come within one inch of the top of the slab and extend sixteen inches below grade.

P = Perimeter dimension (feet)

552 = Davis Design Day Degree Hours ([Deg. F] [hours]/[Day])

(5) Calculation of Solar Heat Gain Credit (SHGC). Direct use of solar energy is dependent on the Day's Solar Heat Gain (DSHG) through the glazing, the Heat Storage (HS) characteristics of the

building, and the Solar Climatic Variable (SCV). The following steps are to be followed to calculate the SHGC:

(i) Calculate the Day's Solar Heat Gain (DSHG), by adding up the Solar Heat Gain for each daylight hour of December 21 design day for each square foot of glazing receiving sun.

$$DSHG = (HSHG_1 + HSHG_2 + \ldots + HSHG_n)\ (SCV)$$

Where:

DSHG = Day's Solar Heat Gain (BTU's/Day)

HSHG = Hour's Solar Heat Gain. HSHG is found according to the procedure described in Definition I. The number of hours added depends on the hours of sunlight on the glazing surface in question. (BTU's/hour)

SCV = Solar Climatic Variable (no units). SCV = 0.56 for Davis. This was determined by averaging the mean fraction of possible sunshine available for each month of the winter heating season (November, December, January, February, March).

(ii) Calculate the Heat Storage capacity of the building (HS). (See Definition K for calculation procedure.)

(iii) Then the Solar Heat Gain Credit (SHGC) (BTU's/Day) equals:

SHGC = DSHG or HS, whichever is less.

B. Summer Calculations.

(1) The Total Day's Heat Gain (TDHG) shall not exceed the standard set in the Residential Energy Conservation Ordinance, Section 3.

(2) Summer heat gain calculations shall be based on the following formula:

$$TDHG = (DHG - HS)/FA$$

Where:

TDHG = Total Day's Heat Gain (BTU's/[sq.ft.][Day])

DHG = Day's Heat Gain (BTU's/Day)

HS = Heat Storage (BTU's/Day)

FA = Floor Area of the dwelling unit (sq. ft.)

(3) The calculations below are based on the design day cited in the Residential Energy Conservation Ordinance taken at the five hours of 8:00 a.m., 10:00 a.m., 12:00 noon, 2:00 p.m., and 4:00 p.m.

(4) The Day's Heat Gain (DHG) is based on the weighted sum of calculations done at each of the five heat gain calculation hours (see equation [a] below). Structures without elevations oriented to the intercardinal directions may delete calculations for 10:00 a.m. and 2:00 p.m. and equally weigh the remaining three calculation hours by multiplying them by four (see equation [b] below). The following two weighted sun equations hold respectively.

(a) $$DHG = ([HG_{8:00\ a.m.}][3]+[HG_{10:00\ a.m.}][2] +[HG_{12:00\ noon}][2]+[HG_{2:00\ p.m.}][2] +[HG_{4:00\ p.m.}][3])$$

or

(b) $$DHG = ([HG_{8:00\ a.m.} + HG_{12:00\ noon} + HG_{4:00\ p.m.}][4])$$

Where:

DHG = Day's Heat Gain (BTU's/[Day])

HG = Heat Gain at the hour calculated (BTU's/hour)

(NOTE: More detailed analysis of Heat Gain may be done by calculating each hour's heat gain for the daylight hours. The digits "2", "3" and "4" in equations (a) and (b) above have the units of hours.)

(5) The Heat Gain (HG) may be calculated by using the following formula:

$$HG = WHG + OHG$$

Where:

HG = Heat Gain (BTU's/hour) at one of the design hours.

WHG = Heat Gain through Windows (BTU's/hour)

OHG = Heat Gain through Opaque surfaces (BTU's/hour)

(i) Heat Gain through Opaque surfaces. Calculations will be based on the Total Equivalent [illegible] Potential Method (TETD) as described in ASHRAE Handbook of Fundamentals 1972, Chapter 22, pages 411-417. The [illegible] for the [illegible] roof section is found in attached Tables 2 and 3. Since the [illegible] design day temperature is 5°F less than that used by ASHRAE, 5°F should be subtracted from the TETD values given in attached Tables 2 and 3 in accordance with ASHRAE procedures, as shown in the calculation below. (The interior temperature is assumed to be 75°F in accordance with ASHRAE.) The Heat Gain through Opaque surfaces is calculated as follows:

$$OHG = A_1(TETD-5)/Rt_1 + A_2(TETD-5)/Rt_2 + \ldots + A_n(TETD-5)/Rt_n$$

Where:

OHG = Heat Gain through opaque surfaces at the calculation hour (BTU's/hour)

A = Area of the outside surface element (sq. ft.)

Rt = The element's composite thermal Resistance ([hours][Deg. F] [sq. ft.]/BTU)

TETD = The element's Total Equivalent Temperature Difference from attached Tables 2 and 3

(ii) Glazing. Summer Heat Gain through windows (WHG) shall be calculated using the following formula:

$$WHG = ([A][SC][SHGF]+[\Delta T][A]/Rt)_1 + (A \ldots)_2 + \ldots + (A \ldots)_n$$

Where:

WHG = Direct solar heat gain plus conducted heat gain through windows at the calculation hour (must be done for each wall or roof section with glazing). (BTU's/hour)

A = Area of glazing surface being calculated (sq. ft.)

SC = Shading Coefficient (see Definition H). (Unitless)

SHGF = Solar Heat Gain Factor at the hour being calculated. (BTU's/[hours][sq. ft. of glazing])

Rt = Thermal Resistance of the glass (0.9 for single [illegible] glass [illegible] double-pane). ([illegible] ft.]/BTU's)

ΔT = Difference between the [illegible] inside temperatures, [illegible] taken as the inside temperature. (Deg. F)

(6) Heat Storage Capacity (HS). Where the building design provides for ventilation in minimum conformance with Section 4 F, credit can be taken for the Heat Storage capacity of the structure. (NOTE: When calculating the heat storage capacity for the summer, no credit may be taken for exterior elements.)

Section 6. Fees.

The following schedule of fees shall be applicable for the checking of plans for conformity with the performance standards of the Residential Energy Conservation Code:

Path I	(No Exceptions)	No Charge
Path I	(Exercising Exceptions)	$20.00
Path II		$25.00

PASSED AND ADOPTED by the City Council of the City of Davis on this 15th day of October, 1975, by the following vote:

AYES : Councilmen Black, Holdstock, Stevens, Tomasi, Mayor Poulos.

NOES : None.

ABSENT: None.

JOAN G. POULOS
Mayor

ATTEST:

HOWARD L. REESE
City Clerk

TABLE 1

Solar Position and Intensity; Solar Heat Gain Factors[a] for 40 Deg North Latitude

	Date	Solar Time A.M.	Solar Position		Direct Normal Irradiation, Btuh/sq ft	Solar Heat Gain Factors, Btuh/sq ft									Solar Time P.M.
			Alt.	Azimuth		N	NE	E	SE	S	SW	W	NW	Hor.	
Summer	Aug 21	6	7.9	93.5	80	12	67	82	48	5	5	5	5	11	6
		7	19.3	90.0	191	17	135	191	135	17	15	15	15	62	5
		8	30.7	79.9	236	23	126	216	180	40	22	22	22	125	4
		9	41.8	67.9	259	28	82	197	196	79	28	28	28	174	3
		10	51.7	52.1	271	32	40	149	187	116	34	32	32	213	2
		11	59.3	29.7	277	34	35	81	156	140	32	34	34	238	1
		12	62.3	0.0	279	35	35	38	105	149	105	38	35	247	12
	Half Day Totals					161	503	936	961	471	202	154	151	945	
Winter	Dec 21	8	5.5	53.0	88	2	7	67	83	49	3	2	2	6	4
		9	14.0	41.9	217	9	10	135	205	151	12	9	9	39	3
		10	20.7	29.4	261	14	14	113	232	210	35	14	14	77	2
		11	25.0	15.2	279	16	16	56	217	242	120	16	16	103	1
		12	26.6	0.0	284	17	17	18	177	253	177	18	17	112	12
	Half Day Totals					49	54	380	831	781	273	56	49	242	
						N	NE	E	SE	S	SW	W	NW	HOR.	← P.M.

[a] Total solar heat gains for 1/8 in. (3.18 mm) sheet glass. Based on a room [illegible] and [illegible] Table [illegible].

From Handbook of Fundamentals, 1972, American Society of Heating, Refrigeration and Air Conditioning Engineers.

TABLE 2

Total Equivalent Temperature Differentials for Calculating Heat Gain Through Flat Roofs

Description of Roof Construction[a,b]	Wt, lb per sq ft	U value Btu/(hr)(ft²)(F°)	Sun Time A.M. 8 D	8 L	10 D	10 L	12 D	12 L	P.M. 2 D	2 L	4 D	4 L	6 D	6 L	8 D	8 L	10 D	10 L	12 D	12 L	λ	δ
Light Construction Roofs—Exposed to Sun																						
1" insulation + steel siding	7.4	0.213	28	11	65	31	90	48	95	53	78	45	43	27	8	6	1	1	−3	−3	1.0	0
2" insulation + steel siding	7.8	0.125	24	8	61	29	88	46	96	53	81	46	46	30	10	8	2	2	−3	−3	0.99	1
1" insulation + 1" wood[c]	8.4	0.208	12	2	47	21	77	39	92	50	86	48	61	36	25	16	7	5	0	−1	0.93	2
2" insulation + 1" wood[c]	8.5	0.122	8	0	41	18	72	36	90	48	88	49	65	38	30	19	9	7	4	0	0.93	2
1" insulation + 2.5" wood[c]	12.7	0.193	2	−2	23	8	48	23	70	36	79	42	71	40	50	29	29	17	15	9	0.74	3
2" insulation + 2.5" wood[c]	13.1	0.117	1	−2	19	6	43	20	65	33	76	41	72	40	53	31	33	20	18	11	0.68	4
Medium Construction Roofs—Exposed to Sun																						
1" insulation + 4" wood[c]	17.3	0.183	3	0	14	5	31	14	49	24	62	32	65	35	56	31	41	24	29	17	0.51	5
2" insulation + 4" wood[c]	17.8	0.113	6	1	13	4	28	12	45	22	58	30	62	34	56	31	43	25	32	18	0.45	5
1" insulation + 2" h.w. concrete	28.3	0.208	4	−1	27	11	54	26	74	39	81	44	70	40	45	27	24	15	12	7	0.75	3
2" insulation + 2" h.w. concrete	28.3	0.122	2	−2	23	0	49	23	70	36	79	43	71	40	49	29	28	17	15	9	0.73	3
1" [illegible]	17.8	0.213	1	−3	28	11	59	28	82	43	88	48	74	42	44	27	19	12	6	4	0.67	3
1" [illegible]	24.5	0.157	−2	−4	9	2	31	13	53	27	72	38	76	41	64	36	42	25	25	15	0.67	5
2" [illegible]	31.2	0.125	6	2	6	1	16	6	32	14	49	24	61	32	63	34	53	31	41	24	0.50	6
Heavy Construction Roofs—Exposed to Sun																						
1" [illegible] + 4" h.w. concrete	51.6	0.199	7	1	17	6	33	15	50	25	61	32	63	34	53	30	40	23	28	16	0.48	5
2" [illegible] + 4" h.w. concrete	52.1	0.120	7	2	13	6	30	13	46	23	58	30	61	33	54	30	41	23	31	17	0.45	5
1" [illegible] + 6" h.w. concrete	73.0	0.193	13	6	17	7	26	12	38	18	48	25	53	28	51	27	43	24	35	19	0.33	6
2" [illegible] + 6" h.w. concrete	73.4	0.117	15	7	17	7	25	11	36	17	46	23	51	27	50	27	43	24	36	20	0.30	6

[a] Inside and outside surface resistance, ½" slag, membrane and ½" felt on the top (code number A4 of Table 41) and inside surface resistance on the bottom (code number [illegible] of Table 41). The property data for components are listed in Table 41.

[b] [illegible] = 0.30; light roof, a/h_o = 0.15.

[c] Nominal thickness of wood.

$$\text{Equivalent Temperature} = \frac{\text{Total heat transmission from solar radiation and temperature difference between outdoor and room air, Btu per (hr) (sq ft) of roof area}}{\text{Heat transmission coefficient, Btu per (hr) (sq ft) (F deg)}} + \text{Differential from above, table}$$

1. [illegible] These values may be used for all normal air conditioning estimates; usually without correction (except as noted below) in latitude 0 deg to 50 deg north [illegible] load is computed for the hottest weather.

2. [illegible] values in the table were calculated for an inside temperature of 75 F and an outdoor maximum temperature of 95 F with an outdoor daily range of [illegible] F. The table remains approximately correct for other outdoor maximums (85-102 F) and other outdoor daily ranges (16-34 F deg) provided the outdoor daily average temperature remains approximately 85 F. If the room air temperature is different from 75 F and, or the outdoor daily average temperature is different [illegible] equation 43 can be used for computing new values or the following rules can be applied:

a. [illegible] temperature less than 75 F, add the difference between 75 F and room air temperature; if greater than 75 F, subtract the difference.

b. For outdoor daily average temperature less than 85 F, subtract the difference between 85 F and the daily average temperature; if greater than 85 F, add the difference.

3. *Attics or other spaces between the roof and ceiling.* If the ceiling is insulated and a fan is used for positive ventilation in the space between the ceiling and roof, the total temperature differential for calculating the room load may be decreased by 25 percent.

From Handbook of Fundamentals, 1972, American Society of Heating, Refrigeration and Air Conditioning Engineers.

NOTE: Standard residential roof construction is in the first light group. The line titled '2" insulation + 1" wood' is to be used. The designations "D" and "L" are to mean dark and light per the definitions of this resolution. (See Definition F.)

TABLE 3

Total Equivalent Temperature Differentials for Calculating Heat Gain Through Sunlit Walls

Description of Wall Constructions[a]

Group	Components	Wt, lb per sq ft	U Value
A	1" stucco + 4" l.w. concrete block + air space	28.6	0.267
	1" stucco + air space + 2" insulation	16.3	0.106
B	1" stucco + 4" common brick	55.9	0.393
	1" stucco + 4" h.w. concrete	62.5	0.451
C	4" face brick + 4" l.w. concrete block + 1" insulation	62.5	0.158
	1" stucco + 4" h.w. concrete + 2" insulation	62.9	0.114
D	1" stucco + 8" l.w. concrete block + 1" insulation	41.4	0.141
	1" stucco + 2" insulation + 4" h.w. concrete block	36.6	0.111
E	4" face brick + 4" l.w. concrete block	62.2	0.333
	1" stucco + 8" h.w. concrete block	56.6	0.319
F	4" face brick + 4" common brick	89.5	0.360
	4" face brick + 2" insulation + 4" l.w. concrete block	62.5	0.103
G	1" stucco + 8" clay tile + 1" insulation	62.8	0.141
	1" stucco + 2" insulation + 4" common brick	56.2	0.108
H	4" face brick + 8" clay tile + 1" insulation	96.4	0.137
	4" face brick + 8" common brick	129.6	0.280
	1" stucco + 12" h.w. concrete	155.9	0.365
	4" face brick + 2" insulation + 4" common brick	89.8	0.105
	4" face brick + 2" insulation + 4" h.w. concrete	96.5	0.111
	4" face brick + 2" insulation + 8" h.w. concrete block	90.6	0.102
I	1" stucco + 8" clay tile + air space	62.6	0.209
	4" face brick + air space + 4" h.w. concrete block	69.9	0.282
J	face brick + 8" common brick + 1" insulation	129.8	0.145
	4" face brick + 2" insulation + 8" clay tile	96.5	0.094
	1" stucco + 2" insulation + 8" common brick	96.3	0.100
K	4" face brick + air space + 8" clay tile	96.2	0.200
	4" face brick + 2" insulation + 8" common brick	129.9	0.098
	4" face brick + 2" insulation + 8" h.w. concrete	113.3	0.107
L	4" face brick + 8" clay tile + air space	96.2	0.290
	4" face brick + air space + 4" common brick	89.5	0.265
	4" face brick + air space + 4" h.w. concrete	96.2	0.301
	4" face brick + air space + 8" h.w. concrete block	90.2	0.248
	1" stucco + 2" insulation + 12" h.w. concrete	156.3	0.100
M	4" face brick + air space + 8" common brick	129.6	0.218
	4" face brick + air space + 12" h.w. concrete	189.5	0.251
	4" face brick + 2" insulation + 12" h.w. concrete	189.9	0.104

[a] In addition to the structure components listed above, all walls had an outside surface resistance (code number A0 of Table 41) and on the inside, a ½ in. layer of plaster, gypsum or other similar building material and an inside surface resistance (code numbers E1 and E0 respectively of Table 41).

North Latitude Wall Facing	Sun Time: A.M. 8		A.M. 10		A.M. 12		P.M. 2		P.M. 4		P.M. 6		P.M. 8		P.M. 10		P.M. 12		Amplitude Decrement Factor, λ	Time Lag, δ hr	South Latitude Wall Facing
	Exterior color of wall—D = dark, L = light																				
	D	L	D	L	D	L	D	L	D	L	D	L	D	L	D	L	D	L			
Group A[a]																					
NE	27	16	31	18	28	17	24	17	24	18	23	17	20	15	17	13	15	11	0.34	2	SE
E	32	18	41	24	37	22	29	20	28	20	26	19	23	16	20	14	18	13			E
SE	25	15	36	21	38	23	33	21	28	20	26	18	22	16	19	14	18	12			NE
S	14	9	20	13	28	18	33	22	31	21	25	18	20	15	17	13	15	11			N
SW	17	11	20	13	24	16	34	22	42	27	41	26	28	19	20	14	18	12			NW
W	17	11	20	13	24	16	30	20	42	27	48	30	33	22	22	15	19	13			W
NW	14	9	17	11	21	14	23	17	31	21	38	25	28	19	18	13	16	11			SW
N	14	9	15	10	17	12	20	13	21	16	21	16	18	14	14	11	12	9			S
Group B[a]																					
NE	12	7	27	14	31	17	30	19	31	21	30	22	27	20	21	17	16	13	0.51	3	SE
E	14	8	34	18	45	24	43	25	39	25	35	24	30	22	23	18	17	14			E
SE	9	5	25	13	39	21	44	26	41	26	37	25	31	23	24	18	17	14			NE
S	4	3	7	4	18	11	32	19	41	26	39	27	33	24	25	19	18	15			N
SW	5	3	7	4	11	7	23	15	41	26	54	34	51	33	38	25	26	19			NW
W	6	4	7	4	11	7	18	12	35	23	55	34	59	37	43	28	30	20			W
NW	5	3	6	4	11	7	17	12	26	18	41	27	47	31	36	24	25	18			SW
N	6	4	9	5	12	8	18	12	22	17	25	20	27	21	22	17	16	14			S
Group C[a]																					
NE	9	6	19	10	26	15	28	17	29	18	29	20	28	20	24	19	20	16	0.40	4	SE
E	10	7	22	12	36	19	40	23	39	23	36	24	33	23	28	20	22	17			E
SE	8	6	16	9	29	16	38	21	39	24	37	24	34	23	28	21	23	17			NE
S	7	5	7	4	12	7	22	14	32	20	36	24	34	24	29	21	23	17			N
SW	9	6	8	5	10	6	16	10	28	18	42	26	48	30	42	28	33	22			NW
W	10	7	9	5	10	6	14	9	24	16	40	25	52	32	47	30	37	24			W
NW	8	6	8	5	9	6	13	9	19	14	30	20	40	27	38	28	30	21			SW
N	7	5	8	5	10	7	14	9	18	13	22	16	25	19	23	18	19	16			S

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TABLE 3 (Continued)

Total Equivalent Temperature Differentials for Calculating Heat Gain Through Sunlit Walls (Continued)

North Latitude Wall Facing	Sun Time: A.M. 8		A.M. 10		A.M. 12		P.M. 2		P.M. 4		P.M. 6		P.M. 8		P.M. 10		P.M. 12		Amplitude Decrement Factor, λ	Time Lag, δ hr	South Latitude Wall Facing
	Exterior color of wall—D = dark, L = light																				
	D	L	D	L	D	L	D	L	D	L	D	L	D	L	D	L	D	L	λ	δ	
Group D[a]																					
NE	8	5	19	10	28	15	29	17	30	19	30	21	28	21	24	19	19	16	0.45	4	SE
E	9	6	23	12	38	20	42	24	40	24	37	24	33	23	27	20	21	17			E
SE	7	5	16	9	30	16	40	22	41	25	38	25	34	24	28	21	22	17			NE
S	5	4	6	4	12	7	23	14	34	21	38	25	35	24	29	21	23	17			N
SW	8	5	7	4	9	6	16	10	30	19	44	28	51	32	43	28	33	22			NW
W	8	6	7	5	9	6	14	9	25	16	42	27	55	34	49	31	37	25			W
NW	7	5	7	4	9	6	13	9	20	14	31	21	42	28	40	27	31	21			SW
N	6	4	8	5	10	6	14	10	19	14	23	17	25	19	24	19	19	16			S
Group E[a]																					
NE	10	6	23	12	30	16	30	18	30	20	30	21	28	21	23	18	18	14	0.48	4	SE
E	11	6	28	15	42	22	43	24	39	24	36	24	32	23	25	19	19	15			E
SE	8	5	20	11	35	19	42	24	41	25	38	25	33	23	26	20	20	16			NE
S	4	3	6	4	15	9	28	17	38	24	39	26	34	24	27	20	20	16			N
SW	6	4	7	4	10	6	19	12	35	22	49	31	52	33	41	27	30	21			NW
W	7	5	7	4	10	6	16	11	30	20	48	31	57	36	47	30	34	23			W
NW	6	4	6	4	10	6	15	10	23	16	36	24	45	30	38	26	28	20			SW
N	6	4	8	5	11	7	16	11	21	15	24	18	26	20	23	18	18	15			S
Group F[a]																					
NE	9	7	14	9	21	12	25	15	27	17	29	19	28	20	26	19	23	17	0.32	6	SE
E	10	8	17	10	28	15	35	19	37	22	37	23	35	23	31	22	26	19			E
SE	10	7	13	8	22	12	31	17	36	21	37	23	35	23	32	22	27	19			NE
S	9	7	7	5	10	6	17	10	26	16	32	20	33	22	31	22	27	19			N
SW	12	9	10	6	9	6	13	8	22	14	33	21	42	27	42	27	37	25			NW
W	14	9	11	7	10	6	12	8	19	12	31	20	43	27	46	29	41	27			W
NW	12	8	9	6	9	6	11	8	16	11	24	16	33	22	36	24	33	23			SW
N	8	7	8	6	9	6	12	8	15	11	19	14	22	17	23	18	21	17			S
Group G[a]																					
NE	11	9	10	15	20	12	24	14	25	16	26	17	27	18	26	18	23	17	0.25	6	SE
E	13	9	17	11	26	15	32	18	34	20	34	21	33	22	31	21	27	19			E
SE	13	9	14	9	21	12	28	16	33	19	34	21	33	22	31	21	27	19			NE
S	12	9	10	7	11	8	16	10	23	15	29	18	30	20	29	20	26	19			N
SW	16	11	13	9	13	8	14	9	20	13	29	19	37	24	39	25	35	23			NW
W	18	12	15	10	14	9	14	9	18	12	27	18	38	24	42	26	38	25			W
NW	14	10	12	8	12	8	13	9	16	11	21	15	29	20	33	22	31	21			SW
N	10	8	10	7	10	7	12	8	15	10	18	13	20	15	21	16	20	16			S
Group H[a]																					
NE	15	11	16	11	18	12	20	13	22	14	24	15	25	16	25	17	24	17	0.14	8	SE
E	18	13	18	12	22	14	26	16	29	17	30	19	31	20	30	20	29	19			E
SE	18	13	17	12	19	12	23	14	27	16	29	18	30	19	30	20	28	19			NE
S	16	12	14	10	14	10	15	10	19	12	23	15	25	17	26	18	26	18			N
SW	22	14	19	12	17	11	16	11	18	12	23	15	29	18	32	21	32	21			NW
W	23	15	20	13	18	12	17	11	18	12	22	15	29	18	33	21	34	22			W
NW	19	13	17	11	15	10	15	10	15	11	18	12	23	15	26	18	27	19			SW
N	13	10	12	9	11	9	12	9	13	10	15	11	17	13	18	14	19	14			S
Group I[a]																					
NE	16	11	18	12	20	13	22	14	23	15	24	16	24	16	23	16	22	16	0.13	6	SE
E	19	13	21	14	25	16	29	17	30	18	30	19	29	19	28	19	26	18			E
SE	19	13	19	13	22	14	26	16	28	18	29	18	29	19	28	18	26	18			NE
S	16	12	15	11	16	11	18	12	21	14	24	16	25	17	25	17	23	16			N
SW	20	14	19	13	18	12	19	13	22	14	27	17	31	20	32	20	30	20			NW
W	22	14	20	13	19	13	20	13	22	14	26	17	31	20	33	21	32	21			W
NW	18	12	16	11	16	11	17	11	18	12	21	14	25	17	27	18	26	18			SW
N	13	10	12	9	13	9	13	10	15	11	16	12	18	13	18	14	18	14			S

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TABLE 3 (Continued)

Total Equivalent Temperature Differentials for Calculating Heat Gain Through Sunlit Walls (*Concluded*)

North Latitude Wall Facing	Sun Time: A.M. 8		A.M. 10		A.M. 12		P.M. 2		P.M. 4		P.M. 6		P.M. 8		P.M. 10		P.M. 12		Amplitude Decrement Factor, λ	Time Lag, δ hr	South Latitude Wall Facing
	Exterior color of wall—D = dark, L = light																				
	D	L	D	L	D	L	D	L	D	L	D	L	D	L	D	L	D	L	λ	δ	
Group J[a]																					
NE	18	13	17	12	18	12	19	13	21	13	22	14	23	15	23	16	23	16	0.10	9	SE
E	22	15	20	14	21	14	24	15	26	16	28	17	29	18	29	19	29	19			E
SE	21	15	20	14	20	13	21	14	24	15	26	16	28	17	28	18	28	18			NE
S	19	14	17	12	18	11	16	11	17	12	20	13	22	15	24	16	24	16			N
SW	24	16	22	15	20	13	19	13	19	13	21	14	24	16	28	18	30	19			NW
W	26	17	24	16	22	14	20	13	20	13	21	14	24	16	28	18	31	20			W
NW	21	15	19	13	18	12	17	11	17	11	17	12	19	13	22	15	25	17			SW
N	15	11	14	11	13	10	13	9	13	10	14	10	15	11	17	12	17	13			S
Group K[a]																					
NE	19	14	19	13	19	13	20	13	20	14	21	14	22	15	22	15	22	15	0.08	11	SE
E	23	16	22	15	23	15	24	16	26	16	27	17	27	17	28	18	27	18			E
SE	23	15	22	15	22	14	22	15	24	15	25	16	26	17	27	17	27	17			NE
S	20	14	19	13	18	12	18	12	18	13	20	13	21	14	22	15	23	15			N
SW	25	16	23	15	22	14	21	14	21	14	22	15	24	16	26	17	27	18			NW
W	26	17	24	16	23	15	22	15	22	14	23	15	24	16	27	17	28	18			W
NW	21	15	20	14	19	13	18	13	18	12	19	13	20	14	22	15	23	16			SW
N	15	11	14	11	14	10	14	10	14	10	14	11	15	11	16	12	16	12			S
Group L[a]																					
NE	18	13	18	13	19	13	20	13	21	14	22	15	23	15	23	16	22	15	0.08	8	SE
E	22	15	22	14	23	15	25	16	27	17	28	18	28	18	28	18	27	18			E
SE	21	14	21	14	22	14	23	15	25	16	27	17	27	17	27	17	26	18			NE
S	19	13	17	12	17	12	18	12	19	13	21	14	23	15	23	16	23	16			N
SW	23	15	22	14	21	14	20	13	21	14	23	15	26	17	28	18	28	18			NW
W	25	16	23	15	22	14	21	14	22	14	24	15	26	17	29	19	30	19			W
NW	20	14	19	13	18	12	18	12	18	12	19	13	21	15	23	16	24	16			SW
N	14	11	14	10	13	10	13	10	14	10	15	11	16	12	17	13	17	13			S
Group M[a]																					
NE	20	14	20	14	19	13	20	13	20	14	20	14	21	14	21	14	22	15	0.05	12	SE
E	25	16	24	16	24	16	24	16	25	16	25	16	26	17	27	17	27	17			E
SE	24	16	23	15	23	15	23	15	23	15	24	16	25	16	25	16	26	17			NE
S	21	14	20	14	19	13	19	13	19	13	19	13	20	14	21	14	21	15			N
SW	25	17	25	16	24	16	23	15	22	15	22	15	23	15	24	16	25	17			NW
W	27	17	26	17	25	16	24	16	23	15	23	15	24	15	25	16	26	17			W
NW	22	15	21	14	20	14	20	13	19	13	19	13	19	13	20	14	21	15			SW
N	15	12	15	11	14	11	14	11	14	11	14	11	15	11	15	11	16	12			S

[a]See "Description of Wall Construction" table above for details of each wall grouping.

Explanation: {Total heat transmission from solar radiation and temperature difference between outside and room air, Btu per (hr) (sq ft wall area)} = {Equivalent temperature differential from above table} × {Heat transmission coefficient for wall, Btu per (hr) (sq ft) (F deg)}

1. *Application:* These values may be used for all normal air-conditioning estimates; usually without correction (except as noted below) when the load is taken for the hottest weather.

2. *Corrections:* The values in the table were calculated for an inside temperature of 75 F and an outdoor maximum temperature of 95 F with an outdoor daily range of 21 F deg. The table remains approximately correct for other outdoor maximums (93–102 F) and other outdoor daily ranges (to 34 F deg) provided the outdoor daily average temperature remains approximately 85 F. If the room temperature is different from 75 F and/or the outdoor daily average temperature is different from 85 F, Equation 43 can be used for computing new values or the following rules can be applied:

a. For room air temperature less than 75 F, add the difference between 75 F and room air temperature; if greater than 75 F, subtract the difference.

b. For outdoor daily average temperature less than 85 F, subtract the difference between 85 F and the daily average temperature; if greater than 85 F, add the difference.

The table values will be approximately correct for the east or west wall in any latitude (0 deg to 50 deg North or South) during the hottest weather. Equation 43 should be used for obtaining values for the north or south wall in latitudes other than 40 deg.

3. *Color of exterior surface of wall:* Use temperature differentials for light walls only when the permanence of the light wall is established by experience. For cream colors use the values for light walls. For medium colors interpolate half way between the dark and light values. Medium colors are medium blue, medium green, bright red, light brown, unpainted wood, natural color concrete, etc. Dark blue, red, brown, green, etc., are considered dark colors.

From Handbook of Fundamentals, 1972, American Society of Heating, Refrigeration and Air Conditioning Engineers.

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APPENDIX C

Village Homes

"The real story behind Village Homes is as much one of personalities, politics, administrative red tape and economic realities as it is of design features for environmental conservation and social interaction." (Thayer, 1977).

At approximately the same time the City of Davis was developing its energy conservation building code and energy planning politics, Mike Corbett, a local builder/developer, was in the process of designing a seventy acre subdivision in the Davis area that was to demonstrate many of the principles of wise land use that the consultants had proposed. The primary purpose of the proposed development was to reduce energy use at the neighborhood level through various physical and social design measures. Corbett's proposal generated a great deal of controversy over several design features (e.g., minimum lot size and narrow streets) in the Davis community, and, as an innovative developer, he personally encountered much frustration and opposition from financial institutions and governmental agencies. The following pages briefly examine Village Homes and the political conflict surrounding its development as an example of the challenges an innovative developer must face.

In 1970, Mike Corbett and other concerned individuals formed a Cooperative Community Group to explore in depth issues involving the development of a self-sufficient community (I: Corbett). Subcommittees were established for finding land, starting a food co-op, and planning social activities. The Group disbanded in the summer of 1972, but by this time Corbett had started designing a self-sufficient community and had begun to search for loans for financing the proposed development. During the period when he was turned down by some twenty lending institutions, Corbett was forced to cut back on his innovative ideas and was compelled to emphasize the traditional aspects of his development (DePrato, 1978). For example, in his attempt to satisfy loan requirements, he deleted any plans for solar systems in the development's first phase (38 units) because banks had insisted that no solar systems be built on speculation. After encountering strong objections by the Federal Housing Authority to most of his innovative design features, Corbett was able to secure a $200,000 construction loan from a local bank.

In the Fall of 1975, construction started on the first phase of Village Homes. At the time of this writing, 100 homes have been built, and by 1982, the completed development will have a total of approximately 200 single-family homes and 26 apartments. All of the housing units are oriented to the south and have awnings or arbors over the south facing windows. The houses also contain the following energy conservation features: double-pane glass, tile roofs and floors, perimeter slab insulation, weatherstripping, R-30 insulation in the ceilings and R-11 and R-19 insulation in the walls. Owners of the first lots had the option of installing solar hot water heaters, and by 1976 they had become standard items in the new units. By mid-1977, passive solar space heating had also become a standard feature in the Corbett-built homes. No air-conditioning was required for those new units utilizing both passive solar technology and natural cooling methods. Village Homes now utilizes three types of solar hot water heaters (breadbox, flat plate with pumps, and flat plate with thermsiphon) and numerous types of solar heating and cooling designs based on passive and active passive systems. Thus far, of the 100 homes that have been constructed, 82 use passive solar systems and 75 use solar hot water heating systems (Mike Corbett, personal communication). Most systems are designed for providing 28-75% of the heating load while backup systems (e.g., wood burning stoves and gas heaters) provide the remaining energy. Homes are not constructed for 100 percent solar due to the long periods of cloudiness and fog that characterize Davis' winter season.

Village Homes also encompasses many other physical and social design measures that are aimed at reducing energy consumption at the neighborhood level (City of Davis, 1977b; De Prato, 1978; Thayer, 1977; I: Corbett):

1. Narrow streets: The width of some private streets in Village Homes is as narrow as 20 feet (curb-to-curb). These streets have no sidewalks, bike lanes, parking areas or drainage systems. Three-foot easements on each side of the street ensure that no permanent obstructions are constructed (e.g., fire hydryants, tall shrubs or street lights) in order to provide maneuverability for emergency vehicles (e.g., fire trucks).

a. Bicycle traffic is directed onto bike lanes which are located in the greenbelt area in the back of houses and provide direct access throughout the community.

b. Open channel drains, which parallel the bike lanes, collect runoff water and deposit it in natural drainage areas in order to replenish the groundwater system.

c. The amount of street lighting has been reduced.

d. Carports and concrete parking bays provide off-street parking for residents and visitors, respectively.

2. Flexible setbacks: Homes are encouraged to be sited close to the street so that "backyard space" can be utilized for common open space and greenbelts.

3. Minimum lot size: Generally, most single-family homes are on lots under 5,000 square feet.

4. Clustering: Village Homes is designed so that 8 houses are "clustered" together in order to make maximum use of the land. These houses collectively own and maintain the common space around their houses.

5. Community ownership: Residents of Village Homes communally own a greenbelt that runs throughout the development, farming plots, and land that is the site for future, small scale, commercial and light industrial businesses (e.g., co-op food store, tavern, bakery, and professional offices). It is expected that many of the community's residents will be employed in these businesses so that commuting to work will be reduced.

6. Agricultural projects: 50 percent of the land is expected to be used for food production and 12 acres for agriculture (e.g., orchards and vineyards) have already been reserved. It is envisioned that one-half to one-third of the residents' food requirements will be met by agricultural and small garden production in Village Homes.

7. Solar access protection: Solar access is protected by mandating in a covenant that collector area on the roof would be clear from 10:00 a.m. to 2:00 p.m. An Architectural Review Board examines scale models of proposed houses to make sure that solar access is protected.

It should be noted that all of these amenities have increased the basic cost of homes by $4,000 to $8,000 (the lot itself costs $2,000 more) in comparison to conventional homes (Mike Corbett, personal communication). However, it is expected that these costs can be repaid in less than ten years by savings on utility bills which are 50 percent of conventional housing bills.

Corbett encountered a great deal of resistance to many of his innovative ideas inside city government. In particular, the Buidling Division, Planning Division and Public Works Department were concerned about the open drains, polybutylene plumbing, cul-de-sac streets (instead of loop roads), narrow streets, narrow carports and narrow setback requirements (see Sections 3 and 4). Most of these issues were eventually resolved in favor of Corbett by the City Council and have been implemented. However, in Corbett's successful attempt in circumventing the traditional actors in the planning process, the strain between innovative developer and planning personnel intensified. Traditionally, the Planning Director implemented existing standards on subdivision developments which the developer was obligated to follow (I: Corbet, McGregor). However, in this case, the developer told the Planning Director what he wanted and, after receiving a negative response from the Director, the developer was able to get approval from the Planning Commission and the City Council. The basic philosophical differences between Corbett and the Planning Director remain and continue to be a sources of frustration for further efforts in incorporating innovative, energy conserving features in Village Homes (I: Corbett, McGregor).

APPENDIX D

Davis Interviews

Interviewee	Occupation	Date and Location of Interview*
Armstrong, Robert	Banker (Wells Fargo Bank-Davis Branch)	October 12, 1978
Bainbridge, Dave	Formerly, employee of Living Systems; presently, the President of the Passive Solar Institute	September 20, 1978
Bertero, Fred	Builder (Stanley Davis Homes)	October 4, 1978
Black, Bob	Formerly, Mayor of City of Davis; presently, Attorney at Law and County Supervisor of Yolo County	October 6, 1978
Broward, Ron	Builder (Broward Associates)	September 21, 1978
Corbett, Mike	Builder (Village Homes)	October 18, 1978
Cramer, Richard	Professor of Architecture University of California, Davis	September 20, 1978
Figueroa, Dan	Formerly, Associate Planner of City of Davis; presently, City Planner of City of Dixon	September 28, 1978 (Dixon)
Hammond, Jon	Builder and energy consultant (Living Systems)	October 6, 1978 (Winters)
Hardy, Alan	Banker (Sacramento Savings-Davis Branch)	October 12, 1978
Hornbeek, Larry	Architect (Hornbeek Associates)	September 27, 1978
Hunt, Marshall	Formerly, employee and partner of Living Systems; presently, Passive Solar Team leader of Solar Office of Califfornia Energy Commission	October 5, 1978

Interviewee	Occupation	Date and Location of Interview*
Jacobsen, Jan	Formerly, CETA employee, City of Davis; presently, employee of Davis Alternative Technology Associates	September 27, 1978
Johnston, Robert	Professor of Environmental Studies, University of California, Davis	September 28, 1978
Kopper, Bill	Formerly, employee of Living Systems; presently, member of Davis City Council and energy consultant	October 6, 1978
Leber, Angelo	Formerly, Senior Building Inspector, City of Davis; presently, Building Offical, City of Cupertino	October 16, 1978 (Cupertino)
Lumbrazo, Tom	Associate Planner, City of Davis	September 21, 1978
Maeda, Bruce	Formerly, employee of Living Systems; presently, Managing Principal of Davis Alternative Technology Associates	October 4, 1978
Maxwell, Doran	Building Official, City of Davis	September 20, 1978
McGregor, Gloria	Planning Director, City of Davis	October 11, 1978
Neubauer, Loren	Professor Emeritus of Agricultural Engineering, University of California, Davis	September 20, 1978
Owen, Bill	City Attorney, City of Davis	October 11, 1978
Pelz, Dave	Public Works Director, City of Davis	October 12, 1978
Reese, Howard	City Manager, City of Davis	September 21, 1978
Roe, Bill	Builder (Tandem Associates)	September 21, 1978

Interviewee	Occupation	Date and Location of Interview*
Streng, Bill	Builder (Streng Associates)	September 28, 1978
Whitcombe, John	Builder (Tandem Associates)	October 11, 1978

*All interviews were conducted in Davis except where noted in parentheses.

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