# BUILDING APPLICATION OF SOLAR ENERGY

## STUDY NO. 2: REPRESENTATIVE BUILDINGS FOR SOLAR ENERGY PERFORMANCE ANALYSIS AND MARKET PENETRATION

5040-3 September 19, 1975

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JET PROPULSION LABORATORY
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By

Alan Hirshberg

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Many people from the Southern California Edison Company helped with this report. In particular we would like to thank Mr. Leon Dame and Mr. Ed Gould for their assistance and patience. Particular thanks to Mr. Jerry Braun who helped us steer the work in the direction of most relevance to Southern California Edison.

# SECTION I

# INTRODUCTION

They said, "You have a blue guitar
You do not play things as they are."
The man replied, "Things as they are
are changed upon the blue guitar."
And they said then, "But play, you must
A tune beyond us, yet ourselves,
A tune upon the blue guitar
Of Things exactly as they are."

Wallace Stevens: "The Man with the Blue Guitar"

This report presents essential data for use in the Building Applications for Solar Energy (BASE) project, to assess the potential interaction between the utilization of solar energy for heating and cooling of buildings in Southern California and operations of the Southern California Edison Company (SCE). The overall goal of the project is to provide a basis for defining appropriate SCE objectives and R&D activities in solar energy.

The project is organized into four separate but interrelated parts, covering subjects as follows: Study 1 — (1) preliminary weather study, (2) region definition, and (3) weather information organization; Study 2 — (1) building size definition, (2) building population projection, (3) selection of representative buildings, and (4) specification of HVAC energy requirements; Study 3 — case studies on selected buildings; and Study 4 — (1) market penetration scenarios, (2) peak load analysis, and (3) average load analysis.

The information organized and presented in this report is essential data for Studies 3 and 4 of the project. Study 3 of the project will use the representative buildings defined herein to perform thermal analysis and solar energy application studies. Study 4 will use the number of buildings, with their assumed HVAC configurations, to estimate the market penetration of solar thermal systems for buildings. Figure 1 indicates the parts of Study 2 which are inputs to Studies 3 and 4.

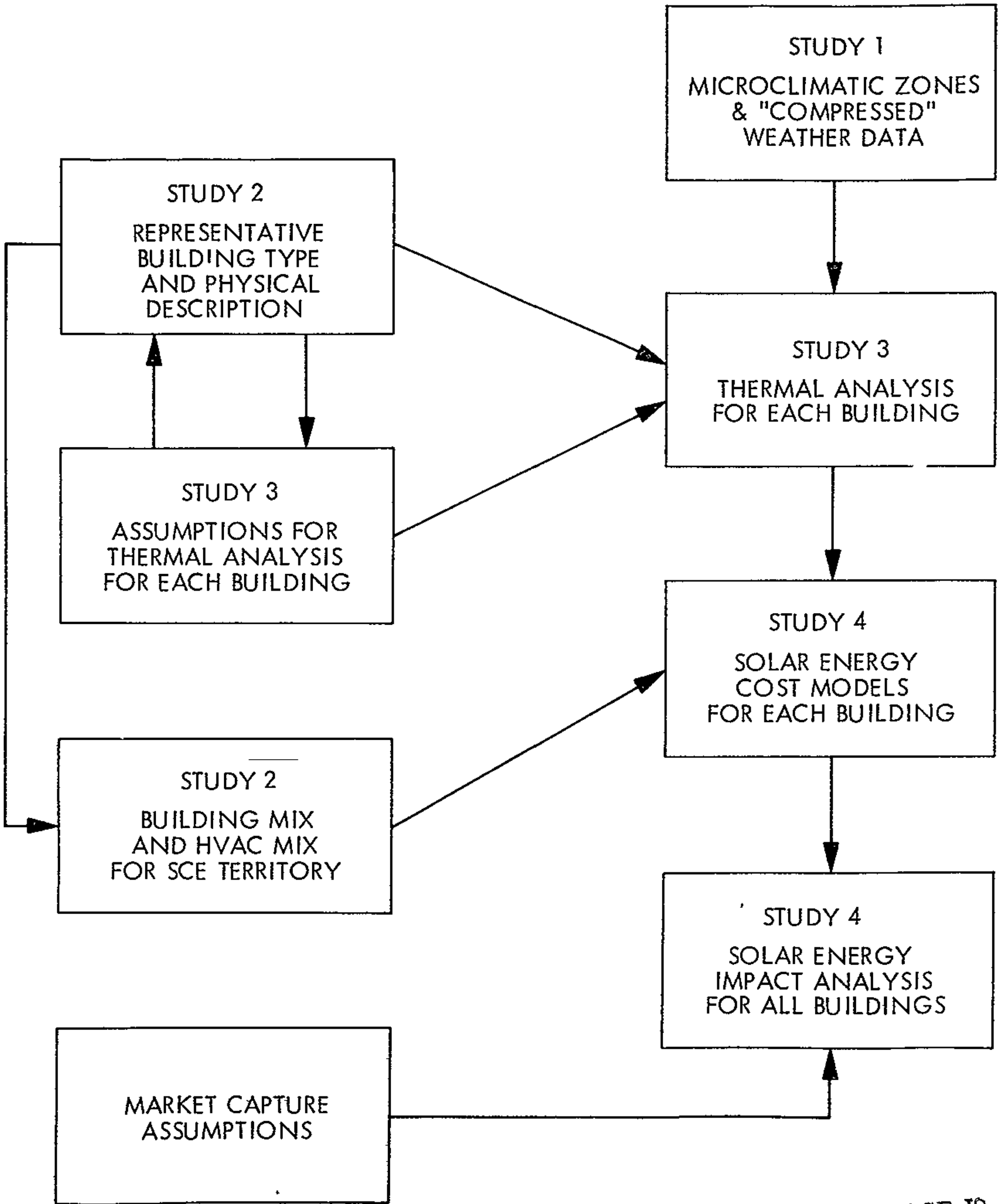




Fig. 1. Work flow diagram showing the parts of Study 2 which will be used in Studies 3 and 4

The purpose of the present task, Study 2, was to provide descriptions of 10 buildings which typify the nonindustrial building market, both in 1975 and in 1990, for the SCE service territory. In addition, the fraction of each building type (called the building mix) and fractional distribution of gas and/or electric heating, cooling, and ventilating systems for each building type (called the HVAC mix) is also determined. In Study 3 each representative building will be fitted, on paper, with a solar heating and cooling system and the system performance will be optimized using a computer thermal simulation model (CINDA) of each of three microclimatic regions in the SCE territory. In Study 2, because a major project objective is to estimate the potential impact of solar energy utilization on SCE through 2000, buildings were selected which it is believed will have maximum impact upon SCE load characteristics if solar HVAC systems are applied to them. The impact will be estimated in Study 4 of the project by first estimating the market penetration rates for each building type with its solar HVAC systems. The impact will be determined using a combination of a cost model for each solar energy system (SES) considered and the results of the computer thermal simulation model which will determine the heating and cooling performance of each SES as a function of solar collector size.

The matrix in Fig. 2 illustrates the initial approach to BASE. Seven microclimatic zones (the rows of the matrix) were defined in Study 1.* Ten representative buildings (the columns of the matrix) are defined in this study. The matrix (Fig. 2) includes a third dimension which represents the 16 different solar collector configurations whose thermal performance will be analyzed in the thermal simulation. In addition, the buildings will each be fitted with an energy-conserving package (such as increased insulation and/or more window shading) and re-run through the computer simulation. This will allow cost comparisons to be made between solar energy systems and energy-conserving measures. The relative economics of this particular comparison will influence if, when, and at what rate solar HVAC systems for each building will penetrate the market.

*These seven zones were later reduced to five and finally to four zones, cf. Section V.

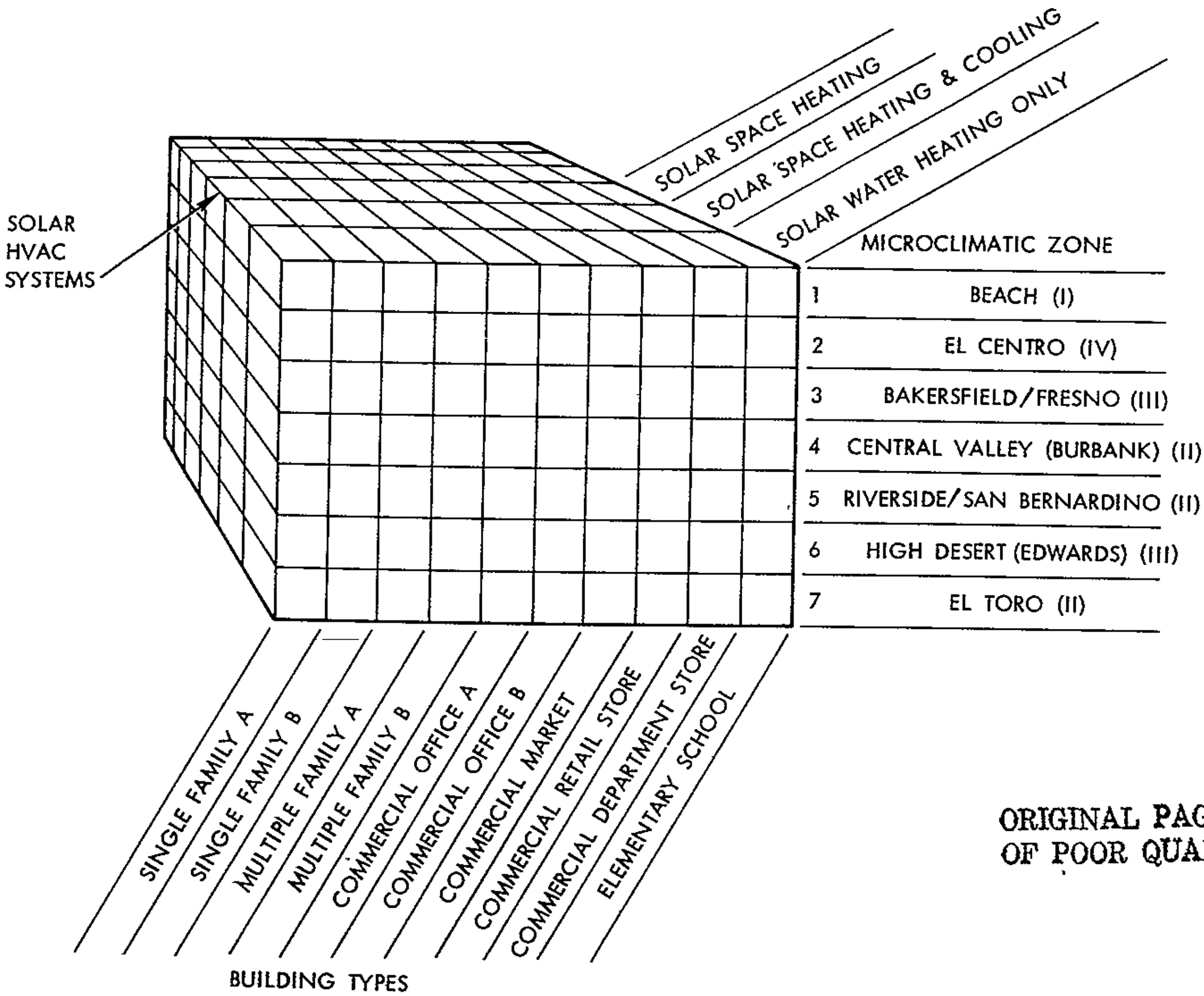


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Fig. 2. Microclimatic zone/building type/HVAC system matrix

Following discussions with SCE, the matrix shown in Fig. 2 will be reduced to four buildings and three microclimatic zones by collapsing the seven zones defined in Task 1 and using only the four highest priority buildings (as determined by SCE). The result of the thermal analysis will be (1) 24 cases (4 x 3 x 2) with thermal analysis and (2) simulated HVAC solar system performance for each of the four representative buildings in each of the three microclimatic zones for both energy-conserving and non-energy-conserving packages. Section I states the objectives of the study. Section II summarizes the major results. Section III describes the building selection procedure, the fraction of each building type by submarket, and the priority ranking for each of the buildings; also given are the criteria for the selection of each of the buildings. A detailed description of each of the 10 buildings is provided in Section III-C. Because existing buildings with known utility bills were chosen as the representative building wherever possible, the building summaries also contain data concerning the actual utility bills for each. Section IV describes the energy-conserving package for each building and the building mix and HVAC mix in each of the three microclimatic zones chosen for analysis.

The study team for this phase of the project consisted of E. S. (Ab) Davis (Task Manager), R. French, A. S. Hirshberg, and L. C. Wen. A. Hirshberg provided the rationale for building selection and the descriptions of the typical buildings for solar system design. He also provided the assumptions for the building mix and HVAC system mix. The thermal characteristics of each building were defined in conjunction with L. C. Wen. R. French provided assumptions about the energy-conserving packages for each building.

# SECTION II

# SUMMARY OF RESULTS

The major results of this study fall into six categories: (1) the assignment of population to microclimatic zones, (2) specifications of the mix of buildings in the SCE territory, (3) specification of four typical buildings for thermal analysis and market penetration studies, (4) identification of the materials and energy-conserving characteristics of these typical buildings, (5) specifications of the HVAC functions used in each typical building, and determination of the HVAC systems used in each building, and (6) identification of the type of fuel used in each building

## Population of Microclimatic Zones

The five microclimatic weather zones originally defined in Study 1 were consolidated into four zones The first of these is the Beach zone which, as of 1973, included 856, 000 SCE customers (or 33% of all SCE customers) and accounted for 31% of SCE KWH sales. The Inland zone, covering the inland valleys to San Bernardino and Riverside, included 1. 5 million customers (57%), and produced 57% of SCE KWH sales in 1973 The High Desert zone, as of 1970, contained 175, 000 customers (7%), and was responsible for 6% of the KWH sales. The fourth zone is a miscellaneous zone, called Unassigned, composed of widely scattered sets of customers in the El Centro area or in the mountains. In 1973 it included 95, 000 customers (3%) and accounted for approximately 6% of all KWH sales Because of the differences between these customers, the potential for solar energy in this zone was not analyzed. Since this excludes only 3% of SCE customers, the decision to exclude Zone 4 from the market penetration analysis will not greatly impact the overall results of Study 4 Table 1 is a summary description of each of these four weather zones Maps of these weather zones are given in Section V-B





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Table 1. SCE customers and sales in each BASE weather zone

| Final Weather Zone | Weather Stations | SCE Districts in Zone | Number of Customers | Fraction of Customers | Fraction of KWH Sales |
|---|---|---|---|---|---|
| I. Beach | LAX<br>Pt. Mugu<br>Long Beach<br>Santa Barbara<br>San Diego | 29, 33, 35, 37,<br>41, 42, 43, 44,<br>46, 47, 49 | 855,944 | 0.33 | 0.31 |
| II. Inland Valleys | Burbank<br>Riverside,<br>San Bernardino<br><br>El Toro | 59<br>26, 27, 28, 30,<br>31, 34, 76, 77,<br>78, 79<br>29, 43 | 1,495,020 | 0.57 | 0.57 |
| III. High Desert + San Joaquin Valley | Bakersfield,<br>Fresno<br>Edwards | 50, 51, 52, 53,<br>54<br>36, 72 | 174,162 | 0.07 | 0.06 |
| IV. Unassigned* | El Centro | 79 | 94,893 | 0.03 | 0.06 |

*Including many mountain areas.

Specification of the Building Mix

The relative size of the four major building submarkets (residential, commercial, industrial, and institutional) in California was determined for 1970 and projections were made for 1990 The relative size was defined in terms of both the number of buildings and the floor area. This provided a means of identifying both the magnitude of each submarket and its relative growth rates and was the first step in defining typical buildings for the thermal analysis (see Table 2)

As of 1970, there were 100, 000 industrial buildings, comprising 2% of all in-place buildings and 37% of all in-place floor area;* there were about 5 million residential buildings in place. This was 92% of all in-place nonindustrial buildings and 71% of the total nonindustrial floor area In 1990 residential buildings will grow to 6 5 million and will comprise 90% of all buildings projected to be in place by that time and 70% of the in-place floor area. This amounts to an average annual growth rate of 1. 15% for residential buildings. The commercial submarket, which includes office buildings, retail stores, department stores, etc., had 240, 000 buildings in place in 1970. This comprised 4. 4% of all nonindustrial buildings and 16% of nonindustrial floor space. California commercial buildings are projected to grow at 1. 84% per year to 340, 000 buildings in 1990** and 19% of all nonindustrial floor space. In 1970 the institutional submarket, which includes schools, hospitals, public buildings, etc , had 79, 000 buildings or 1. 5% of all nonindustrial buildings. Institutional buildings comprised 9% of all in-place nonindustrial floor area in 1970***. The number of institutional buildings is projected to grow at an average rate of 1 34% per year reaching 100, 000 buildings by 1990, and 8% of all in-place floor area.

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*This information provided for the reader's general interest — the industrial submarket was excluded from the BASE study, and all other percentage findings are given excluding the industrial submarket

**In 1990 commercial buildings will comprise 5% of all in-place nonindustrial buildings up from 4. 4% in 1970.

***The reader should note that neither the percentages for floor area nor for buildings add up to 100% because of the exclusion of agricultural and miscellaneous submarkets.

Table 2. California building mix[a] (data aggregated for major California Business Economic Areas; Source: U.S. Department of Commerce and F.W. Dodge Forecasts)

| Submarket | 1970 | | | 1990 | | | Average[c] Area ($ft^2$)[d] | Average Annual Growth Rate |
|---|---|---|---|---|---|---|---|---|
| | No. Buildings | % | % Area | No. Buildings | % | % Area | | |
| Residential | 4,978,600 | 92 | 71 | 6,251,933 | 90 | 70 | | 1.15% |
| Single Family | 4,584,600 | 85 | 46.2 | 5,466,400 | 79 | 38.4 | 1,630 | |
| Multiple Family (Low Rise) | 196,500[c] | 4 | 23.8 | 354,600[c] | 5.1 | 29.9 | 14,650[e] | |
| Multiple Family (High Rise) | 100[b] | 0.0 | 0.1 | 135[b] | 0.0 | 0.2 | 165,000 | |
| Mobile Home | 197,400 | 4 | 0.9 | 430,800 | 6.3 | 1.4 | 845 | |
| Commercial | 236,781 | 4.4 | 16 | 341,230 | 5.0 | 19 | | 1.84% |
| Office (Low Rise) | 36,907 | 0.7 | 4.1 | 70,971 | 1.0 | 5.5 | 40,000 | |
| Office (High Rise) | 990 | 0.02 | 3.3 | 1,991 | 0.03 | 4.7 | 160,000 | |
| Retail Store | 191,052 | 3.5 | 5.6 | 253,731 | 3.7 | 5.1 | 5,200 | |
| Department Store | 3,131 | 0.01 | 2.1 | 4,185 | 0.06 | 2.0 | 120,000 | |
| Motel | 4,559 | 0.1 | 1.0 | 10,041 | 0.1 | 1.6 | 40,000 | |
| Industrial (Excl.) | 101,703 | 1.9 | 37.0 | | | | | |
| Institutional | 79,338 | 1.5 | 9 | 103,593 | 1.5 | 8 | | 1.34% |
| Elementary | 14,087 | 0.3 | 0.8 | 16,264 | 0.2 | 0.9 | 9,600 | |
| Hospital | 1,972 | 0.04 | 0.5 | 2,600 | 0.03 | 0.5 | 47,880 | |
| Misc. | 59,384 | 1.1 | 7.3 | 78,853 | 1.1 | 6.8 | | |

[a] Projections were made from a GNP/Population Growth Model with 1970 (GNP = 977 billion, population = 204 million), and 1990 (GNP = 1.8 trillion, population = 247 million) for the USA.

[b] The estimates for high-rise apartment buildings for California appear to be low by a factor of 5 or so.

[c] The average low-rise apartment has about 18 units, which means that residential dwelling units are split roughly 50/50 between single family and multiple family (cf. TRW Table 7.3-2).

[d] From NAHB Research Foundation survey of low-rise apartments.

[e] Cf. TRW estimates 6400, Table 3.5-7, Westinghouse estimates 7,680 $ft^2$ average, p. 2-21; General Electric estimates 7,992 $ft^2$ average for 9 units, see Appendix C.

Analysis of these findings indicates the relative importance of each submarket. Although residential buildings form the largest set of buildings in terms of numbers and floor space, the commercial sector is projected to grow much faster than the residential between now and 1990 The overall growth rate for residential buildings in the SCE territory was found to be 2.3% per year or twice that for California on the average. The growth rate for commercial buildings was determined to be 5.5% per year or three times the California average In the SCE territory the institutional submarket is projected to grow at the same rate as the commercial submarket.

The mix of building types within each submarket was also examined In the residential submarket as of 1970, low-rise multifamily buildings comprised 4% of the total number of nonindustrial in-place buildings; this increases to 5 1% by 1990. The single family residential market includes (as expected) the largest number of in-place buildings, comprising 85% in 1970 and decreasing to 79% by 1990. However, when floor area is computed, the single-family residences fall to less than half of the total in-place floor area (46% in 1970 and 38% in 1990), whereas the floor area in multiple family buildings increases from roughly 24% in 1970 to 30% in 1990. Mobile homes comprised less than 1% of the in-place floor area in 1970 and are projected to grow to 1.5% of floor area by 1990. The commercial submarket is more diverse than the residential. Four building types comprise most of the commercial floor space. They are low-rise office buildings (3 stories or less), high-rise office buildings, small retail stores (in the 5,000 sq ft size area) and department stores The institutional submarket is more diverse than the commercial submarket No single institutional building type comprises more than 1% of the in-place floor area.

Specification of Typical Buildings

Using this analysis of the primary nonindustrial building submarkets, 12 "typical" buildings were defined * Six typical buildings were defined for the

*Twelve buildings were thought to be the maximum number of buildings for which detailed thermal analysis could be performed in Study 3 This was later reduced to four buildings This was an extremely difficult task because of the variation of building configuration, materials, and other characteristics. The buildings finally selected are best referred to as representative rather than typical.

residential submarket (3 single family buildings and 3 multifamily buildings). Five buildings were defined for the commercial submarket and one for the institution submarket

The median single family building was determined to be 1630 sq ft in area, of stucco and wood frame construction, and one story high. Since 85% of all single family buildings fell between 1200 sq ft and 2400 sq ft, three single family buildings were chosen to represent all single family types. These buildings (called single family A, single family B, and single family C) were chosen to reflect the difference in life styles and socioeconomic characteristics of the residences since we found that energy use is extremely sensitive to these characteristics.

The median multiple family apartment was determined to be two stories, of wood frame construction and with units of 910 sq ft size There are 18 units in the median low rise apartment building. In order to adequately represent the low-rise multiple family type of building, two different buildings were selected: one of 9 units with 910 sq ft per unit and one of 14 units of 850 sq ft per unit.* In addition, one high-rise multiple family building consisting of 150 units (16 stories) was chosen.

The commercial submarket was represented by five buildings Two office buildings, one low-rise and one mid-rise, were chosen to reflect the range of variation of typical office buildings. Office building A was chosen to be a 6 story, 50,000 sq ft building with curtain wall construction located in Long Beach Office building B was chosen to be a 3 story, 11,000 sq ft concrete and masonry bank building located near Pasadena. The department store was chosen to be a 3 story, 120,000 sq ft concrete building located in San Bernardino. The retail store was chosen to be a 5200 sq ft, one story building in Burbank. Finally, a market was chosen to be 27,000 sq ft of brick and concrete design and located in Cudahy.

*Wherever possible, buildings chosen were real buildings for which actual electric and gas utility bills were available This offers the potential of calibrating the results of the thermal analysis in Study 3 with actual data.

The institutional market was represented by a one-story elementary school of 20, 000 sq ft, constructed of concrete

These 12 representative buildings were ranked in order of priority for thermal analysis from 1 to 12 The resulting rank order and a brief description of each building are given in Table 3. A detailed description of each building is given in the Building Description Summaries (Section III-C). It should be noted that, with exception of the retail store, each representative building is an existing building for which electric and gas utility bills are available.

Detailed thermal analysis was performed for the four buildings with the highest priority. Table 4 summarizes the description of each of these four buildings: (1) a single family building of 2250 sq ft, (2) a multiple family building of 9 units with 910 sq ft per unit, (3) a 50, 000 sq ft, 6 story office building, and (4) a 120, 000 sq ft, 3 story department store. These four buildings represent about 90% of the number of buildings and 75% of the nonindustrial floor area.

Because the time frame of the study included the year 2000, estimates of the growth rate of each of these building categories is important. Using data on new construction between 1971 and 1974, the rate of growth of each of these four typical building categories was estimated. Table 5 summarizes the data for these buildings. Significantly, multiple family units constitute about 2/3 of all new residential construction. The trend toward multiple family building construction is indicated in the higher growth rate of 3. 9% per year compared to 1. 4% for single family units. The growth rates for office buildings and department stores is estimated to be 5 5% per year. Although this is a very large growth rate, the in-place low-rise office buildings and department stores numbered only 16, 442 and 1, 359, respectively, as of 1975 Because of the differences between building activity and land values in the microclimatic regions, the building activity per unit population for multiple family buildings was estimated to be 2. 5 times higher in the Beach and Inland zones than in the High Desert zone. The building mix was adjusted to reflect these differences (cf Tables 13 and 14). Similar differences in building rate were used to estimate different building activity for commercial buildings in each of the zones (cf Tables 15 and 16).

Table 3. Building configuration and internal loads

| Building Priority/Type | Size | Physical Description: Materials: Ext Walls | % Glass | HVAC System: Space Heating | Space Cooling | Water Heating | Hot Water (gal/day) | Internal Loads: Infiltration (cfm) | Lights (Watts/ft$^2$) | Appliances (KW/wk) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 Single family C | 2, 250 ft$^2$, 1 story | Stucco | 20 | Gas | Electric | Gas | 120 | 215 | 1 0 | 20.9 |
| 2 Multiple family (low rise) | Nine 910 ft$^2$ (ave ) units, 2 stories | Wood frame | 67 | Electric (45) | Electric | Gas | 1, 100 | 120 | 0 75 | 170 |
| 3 Office A (mid-rise) | 50, 000 ft$^2$, 6 stories and penthouse | Curtain wall | 45 | Four pipe Electric (45%) | Electric | Gas | 600 | 2, 500 | 3 5 | 430 |
| 4 Department Store | 120, 000 ft$^2$, 3 stories | Concrete | 30 | Electric | Electric | Gas | 115 | 14, 000 | 6 0 | 1020 |
| 5. Retail Store | 5, 200 ft$^2$, 1 story | Concrete | 30 | Roof top gas | Electric | Gas | 20 | 1, 050 | 4 0 | 92 |
| 6 Single family B | 1, 630 ft$^2$, 1 story | Stucco | 25 | Electric | Electric | Gas | 120 | 215 | 1 0 | 16 9 |
| 7 Office B (low-rise) | 11, 000 ft$^2$, 3 stories | Concrete and Masonry | 20 | Electric | Electric heat pump | Electric | 150 | 8, 000 | 4 0 | 125 |
| 8 Elementary school (Smith Elem School) | 19, 600 ft$^2$, 1 story | Concrete | 25 | Electric | Electric | Electric | 558 | 6, 2000 (T 0. 5 cfm/ft$^2$) | 3 0 | 70 |
| 9 Market | 26, 850 ft$^2$, 1 story | Brick and Concrete | | Electric | Electric | Electric | | 1, 340 | 4 0 | |
| 10 Multiple family (high-rise) | 158 1200-ft$^2$ units, 16 stories | Steel and concrete | 67 | Electric hydronic heat pump | Electric hydronic heat pump | Gas | 7, 500 | (T 0. 1 cfm/ft$^2$) | 0 75 | 1575 |
| 11 Single family A | 1, 250 ft$^2$, 1 story | Stucco | 20 | Gas | None | Gas | 80 | 215 (T 0. 1 cfm/ft$^2$) | 1 0 | 10 9 |
| 12. Multiple family B | 14 850-ft$^2$ units, 2 stories | Stucco | 25 | Electric | Electric | Electric | 1, 700 | 120 | 0 75 | 170 |

## Table 4. Summary of representative buildings

| Priority and ID No. | Building | Physical Description: Size | Materials: Exterior Walls | Materials: Glass (%) | HVAC System: Space Heating and Water Heating | HVAC System: Space Cooling | Sector and Fraction 1970: No. Bldgs (%) | 1970: Floor Area (%) | 1990: No. Bldgs (%) | 1990: Floor Area (%) | Location |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Single family C | 2250 $ft^2$, 1 story | Wood and stucco | 20 | Forced air, gas | Compression, electric (5 ton) | 85 | 46.2 | 79 | 38.4 | Tarzana |
| 2 | Multiple family A | Nine 910 $ft^2$ units, 2 stories | Stucco | 25 | Fan coil electric | Fan coil, electric | 4 | 23.8 | 5.1 | 29.9 | Inglewood |
| 3 | Office A | 50,000 $ft^2$, 6 stories & penthouse | Curtained wall | 45 solar grey | Single duct | Single duct, electric (25 tons) | 0.02 | 3 3 | 0.03 | 4.7 | Long Beach |
| 4 | Department store | 120,000 $ft^2$, 3 stories | Exposed concrete | 15 | Single duct with terminal reheat | Single duct forced air | 0.01 | 2.1 | 0.06 | 2.6 | San Bernardino |

Table 5. Annual building growth rates (1971-74) for SCE territory (Source: Security Pacific Bank "Monthly Report of Building Permit Activity")

| | New Buildings | Annual Growth Rate (%) | Existing Buildings, 1975 |
|---|---|---|---|
| Total Residential Buildings | 58, 406 | 2.3 | 2, 526, 000 |
| Single Family | 23, 362 | 1.4 | 1, 635, 930 |
| Multiple Family | 35, 043 | 3.9 | 890, 095 |
| Total Commercial Buildings | 5, 652 | 5 5 | 102, 765 |
| Office | 904 | 5.5 | 16, 442 |
| Department Store | 75 | 5.5 | 1, 359 |
| Total Institutional Buildings | 1, 055 | 3.4 | 31, 021 |
| Schools | 165 | 3 0 | 5, 513 |

Notes:
1. Four-year, five-county average, residential = 89, 634.
2 SCE population/five-county average = 0 6515.
3 The average annual value of new construction was $616 million for single family buildings and $555 million for multiple family buildings.

Energy-Conserving Characteristics of Buildings

The final set of characteristics which are important for determining the building mix consists of the energy-conserving aspects of each building Because the single family building is the most weather-dependent building, the nature of the energy-related variables such as insulation, the amount of fenestration, infiltrations, thermostat settings, and internal loads such as lighting and appliances makes a large difference in the energy requirements of each of the typical buildings. In order to account for the variation of these variables in our analysis of solar energy systems, two types of buildings were defined for each of the four typical buildings. The first type contained a nonconserving package of materials and was defined as representative of most existing buildings. The second type contained an energy-conserving package which was judged to be feasible. For the single family buildings, the basic difference between the energy-conserving and nonconserving packages was the inclusion of 4 inches of insulation in the walls of the residential buildings and a reduction in the infiltration by 25%.* The possibilities for energy conservation in the office and department store are more limited. The effect of the energy-conserving package for the single family building in each microclimatic zone is shown in Table 6. Note that the use of an energy-conserving package can reduce the thermal requirements of the single family building by 50 to 70%.

Table 6. Annual heating load for the single family building

| Zone | Annual Heating Load (KWH) | | % Reduction |
|---|---|---|---|
| | Without Energy-Conserving Package | With Energy-Conserving Package | |
| I Beach | 18, 600 | 5, 422 | 71% |
| II Inland Valley | 18, 700 | 5, 747 | 69% |
| III. High Desert | 31, 040 | 14, 700 | 53% |

## HVAC System Mix

Once the physical characteristics of the typical buildings were determined, the fraction of various types of HVAC systems in each typical building was estimated. There are three major components to the HVAC characterization (called the HVAC mix) First, the fraction of buildings with water heating and space heating only (called the HVAC functions mix) was obtained. Second, the types of possible HVAC systems (called HVAC combinations) were determined.

*It should be noted that the thermostat settings for heating and cooling have a large effect on the thermal requirements of a building We assumed a 70° F setting for heating in the winter and a 75° F setting for cooling in the summer.

Third, the fraction of systems which use electricity or gas (called HVAC fuel mix) was determined. In order to provide a basis of analysis through the year 2000, these three HVAC mix characteristics were determined both for existing 1975 buildings and for the projected percentage of new buildings.

In order to provide a logical framework for analyzing the complex HVAC mix, a method was developed to enumerate all of the possible fuel and function combinations. This method makes use of the fact that functions can be provided by various fuels as shown below:

| Function | Fuel | Abbreviation |
|---|---|---|
| Water heating | Electricity | E |
| | Gas | G |
| Space heating | Electricity | E |
| | Gas | |
| | Heat pump | HP (only if also used for cooling) |
| Space cooling | Electricity | E |
| | Gas | G |
| | Heat pump | HP (only if also used for cooling) |

The possible combinations are shown in Table 7 in the following order: water heating, space heating, space cooling. For example, E-G-G indicates electric water heating plus gas space heating plus gas space cooling Note that Table 7 is limited to single family dwellings since in multiple family or commercial buildings, functions can be provided centrally, individually, or in a distributed fashion.

The HVAC mix is complex. For example, multiple family buildings have 144 possible HVAC mixes. The single family market is less complex but still has 48 possibilities. The prime space cooling combinations are forced air using

Table 7. Possible HVAC combinations

| Functions | Combinations |
|---|---|
| Water heating, space heating | E-E |
| | E-G |
| | G-E |
| | G-G |
| Water heating, space heating, space cooling | E-E-E |
| | E-E-G |
| | E-G-E |
| | E-G-G |
| | E-HP-HP |
| | G-E-E |
| | G-G-E |
| | G-G-G |
| | G-HP-HP |

a compressor, window, fan coil, and heat pumps. For space heating, there are five prime possible combinations: (1) forced air, (2) hydronic baseboard or floor, (3) electric resistance, (4) fan coil, and (5) heat pump. Table 8 presents a summary of the HVAC combinations and fuel mix for single and multiple family buildings. As shown in this table about 21% of multiple family buildings have either heat pumps, fan coil, or central baseboard systems which could be retrofitted with solar energy systems with relative ease.

## HVAC Fuel Mix

Table 9 shows the HVAC fuel mix for residential buildings both for each zone and for the entire SCE territory. As of 1973 about 17% of all single family units and 15% of all multiple units had central space cooling while 25 and 27%, respectively, had window units. The remaining 58% of single family units and 58% of multiple family units had either no cooling or utilized evaporative coolers

Table 8. HVAC system mixes for single and multiple family units

| HVAC Combination | Fuel | For Apts 1970: National(1) | For Apts 1970: West(3) | All SCE(2) | Western U.S.(3) | SCE Single Family(2) Growth Rate: 1970 | SCE Single Family(2) Growth Rate: 1973 | SCE Single Family(2) Growth Rate: New | SCE Multiple Family(2) Growth Rate: 1970 | SCE Multiple Family(2) Growth Rate: 1973 | SCE Multiple Family(2) Growth Rate: New |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **SPACE COOLING** | | | | | | | | | | | |
| Inc. all forced air | | 58 | 18 | | | | | | | | |
| Window | | 30 | 64 | | | | | | | | |
| Central chiller with air handler | | 8 | 0 | | | | | | | | |
| Heat pumps | | 2 | 5 | | | | | | | | |
| Central with fan coil | | 2 | 5 | | | | | | | | |
| Other | | 4 | 9 | | | | | | | | |
| | Gas | 8 | 5 | | | | | | | | |
| | Electric | 92 | 95 | | | | | | | | |
| Room (window) | | | | 19.6 | 25.4 | 18.3 | 25.0 | 170%* | 24.0 | 27.4 | 51% |
| Central | | | | 9.7 | 16.9 | 10.4 | 17.2 | 164%* | 7.3 | 14.6 | 60% |
| **SPACE HEATING** | | | | | | | | | | | |
| Individual forced air | | 58 | 33 | | | | | | | | |
| Central baseboard | | 20 | 13 | | | | | | | | |
| Electric resistance | | 11 | 45 | | | | | | | | |
| Central fan coil | | 3 | 3 | | | | | | | | |
| Heat pump | | 3 | 5 | | | | | | | | |
| Other | | 8 | 16 | | | | | | | | |
| | Gas | 68 | 48 | 85.8 | 86.5 | 89.4 | 90.6 | 117%* | 74.7 | 72.8 | 60% |
| | Electric | 33 | 61 | 9.3 | 9.5 | 5.4 | 5.3 | 3% | 22.3 | 24.3 | 38% |
| **WATER HEATING** | | | | | | | | | | | |
| Central | | 24 | 23 | | | | | | | | |
| Individual | | 45 | 48 | | | | | | | | |
| Distributed | | 34 | 29 | | | | | | | | |
| | Gas | 59 | 58 | 82.4 | 83.8 | 87.7 | 90.0 | 140%* | 65.6 | 62.6 | 42% |
| | Electric | 35 | 42 | 9.4 | 10.5 | 6.5 | | 25% | 18.8 | 21.5 | 40% |

*Percentages greater than 100% indicate retrofit.

(1) National Association of Home Builders Research Foundation, "Low Rise Apartment Survey," 1972.
(2) SCE Residential Electrical Applicance Survey 1973
(3) Intertechnology Report on Energy Use in Buildings

Table 9. Market saturation of HVAC systems in SCE territory in 1973
(Source: SCE Market Saturation Survey)

| HVAC System | Beach | | | | Inland Valley | | | | High Desert | | | | All SCE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Single Family Buildings | | Multiple Family Buildings | | Single Family Buildings | | Multiple Family Buildings | | Single Family Buildings | | Multiple Family Buildings | | Single Family Buildings | Multiple Family Buildings |
| | % | Growth Rate | % | Growth Rate | % | Growth Rate | % | Growth Rate | % | Growth Rate | % | Growth Rate | % | % |
| **Space Cooling** | | | | | | | | | | | | | | |
| Central | 10.4 | 1.7 | 10.6 | 2.0 | 18.4 | 2.3 | 19.9 | 3.0 | 31.8 | 3.5 | 42.7 | 5.2 | 17.2 | 14.6 |
| Room | 15.9 | 0.5 | 24.0 | 1.0 | 28.8 | 2.4 | 39.5 | 1.9 | 25.0 | 4.0 | 29,5 | 3 4 | 25.0 | 27.4 |
| Evaporative | 6.8 | 0.6 | 2.9 | 0.0 | 14.5 | 0.8 | 9.2 | -0.4 | 51.8 | 1.0 | 58.6 | 1 0 | 15.0 | 6 4 |
| **Space Heating** | | | | | | | | | | | | | | |
| Electric | 3 7 | -0.1 | 26.0 | 0.9 | 5.0 | 0.2 | 24.1 | 0.8 | 10.8 | -0 6 | 14.3 | -3 0 | 5.3 | 24,3 |
| Gas | 93.7 | 0.3 | 70.1 | -0.1 | 90.7 | -0.3 | 73.4 | -0.7 | 75 2 | 0.6 | 82 0 | 4 4 | 90.6 | 72.8 |
| **Water Heating** | | | | | | | | | | | | | | |
| Electric | 5.1 | 0 2 | 20.5 | 0.6 | 7,1 | 0,4 | 22.0 | 1.0 | 19.5 | -0.1 | 15 1 | -1 4 | 7 4 | 21 5 |
| Gas | 93.4 | 0.8 | 62.0 | -1.2 | 90.4 | 0.7 | 64.7 | -0 4 | 72.8 | 0.6 | 76.8 | 1 2 | 90.0 | 62.6 |

Note Penetration = division rate weighted by fraction of KWH sales which the division supplies to the weather zone.

The number of new units with central space cooling is increasing with nearly all new single family units and 60% of new multiple units having central space cooling

The greatest difference between single and multiple units occurs for space heating and water heating. In 1973 only 5% of all single family buildings used electric space heating while over 24% of multiple family units used electric space heating For water heating 7% of single family units used electric water heating compared to 22% of multiple family units; furthermore, about half of the water heating systems were individual with the remaining 52% either central or distributed.

Comparing zones, the beach zone had the highest percentage of multiple family units using electric space heating (26%) but the lowest percentage of single family units using electric space heating (4%). As expected, the highest use of central space cooling was in the high desert (43% multiple and 32% single) while the lowest was in the beach zone (11% multiple and 10% single)

Because most buildings with electric space heating will tend to be all-electric buildings, the growth rate of electric systems can be estimated from the growth rate of all-electric buildings Although the percentage of new units added with all-electric has declined from the high mark in 1972 of 18% of new single family and 22% of new multiple family units, in 1974 a significant fraction of new dwellings were all-electric (14% single family and 12% multiple family). Furthermore, roughly 2/3 of the new single family all-electrics are cooled while virtually all of the multiple all-electrics are cooled. Table 10 summarizes this data.

Table 10. All-electric units added — residential (Source: SCE Information Sheet)

| | 1971 | | 1972 | | 1973 | | 1974 | | 4-Yr SCE Average |
|---|---|---|---|---|---|---|---|---|---|
| | Number | % of New | Number | % of New | Number | % of New | Number | % of New | Number or % |
| Single Family Total Per Year | | | | | | | | | 23, 567 |
| All-electric units added | 3, 506 | 14. 1 | 5, 158 | 17 9 | 4, 021 | 16 4 | 2, 291 | 14 2 | 15 7% |
| All-electric units with space cooling | 2, 159 | 8. 7 | 3, 592 | 12. 5 | 2, 458 | 10 0 | 1, 419 | 8. 8 | 10. 0% |
| % with space cooling | 61 6 | | 69. 6 | | 61. 1 | | 61. 9 | | 63 0% |
| Ave. KWH/unit $X10^3$ | 20. 6 | | 19. 0 | | 18 4 | | 15. 5 | | 18 4 |
| Multiple Family Total Per Year | | | | | | | | | 34, 838 |
| All-electric units added | 9, 106 | 22. 3 | 7, 892 | 16. 8 | 3, 737 | 10. 4 | 1, 937 | 12. 1 | 15 4% |
| Ave. KWH/unit $X10^3$ | 9. 8 | | 9 3 | | 9 1 | | 8 1 | | 9 1 |

Note: Average per year decline from the 4-year average to the 1974 figure is: -0 38% per year for single family all-electric units added and -0 83% per year for multiple family units

# SECTION III

# BUILDING SELECTION

## A. SELECTION CRITERIA

The building selection procedure (described in Paragraph B below) may appear to have been a clear, sequential process. In actuality the 10 buildings were selected by merging many, often conflicting, data sources and by making trade-offs between competing requirements. Such is the logic "in use" of selecting a small number of buildings to represent a complex building market. By considering the selection procedure, a set of criteria can be isolated which defines what Kaplan might call the "reconstructed logic" of the building selection process.* (This discussion will help elucidate the operational meaning of the final buildings selected and should hence help provide the reader with an improved perspective for judging the final impact estimates in Study 4 which rely, in part, upon the choice of typical buildings.)

Because of the extreme variations between buildings, it is difficult to specify average characteristics of the entire building market by selecting 10 (so-called) typical buildings. Consider, for example, the single family submarket. Buildings in this submarket can range in size and type of construction material. The HVAC systems can incorporate two types of electric heating systems (strip or heat pump) or gas heating. The building orientation and location may be favorable for solar energy utilization or may not, etc.

In essence, what this means is that the term "typical" is ambiguous. It is a multiordinal term having different meanings for different purposes. In the context of this project, "typical" has several different meanings: (1) typical of building submarket, (2) typical of SCE load categories, (3) typical of existing or of projected new buildings, (4) typical of buildings which are congenial to solar energy designs, (5) typical of building configurations and therefore of their

*Kaplan, A., The Nature of Inquiry, Norton, New York, 1967.

thermal properties (e.g., size, shape, materials, orientation), (6) typical of internal load demands, (7) typical of HVAC system configuration, and (8) typical of a microclimatic region.

Obviously, each building selected could not be "typical" in each of these eight senses of the word. To form a reasonable composite definition of "typical" for the selection process, criteria were developed and used sequentially in choosing the buildings, their characteristics and configurations, etc. These criteria were ranked in order of importance and sorted into four distinct steps for the building selection process.

The four-step process involved: first, determining the important non-industrial submarkets for the SCE territory; second, selecting representative buildings using the selection criteria from each submarket; third, defining the critical characteristics of each building which determine the amount of energy which can be displaced by solar systems; and fourth, determining the fractional mix of each building type for each of the microclimatic zones. (The building mix and HVAC mix data are given in Section IV.)

Table 11 lists the building variables used in each step of the selection process. The third column gives the criteria used to define each of the building variables. Each criteria is specified in operational terms, that is, in terms of the process which was used to define the building variable. These operational definitions expose the explicit set of data and procedures used to choose the 10 typical buildings and therefore facilitate useful criticism of both the selection method and the final choice of buildings. Understanding of the operational definitions of the criteria should help the reader understand the meaning of particular set of 10 buildings chosen.

After final specification of the 10 representative buildings, real buildings were identified which matched as closely as possible to each one on the list of representative buildings. These real buildings became the final list of buildings as given in Section III.

Table 11. Building selection criteria

| Step in the Selection Process | Building Variables | Selection Criteria |
|---|---|---|
| Step 1: Identification of important nonindustrial submarkets | Building submarkets | Percentage of buildings in each submarket. Percentage of floor space in each submarket. |
| | Impact on SCE sales | Percentage of KWH sales for each submarket. SCE staff judgment of most important submarket. |
| Step 2: Identification of representative buildings within each submarket | Existing vs. new | Percentage change of each building within a submarket between 1970 and 1990, both in total numbers and floor area. |
| | Solar system compatibility | Building height and room area |
| Step 3: Identification of thermal characteristics for each building | Building configuration | National Association of Home Builders Research Foundation's definition of typical materials for buildings in California. ASHRAE Thermal Performance Standards for materials. NSF Report by TRW on Thermal Properties of California buildings. (The three NSF-sponsored reports on solar energy were used to define candidate buildings for consideration.) |
| | Building use and internal loads | ASHRAE load specifications. Judgement of HVAC system engineer (Feuer Corporation). |
| | HVAC system type | NAHB Research Foundation research of split between electric and gas use in California buildings. SCE data on appliances and other energy use items. |
| Step 4: Assignment to microclimatic regions | Building location | The four final BASE weather zones. |

## B. SELECTION PROCEDURE

Building selection was performed in three main steps. First, the import-and building submarkets were identified. Excluding the industrial submarket (which is not a part of this study), the numbers of buildings in place for each submarket was determined as well as the approximate square footage of floor area. The numbers of each building type and their floor area were determined for 1970 and 1990 using a variety of sources.* Table 12 summarizes this data for each of the major nonindustrial building submarkets for the California area. These numbers were used as initial indicators of the buildings which would have the greatest potential for solar heating and cooling applications. The number of in-place buildings for each year is a direct indicator of the total market for solar energy HVAC systems, and the floor area is an approximate measure of the heating and cooling requirements. The change in each of these numbers for 1970 vs. 1990 is an indicator of the relative growth rate of each submarket. Submarkets (e.g., the multiple family submarket) which substantially increase their relative percentage penetration either in terms of numbers of buildings or floor area are good candidates for solar energy, since it is expected that installation on new buildings will be more economically attractive than the retrofitting of existing buildings. The results of the first step in the building selection procedure show that the single family residential submarket comprises (as expected) the largest number of in-place buildings -- 85% in 1970, decreasing to 79% by 1990. When floor area is computed,** however, the single family submarket falls to less than half of the total in-place floor area (46% in 1970 and 38% in 1990), and floor area in multiple family buildings increases from roughly 24% in 1970 to 30% in 1990. Because the combined floor area and in-place buildings for the residential market represent nearly 75% of total floor area, it was decided to choose at least half of the typical buildings from this submarket.

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*The sources are given at the end of this section.

**Floor area was computed using the average floor area for each building type times the number of buildings in-place. Although there are biases which are introduced using this method of calculating floor area, the biases are probably not large and would tend to bias in the same direction for all submarkets; therefore, the results using this method should be quantitatively accurate.

Table 12. California building mix[a] (data aggregated for major California Business Economic Areas; Source: I. S. Department of Commerce and F. W. Dodge Forecasts)

| Submarket | 1970 | | | 1990 | | | Average[c] Area ($ft^2$)[d] | Average Annual Growth Rate |
|---|---|---|---|---|---|---|---|---|
| | No. Buildings | % | % Area | No. Buildings | % | % Area | | |
| Residential | 4,978,600 | 92 | 71 | 6,251,933 | 90 | 70 | | 1.15% |
| Single Family | 4,584,600 | 85 | 46.2 | 5,466,400 | 79 | 38.4 | 1,630 | |
| Multiple Family (Low Rise) | 196,500[c] | .4 | 23.8 | 354,600[c] | 5.1 | 29.9 | 14,650[e] | |
| Multiple Family (High Rise) | 100[b] | 0.0 | 0.1 | 135[b] | 0.0 | 0.2 | 165,000 | |
| Mobile Home | 197,400 | 4 | 0.9 | 430,800 | 6.3 | 1.4 | 845 | |
| Commercial | 236,781 | 4.4 | 16 | 341,230 | 5.0 | 19 | | 1.84% |
| Office (Low Rise) | 36,907 | 0.7 | 4.1 | 70,971 | 1.0 | 5.5 | 40,000 | |
| Office (High Rise) | 990 | 0.02 | 3.3 | 1,991 | 0.03 | 4.7 | 160,000 | |
| Retail Store | 191,052 | 3.5 | 5.6 | 253,731 | 3.7 | 5.1 | 5,200 | |
| Department Store | 3,131 | 0.01 | 2.1 | 4,185 | 0.06 | 2.0 | 120,000 | |
| Motel | 4,559 | 0.1 | 1.0 | 10,041 | 0.1 | 1.6 | 40,000 | |
| Industrial (Excl.) | 101,703 | 1.9 | 37.0 | | | | | |
| Institutional | 79,338 | 1.5 | 9 | 103,593 | 1.5 | 8 | | 1.34% |
| Elementary | 14,087 | 0.3 | 0.8 | 16,264 | 0.2 | 0.9 | 9,600 | |
| Hospital | 1,972 | 0.04 | 0.5 | 2,600 | 0.03 | 0.5 | 47,880 | |
| Misc. | 59,384 | 1.1 | 7.3 | 78,853 | 1.1 | 6.8 | | |

[a]Projections were made from a GNP/Population Growth Model with 1970 (GNP = 977 billion, population = 204 million), and 1990 (GNP = 1.8 trillion, population = 247 million) for the USA.

[b]The estimates for high-rise apartment buildings for California appear to be low by a factor of 5 or so.

[c]The average low-rise apartment has about 18 units, which means that residential dwelling units are split roughly 50/50 between single family and multiple family (cf. TRW Table 7.3-2).

[d]From NAHB Research Foundation survey of low-rise apartments.

[e]Cf. TRW estimates 6400, Table 3.5-7, Westinghouse estimates 7,680 $ft^2$ average, p. 2-21, General Electric estimates 7,992 $ft^2$ average for 9 units, see Appendix C.



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This selection decision is further supported by the fact that roughly 50% of the nonindustrial 1970 SCE sales (excluding public authority and resale) fell into the residential area (see Table 13), even though over 90% of all SCE customers are residential. Because commercial sales are nearly equal to residential sales (and are projected to exceed residential sales by 1990), 40% of the typical buildings were selected from the commercial submarket. The remaining buildings were chosen from the institutional submarket, since SCE sales to public authorities rank third in total nonindustrial sales and are projected to increase by about 15% per year between 1970 and 1990.

The second step in the building selection process involves choosing appropriate representative ("typical") buildings from each submarket. The selection of typical buildings within each submarket was performed in such a way that the variation of characteristics within each submarket would be represented. The main characteristics used in making this selection included: (1) building use (which represents the building's energy load characteristics) and (2) building configuration variations including variations in size of the building and number of stories, variations in materials used in the building, etc. Variations in orientation were eliminated from consideration because the TRW Phase 0 report found that the main effect of orientation changes was to reduce the available collector area by at most 30%. The final choice was limited to a total of 10 buildings so as to keep the costs of running the thermal analysis computer program within budget. Table 14 summarizes the characteristics of the 10 buildings selected. Table 15 gives a more detailed description of the internal bonds of each building.

## Residential Submarket

Five buildings were chosen from the residential submarket -- three single family and two multiple family buildings. The three single family dwellings span the most prevalent floor area size categories, ranging from 1200 to 2250 $ft^2$. (The average size of a single family house in California is about 1665 $ft^2$ according to the National Association of Homebuilders Research Foundation.) It was specified that each house be one-story and made of stucco. The exterior-wall glass area increases from 20% for the 1200 $ft^2$ house to 35% for the 2400 $ft^2$

Table 13. SCE customers, KWH sales and growth rates
(Source: 1973 SCE System Forecast: 1972-1995)

| Type of Customer | 1970 | | | 1990 | | |
|---|---|---|---|---|---|---|
| | Total (KWH x $10^6$) | % Total | % Non-Ind. | Total (KWH x $10^6$) | % Total | % Non-Ind. |
| Residential | | | | | | |
| Sales | 11, 154 | 24. 8 | 37. 0 | 46, 030 | 27. 0 | 36. 6 |
| Customers | 2, 152, 400 | | 90. 0 | 3, 489, 000 | | |
| Commercial | | | | | | |
| Sales | 10, 118 | 22 5 | 34. 0 | 51, 750 | 31. 0 | 41. 1 |
| Sales Growth Rate | | | | | | |
| Customers | 205, 200 | | 8. 5 | 284, 000 | | |
| Agriculture | | | | | | |
| Sales | 1, 152 | 2. 6 | 4. 0 | 1, 040 | 0. 0 | 0. 8 |
| Customers | 24, 500 | | | 17, 600 | | |
| Public Authority | | | | | | |
| Sales | 3, 905 | 8. 7 | 13. 0 | 15, 270 | 9. 0 | 12. 1 |
| Customers | 27, 400 | | | 17, 730 | | |
| Resale | | | | | | |
| Sales | 3, 629 | 8. 1 | 13. 0 | 11, 830 | 7. 0 | 9. 3 |
| Industrial | | | | | | |
| Sales | 14, 962 | 33. 3 | ---- | 40, 560 | 24. 0 | |
| Customers | 29, 100 | | | 30, 000 | | |
| Net Sales | 44, 920 x $10^6$ KWH | | | 166, 480 x $10^6$ KWH | | |
| Annual Growth Rate | 8. 3% | | | 5. 7% | | |
| Net Customers | 2, 438, 400 | | | 3, 888, 000 | | |
| SCE Area Population | 6, 844, 000 | | | 9, 730, 000 | | |

Table 14. Priority rank of each selected building

| Priority | Building | Brief Description |
|---|---|---|
| 1 | Single family C | 2250 $ft^2$ |
| 2 | Multiple family B | Low rise (4 units, 2 stories) |
| 3 | Office A | Mid-rise (6 stories) |
| 4 | Department store | 40, 000 $ft^2$/story (3 stories) |
| 5 | Retail store | 5200 $ft^2$ |
| 6 | Single family B | 1630 $ft^2$ |
| 7 | Office B | Low rise (2 stories) |
| 8 | Elementary school | 19, 600 $ft^2$ |
| 9 | Market | ---- |
| 10 | Multiple family C | Mid-rise (15 units, 16 stories) |
| 11 | Single family A | 1200 $ft^2$ |
| 12 | Multiple family A | Low rise |

house. One of the three heating systems was assumed to be electric (reflecting the 30% electric-heating market penetration) and the 1630 and 2250 $ft^2$ houses were chosen to have electric space cooling whereas the 1200 $ft^2$ home was not. Each of these is an existing building. The 1200 $ft^2$ and 1630 $ft^2$ buildings were chosen from SCE summary material supplied by L. Dame. The 2250 $ft^2$ building belongs to R. Schlesinger and has been carefully calibrated by him under an NSF grant.

Two multiple family buildings were chosen. One of these is a low-rise (two-story) wood-frame structure containing nine units that average 910 $ft^2$ in floor area. The building has exterior walls of about 2/3 glass and utilizes electric space heating and cooling. It is all-electric, and is located in Inglewood. The other multifamily building is a 16-story, mid-rise unit in the beach area. Although it is taller than most mid-rises, it does seem to reflect a large and attractive potential market for solar heating and cooling. This building, located in Santa Monica, is representative of mid-rise construction along the California coastline: It has 150 units of about 1100 $ft^2$ per unit average, is made of steel

## Table 15. Building configuration and internal loads

| Building Priority/Type | Size | Physical Description | | | | | | Internal Loads | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Materials | | HVAC System | | | | | | |
| | | Ext Walls | % Glass | Space Heating | Space Cooling | Water Heating | Hot Water (gal/day) | Infiltration (cfm) | Lights (Watts/ft$^2$) | Appliances (KW/wk) |
| 1 Single family C | 2, 250 ft$^2$, 1 story | Stucco | 20 | Gas | Electric | Gas | 120 | 215 | 1 0 | 20 9 |
| 2 Multiple family (low rise) | Nine 910 ft$^2$ (ave ) units, 2 stories | Wood frame | 67 | Electric (45) | Electric | Gas | 1, 100 | 120 | 0 75 | 170 |
| 3 Office A (mid-rise) | 50, 000 ft$^2$, 6 stories and penthouse | Curtain wall | 45 | Four pipe Electric (45%) | Electric | Gas | 600 | 2, 500 | 3 5 | 430 |
| 4 Department Store | 120, 000 ft$^2$, 3 stories | Concrete | 30 | Electric | Electric | Gas | 115 | 14, 000 | 6 0 | 1020 |
| 5 Retail Store | 5, 200 ft$^2$, 1 story | Concrete | 30 | Roof top gas | Electric | Gas | 20 | 1, 050 | 4 0 | 92 |
| 6 Single family B | 1, 630 ft$^2$, 1 story | Stucco | 25 | Electric | Electric | Gas | 120 | 215 | 1 0 | 16 9 |
| 7 Office B (low-rise) | 11, 000 ft$^2$, 3 stories | Concrete and Masonry | 20 | Electric | Electric heat pump | Electric | 150 | 8, 000 | 4 0 | 125 |
| 8 Elementary school (Smith Elem School) | 19, 600 ft$^2$, 1 story | Concrete | 25 | Electric | Electric | Electric | 558 | 6, 2000 (T 0. 5 cfm/ft$^2$) | 3 0 | 70 |
| 9 Market | 26, 850 ft$^2$, 1 story | Brick and Concrete | | Electric | Electric | Electric | | 1, 340 | 4 0 | |
| 10 Multiple family (high-rise) | 158 1200-ft$^2$ units, 16 stories | Steel and concrete | 67 | Electric hydronic heat pump | Electric hydronic heat pump | Gas | 7, 500 | (T 0. 1 cfm/ft$^2$) | 0 75 | 1575 |
| 11 Single family A | 1, 250 ft$^2$, 1 story | Stucco | 20 | Gas | None | Gas | 80 | 215 (T 0. 1 cfm/ft$^2$) | 1 0 | 10 9 |
| 12. Multiple family B | 14 850-ft$^2$ units, 2 stories | Stucco | 25 | Electric | Electric | Electric | 1,700 | 120 | 0.75 | 170 |

and concrete, and has 67% glass exterior walls. It is electrically heated and cooled with a hydronic heat pump system.

Commercial Submarket

Four buildings were chosen from the commercial submarket — an office building, a small retail store, a department store, and a motel. The office building is a low-rise six-story structure of glass wall construction with 8,000 $ft^2$ per floor and 45% exterior-wall glass area (solar grey). This building has a low velocity single duct HVAC system with electric terminal reheaters. This system has the lowest initial cost of any in current use. NAHB statistics indicate that about 45% of such buildings have electric heating and cooling.

The retail store is a small, one-story, 5200 $ft^2$ building of simple concrete construction. The store is specified to be cooled using electricity with a gas roof-top heating system. The department store is a three-story concrete building having 40,000 $ft^2$ of floor space per story. The cooling system is electric. The motel, which contains 60 units, is a two-story concrete building, with 20,000 $ft^2$ per story. The HVAC system is an individual through-the-wall electric heat pump system.

Institutional Submarket

The institutional submarket is represented by a concrete elementary school building of 19,800 $ft^2$ total area. The school is assumed to be all electric.

After the 10 buildings had been chosen and their physical characteristics specified, the third and final step in the selection process was performed. This involved specifying the internal loads of each of the buildings and trying to choose real buildings for each of these categories, so that actual thermal performance could be used to calibrate or at least cross-check our thermal program.

Before this was done, however, project members met with SCE staff to review the list of buildings. As a result, the list of buildings was changed and the buildings were ranked in priority from most significant to least significant.

The final list of buildings is given in Table 14. It is basically the same list as presented in Table 15 with the 1200 $ft^2$ single family and the motel dropped out and a market and a second office building added.

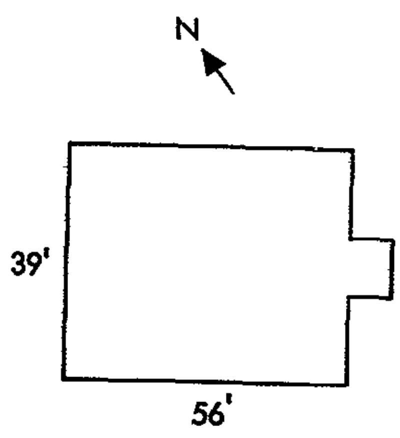
C. BUILDING DESCRIPTION SUMMARIES

In the pages that follow the buildings selected for analysis are described in detail, together with their use and demand profiles. The selected buildings are listed in the same priority order as the list in Table 14. Each building is a "real" building for which there is data on actual electric and/or gas energy demand. This data is listed under item H of the building summary. The internal loads (people, lights, and miscellaneous utilities) are given in item G and infiltration in item F. Items A through E give a physical description of the building and the materials used in its construction including: the floor plan (item A), the orientation (item B), the roof type and material (item C), the type and amount of insulation in walls, ceilings and floors (item D), and the type and extent of fenestration (item E). The location of the building is also given as well as the source of the description data.

## BUILDING DESCRIPTION

Master ID: Building 1, Single Family C
Location: Tarzana
Type: Single family
2250 $ft^2$ (56 x 39 x 8)

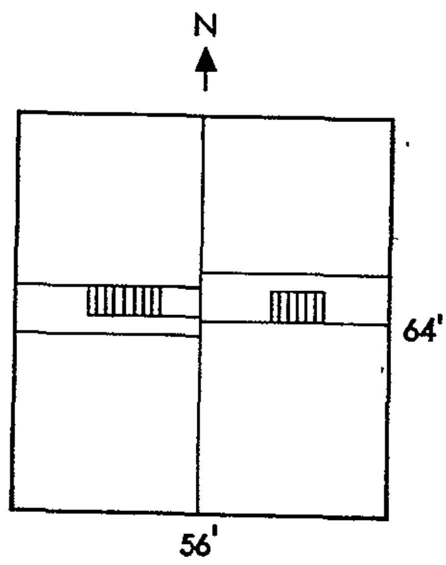
A. Floor Plan: 56 x 39 x 8 ft
B. Orientation: See diagram
C. Roof: White rock (30% slope)
D. Insulation:
  1. Roof: 6 in. fiberglass
  2. Walls: Stucco (5/8 in.) + 1/2 in. lath plaster + no insulation + 1/2 in. stucco
  3. Floor: Wood foundation, 3/4 in. carpet
E. Windows:
  1. Exterior walls: 204/1520 or 20%
  2. Sliding glass doors: 126 $ft^2$
F. Infiltration: 300 cfm
1400 cfm blower about 10% outside 3 hours/day
G. Internal Load:
  1. People: 4 people, 2 people (10 a.m.-6 p.m.); 4 people (6 p.m.-10 a.m.)
  2. Lights: 3/4 watts/$ft^2$, none (10 a.m.-6 p.m.); full (6 p.m.-12 p.m. and 6 a.m.-10 a.m.); none (12 p.m.-6 a.m.)
  3. Utilities: Gas heater (120,000 Btu), electric air (5 ton)
57% efficient at 1400 cfm without distribution losses
Hot water - 80 gal/day
H. Utility Company: No data available.



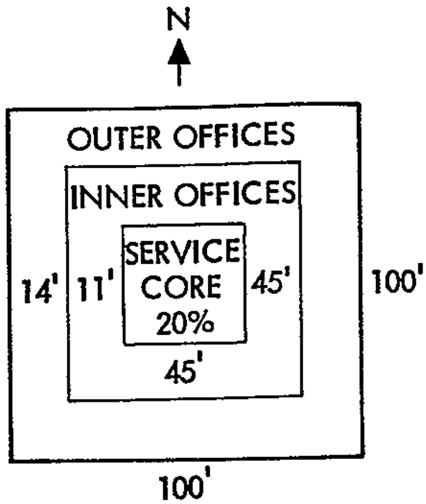
## BUILDING DESCRIPTION

Master ID: Building 2, Multiple Family Low Rise B
Location: Inglewood
Type: Rectangular, 9 units/2 stories, stucco, 910 $ft^2$/unit (28 x 32) (approximately)

A. Floor Plan: 64 x 56 x 8 ft
B. Orientation: Long side north/south
C. Roof: Flat and built up
D. Insulation:
   1. Roof: Built up - 6 in. batts + 1/2 in. plywood ceiling + 1/2 in. plaster + 1/4 in. topping
   2. Exterior Walls: Stucco (5/8 in.) + 1/2 in. batts + 1/2 in. dry wall
   3. Foundation/Floor: Carpeting (pad 3/4 in.) Slab (3.5 in. concrete)
E. Windows:
   1. Walls: 25% evenly distributed (for energy conservation: Fully shaded east/west windows by exterior shade)
   2. Sliding glass doors: 35 $ft^2$/unit (drapes will be used about half of the time)
F. Infiltration: 120 cfm (1 air change/hr) per unit
G. Internal Heat Loads:
   1. People: 2.1 people/unit, distribution: Half day/full night
   2. Lights: 3/4 watts/$ft^2$, 0.08 watts/$ft^2$ (midnight to 6 a.m.), 0.25 watts/$ft^2$ (6 a.m.-5 p.m.), 3/4 watts/$ft^2$ 9 p.m.-12 p.m.)
   3. Utilities: 9.4 KWH/day average all day
      All electric: Radiant cable, no air, range, water heater, refrigerator, disposal; 42 gal/day hot water
H. Utility Company: All electric - from SCE book, p. 16
   Average bill per unit: $13.21 per month, $158.52 per year, on 1540 degree days



## BUILDING DESCRIPTION




Master ID: Building 3, Office (6 stories)
Location: Long Beach
Type: Bank and office building
6 stories, 50,000 $ft^2$ with 8,000 $ft^2$ per floor with 2,300 $ft^2$ penthouse (7th floor)

A. Floor plan: See diagram
B. Orientation: See diagram
C. Materials: Structural steel with concrete facing aluminum-bronze on present concrete columns
Flat roof with 4-ft overhang
D. Insulation:
1. Roof -- concrete -- lightweight concrete insulation (8 in.)
2. Walls -- insulated single pane curtain wall (55% backed by 8-in. lightweight concrete)
3. Floor -- concrete foundation with partial basement
E. Windows: 45% solar grey glass --- shaded by draperies and tinting (drapes closed 10% of the time)
F. Infiltration: 1-1/2 volume changes per hr, 1 per hr for energy conservation
G. Internal loads:
1. People: 500 people (100 $ft^2$/person)
100% occupied 8 a.m.-6 p.m.; 5% occupied 6 p.m.-8 a.m.
2. Lights: Fluorescent, 130 foot-candles (average)
6 watts/$ft^2$
Exterior 20-500 watt spot lights (5% interior lights on at night)
3. Utilities: All electric
Single duct, low velocity with reheat
6-25 ton air conditioners (1 per floor), 130 ton total
Heating design temperature 31°F
Cooling design temperature 87°F
Water heating -- separate units, 252 gallons total
H. Utility Company
277/480 3-phase, 4-wire electric service

| | | |
|---|---|---|
| Connected load: | Interior lights | 265 KW |
| | Exterior lights and signs | 6 KW |
| | Space cooling | 165 KW |
| | Electric heat | 270 KW |
| | Water heating | 27 KW |
| | Miscellaneous | 49 KW |

Operating costs: August 1969 - August 1970 1,331,640 KWH, $18,539
Average cost $0.371 per $ft^2$ per year

# BUILDING DESCRIPTION

Master ID: Building 4, Department Store
Location: San Bernardino
Type: Department store
3 stories, approximately 40,000 $ft^2$ per story with penthouse - 144,800 $ft^2$ total - first floor, 853,400; second and third, 40,600; penthouse, 8,900.
Broadway-Hale store (SCE electric load study)

A. Floor plan: Rectangular (270 x 150 ft approximately)
B. Orientation: Standard (unimportant for this type)
C. Materials: Structural steel and concrete
Flat roof
D. Insulation:
1. Roof: Lightweight concrete
2. Walls: Assumed lightweight concrete
3. Floor: Slab over small basement (900 $ft^2$)
E. Windows:
Minor, entrance doors only
F. Infiltration: (0.4-0.55 cfm/$ft^2$ TRW Chicago) 70,000 cfm 9 a.m. to 6 p.m.
16,000 cfm 6 a.m. to 9 p.m.
G. Internal Loads:
1. People: 1 person per 60 $ft^2$ during normal hours
2. Lights: Fluorescent, 3 watts/$ft^2$ (normal hours) 9 a.m. to 7 p.m. <u>all</u> days
3. Utilities: Total connected load 2,594 KW (base load 1919)
Space cooling: Chillers, 378 KW, auxiliary, 91 KW
Heating, 206 KW.
H. Utility use (from SCE load study):
For year 1969 using 15-minute interval data: 1 degree hours 48997 (heatin[g]) 29078 (coolin[g])

| | | | |
|---|---|---|---|
| Monthly electric usage: | Total | 1326-1338 KW; | 533 K to 606,000 KWH |
| | Base | 1100-1284 KW; | 440 to 510,000 KWH |
| | Chillers | 247-355 KW; | 71 to 113,000 KWH |
| | Heating | 0-116 KW; | 0 to 29,000 KWH |
| Annual usage: | Total 6,799,000 | | Base 5,684,000 KWH (84%) |
| | | | Chillers 992,000 KWH (15%) |
| | | | 122,000 KWH (2%) |

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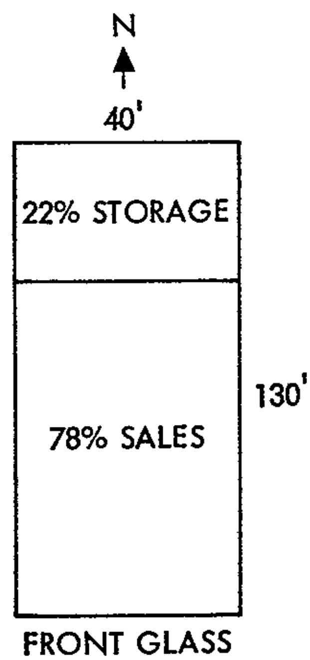
## BUILDING DESCRIPTION

| | |
|---|---|
| Master ID: | Building 5, Retail Store |
| Location: | Burbank |
| Type: | Small retail store<br>1 story, 5200 $ft^2$ |




A. Floor Plan: Rectangle (40 x 130 ft)
78% sales area, 22% storage

B. Orientation: Standard

C. Materials: Brick with front wall insulated glass
Flat roof - built up

D. Insulation:
1. Roof: Standard U = 0.19
2. Walls: Party walls -- 12 in. concrete block; rear wall -- dry wall and stucco with 2 in. fiberglass (U = 0.3)
3. Floor: Linoleum over slab

E. Windows: 25% (front wall insulated glass)

F. Infiltration: 1250 cfm (1-1/2 change per hr) 8 a.m. to 6 p.m.
1000 cfm (1 change per hr) 7 p.m. to 7 a.m.

G. Internal Loads:
1. People: 100 people (50 $ft^2$/person)
2. Lights: 3 watts per $ft^2$
3. Utilities: 92 KWH/week

H. Utility Use:
No data available

## BUILDING DESCRIPTION

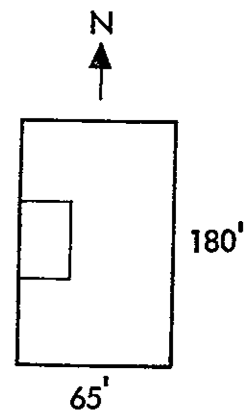
Master ID: Building 6, Single Family B
Location: Highlands (Redlands district, microclimate III)
Type: Rectangular, single family, 1 story
1630 $ft^2$

A. Floor Plan: Unknown (54 x 30 x 8)
B. Orientation: Long axis in N/S direction
C. Materials: Frame and stucco, sloped roof with composition shingles
D. Insulation:
   1. Roof: 4 in. batts (fiberglass)
   2. Walls: 4 in. batts with stucco
   3. Floor: Slab with 3/4 in. carpet
E. Windows:
   1. Walls: 20% mostly N/S exposure
   2. Sliding glass doors: Unknown
F. Infiltration: 225 cfm (1 air change per hour)
G. Internal Load:
   1. People: 4 (2 adults/2 children)
   2 Lights: 3/4 watts/$ft^2$
   3. Utilities: All electric -- range, water heater, dishwasher, clothes dryer, freezer, TV, refrigerator, garbage disposer; 6 KW electric strip heat; GE air/air heat pump 2-1/2 ton capacity
H Utility Company:
   Annual cost phase: Annual 18,335 KWH, $297
   Annual heat pump 6434 KWH, $211
   Annual degree days: 1,900
   Average monthly KWH -- 1941 (January) to 1225 (September)
   (Owner works for SCE)

## BUILDING DESCRIPTION

Master ID: Building 7, Office (3 story)
Location: San Marino
Type: First Federal Savings Building (All-Electric Building of Month October 1965)
3 stories, 11,000 $ft^2$ per story with 3,000 $ft^2$ interior walls

A. Floor Plan: See diagram
B. Orientation: See diagram
C. Materials: Steel, concrete, and masonry
Flat roof, minimum windows



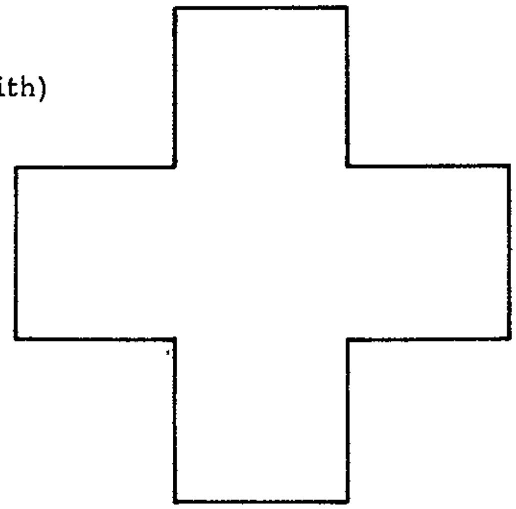

D. Insulation:
1. Roof: U factor = 0.19
2. Walls: U factor = 0.30
3. Floor: Concrete slab
E. Windows
1. Minimum windows, all shaded
F. Infiltration: 8000 cfm
G. Internal Loads:
1. People: 360 people (100 $ft^2$/person) 8 a.m. to 6 p.m.
2. Lights: 4 watts/$ft^2$
3. Utilities: All electric

| | |
|---|---|
| Lighting and miscellaneous | 100 KW |
| Heat pump -- 80 tons | 110 KW |
| Electric duct heating | 60 KW |
| Electric water heating | 18 KW (6 units) |
| Elevator | 22 KW |
| Lighting in parking area | 45 KW |
| Electric cooking equipment | 15 KW |

H. Utility company:
All-Electric Building of the Month October 1965
Costs \$0.38 per $ft^2$ per year (1965) = \$23,940 per year (1965)

# BUILDING DESCRIPTION

Master ID: Building 8, Elementary School
Location: Bloomington, California
Type: 1 story, school (Dr. G. A. Smith)
19,422 $ft^2$




A. Floor Plan: See diagram
B. Orientation: See diagram
C. Materials: Concrete
Flat roof
D. Insulation:
1. Roof: U factor = 0.19
2. Walls: U factor = 0.30
3. Floor: Linoleum
E. Windows:
40% single pane
F. Infiltration: 2200 cfm
G. Internal Loads:
1. People: 650 (30 $ft^2$/person)
2. Lights: Fluorescent, 100 foot-candles, 4.5 watts/$ft^2$
3. Utilities: All electric
Connected load:

| | |
|---|---|
| Strip electric in ducts | 122 KW |
| Space cooling | 71 KW |
| Electric water heating | 38 KW |
| Commercial cooking | 25 KW |

H. Utility Company:
Average cost \$0.23 per $ft^2$/year = \$4,467

# BUILDING DESCRIPTION

Master ID: Building 9, Market
Location: Cudahy
Type: All electric market, SCE Award November 1967, Boy's Market #29, 1 story, 26,850 $ft^2$, brick and concrete

A. Floor Plan: Simple rectangle (215 x 125 x 12)
B. Orientation: N/S on long side
C. Materials: Brick and concrete
Flat roof, front side glass
D. Insulation:
1. Roof: U factor = 0.25 (to 0.19)
2. Walls: U factor = 0.30
3. Floor: Linoleum over correct slab (U = 0.27)
E. Windows:
1. Front wall 215 x 12 = 2580 $ft^2$ windows = 25%
F. Infiltration: 1340 cfm (4 changes per hour)
G. Internal loads:
1. People: 1600 (20 $ft^2$/person)
2. Lights: 4 watts/$ft^2$ (100 foot-candles)
3. Utilities: All electric
180 KW connected load
Operates 7 days per week, 16 hours per day at 68¢ per square foot per year (1967) = 18,258 (1967)
Electric space conditioning with heat recovery system
All-Electric Building of the Month November 1967

# BUILDING DESCRIPTION

Master ID: Building 10, Multi-Family, Mid-Rise

Location: Santa Monica (Ocean Avenue Towers)

Type: Mid-rise multiple family
13,808 $ft^2$ per floor
16 stories -- 158 units
1200 $ft^2$ average

A. Floor Plan: 150 x 139 ft with cutout square 86 x 86 ft, floor height, 8 ft

B. Orientation: See drawing

C. Roof: Flat

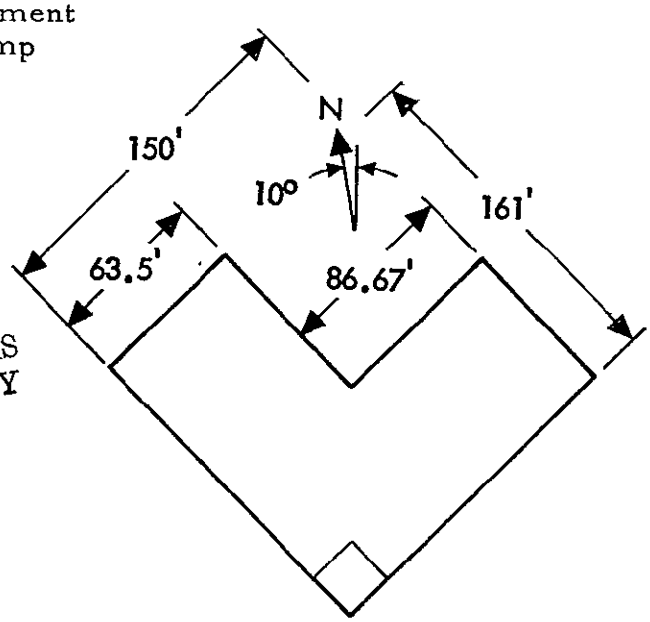
D. Insulation:
1. Roof: U = 0.1, concrete (12 in.)
2. Walls: Concrete and steel, U = 0.4 concrete/with 6 feet balconies
3. Floor: Concrete (12 in.)

E. Windows:
1. Walls: 67% average -- stacked glass 106 x 35/160 x 140 = 0.25
balcony 160 x 80/160 x 40 = 0.57
2. Sliding glass doors: Included as windows

F. Infiltration: 120 cfm per unit

G. Internal Load (per unit):
1. People: 400 maximum, half day/full after 6 p.m. to 7 a.m.
2. Lights: 0.75 watts/$ft^2$
3. Utility-Loads (average): 1575 KWH/week, hot water -- 7500 gallons/day average

H. Utility Company:
1. Gas water heating: Water use 35-60 therm/month average apartment
2. Electric hydronic heat pump



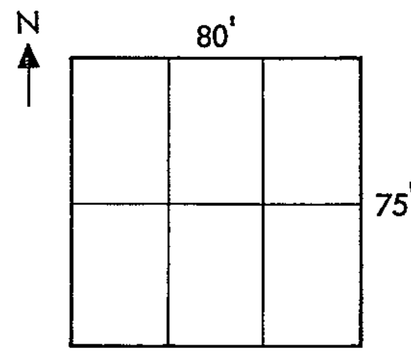
## BUILDING DESCRIPTION

Master ID: Building 11, Single Family A
Location: Palmdale
Type: Single family, rectangular, 1 story
1250 ft$^2$, frame and stucco

A. Floor Plan: Unavailable (50 x 25 x 8)
B. Orientation: Long axis N/S
C. Materials: Frame and stucco
Sloped roof with wood shingles
D. Insulation:
   1. Roof: Aluminum foil no insulation
   2. Walls: Aluminum foil no insulation
   3. Floor: Slab with 3/4 in. carpet
E. Windows:
   1. Walls: 15%
   2. Sliding glass doors: Unknown
F. Infiltration: 175 cfm (change per hour)
G. Internal Loads:
   1. People: 6 people (2 adults, 4 children)
   2. Lights: 3/4 watt/ft$^2$
   3. Utilities: All electric
   Range, water, auto washer, clothes dryer, dishwasher, disposer, TV, refrigerator, GE air/air heat pump, 12 KW electric strip heat
H. Utility Company (estimate)
   Annual volume 19,768 KWH -- $331 3150 degree days
   Heat pump —— 8,400 KWH -- $120
   Average monthly 2,857 KWH (February) to 510 (July)

# BUILDING DESCRIPTION

Master ID: Building 12, Multifamily Low-Rise A
Location: Alhambra
Type: 14 apartments, 2 stories
850 $ft^2$/unit -- average (30 x 29)




A. Floor Plan: 75 x 80 x 8 ft, per floor
B. Orientation: Long side facing N/S
C. Roof: Flat, with small overhang
D. Insulation:
1. Roof: Built-up roof and ceiling - 0.25 in. topping + 1/2 in. plywood + 3.5 in. batts + 1/2 in. dry wall
2. Exterior Walls: Stucco (5/8 in.) + 2.25 in. batts + 1/2 in. dry wall
3. Foundation/Floor: Carpet (3/4 in.) Slab (3/5 in.)

E. Windows:
1. On walls: $\frac{88 \times 2}{736}$ or 25% evenly distributed
2. Sliding glass doors: 35 $ft^2$ per unit

F. Infiltration: 120 cfm (1 change/hr)
G. Internal Loads:
1. People: 1.8 people/unit, normal distribution half daytime/full nighttime
2. Lights: 0.75 watts/$ft^2$
3. Utilities: 170 KWH/wk, electric heat, wall unit cooling Electric range/water heating/refrigerator/disposal

H. Utility Company:
All electric from SCE book of multiples
Average bill of units, \$11.44 per mo or \$138 per year

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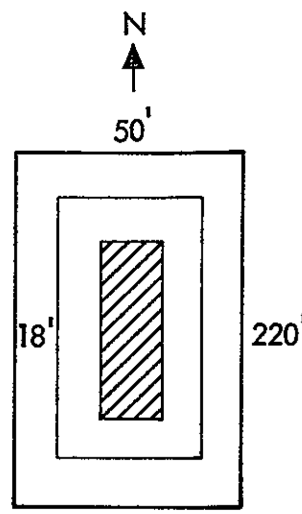
## BUILDING DESCRIPTION

Master ID: Buildıng 13, Offıce C (10 stories)
Location: Commerce
Type: Offıce buıldıng, hıgh rıse
10 stories, 110,000 $ft^2$ (11,000 $ft^2$/floor)
First Western Bank Buıldıng (SCE electric load study)

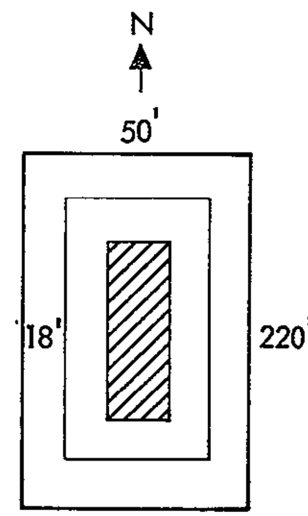



A. Floor Plan: See dıagram
B. Orientation: See dıagram
C. Materıals: Steel and concrete wıth curtaın wall and window facade
D. Insulation:
1. Roof: U factor = 0.25 (to 0.19)
2. Walls: U factor = 0.30
3. Floors: Cement over garage U = 0.25
E. Windows: 20% standard glass
F. Infiltration: 20,000 cfm
G. Internal Loads:
1. People: 1 person/60 $ft^2$ normal hours (8 a.m. - 6 p.m.)
2. Lights: 3-1/2 watts/$ft^2$ fluorescent (recessed 2 x 4 ft)
3. Utilities: Two-160 ton carrier, 190-160 chıllers with low velocıty double duct system. Chilled water is circulated through vertical risers to central aır handling unıts.
H. Utilıty Usage:
Connected load, 400 KW; miscellaneous load, 645 KW; air conditioning, 457 KW; heating, 643 KW; electric water heating, 45 KW

Average Monthly Energy Use (1969)

| | KW | KWH |
|---|---|---|
| Total buıldıng | 787 | 279,000 |
| Total heating | 97 | 18,995 |
| Total air conditioning | 380 | 128,000 |
| Water heating | 13 | 1,200 |
| Lighting | 291 | 102,800 |
| Elevators | 18 | 5,800 |
| Receptacles | 67 | 29,600 |

## BUILDING DESCRIPTION




Master ID: Building 13, Office C (10 stories)
Location: Commerce
Type: Office building, high rise
10 stories, 110,000 $ft^2$ (11,000 $ft^2$/ floor)
First Western Bank Building (SCE electric load study)

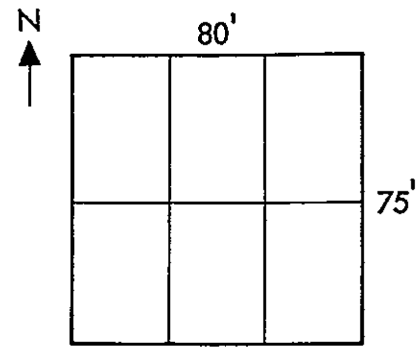
A. Floor Plan: See diagram
B. Orientation: See diagram
C. Materials: Steel and concrete with curtain wall and window facade
D. Insulation:
1. Roof: U factor = 0.25 (to 0.19)
2. Walls: U factor = 0.30
3. Floors: Cement over garage U = 0.25
E. Windows: 20% standard glass
F. Infiltration: 20,000 cfm
G. Internal Loads:
1. People: 1 person/60 $ft^2$ normal hours (8 a.m. - 6 p.m.)
2. Lights: 3-1/2 watts/$ft^2$ fluorescent (recessed 2 x 4 ft)
3. Utilities: Two-160 ton carrier, 190-160 chillers with low velocity double duct system. Chilled water is circulated through vertical risers to central air handling units.
H. Utility Usage:
Connected load, 400 KW; miscellaneous load, 645 KW; air conditioning, 457 KW; heating, 643 KW; electric water heating, 45 KW

Average Monthly Energy Use (1969)

| | KW | KWH |
|---|---|---|
| Total building | 787 | 279,000 |
| Total heating | 97 | 18,995 |
| Total air conditioning | 380 | 128,000 |
| Water heating | 13 | 1,200 |
| Lighting | 291 | 102,800 |
| Elevators | 18 | 5,800 |
| Receptacles | 67 | 29,600 |

# BUILDING DESCRIPTION

Master ID: Building 12, Multifamily Low-Rise A
Location: Alhambra
Type: 14 apartments, 2 stories
850 $ft^2$/unit -- average (30 x 29)




A. Floor Plan: 75 x 80 x 8 ft, per floor
B. Orientation: Long side facing N/S
C. Roof: Flat, with small overhang
D. Insulation:
  1. Roof: Built-up roof and ceiling - 0.25 in. topping + 1/2 in. plywood + 3.5 in. batts + 1/2 in. dry wall
  2. Exterior Walls: Stucco (5/8 in.) + 2.25 in. batts + 1/2 in. dry wall
  3. Foundation/Floor: Carpet (3/4 in.) Slab (3/5 in.)
E. Windows:
  1. On walls: $\frac{88 \times 2}{736}$ or 25% evenly distributed
  2. Sliding glass doors: 35 $ft^2$ per unit
F. Infiltration: 120 cfm (1 change/hr)
G. Internal Loads:
  1. People: 1.8 people/unit, normal distribution half daytime/full nighttime
  2. Lights: 0.75 watts/$ft^2$
  3. Utilities: 170 KWH/wk, electric heat, wall unit cooling
     Electric range/water heating/refrigerator/disposal
H. Utility Company:
All electric from SCE book of multiples
Average bill of units, \$11.44 per mo or \$138 per year

# SECTION IV

# BUILDING AND HVAC SYSTEM MIX

To analyze the potential for the use of solar energy on buildings in each zone of the SCE territory, it was necessary to determine the number of buildings of each type, and of each HVAC system by zone. This broke the job into six steps: First, identify the various building submarkets; second, determine the number of buildings of each type (e.g., single family, multiple family); third, estimate the number of buildings using energy conservation; fourth, determine the HVAC functions appropriate for each building type; fifth, determine the various combinations of functions (e.g., water-heating-and-space-heating-only is a particular combination); and sixth, define the fuel (electric or gas) used to provide the HVAC function.

These six steps are shown in Fig. 3. The figure indicates that these six steps were used to calculate the number of buildings (both for existing and for new) by zone in each of the six categories. These six steps can be broken into two basic groups. The first is called the "building mix" and is determined in steps 1, 2, and 3 of the typology. The second group is called the "HVAC system mix" and is determined in steps 4, 5, and 6.

## A. BUILDING MIX

The first question to be asked in defining which types of buildings should be selected as "typical" is: "How many buildings of a given type exist in each of the four microclimatic zones?" This section answers the question, for the present project, and describes the method used in arriving at the answer.

### 1. Submarket Building Mix (Step 1, Fig. 3)

The total number of buildings in the SCE territory of a given type was computed from the 1970 census figures (for all of California) and the F. W. Dodge forecasts for 1990. The number in the SCE territory was assumed to be

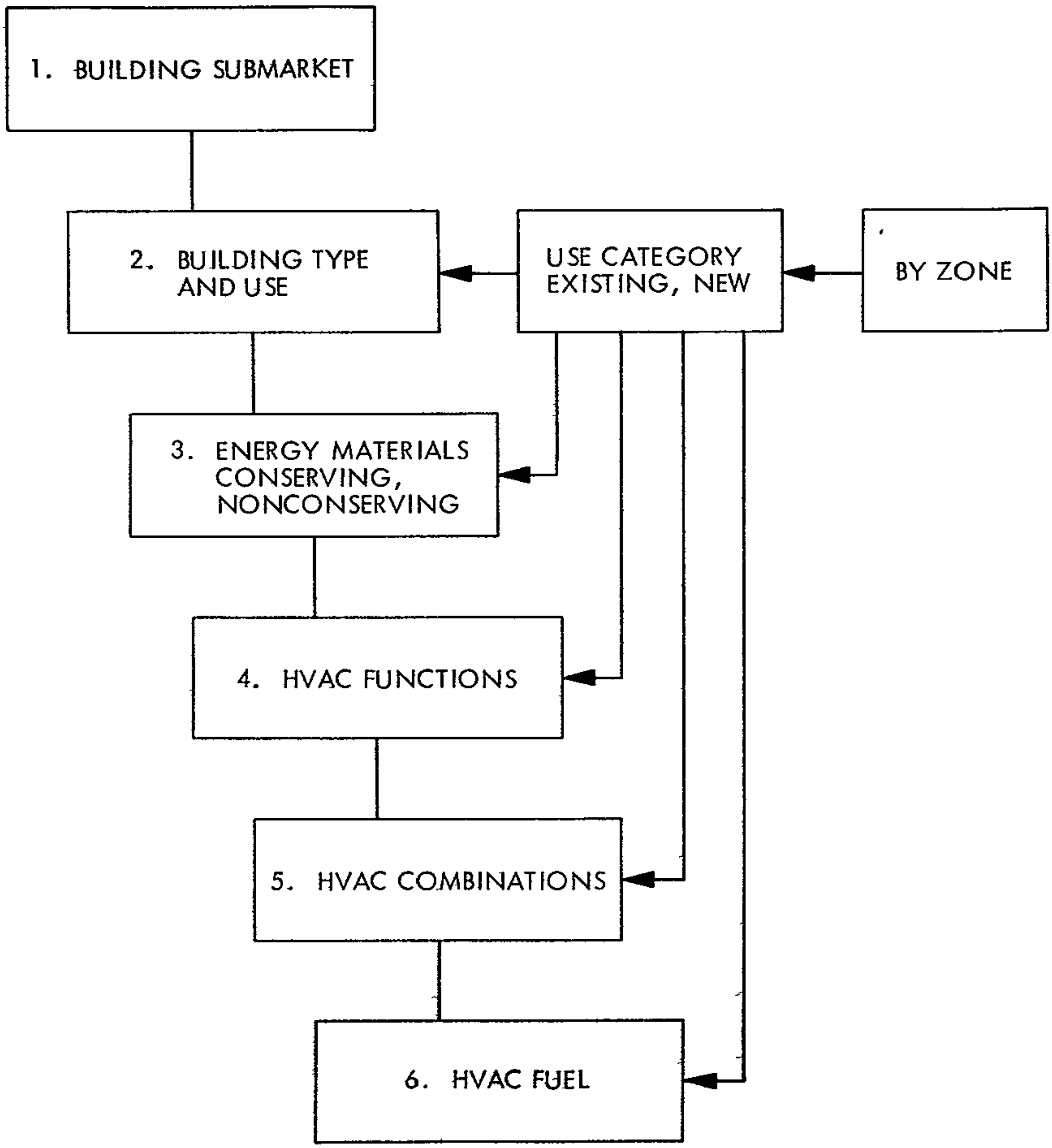



Fig. 3. HVAC typology selection tree

proportional to the population ratio between the SCE territory and all of California. In 1970, the population of the SCE territory was about 6,840,000, whereas for the 12 business economic areas (BEAs) of California, the population was 20,106,000 in 1970. This yields a scalar of 0.34 which in turn yields the number of buildings of each type in the SCE territory. Since studies indicate that the number of commercial buildings is also a function of population,* the allocation of buildings to the SCE territory by population seems reasonable. However, because we suspect that the SCE territory has a higher than average percentage of multiple family buildings, the percentage of multiple family buildings was assumed to be about 20% higher than for California as a whole. Thus, we allocated apartment buildings to the SCE territory in such a way as to make the fraction of apartment dwelling units 32% of the total, compared to the 27% average for all of California. Table 16 gives the building mix for the buildings used in the study for all of California and for the SCE territory.

To update these numbers to the year 1975, the growth patterns for the five-county Southern California area were analyzed. This data is available from the Security-Pacific Bank, which publishes yearly summaries of building activity in California. The four years from 1971 to 1975 were taken as average years (one very good "record" year, 1973; and one very poor year, 1974). The 5-year average building rates were then computed. The building activity in the SCE territory was assumed to be the same as this five-county average as adjusted by population (ratio = 0.6515). These results are given in Tables 17 and 18. The total of new commercial starts was calculated using the long-term average relationship between residential and commercial buildings (commercial = 5% of residential).

2. Building Type and Use Mix (Step 2, Fig. 3)

The distribution of buildings was determined at first by assuming that the mix of buildings is proportional to the number of SCE customers in each zone. This is tantamount to assuming that the building mix is proportional to population, because the distribution of SCE customers by zone is closely correlated

*See Bibliography: Item 1 (1974 Appendix) and item 2 (Appendix C).

Table 16. Aggregate building mix for different submarkets and building types in the SCE territory

| | California | | SCE Territory** | | | |
|---|---|---|---|---|---|---|
| | 1970 | %* | 1970 | 1975 | % | Annual Growth Rate (%) |
| Residential Dwelling Units | 6,571,600 | 100 | 2,234,000 | 2,526,000 | 100 | 3.9 |
| Single Family | 4,584,600 | 72 | 1,519,120 | 1,635,930 | 65 | |
| Multiple Family | 1,789,600 | 27 | 714,880 | 890,095 | 35 | |
| Commercial Units (4.4% of Residential) | 236,780 | 100 | 80,600 | 102,765 | 100 | 5.5 |
| Office Buildings (Low Rise) | 36,907 | 4.1 | 12,900 | 16,442 | 16 | |
| Department Stores | 3,131 | 2.1 | 1,050 | 1,359 | 1.3 | |
| Other | 196,742 | | 66,650 | 84,964 | | |
| Institutional (1.5% of Residential) | 79,338 | 100 | 26,975 | 31,021 | 100 | 3.4 |
| Schools | 14,100 | 18 | 4,794 | 5,513 | 18 | |

*For residential, the percentage is percentage of total residential buildings; for nonresidential, the percentage is the percentage of total floor area.

**The SCE territory contains about 34% of all California residents and about 65% of all South Coast Basin residents.

Table 17. Summary of Building Activity in California, 1971-1974 (from: "Monthly Report of Building Permit Activity", Security Pacific Bank, December issues)

| Year | All California | | | Five-County Area, So. Calif. (1) | | |
|---|---|---|---|---|---|---|
| | Single Family | Multiple Family | Total | Single Family | Multiple Family | Total |
| 1971 | 113,348 (2)<br>(2.447) (3) | 143,328 (2)<br>(1.777) (3) | 256,676<br>(4.526) | 38,156<br>(0.896) | 62,634<br>(1.818) | 100,190<br>(1.860) |
| 1972 | 123,990<br>(2.872) | 156,861<br>(2.205) | 280,851<br>(5.407) | 44,102<br>(1.087) | 72,226<br>(1.075) | 116,328<br>(2.328) |
| 1973 | 102,734<br>(2.671) | 114,130<br>(1.871) | 216,864<br>(4.892) | 37,676<br>(1.016) | 55,122<br>(0.994) | 92,798<br>(2.171) |
| 1974 | 76,205<br>(2.244) | 53,321<br>(1.013) | 129,526<br>(3.691) | 24,738<br>(0.783) | 24,481<br>(0.521) | 49,219<br>(1.508) |
| 4 Year Total | 416,277<br>(10.234) | 467,640<br>(6.866) | 883,917<br>(18.516) | 144,672<br>(3.782) | 213,863<br>(3.408) | 358,535 |
| Ave. per Year | 104,069<br>(2.559)<br>(47%) | 116,910<br>(1.717)<br>(53%) | 220,979<br>(4.629) | 36,168<br>(0.946)<br>(40%) | 53,466<br>(0.852)<br>(60%) | 89,634 |
| SCE Ave. per Year | - | - | - | 23,567<br>(0.616) | 34,838<br>(0.555) | 58,405 |

(1) Riverside, San Bernardino, Ventura, Los Angeles, Orange

(2) Number of dwelling units

(3) \$ valuation given in parentheses x $10^9$



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Table 18. Annual building growth rates (1971-74) for SCE territory (Source: Security Pacific Bank "Monthly Report of Building Permit Activity")

| | New Buildings | Annual Growth Rate (%) | Existing Buildings, 1975 |
|---|---|---|---|
| Total Residential Buildings | 58, 406 | 2 3 | 2, 526, 000 |
| Single Family | 23, 362 | 1 4 | 1, 635, 930 |
| Multiple Family | 35, 043 | 3 9 | 890, 095 |
| Total Commercial Buildings | 5, 652 | 5 5 | 102, 765 |
| Office | 904 | 5 5 | 16, 442 |
| Department Store | 75 | 5. 5 | 1, 359 |
| Total Institutional Buildings | 1, 055 | 3 4 | 31, 021 |
| Schools | 165 | 3 0 | 5, 513 |

Notes:
1. Four-year, five-county average, residential = 89, 634
2. SCE population/five-county average = 0 6515
3. The average annual value of new construction was $616 million for single family buildings and $555 million for multiple family buildings

with the population in each zone. To account for variations between zones, the final number of buildings of a particular type in a zone was modified to reflect assumed differences between zones. For example, most of the apartment buildings in the SCE territory are probably located either in the beach or the inland valley zone. We assume that the number of apartments per unit population in these zones is 5* times the number for the mountain zone and 2.5* times the number in the high desert zone. This yields a multiplier which reallocates the total number of apartments into each zone as follows:

$$\Sigma f_i x_i = 1$$

where $x_i$ = apartment rate per population in the $i^{th}$ weather zone and $f_i$ = fraction of SCE population in each zone and

$$Z_i = f_i x_i T$$

*This represents the approximate ratio between land values in the four zones.

where $Z_i$ = the total number of apartments in each zone and T is the total number of apartments in the SCE territory. For apartments the per capita apartment rates in the four zones are related approximately by the ratio of their land values: $x_1 = x_2 = 2.5x_3 = 5x_4$ where 1 represents the Beach; 2, Inland Valleys; 3, High Desert; and 4, Unassigned. Using these equations, $x_1 = 1.07 = x_2$, $x_3 = 0.428$ and $x_4 = 0.214$ and $Z_1 = 0.33 \times 1.07 \times 890{,}095 = 314{,}493$, $Z_2 = 0.57 \times 1.07 \times 890{,}095 = 543{,}069$, $Z_3 = 0.07 \times 0.428 \times 890{,}095 = 26{,}667$, and $Z_4 = 0.03 \times 0.214 \times 890{,}095 = 5{,}714$. Table 19 gives the values of the $x_i f_i$ product for each zone; that is, the fraction of each building type in each zone.

Table 19. $x_i f_i$ multiplier fraction of total

| Zone | $x_i$ | $f_i$ | $x_i f_i$ |
|---|---|---|---|
| I. Beach | 1.07 | 0.33 | 0.35 |
| II. Inland Valley | 1.07 | 0.57 | 0.61 |
| III. High Desert | 0.428 | 0.07 | 0.03 |
| IV. Unassigned | 0.214 | 0.03 | 0.01 |

The number of customers allocated to each of the four microclimatic zones is given in Table 20. The fraction of customers in each zone is approximately equal to the fraction of total sales in each zone. The only major discrepancy occurs in the Unassigned area, which has 6% of SCE sales but only 3% of SCE customers. This is explained by the probable higher use of electric space and water heating in these areas because of the unavailability of natural gas. Tables 21 and 22 give the building mix for each zone for single and multiple family dwelling units, respectively. The growth rates for multiple family dwelling units were assumed to increase between 1975 and 2000 for the beach and inland valley zones, reflecting higher land values and a switch to apartments and condominiums. (Note that the project's definition of multifamily units includes condominiums.) The new units were then allocated between the four zones and reflect different growth rates in each of the zones.

Analysis of these results yields a basic scenario for the SCE territory as follows:

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Table 20. SCE customer allocation to weather zones

| Zones | Representative Weather Station | SCE Customers | | | |
|---|---|---|---|---|---|
| | | Weather Stations In Zone | Number | % of Total | Fraction of SCE 1973 KWH Sales |
| I. Beach | LAX | LAX<br>Santa Barbara<br>Pt. Mugu<br>Long Beach<br>San Diego | 855,944 | 33 | 0.31 |
| II. Inland Valley | Burbank | Burbank<br>El Toro<br>San Bernardino<br>Riverside | 1,495,020 | 57 | 0.57 |
| III. High Desert & San Joaquin Valley | Edwards | Edwards<br>Inyokern<br>Fresno<br>Bakersfield | 172,162 | 7 | 0.06 |
| IV. Unassigned | None | Misc. Mountain Areas | 44,893 | 3 | 0.06 |
| Grand Total | | | 2,620,029 | | |
| SCE Total | | | 2,620,899 | | |



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Table 21. Building mix - single family dwelling units

| Zone | 1975 Existing Units | 1975 New Units | | Annual Growth Rate (%) | |
|---|---|---|---|---|---|
| | | Number | % of Total | 1975 | 2000 |
| I. Beach | 539, 857 | 5, 841 | 25 | 1. 1 | 0 75 |
| II. Inland Valley | 932, 480 | 9, 345 | 40 | 1. 0 | 0. 55 |
| III. High Desert | 114, 515 | 5, 841 | 25 | 5 1 | 4. 00 |
| IV Unassigned | 49, 078 | 2, 336 | 10 | 4 8 | 4 00 |
| Total | 1, 635, 930 | 23, 362 | 100 | 1 4 | |

Table 22. Building mix - multiple family dwelling units

| Zone | 1975 Existing Units | 1975 New Units | | Annual Growth Rate (%) | |
|---|---|---|---|---|---|
| | | Number | % of Total | 1975 | 2000 |
| I Beach | 314, 493 | 12, 580 | 36 | 4 0 | 3. 2 |
| II Inland Valley | 543, 069 | 21, 723 | 62 | 4 0 | 2. 4 |
| III. High Desert | 26, 667 | 800 | 2 3 | 3. 0 | 2. 0 |
| IV. Unassigned | 5, 765 | 300 | 0. 8 | 5. 0 | 6 0 |
| Total | 890, 095 | 35, 043 | 100 | 3 94 | |

The growth in residential units will average about 2.3% per year from 1975 to 2000. New multiple family units will comprise 60% of all new residential units. Commercial buildings will grow in number at the same rate as residential units (reflecting the long term average relationship, commercial buildings = 4.47% of residential buildings). The beach and inland valley zones will experience most of the multiple family building growth, reflecting the relatively higher land values in those zones.

Tables 23 and 24 give the building mix for each zone for low-rise office buildings and department stores. In 1975 there are, in the SCE territory, approximately 16,400 low-rise office buildings (six stories or less) and 1,360 department stores. About 95% of these buildings are either in the beach zone or the inland valley zone.* The growth rate for both types of commercial buildings is estimated to be 5.5%, with most of the additional buildings going either into the beach zone or the inland valley zone. The growth rate of 5.5% reflects a continuing urbanization of the SCE territory and a continuation of the rise in land prices. Higher land prices will tend to encourage large commercial buildings as opposed to small commercial buildings. At present a great deal of activity in office building construction is concentrated at the beach and in the inland valleys, confirming the higher growth rates. Because of the continuing commercial growth within the SCE territory, these high growth rates of commercial buildings are expected to continue through 2000. Even though the growth rates are high, the number added each year is relatively small (e.g., 550 low-rise offices in the 1.5 million population inland valley areas), because the base numbers are small.

To estimate the impact of commercial buildings as a class, the number of total commercial buildings was calculated along with comparable growth rates. This data is presented in Table 25. Similar data for institutional buildings is given in Table 26. The 16,442 office buildings in place in 1975 comprise about 16% of the total 102,765 commercial buildings in the SCE territory. Department stores comprise another 170.

*Because heating and cooling loads for commercial buildings are less sensitive to external weather fluctuations than are those for residential buildings, the relative assignment to the different zones is not as significant as it is for the residential buildings.

Table 23. Building mix - office buildings

| Zone | 1975 Existing Units | 1975 New Units | | Annual Growth Rate (%) | |
|---|---|---|---|---|---|
| | | Number | % of Total | 1975 | 2000 |
| I Beach | 5,806 | 319 | 35 | 5 6 | 5.6 |
| II Inland Valley | 10,028 | 551 | 61 | 5.8 | 5.8 |
| III. High Desert | 493 | 27 | 3 | 2 0 | 2 0 |
| IV. Unassigned | 108 | 6 | 1 | 2 0 | 2 0 |
| Total | 16,442 | 904 | 100 | 5.5 | 5 5 |

Table 24. Building mix - department stores

| Zone | 1975 Existing Units | 1975 New Units | | Annual Growth Rate (%) | |
|---|---|---|---|---|---|
| | | Number | % of Total | 1975 | 2000 |
| I. Beach | 480 | 26 | 35 | 5.8 | 6 0 |
| II. Inland Valley | 829 | 46 | 61 | 6.0 | 6.3 |
| III High Desert | 41 | 2 | 3 | 2.2 | 2.2 |
| IV. Unassigned | 9 | 0 | 1 | 2 0 | 2.0 |
| Total | 1,359 | 75 | 100 | 5.5 | 5 5 |

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Table 25. Building mix - commercial buildings

| Zone | 1975 Existing Units | 1975 New Units | | Annual Growth Rate (%) | |
|---|---|---|---|---|---|
| | | Number | % of Total | 1975 | 2000 |
| I Beaches | 36, 286 | 1992 | 35 | 5. 6 | 5. 6 |
| II. Inland Válley | 62, 676 | 3447 | 61 | 5. 8 | 5. 8 |
| III. High Desert | 3, 079 | 169 | 3 | 2. 0 | 2. 0 |
| IV. Unassigned | 672 | 36 | 1 | 2. 0 | 2 0 |
| Total | 102, 765 | 5652 | 100 | 5. 5 | 5 5 |

Table 26. Building mix - institutional buildings

| Zone | 1975 Existing Units | 1975 New Units | | Annual Growth Rate (%) | |
|---|---|---|---|---|---|
| | | Number | % of Total | 1975 | 2000 |
| I. Beaches | 10, 954 | 373 | 33 | 3. 0 | 2. 8 |
| II. Inland Valley | 18, 920 | 643 | 57 | 3. 5 | 3. 2 |
| III. High Desert | 929 | 32 | 7 | 4. 2 | 3 8 |
| IV. Unassigned | 203 | 7 | 3 | 4. 0 | 3. 6 |
| Total | 31, 021 | 1055 | 100 | 3. 5 | 3. 0 |

3. Building Mix for Energy-Conserving Measures (Step 3, Fig. 3)

Once the number of buildings in each submarket (residential, commercial, and institutional) has been defined for both new and existing uses and for each zone, the question of the energy-conserving features for each building can be addressed. As a result of the OPEC Oil Embargo of 1973, the project members, in consultation with SCE staff, concluded that new buildings would be a radical departure from buildings of the past. These differences are most likely to occur in the specification of the materials and operation of the HVAC systems in buildings. Few radical design changes in the building envelope itself are anticipated, but rather simple changes to the components of buildings may occur. The most likely changes are (1) use of more insulation, (2) shading windows or using better insulating glass, (3) increased use of weather stripping to reduce infiltration, and (4) altering thermostat settings to reduce overall demand. Some HVAC systems could be modified for more efficient operation. Each of these possibilities was examined and an energy-conserving package for each building type was defined, using several computer runs on the effects of different combinations of energy-conserving measures and project judgements concerning the economic feasibility of each combinations. The impact of the energy-conserving package can be quite large, particularly for the highly weather-dependent single family buildings.

A dramatic demonstration of the effect of an energy-conserving package is shown in Table 27. The comparison shows annual heating load for the Single Family C Building with and without the conservation package. The conservation package reduces the annual heating load by a factor of 3 in the beach and inland valley zones and by a factor of 2 in the high desert.

a. Design of Energy-Conserving Packages

Energy-conserving packages can take many forms ranging from simple thermostat adjustments to fully insulated buildings with highly efficient HVAC units. Greatest returns are achieved when conservation is integrated into new building construction. In concept, old buildings can be equally well insulated but, in practice, costs become excessive. Therefore, in the insulation packages

Table 27. Annual heating load for the single family building

| Zone | Annual Heating Load (KWH) | | % Reduction |
|---|---|---|---|
| | Without Energy-Conserving Package | With Energy-Conserving Package | |
| I. Beach | 18,600 | 5,422 | 71% |
| II. Inland Valley | 18,700 | 5,747 | 69% |
| III. High Desert | 31,040 | 14,700 | 53% |

conceived for this study, existing or old buildings were assumed to have been treated with a minimum package while new buildings were assumed to have more extensive insulation. Energy-conserving packages are therefore mostly applicable to new buildings.

Conservation packages were made up of one or more items taken from the following list:

1) Insulation.

   a) Ceiling.
   b) Walls.
   c) Floors.

2) Windows.

   a) Heat-absorbing glass.
   b) Double-paned glass.
   c) Reduced glass area.
   d) Internal/external shading.

3) Weather stripping.

4) Operational changes.

   a) Thermostat settings.
   b) More efficient use of outside air.

Conservation packages for new construction were selected to parallel expected California State building requirements. Thus, ceiling and wall insulation, but not floor insulation, became part of the specification. Each building presented its own special problems and will be discussed specifically. Several of the representative buildings are all-electric and have some energy-conserving design features. The conservation packages for these existing buildings are probably irrelevant since all-electric buildings have historically been well insulated.

Building 1, Single Family C, Table 28

Building 1 is a wood frame and stucco, single-story structure, with moderate window area. This building has an unusually high amount of ceiling insulation, but represents an easily attainable condition for existing similar buildings. For new structures, the conservation packages will include wall insulation and better weather stripping to achieve a lower infiltration (3/4 building volume per hour). Double-pane windows have not been included in the energy-conserving package. This decision was based upon an expectation that building codes in Southern California will not require the use of double glazing in buildings with moderate-to-low window areas. Thermostat settings can have a significant impact on energy use. However, consumer reluctance to sacrifice comfort was judged to be strong and campaigns to change individually controlled units appears to be unsuccessful.

Building 2, Multiple Family Low-Rise, Table 29

Building 2 is similar in construction to the single-family dwelling. The ratio of exterior wall surface to room volume is lower in the multiple-family building and therefore the building is basically more energy-conserving than a single-family dwelling. The energy-conserving package for Building 2 consists

Table 28. Energy conservation building summary: Building 1, Single Family C

| Basic Description: Wood frame, 1 story, stucco 2250 ft$^2$, sloped roof, wood floor, carpeted | | |
|---|---|---|
| | Thermal Model Value | |
| Thermal Variable | Nonconserving Existing Building | Energy-Conserving Package for New Buildings |
| Insulation* | | |
| Ceiling | 6 in. | 6 in. |
| Walls | --- | 4 in. |
| Floor | --- | --- |
| Windows | 20% single pane | No change |
| Infiltration | 300 cfm | 225 cfm + outside air for cooling when $T_{AMB} < 75^{\circ}F$ |
| Thermostat | | |
| Heating | 70°F | 70°F |
| Cooling | 75°F | 75°F |
| Internal Loads | 0.75 watts/ft$^2$ | No change |

*Insulation: Rock wool with k = 0.31 Btu/hr ft$^2$/in.

Table 29. Energy conservation building summary: Building 2, Multiple Family, Low Rise B

Basic Description: Wood frame, 2 story, stucco, 9 units, 910 $ft^2$/unit, concrete slab floor

| Thermal Variable | Thermal Model Value: Nonconserving Existing Building | Thermal Model Value: Energy-Conserving Package for New Buildings |
|---|---|---|
| Insulation* | | |
| Ceiling | 2 in | 4 in. |
| Walls | --- | 4 in. |
| Floor | --- | No change |
| Windows | 25% single pane<br>35 $ft^2$ glass doors<br>1/2 shaded | No change |
| Infiltration | 120 cfm | 90 cfm + outside air cooling when $T_{AMB} < 75^oF$ |
| Thermostat | | |
| Heating | $70^oF$ | No change |
| Cooling | $75^oF$ | |
| Internal Loads | 0.75 watts/$ft^2$ | No change |

*Insulation: Rock wool with k = 0.31 Btu/hr $ft^2$/in.

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of adding insulation to the ceiling and walls and more control over outside air infiltration. Cooling loads have been tempered by using outside air directly when the ambient temperature is below the thermostat setting of 75°F.

Building 3, Office, Table 30

Building 3, a six-story office building, is an all-electric moderately energy-conserving structure. The energy-conserving package consists of insulation to lower wall conductance and double-pane, solar grey windows. Infiltration was reduced to one building volume per hour and the HVAC system cycled off during nonoccupied periods.

Building 4, Department Store

Building 4 is described in Section III. The building has no windows and the walls have good thermal characteristics. Buildings of this nature typically generate more internal heat than is required for heating, so coolers are used 12 months a year. Energy conservation is primarily associated with HVAC design and operation and effort is routinely expended to achieve lowest energy consumption. Therefore, Building 4 represents an energy-conserving design and no conservation package has been specified for this building.

b. Application of Energy-Conserving Packages

The following basic assumptions have been made concerning the current and future application of energy-conserving measures:

1) Existing all-electric buildings are energy-conserving.
2) Existing gas-heated buildings are non-energy-conserving.
3) All nonconserving existing single- and multiple-family dwellings will be retrofit with 6 inches of ceiling insulation.
4) All new buildings will be energy-conserving.

Table 30. Energy conservation building summary: Building 3, Office (6 stories)

| Basic Description: Bank and office building, 6 stories, 50,000 $ft^2$, structural steel with concrete facing, curtain walls | | |
|---|---|---|
| Thermal Variable | Thermal Model Value | |
| | Nonconserving Existing Building | Energy-Conserving Package for New Buildings |
| Insulation | | |
| Ceiling | Lightweight concrete | |
| Walls | Insulated single pane curtain wall (55% backed by 8 inches lightweight concrete) Overall conductance = 0.63 | Overall conductance = 0.19 |
| Floor | Concrete with partial basement | |
| Windows | Exterior wall 45% (solar grey), single pane glass | Solar grey, double pane glass |
| Infiltration | 1-1/2 volume/hr | 1 volume/hr |
| Thermostat | | |
| Heating | 70°F | 70°F cycled off at night |
| Cooling | 75°F | 75°F cycled off at night |
| Internal loads | 100 $ft^2$/person | No change |

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## B. HVAC SYSTEM MIX

A second important question for the description of buildings in the SCE territory is: "What kinds of HVAC systems exist in each building type by zone and how will these change between now and 2000? ".

Referring back to Fig. 3, we see that this is equivalent to asking three related questions:

1) What is the existing and projected mix of HVAC functions? (Step 4)
2) What is the existing and projected mix of HVAC systems which can provide each function? (Step 5)
3) What is the existing and projected mix of fuels used to fire each of the HVAC systems? (Step 6)

As with each of the other steps, these questions must be answered for existing and new systems and for each zone.

To answer the questions, the possible HVAC combinations for each building type were first defined. Table 31 gives the possible combinations for single-family buildings. Two basic types are possible: (1) water heating and space heating only and (2) water heating, space heating, and space cooling. For each of these types, the number of buildings, by zone, is given in Table 32. Within each of these types, there are various possible combinations of conventional fuels (gas or electric) which provide the HVAC function. These combinations, for each type of system, are given in Table 31 for single-family units.

Table 33 gives the assumed HVAC mix for each possible HVAC system combination for existing buildings and new buildings in 1975 and new buildings in 2000.

### 1. HVAC Function Mix (Step 4, Fig. 3)

In terms of HVAC functions, two major categories exist in the residential market because some buildings have two functions — water heating and space heating only — and others have three functions — water heating, space heating, and

Table 31. Market penetration possibilities for HVAC system mixes - single family buildings

| HVAC System Mix* | Market Penetration |
|---|---|
| <u>Water Heating and Space Heating Only*</u> | |
| E-E | - |
| E-G | - |
| G-E | Negligible |
| G-G | - |
| <u>Water Heating, Space Heating, and Space Cooling</u> | |
| E-E-E | - |
| E-E-G | Negligible |
| E-G-E | Negligible |
| E-G-G | Negligible |
| G-E-E | - |
| G-G-E | - |
| G-G-G | Negligible |
| G-HP-HP | - |

*Note: E = electric; G = gas; HP = heat pump. In this table (and subsequent tables as applicable) HVAC systems are identified by combinations of these symbols, used without column headings, and indicating functions in the following order: water heating, space heating, space cooling.

Table 32. 1975 HVAC system mix for single family units

| Zone | Water Heating and Space Heating Only | | Water Heating, Space Heating, and Space Cooling | | Total Single Family Units |
|---|---|---|---|---|---|
| | Number | % of Zone Total | Number | % of Zone Total | |
| I. Beach | 458, 878 | 85 | 80, 978 | 15 | 539, 857 |
| II. Inland Valley | 606, 112 | 65 | 326, 368 | 35 | 932, 480 |
| III. High Desert | 57, 527 | 50 | 57, 257 | 50 | 114, 515 |
| IV. Unassigned | | | | | 49, 078 |
| Total | | | | | 1, 635, 930 |

space cooling. This division is most apparent in the residential market, since nearly all commercial establishments have space cooling. In fact, the cooling loads on commercial buildings are much higher than either the space heating or water heating loads. Therefore, only the three-function combination will be considered for commercial buildings.

Tables 34 and 35 summarize the mix of HVAC functions for single-family and multiple-family buildings for each zone. This data was obtained from Table 28 using the assumption that the fraction of buildings with space cooling is approximately equal to the sum of the penetration rates of central space cooling and room space cooling.

2. HVAC Combinations (Step 5, Fig. 3)

The HVAC combinations are the various distinct systems used to provide one or more HVAC functions. For the single-family building, the HVAC combinations are relatively straightforward. If space cooling is used it is provided either by a gas absorption cooler or an electric compressor. Space heating can be provided by either a forced air system, a hydronic system, or a

Table 33 Market penetration of HVAC system mixes - all zones

| HVAC System Mix* | Existing Systems 1975 | New Systems | |
|---|---|---|---|
| | | 1975 | 2000 |
| Water Heating and Space Heating Only | 85% | 65% | 35% |
| E-E | (0.07) | (0.15) | (0.55) |
| E-G | (0.02) | (0.05) | (0.05) |
| G-E | - | - | - |
| G-G | (0.91) | (0.80) | (0.45) |
| Water Heating, Space Heating, and Space Cooling | 15% | 35% | 65% |
| E-E-E | (0.15) | (0.25) | (0.25) |
| E-E-G | - | - | - |
| E-G-E | - | - | - |
| E-G-G | - | - | - |
| E-HP-HP | (0.15) | (0.25) | (0.25) |
| G-E-E | (0.10) | (0.10) | (0.10) |
| G-E-G | - | - | - |
| G-G-E | (0.35) | (0.25) | (0.25) |
| G-G-G | (0.05) | (0.00) | (0.00) |
| G-HP-HP | (0.20) | (0.15) | (0.15) |

*See Note, Table 31

Table 34 1975 HVAC functions mix for single family units

| Zone | Water Heating and Space Heating only | | Water Heating, Space Heating, and Space Cooling | | Total Single Family Units |
|---|---|---|---|---|---|
| | Number | % of Zone Total | Number | % of Zone Total | |
| I. Beach | 399, 494 | 74 | 140, 363 | 26 | 539, 857 |
| II Inland Valley | 494, 214 | 53 | 438, 265 | 47 | 932, 480 |
| III. High Desert | 49, 241 | 43 | 65, 274 | 7 | 114, 515 |
| IV Unassigned | 24, 539 | 50 | 24, 539 | 50 | 49, 078 |
| Total | 967, 488 | 59 | 668, 414 | 41 | 1, 635, 930 |

Table 35. 1975 HVAC functions mix for multiple family units

| Zone | Water Heating and Space Heating only | | Water Heating, Space Heating, and Space Cooling | | Total Multiple Family Units |
|---|---|---|---|---|---|
| | Number | % of Zone Total | Number | % of Zone Total | |
| I. Beach | 204, 420 | 65 | 110, 073 | 35 | 314, 493 |
| II. Inland Valley | 217, 228 | 40 | 325, 841 | 60 | 543, 069 |
| III. High Desert | 6, 667 | 25 | 20, 000 | 75 | 26, 667 |
| IV. Unassigned | 2, 883 | 50 | 2, 883 | 50 | 5, 765 |
| Total | 431, 198 | 48 | 458, 797 | 52 | 890, 095 |

Table 36. Market saturation of HVAC systems in SCE territory (Source: SCE Market Saturation Survey)

| HVAC System | Beach | | | | Inland Valley | | | | High Desert | | | | All SCE | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Single Family Buildings | | Multiple Family Buildings | | Single Family Buildings | | Multiple Family Buildings | | Single Family Buildings | | Multiple Family Buildings | | Single Family Buildings | Multiple Family Buildings |
| | % | Growth Rate | % | Growth Rate | % | Growth Rate | % | Growth Rate | % | Growth Rate | % | Growth Rate | % | % |
| **Space Cooling** | | | | | | | | | | | | | | |
| Central | 10.4 | 1 7 | 10.6 | 2 0 | 18.4 | 2.3 | 19.9 | 3.0 | 31.8 | 3.5 | 42.7 | 5.2 | 17 2 | 14.6 |
| Room | 15.9 | 0 5 | 24.0 | 1.0 | 28.8 | 2.4 | 39.5 | 1.9 | 25.0 | 4.0 | 29.5 | 3.4 | 25.0 | 27.4 |
| Evaporative | 6 8 | 0.6 | 2 9 | 0.0 | 14.5 | 0.8 | 9.2 | -0.4 | 51 8 | 1 0 | 58.6 | 1.0 | 15.0 | 6.4 |
| **Space Heating** | | | | | | | | | | | | | | |
| Electric | 3.7 | -0 1 | 26 0 | 0.9 | 5.0 | 0.2 | 24.1 | 0 8 | 10.8 | -0 6 | 14.3 | -3.0 | 5.3 | 24.3 |
| Gas | 93.7 | 0.3 | 70 1 | -0.1 | 90.7 | -0.3 | 73.4 | -0 7 | 75.2 | 0.6 | 82.0 | 4.4 | 90.6 | 72.8 |
| **Water Heating** | | | | | | | | | | | | | | |
| Electric | 5.1 | 0 2 | 20.5 | 0.6 | 7.1 | 0 4 | 22.0 | 1.0 | 19.5 | -0.1 | 15.1 | -1.4 | 7.4 | 21.5 |
| Gas | 93 4 | 0 8 | 62.0 | -1.2 | 90.4 | 0 7 | 64.7 | -0.4 | 72.8 | 0.6 | 76.8 | 1.2 | 90.0 | 62.6 |

Note Penetration = division rate weighted by fraction of KWH sales which the division supplies to the weather zone

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radiant system. The mix of these systems (Table 37) is very closely tied to the fuel used to run them.

Multifamily building HVAC combinations are more complex than those for the single family building. There are five major types of cooling systems, five types of heating systems, and three possible arrangements of water heating. Most of these combinations can be fired by fossil fuel or electricity. Table 38 summarizes this data, which has been drawn from a variety of sources.

Table 37. HVAC combination mixes for single-family buildings

| HVAC Combination | Fuel | SCE Single-Family Building 1973 | |
|---|---|---|---|
| | | % of Total | % |
| SPACE COOLING | | | |
| Absorption | Gas | 100 | 5 |
| | Electric | 0 | 0 |
| Compressor | Gas | 0 | 0 |
| | Electric | 100 | 95 |
| SPACE HEATING | | | |
| Forced Air | Gas | 90 | 85 |
| | Electric | 10 | 5 |
| Hydronic | Gas | 95 | 5 |
| | Electric | 5 | |
| Radiant | Gas | 0 | 0 |
| | Electric | 100 | 5 |
| WATER HEATING | | | |
| Direct Fire | Gas | 90 | 90 |
| | Electric | 10 | 10 |

Table 38. HVAC system mixes for single and multiple family units

| HVAC Combination | Fuel | For Apts 1970: National(1) | For Apts 1970: West(3) | For Apts 1970: All SCE(2) | For Apts 1970: Western U.S.(3) | SCE Single Family(2) Growth Rate: 1970 | SCE Single Family(2) Growth Rate: 1973 | SCE Single Family(2) Growth Rate: New | SCE Multiple Family(2) Growth Rate: 1970 | SCE Multiple Family(2) Growth Rate: 1973 | SCE Multiple Family(2) Growth Rate: New |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **SPACE COOLING** | | | | | | | | | | | |
| Inc. all forced air | | 58 | 18 | | | | | | | | |
| Window | | 30 | 64 | | | | | | | | |
| Central chiller with air handler | | 8 | 0 | | | | | | | | |
| Heat pumps | | 2 | 5 | | | | | | | | |
| Central with fan coil | | 2 | 5 | | | | | | | | |
| Other | | 4 | 9 | | | | | | | | |
| | Gas | 8 | 5 | | | | | | | | |
| | Electric | 92 | 95 | | | | | | | | |
| Room (window) | | | | 19.6 | 25.4 | 18.3 | 25.0 | 170%* | 24.0 | 27.4 | 51% |
| Central | | | | 9.7 | 16.9 | 10.4 | 17.2 | 164%* | 7.3 | 14.6 | 60% |
| **SPACE HEATING** | | | | | | | | | | | |
| Individual forced air | | 58 | 33 | | | | | | | | |
| Central baseboard | | 20 | 13 | | | | | | | | |
| Electric resistance | | 11 | 45 | | | | | | | | |
| Central fan coil | | 3 | 3 | | | | | | | | |
| Heat pump | | 3 | 5 | | | | | | | | |
| Other | | 8 | 16 | | | | | | | | |
| | Gas | 68 | 48 | 85.8 | 86.5 | 89.4 | 90.6 | 117%* | 74.7 | 72.8 | 60% |
| | Electric | 33 | 61 | 9.3 | 9.5 | 5.4 | 5.3 | 3% | 22.3 | 24.3 | 38% |
| **WATER HEATING** | | | | | | | | | | | |
| Central | | 24 | 23 | | | | | | | | |
| Individual | | 45 | 48 | | | | | | | | |
| Distributed | | 34 | 29 | | | | | | | | |
| | Gas | 59 | 58 | 82.4 | 83.8 | 87.7 | 90.0 | 140%* | 65.6 | 62.6 | 42% |
| | Electric | 35 | 42 | 9.4 | 10.5 | 6.5 | | 25% | 18.8 | 21.5 | 40% |

*Percentages greater than 100% indicate retrofit.

(1) National Association of Home Builders Research Foundation, "Low Rise Apartment Survey," 1972.
(2) SCE Residential Electrical Applicance Survey 1973
(3) Intertechnology Report on Energy Use in Buildings

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3. HVAC Fuel Mix (Step 6, Fig. 3)

The HVAC fuel mix for the residential market is shown in Table 39. It was compiled from the 1973 SCE Residential Electric Appliance Saturation Survey. For comparison, estimates for areas other than the SCE territory are also shown.

To develop the data needed for input to the market penetration program (see Study 4), the HVAC system mix data must be presented for each type of building (e.g., single family) for each of the three weather zones for existing buildings in 1975 and new buildings in 1975. The most convenient way of doing this is to combine HVAC function and fuel data into one table. Table 40 gives the possible combinations of function and fuel. Tables of similar format will be presented, one each for each type of building: single-family, multiple-family, or commercial office building.

Penetration for each function combination ("water heating and space heating only" or "water heating, space heating, and space cooling") will be given in each table for each of the three zones. Penetrations in 1975 were determined from the 1973 SCE electric appliance market saturation survey. (The 1973 rates were projected to 1975 using the average annual growth rate from 1970 to 1973.) The existing penetration rate for each zone was determined either from the rates given by district or division. The SCE districts were assigned to each weather zone as were each of the divisions (see Section V). Tables 41 and 42 show the assignment of each division and district to the weather zones. The penetration rates for each zone were computed from the division penetrations by weighting the division average penetration by the fraction of KWH sales of the weather zone supplied by that division. Table 41 gives the fractional weights used to compute the penetration in each zone.

Tables 43 and 44 summarize the penetration rates by division for each weather zone for 1970 and 1973. The 3-year average growth rates are also given in these tables. Table 36 gives the penetration rates for existing HVAC systems for each zone for single-family and multiple-family buildings. Also given is the average 3-year growth rate.

Table 39. Residential HVAC fuel mix

| Fuel | SCE Territory(1), 1973 | | | Other Areas(2) | |
|---|---|---|---|---|---|
| | Single-Family | Multiple-Family | Totals | Western U.S. 1970 | California 1970 |
| **SPACE COOLING** | | | | | |
| Gas | 4.0 | -- | 4.0 | 5.0 | 3.6 |
| Electric (room) | 25.0 | 27.4 | 25.4 | 19.6 | 36.7 |
| Electric (central) | 17.2 | 14.6 | 16.9 | 9.7 | 12.9 |
| **SPACE HEATING** | | | | | |
| Gas | 90.6 | 72.8 | 86.5 | 85.8 | 96.4 |
| Electric | 5.3 | 24.3 | 9.5 | 9.3 | 3.6 |
| **WATER HEATING** | | | | | |
| Gas | 90.0 | 62.6 | 83.4 | 82.4 | 70.4 |
| Electric | 7.4 | 21.5 | 10.5 | 9.4 | 29.6 |

(1) From SCE Market Saturation Survey.
(2) From S2EGO residential energy use report.

Table 40. Market penetration possibilities for HVAC system mixes for a given type of building and a particular zone

| HVAC System Mix* | Existing Systems 1975 | New Systems | |
|---|---|---|---|
| | | 1975 | 2000 |
| Water Heating and Space Heating Only | | | |
| E-E | - | - | - |
| E-G | - | - | - |
| G-E | - | - | - |
| G-G | - | - | - |
| Water Heating, Space Heating, and Space Cooling | | | |
| E-E-E | - | - | - |
| E-E-G | - | - | - |
| E-G-E | - | - | - |
| E-G-G | - | - | - |
| E-HP-HP | - | - | - |
| G-E-E | - | - | - |
| G-G-E | - | - | - |
| G-G-G | - | - | - |
| G-HP-HP | - | - | - |

*See Note, Table 31.

Table 41. SCE weather zone assignments, market penetration, and KWH sales – by division

(a) SCE division/district assignment to weather zones

| SCE Division | Division Weather Zone Assign. | Division District Nos. | District Weather Zone Assign. |
|---|---|---|---|
| Central | II | 22, 25, 26, 27, 28, 34 | II |
| South-eastern | II | 29<br>33<br>43, 47, 48 | II<br>I<br>II |
| Western | I | 35, 37, 39, 42, 49<br>59 | I<br>II |
| Eastern | II | 30, 31<br>40<br>72<br>73<br>76, 77, 78, 79<br>82, 84, 85, 86, 87 | II<br>IV<br>III<br>IV<br>II<br>IV |
| Southern | I | 24<br>32<br>41, 44, 46 | I<br>II<br>I |
| Northern | III | 36, 50, 51, 52, 53, 54 | III |

Table 41. (Contd)

(b) Market penetration (%) of HVAC functions – by division

| SCE Division | HVAC Function | | Single Family | | | Multiple Family | | |
|---|---|---|---|---|---|---|---|---|
| | | | 1970 | 1973 | 3-Yr Ave Growth | 1970 | 1973 | 3-Yr Ave Growth |
| Central | Space Cooling | C | 12 1 | 19.3 | 2.4 | 9.1 | 19.6 | 3 5 |
| | | R | 32.5 | 41.4 | 2 9 | 45 9 | 49.3 | 1.1 |
| | | EV | 9 8 | 12.6 | 0 9 | 8.5 | 8.2 | -0.8 |
| | Space Heating | E | 3.0 | 2.8 | -0.1 | 13.1 | 15 6 | 0.8 |
| | | G | 93.5 | 94.8 | 0 4 | 84.3 | 81.7 | -0.9 |
| | Water Heating | E | 3.2 | 3.7 | 0.2 | 11 3 | 13.2 | 0.6 |
| | | G | 92 6 | 95.0 | 0.8 | 73 8 | 72.7 | -0.4 |
| South-eastern | Space Cooling | C | 7.2 | 13.6 | 2.1 | 8.3 | 15 6 | 2 4 |
| | | R | 17 1 | 22.9 | 1.9 | 31.7 | 40 4 | 2.9 |
| | | EV | 4 3 | 6.1 | 0.6 | 4 8 | 5.0 | 0.1 |
| | Space Heating | E | 3.3 | 3.9 | 0.2 | 33 9 | 37.1 | 1 1 |
| | | G | 95 2 | 93.8 | -1.4 | 63.5 | 60.8 | -0.9 |
| | Water Heating | E | 4.0 | 5.5 | 0.5 | 30.9 | 34.0 | 1.3 |
| | | G | 92.6 | 93.5 | 0.3 | 55.6 | 51.6 | -1.3 |

Table 41 (Contd)

(b) Market penetration (%) of HVAC functions — by division (Contd)

| SCE Division | HVAC Function | | Single Family 1970 | Single Family 1973 | Single Family 3-Yr Ave Growth | Multiple Family 1970 | Multiple Family 1973 | Multiple Family 3-Yr Ave Growth |
|---|---|---|---|---|---|---|---|---|
| Western | Space Cooling | C | 9.0 | 15.1 | 2.0 | 7.4 | 13.4 | 2.0 |
| | | R | 7.9 | 10.3 | 0 8 | 13.8 | 12.3 | -0 5 |
| | | EV | 8.4 | 10.1 | 0.6 | 2.9 | 2.6 | -0.1 |
| | Space Heating | E | 6.2 | 5.9 | -0.1 | 20.5 | 22.6 | 0.7 |
| | | G | 89.1 | 90.0 | 0.6 | 75 4 | 72.4 | -1.0 |
| | Water Heating | E | 7 7 | 8.0 | 0.1 | 15.2 | 16.6 | 0.5 |
| | | G | 86.9 | 89.8 | 1.0 | 66.0 | 58.9 | -2 4 |
| Eastern | Space Cooling | C | 22.2 | 31.9 | 3.2 | 24.0 | 36 3 | 4.1 |
| | | R | 16.8 | 29.3 | 4.2 | 35.7 | 43 9 | 2.7 |
| | | EV | 34.2 | 36.8 | 0 9 | 27 3 | 24.2 | -1.0 |
| | Space Heating | E | 8.9 | 11.2 | 0 8 | 14.4 | 16.6 | 0.7 |
| | | G | 76 6 | 76.8 | 0.0 | 81 8 | 80.8 | -0.3 |
| | Water Heating | E | 14.4 | 16 8 | 0.8 | 14.0 | 16 8 | 0.9 |
| | | G | 72.1 | 75.8 | 1.0 | 71.4 | 74.6 | 1.1 |

Table 41. (Contd)

(b) Market penetration (%) of HVAC functions — by division (Contd)

| SCE Division | HVAC Function | | Single Family 1970 | Single Family 1973 | Single Family 3-Yr Ave Growth | Multiple Family 1970 | Multiple Family 1973 | Multiple Family 3-Yr Ave Growth |
|---|---|---|---|---|---|---|---|---|
| Southern | Space Cooling | C | 3.1 | 7.2 | 1.4 | 1.3 | 6.3 | 1.7 |
| | | R | 17.0 | 17.2 | 0.1 | 11 6 | 11.6 | - |
| | | EV | 3.5 | 5.3 | 0.6 | 2.7 | 4.2 | 0.5 |
| | Space Heating | E | 3.2 | 2.5 | -0.2 | 21 2 | 22.0 | 0.3 |
| | | G | 94.1 | 95.7 | 0.5 | 76.7 | 75.4 | -0.3 |
| | Water Heating | E | 2.8 | 3.5 | 0.2 | 17.0 | 20.0 | 1.0 |
| | | G | 92.9 | 95.2 | - | 66.8 | 65 1 | -0.6 |
| Northern | Space Cooling | C | 21.1 | 31 7 | 3.5 | 26.5 | 42.7 | 5.4 |
| | | R | 10.9 | 23.0 | 4.0 | 17.6 | 28.1 | 3.5 |
| | | EV | 50.4 | 53.5 | 1.0 | 40.2 | 44 7 | 1.5 |
| | Space Heating | E | 12.6 | 10.5 | -0.7 | 22.5 | 12.6 | -3.3 |
| | | G | 70.8 | 75 1 | - | 70.6 | 84.5 | 4.6 |
| | Water Heating | E | 20.4 | 19.7 | -0.2 | 19.6 | 14.6 | -1.7 |
| | | G | 68.2 | 72.5 | - | 73.5 | 77 0 | 1 2 |

Table 41. (Contd)

(c) SCE KWH sales, 1975, by division and weather zone

| Division | Fraction of Total SCE KWH Sales | KWH (x $10^3$) Sales in Zone Included in Division | Fraction of KWH Sales by Zone | | | |
|---|---|---|---|---|---|---|
| | | | I | II | III | IV |
| Central | 0.17 | II - 9730 | 0.0 | 0.30 | 0 0 | 0.0 |
| South-eastern | 0.24 | I - 2,510<br>II - 11,350<br>13,860 | 0 13 | 0.34 | 0 0 | 0.0 |
| Western | 0.26 | I - 5,995<br>II - 730<br>6,725 | 0.30 | 0 02 | 0.0 | 0.0 |
| Eastern | 0.16 | II - 6,980<br>III - 340<br>IV - 2,330<br>9,650 | 0 00 | | 0 10 | 0 0 |
| Southern | 0.05 | I - 11,260<br>II - 4,190<br>15,450 | 0.57 | 0.13 | 0 0 | 0.0 |
| Northern | 0.11 | III - 3,140 | 0 0 | 0.0 | 0.90 | 0.0 |

Table 42. SCE KWH sales by district and division

(a) SCE KWH sales - 1975 - by district

| SCE District | Area Name | SCE Division | Weather Zone | KWH x $10^6$ |
|---|---|---|---|---|
| 22 | Alhambra | C | II | 1,550 |
| 24 | Vernon | S | I | 1,500 |
| 25 | Montebello | C | II | 1,810 |
| 26 | Covina | C | II | 2,550 |
| 27 | Monrovia | C | II | 1,330 |
| 28 | Pomona | C | II | 1,210 |
| 29 | Santa Ana | SE | II | 4,250 |
| 30 | San Bernadino | E | II | 3,100 |
| 31 | Redlands | E | II | 610 |
| 32 | Compton | S | II | 4,190 |
| 33 | Huntington Beach | SE | I | 2,510 |
| 34 | Ontario | C | II, IV | 1,290 |
| 35 | Thousand Oaks | W | I | 1,040 |
| 36 | Lancaster | N | III | 1,170 |
| 39 | Ventura | W | I | 2,050 |
| 40 | Arrowhead | E | IV | 90 |
| 41 | Inglewood | S | I | 2,710 |
| 42 | Santa Monica | W | I | 2,020 |
| 43 | El Toro | SE | II | 1,050 |
| 44 | Redondo Beach | S | I | 3,160 |
| 46 | Long Beach | S | I | 3,890 |
| 47 | Whittier | SE | II | 3,060 |
| 48 | Fullerton | SE | II | 2,990 |
| 49 | Santa Barbara | W | I | 880 |
| 50 | Visalia | N | III | 560 |
| 51 | Tulare | N | III | 300 |
| 52 | Porterville | N | III | 480 |
| 53 | Delano | N | III | 430 |
| 54 | Hanford | N | III | 200 |
| 59 | San Fernando | W | II | 730 |
| 61 | Catalina | S | IV | 10 |
| 72 | Barstow | E | III | 340 |
| 73 | Victorville | E | IV | 710 |
| 76 | Corona | E | II | 1,650 |
| 77 | Perris | E | II | 440 |
| 78 | Hemet | E | II | 350 |
| 79 | Palm Springs | E | II | 830 |
| 82 | Desert Electric | E | IV | - |
| 84 | Twentynine Palms | E | IV | 160 |
| 85 | Bishop | E | IV | 310 |
| 86 | Ridgecrest | E | IV | 590 |
| 87 | Blythe | E | IV | 470 |

Table 42. (Contd)

(b) SCE KWH sales - 1975, 1985 - by division (Contd)

| SCE Division | Sales (KWH x$10^6$) | | Sales Growth Rates (%) | | | |
|---|---|---|---|---|---|---|
| | 1975 | 1985 | 1965-70 | 1970-75 | 1975-80 | 1980-85 |
| Central | 9, 730 (0 17) | 15, 750 (0. 17) | 8. 2 | 5. 8 | 4. 9 | 5. 0 |
| South-eastern | 13, 860 (0. 24) | 25, 270 (0. 27) | 10. 8 | 7. 5 | 5. 8 | 6 4 |
| Western | 6, 720 (0. 11) | 10, 820 (0 12) | 9. 4 | 4. 0 | 4. 5 | 5. 2 |
| Eastern | 9, 650 (0. 17) | 15, 060 (0. 16) | 7. 7 | 6. 1 | 4. 4 | 4 7 |
| Southern | 15, 450 (0. 26) | 22, 090 (0. 24) | 8. 0 | 3. 8 | 3. 6 | 3·. 7 |
| Northern | 3, 190 (0. 05) | 4, 220 (0. 05) | 7. 1 | 4. 0 | 2. 8 | 3. 2 |
| Totals | 54, 450 | 93, 210 | | | | |

Table 43. Single family market penetration rates for HVAC systems in the BASE weather zones (% penetration)

| Zone | HVAC Function | | 1970 District SE | 1970 District W | 1970 District S | 1973 District SE | 1973 District W | 1973 District S | Growth Rate District SE | Growth Rate District W | Growth Rate District S |
|---|---|---|---|---|---|---|---|---|---|---|---|
| I. Beach | Space Cooling | C | 7.2 | 9.0 | 3.1 | 13.6 | 15 1 | 7.2 | 2.1 | 2 0 | 1.4 |
| | | R | 17 1 | 7 9 | 17.0 | 22.6 | 10 3 | 17.2 | 1.9 | 0.8 | 0.1 |
| | | EV | 4.3 | 8 4 | 3.5 | 6 1 | 10 1 | 5.3 | 0.6 | 0.6 | 0 6 |
| | Space Heating | E | 3.3 | 6.2 | 3.2 | 3.9 | 5.9 | 2.5 | 0.2 | -0.1 | -0.2 |
| | | G | 95.2 | 89.1 | 94.1 | 93.8 | 90.0 | 95.7 | -1.4 | 0.6 | |
| | Water Heating | E | 4.0 | 7.7 | 2.8 | 5 5 | 8 0 | 3.5 | 0 5 | 0.1 | 0.2 |
| | | G | 92.6 | 86.9 | 92.9 | 93.5 | 89.8 | 95.2 | 0.3 | 1 0 | |

| Zone | HVAC Function | | 1970 C | 1970 E | 1973 C | 1973 E | Growth Rate C | Growth Rate E |
|---|---|---|---|---|---|---|---|---|
| II. Inland Valleys | Space Cooling | C | 12.1 | 22.2 | 19.3 | 31.9 | 2.4 | 3.2 |
| | | R | 32.5 | 16.8 | 41.4 | 29.3 | 2.9 | 4 2 |
| | | EV | 9.8 | 34.2 | 12.6 | 36.8 | 0 9 | 0.9 |
| | Space Heating | E | 3.0 | 8.9 | 2.8 | 11.2 | -0.1 | 0.8 |
| | | G | 93.5 | 76.6 | 94 8 | 76.8 | 0 4 | 0.0 |
| | Water Heating | E | 3 2 | 14 4 | 3 7 | 16.8 | 0.2 | 0.8 |
| | | G | 92 6 | 72 1 | 95 0 | 75.8 | 0.8 | 1.0 |

| Zone | HVAC Function | | 1970 N | 1973 N | Growth Rate N |
|---|---|---|---|---|---|
| III. High Desert | Space Cooling | C | 21.1 | 31.7 | 3.5 |
| | | R | 10.9 | 23.0 | 4.0 |
| | | EV | 50.4 | 53 5 | 1.0 |
| | Space Heating | E | 12.6 | 10.5 | -0.7 |
| | | G | 70.8 | 75.1 | |
| | Water Heating | E | 20.4 | 19.7 | -0 2 |
| | | G | 68.2 | 72 5 | |

All SCE Territory

| HVAC Function | | 1970 SF Rate | 1973 SF Rate | 1973 SF No. Households | 1973 All (SF + MF) Rate | 1973 All (SF + MF) No. Households |
|---|---|---|---|---|---|---|
| Space Cooling | C | 10 4 | 17.2 | 280,800 | 16.9 | 394,200 |
| | R | 18.3 | 25.0 | 408,100 | 25.4 | 592,400 |
| | EV | 12.7 | 15.0 | 244,900 | 13.5 | 314,900 |
| Space Heating | E | 5.4 | 5.3 | 86,500 | 9.5 | 221,600 |
| | G | 89 4 | 90 6 | 1,479,000 | 86 5 | 2,017,600 |
| Water Heating | E | 6 5 | 7.4 | 120,800 | 10 5 | 2,249 |
| | G | 87 7 | 90.0 | 1,469,200 | 83.8 | 1,954,600 |

NOTES

C = central cooling, R = room space coolers, EV = evaporative coolers, E = electric, G = gas, SF = Single Family, MF = Multiple Family

SCE Divisions/Districts

C = Central Division (Districts 22, 25, 26, 27, 28, 32)
SE = Southeastern Division (Districts 29, 33, 43, 47, 48)
W = Western Division (Districts 35, 37, 39, 42, 49, 59)
E = Eastern Division (Districts 30, 31, 40, 72, 73, 76, 77, 78, 79, 82, 84, 85, 86, 87)
S = Southern Division (Districts 24, 32, 41, 44, 46)
N = Northern Division (Districts 36, 50, 51, 52, 53, 54)

Table 44. Multiple family market penetration rates for HVAC systems in the BASE weather zones (% penetration)

| Zone | HVAC Function | | 1970 District SE | 1970 District W | 1970 District S | 1973 District SE | 1973 District W | 1973 District S | Growth Rate District SE | Growth Rate District W | Growth Rate District S |
|---|---|---|---|---|---|---|---|---|---|---|---|
| I. Beach | Space Cooling | C | 8 3 | 7 4 | 1 3 | 15 6 | 13 4 | 6.3 | 2 4 | 2 0 | 1.7 |
| | | R | 31 7 | 13 8 | 11 6 | 40 4 | 12 3 | 11 6 | 2.9 | -0.5 | - |
| | | EV | 4.8 | 2 9 | 2 7 | 5.0 | 2 6 | 4.2 | 0.1 | -0.1 | 0.5 |
| | Space Heating | E | 33.9 | 20.5 | 21 2 | 37 1 | 22.6 | 22.0 | 1.1 | 0.7 | 0.3 |
| | | G | 63.5 | 75.4 | 76 3 | 60.8 | 72.4 | 75.4 | -0.9 | -1.0 | -0.3 |
| | Water Heating | E | 30.9 | 15.2 | 17.0 | 34 0 | 16 2 | 20.0 | 1.3 | 0 3 | 1.0 |
| | | G | 55 6 | 66 0 | 66 8 | 51.6 | 58 9 | 65 1 | -1.3 | -2.4 | -0 6 |

| Zone | HVAC Function | | 1970 C | 1970 E | 1973 C | 1973 E | Growth Rate C | Growth Rate E |
|---|---|---|---|---|---|---|---|---|
| II. Inland Valleys | Space Cooling | C | 9 1 | 24.0 | 19 6 | 36 3 | 3.5 | 4 1 |
| | | R | 45.9 | 35 7 | 49.3 | 43 9 | 1 1 | 2.7 |
| | | EV | 8.5 | 27.3 | 6.2 | 24 2 | -0 8 | -1 0 |
| | Space Heating | E | 13 1 | 14 4 | 15 6 | 16 6 | 0 8 | 0 7 |
| | | G | 84.3 | 81.8 | 81.7 | 80 8 | -0 9 | -0 3 |
| | Water Heating | E | 11.3 | 14.0 | 13.2 | 16 8 | 0 6 | 0 9 |
| | | G | 73.8 | 71.4 | 72.7 | 74 6 | -0 4 | 1 1 |

| Zone | HVAC Function | | 1970 N | 1973 N | Growth Rate N |
|---|---|---|---|---|---|
| III. High Desert | Space Cooling | C | 26.5 | 42 7 | 5.4 |
| | | R | 17 6 | 28.1 | 3.5 |
| | | EV | 40.2 | 44.7 | 1 5 |
| | Space Heating | E | 22.5 | 12.6 | -3 3 |
| | | G | 70.6 | 84.5 | 4 6 |
| | Water Heating | E | 19 6 | 14 6 | -1 7 |
| | | G | 73 5 | 77 0 | 1 2 |

All SCE Territory

| HVAC Function | | 1970 MF Rate | 1973 MF Rate | 1973 MF No Households | 1973 All (SF + MF) Rate | 1973 All (SF + MF) No Households |
|---|---|---|---|---|---|---|
| Space Cooling | C | 7 3 | 14 6 | 91,100 | 16 9 | 394,200 |
| | R | 24.0 | 27 4 | 171,600 | 25 4 | 592,400 |
| | EV | 6 7 | 6 4 | 39,900 | 13.5 | 314,900 |
| Space Heating | E | 22 3 | 24.3 | 151,700 | 9 5 | 221,600 |
| | G | 74.7 | 72 8 | 454,400 | 86 5 | 2,017,600 |
| Water Heating | E | 18 8 | 21 5 | 134,200 | 10 5 | 244,900 |
| | G | 65.6 | 62 6 | 390,700 | 83 8 | 1,954,600 |

NOTES

C = central cooling, R = room space coolers, EV = evaporative coolers, E = electric, G = gas, SF = Single Family, MF = Multiple Family.

SCE Divisions/Districts

C = Central Division (Districts 22, 25, 26, 27, 28, 32)
SE = Southeastern Division (Districts 29, 33, 43, 47, 48)
W = Western Division (Districts 35, 37, 39, 42, 49, 59)
E = Eastern Division (Districts 30, 31, 40, 72, 73, 76, 77, 78, 79, 82, 84, 85, 86, 87)
S = Southern Division (Districts 24, 32, 41, 44, 46)
N = Northern Division (Districts 36, 50, 51, 52, 53, 54)

The data in Table 36 was then projected to 1975 using the 3-year average growth rates from 1970 to 1973. Table 45 gives the 1975 penetration rates for existing single and multiple family buildings for each weather zone.

Although the data from the SCE market survey do not give the particular fuel variation for each HVAC system combination the fuel use for HVAC system combinations can be estimated using the data from Table 45. The percentage of existing buildings with three functions (water heating, space heating, and space cooling) is approximately equal to the sum of the penetration of room space coolers and central space coolers. (This is not strictly true since some units have both systems, as reported in the SCE survey.) The percentage of buildings with two functions (water heating and space heating only) is 100 minus the percentage for the three functions. The penetration rates for two-function and three-function systems for each zone are shown in Table 46.

The mix of HVAC fuels for the two-function combination was derived from Table 45 as follows: (1) the penetration rates of the G-E combination (gas-water-heating/electric-space-heating) are assumed to be negligible, since one main advantage of electric space heating is the elimination of a gas line and, if electric space heating is used, it is likely that electric water heating will be used. (2) The penetration rate for all-electric (E-E) is (following the reasoning in (1)) equal to the rate of electric space heating given in Table 45 (3) The penetration rate of the E-G combination (electric-water-heating/gas-space-heating) equals the rate of E-E minus the penetration rate of electric water heaters from Table 45. (4) The all-gas systems (G-G) are given by 100 minus the other three.

The mix for the three-function combination is given as follows: (1) Because the market penetration of gas space cooling is small (4-5%) and occurs only in all-gas buildings, the penetration rate for G-G-G is estimated to equal this rate, i.e., 5%. Furthermore, there are no buildings with gas space cooling which are not all-gas. This makes E-E-G, E-G-G and G-E-G equal to zero penetration. (2) The all-electric buildings (E-E-E) penetration equals the penetration of electric water heating just for two-function buildings. (3) The penetration of heat pump systems is equal to the penetration rate of room space coolers, 50% E-HP-HP and 50% G-HP-HP. (4) The rate of G-E-E is small,

Table 45. 1975 HVAC system mix in BASE weather zones for single- and multiple-family buildings (Source: SCE 1973 Residential Electric Appliance Saturation Survey, Survey Research Division, SCE, Oct. 1973)

| HVAC System | Beach | | | | Inland Valley | | | | High Desert | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Single-Family Buildings | | Multiple-Family Buildings | | Single-Family Buildings | | Multiple-Family Buildings | | Single-Family Buildings | | Multiple-Family Buildings | |
| | % of Existing | Ave.* % Growth per Yr | % of Existing | Ave % Growth per Yr | % of Existing | Ave % Growth per Yr | % of Existing | Ave. % Growth per Yr | % of Existing | Ave. % Growth per Yr | % of Existing | Ave % Growth per Yr |
| Space Cooling | | | | | | | | | | | | |
| Central | 15 6 | 1.7 | 14.6 | 2 0 | 23.0 | 2 3 | 25.9 | 3 0 | 38 8 | 3.5 | 52.9 | 5 2 |
| Room | 17 4 | 0 5 | 26 0 | 1 0 | 33.6 | 2 4 | 43 3 | 1.9 | 33 0 | 4.0 | 36.3 | 3.4 |
| Evaporative | 8.6 | 0.6 | 2.9 | 0 0 | 16.1 | 0 8 | 8.4 | -0.4 | 53 8 | 1 0 | 40.6 | 1.0 |
| Space Heating | | | | | | | | | | | | |
| Electric | 3 5 | -0 1 | 27.8 | 0 9 | 5.4 | 0.2 | 25.7 | 0 8 | 9.2 | -0.6 | 8.3 | -3 0 |
| Gas | 94.3 | 0.3 | 69.9 | -0.1 | 90.1 | -0 3 | 72.0 | -0.7 | 76 4 | 0.6 | 90 8 | 4.4 |
| Water Heating | | | | | | | | | | | | |
| Electric | 5 5 | 0 2 | 21 7 | 0.6 | 7 9 | 0 4 | 24.0 | 1 0 | 19 7 | 0.1 | 13.7 | -1.4 |
| Gas | 95.0 | 0.8 | 59.6 | -1.2 | 89 0 | 0.7 | 63.9 | -0 4 | 74.0 | 0.6 | 78.0 | 1.2 |

*Average growth rate per year from 1970 to 1973 saturation levels.

Table 46. Market penetration of HVAC system mixes - single family buildings

| HVAC System Mix* | Existing Systems 1975 | | | New Systems 1975 | | | New Systems 2000 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Beach | Inland Valley | High Desert | Beach | Inland Valley | High Desert | Beach | Inland Valley | High Desert |
| Water Heating and Space Heating Only | 74% | 53% | 43% | 70% | 70% | 60% | 30% | 30% | 20% |
| E-E | (0.04) | (0.05) | (0 13) | (0 15) | (0.10) | (0.20) | (0 30) | (0 25) | (0.35) |
| E-G | (0 01) | (0 02) | (0 10) | (0.05) | (0.05) | (0 10) | (0.05) | (0 05) | (0 10) |
| G-E | (0.00) | (0 00) | (0 00) | (0 00) | (0.00) | (0.00) | | | |
| G-G | (0 95) | (0 93) | (0.77) | (0 80) | (0 85) | (0.70) | (0 65) | (0 70) | (0.55) |
| Water Heating, Space Heating, and Space** Cooling | 26% | 47% | 57% | 30% | 30% | 40% | 70% | 70% | 80% |
| E-E-E | (0.15) | (0 10) | (0.25) | (0.10) | (0 10) | (0 10) | (0.25) | (0 25) | (0 25) |
| E-E-G | (0 00) | (0 00) | (0 00) | (0 00) | (0.00) | (0 00) | (0 00) | (0 00) | (0 00) |
| E-G-E | (0.25) | (0.27) | (0.15) | (0.25) | (0 25) | (0.25) | (0 10) | (0.10) | (0 10) |
| E-G-G | (0.00) | (0 00) | (0.00) | (0.00) | (0.00) | (0 00) | (0.00) | (0 00) | (0 00) |
| E-HP-HP** | (0 13) | (0 15) | (0 15) | (0.15) | (0 15) | (0 15) | (0.20) | (0 20) | (0.20) |
| G-E-E | (0 09) | (0 10) | (0.10) | (0.10) | (0.10) | (0 10) | (0.15) | (0.15) | (0.15) |
| G-E-G | (0 00) | (0.00) | (0.00) | (0 00) | (0.00) | (0 00) | (0 00) | (0 00) | (0 00) |
| G-G-E | (0.20) | (0 18) | (0.15) | (0.25) | (0 25) | (0.25) | (0 10) | (0.10) | (0.10) |
| G-G-G | (0.05) | (0 05) | (0.05) | (0 00) | (0 00) | (0 00) | (0.00) | (0.00) | (0.00) |
| G-HP-HP** | (0 12) | (0 15) | (0.15) | (0.15) | (0.15) | (0 15) | (0 20) | (0 20) | (0.20) |

*See Note, Table 23

**Includes room space coolers listed as heat pumps. These equal 16%, 29%, and 25%, respectively, for the Beach, Inland Valley, and High Desert Zones for single family buildings.

estimated to be about 10%. The rate of E-G-E and G-G-E are nearly equal and are given by the rate of central space cooling. This logic is summarized in Table 47 Table 46 summarizes the penetration rates for existing 1975 single-family units; Table 48 summarizes the same data for multiple family buildings.

Using the market saturation data for the SCE territory, it is possible to estimate the percentage of new buildings which have the different types of HVAC system functions. Unfortunately, the data has two ambiguities in it. First, small statistical errors (even at the 5% confidence level) can produce wide variations in the estimate. Second, the data aggregates new installations and retrofit installations together and gives only the overall average saturation for a given HVAC appliance. Although this is not a problem for multiple family units, where retrofitting does not occur in significant proportion (except for the possible exception of retrofitting with room air conditioners), it is a major problem with single-family dwelling units where a large number of space coolers have been retrofit. Even so, the following method for estimating the fraction of new buildings with each of the possible HVAC appliances is useful from a heuristic point of view.

The estimate can be made as follows:

$K$ = 3, the number of years between saturation estimates.

$f^{ij}_{1973}$ = the fraction of 1973 buildings of a given class and with a particular HVAC appliance j.

$f^{ij}_{1970}$ = the fraction of 1970 buildings as above.

$f^{ij}_{N}$ = the average fractional building rate per year of new buildings of a given class with a particular HVAC appliance.

$E^{ij}_{1970}$ = the number of existing buildings of a given class j in 1970.

If we assume that the building rate of new buildings is approximately constant for the years 1970 to 1973, then we can calculate $f_N$ which will be the estimate we are looking for. We have the following relationship:

$$f^{ij}_{1973}\,(E^{i}_{1970} + kN^{i}) = f^{ij}_{1970}\,E^{i}_{1970} + kN^{i} f^{ij}_{N}$$

Table 47. Logic used for estimating market penetration of various HVAC system mixes

| |
|---|
| WH + SH Only = 100 - %WH + SH + C<br><br>E-E = %E SH<br>E-G = %E SH - %E WH<br>G-E = 0<br>G-G = 100 - %E-E - %E-G |
| WH + SH + SC = %R + %C<br><br>E-E-E = %E SH<br>E-E-G = 0<br>E-G-E = 100 - others<br>E-G-G = 0<br>E-HP-HP = 1/2 %R<br>G-E-E = Small = 0<br>G-E-G = 0<br>G-G-E = %C<br>G-G-G = Small = 0<br>G-HP-HP = 1/2 %R |
| WH = water heating; SH = space heating; SC = space cooling; E = electric; G= gas; R = room space cooling; C = central space cooling; HP = heat pump |

C-2

Table 48. Market penetration of HVAC system mixes - multiple family buildings

| HVAC System Mix* | Existing Systems 1975 | | | New Systems 1975 | | | New Systems 2000 | | |
|---|---|---|---|---|---|---|---|---|---|
| | Beach | Inland Valley | High Desert | Beach | Inland Valley | High Desert | Beach | Inland Valley | High Desert |
| Water Heating and Space Heating Only | 65% | 40% | 25% | 50% | 50% | 15% | 30% | 30% | 5% |
| E-E | (0 26) | (0 24) | (0.14) | | | | | | |
| E-G | (0 06) | (0 03) | (0.02) | | | | | | |
| G-E | (0 00) | (0 00) | (0 00) | | | | | | |
| G-G | (0.68) | (0.73) | (0.84) | | | | | | |
| Water Heating, Space Heating, and Space Cooling** | 35% | 60% | 75% | 50% | 50% | 85% | 70% | 70% | 95% |
| E-E-E | (0.26) | (0 24) | (0.14) | (0 20) | (0 20) | (0.20) | (0.20) | (0.20) | (0 20) |
| E-E-G | (0.00) | (0 00) | (0 00) | (0 00) | (0 00) | (0.00) | (0 00) | (0 00) | (0 00) |
| E-G-E | (0 15) | (0 16) | (0.14) | (0 20) | (0 20) | (0 20) | (0.20) | (0 20) | (0 20) |
| E-G-F | (0 00) | (0.00) | (0 00) | (0 00) | (0 00) | (0 00) | (0.00) | (0 00) | (0 00) |
| E-HP-HP** | (0 12) | (0 20) | (0 15) | (0 20) | (0 20) | (0 20) | (0.20) | (0.20) | (0.20) |
| G-E-E | (0 00) | (0.00) | (0.00) | (0 00) | (0 00) | (0 00) | (0.00) | (0 00) | (0.00) |
| G-E-G | (0.00) | (0.00) | (0 00) | (0.00) | (0 00) | (0.00) | (0.00) | (0.00) | (0 00) |
| G-G-E | (0.35) | (0.20) | (0 43) | (0.20) | (0 20) | (0 20) | (0.20) | (0.20) | (0 20) |
| G-G-G | (0 00) | (0 00) | (0 00) | (0.00) | (0 00) | (0 00) | (0.00) | (0.00) | (0 00) |
| G-HP-HP** | (0 12) | (0 20) | (0.15) | (0 20) | (0 20) | (0.20) | (0 20) | (0 20) | (0 20) |

*See Note, Table 23

**HP or room space cooling

Since $E^i_{1970}+kN^i$ is the total number of buildings existing in 1973 of class i, assuming a constant building rate per year of $N^i$ for k (=3) years, and $f^{ij}_{1973}$ is the fraction of the buildings of type i with HVAC appliance j, the left side of the equation is the total number of buildings of type i with HVAC appliance j in 1973. Since $f^{ij}_{1970}E^i_{1970}$ is the number of buildings of type i with appliance j, the second term on the right side of the equation is the number of new buildings built between 1970 and 1973 with HVAC appliance j. In the second term $N^i f^{ij}_N$ is the number of new buildings per year of type i built with HVAC appliance j. Rearranging terms,

$$f^{ij}_N = \frac{f^{ij}_{1973}\,(E^i_{1970} + kN^i) - f^{ij}_{1970}\,E^i_{1970}}{kN^i}$$

$E^i_{1970}$ can be obtained from Table 16 or each type of building (single family, multiple family) or by zone in Tables 21 and 22. $f^{ij}_{1970}$ and $f^{ij}_{1973}$ are given in Table 49 as derived from the SCE Residential Electric Appliance Saturation Survey (October 1973). The resulting values of $f^{ij}_N$ are given in Table 50 for single and multiple buildings.

Several of the values for $f_N$ for the single family buildings are greater than 100%. As mentioned previously this probably indicates a significant amount of retrofit. The resulting estimates are extremely sensitive to retrofit rates. For example, if the retrofit rate for central space coolers in single-family dwellings is 1.5%, this would reduce the estimate for the rate of new units with central space cooling from 170% to 60%.

A further check on this penetration data was obtained by examining the recent building rate of two-function all-electric and three-function all-electric buildings in the SCE territory. Table 51 summarizes this data.

Multiple Family Building HVAC Market Structure

The multiple family building HVAC mix is more complicated than that for the single-family buildings. In addition to the variety of different fuels used for each HVAC system function, there are five basic types of heating systems. Table 52 gives these types of systems, with the percentage in the West as given in the NAHB Research Foundation low-rise apartment survey.

Table 49 SCE territory market saturation (%) of various HVAC appliances for single and multiple family buildings (source: SCE 1973 Residential Electric Appliances Saturation Survey, Oct 1973)

| HVAC System | | Single Family Buildings* | | Multiple Family Buildings* | | Combined | |
|---|---|---|---|---|---|---|---|
| | | 1973 | 1970 | 1973 | 1970 | 1973 | 1970 |
| Space Cooling | C | 17.2 | 10.4 | 14.6 | 7.3 | 16.9 | 9.7 |
| | R | 25.0 | 18.3 | 27.4 | 24.0 | 25.4 | 19.6 |
| | EV | 15.0 | 12.7 | 6 1 | 6.7 | 13 5 | 11.6 |
| Space Heating | E | 5.3 | 5.4 | 24.3 | 22.3 | 9.5 | 9.3 |
| | G | 90.6 | 89.4 | 72.2 | 74 7 | 86.5 | 85.8 |
| Water Heating | E | 7.6 | 6.5 | 21.5 | 18.8 | 10.5 | 9.4 |
| | G | 90.0 | 87.7 | 62.5 | 65.6 | 83.8 | 82.4 |
| % Survey Responses | | 77% | - | 22% | | - | |

C = central; R = room space cooler; EV = evaporative; E = electric; G = gas

*Numbers may add up to less than 100% for space heating and water heating because of the use fuels other than gas and electric Numbers under cooling may be greater than 100% because of multiple answers.

Table 50 Estimates of the percentage of buildings fitted with various HVAC systems in 1975

| HVAC System | | Single Family Building | Multiple Family Building |
|---|---|---|---|
| Space Cooling | C | 160* | 60 |
| | R | 170* | 51 |
| Space Heating | E | 4 | 38 |
| | G | 116* | 60 |
| Water Heating | E | 27 | 40 |
| | G | 140* | 42 |

*Percentages over 100% indicate significant retrofit of existing buildings with the particular HVAC system.

Table 51. All-electric units added - residential (Source: SCE Information Sheet)

| | 1971 | | 1972 | | 1973 | | 1974 | | 4-Yr SCE Average |
|---|---|---|---|---|---|---|---|---|---|
| | Number | % of New | Number | % of New | Number | % of New | Number | % of New | Number or % |
| Single Family Total Per Year | | | | | | | | | 23, 567 |
| All-electric units added | 3, 506 | 14 1 | 5, 158 | 17 9 | 4, 021 | 16 4 | 2, 291 | 14 2 | 15.7% |
| All-electric units with space cooling | 2, 159 | 8 7 | 3, 592 | 12 5 | 2, 458 | 10 0 | 1, 419 | 8 8 | 10 0% |
| % with space cooling | 61 6 | | 69 6 | | 61 1 | | 61 9 | | 63 0% |
| Ave KWH/unit $X10^3$ | 20.6 | | 19 0 | | 18 4 | | 15 5 | | 18 4 |
| Multiple Family Total Per Year | | | | | | | | | 34, 838 |
| All-electric units added | 9, 106 | 22 3 | 7, 892 | 16 8 | 3, 737 | 10 4 | 1, 937 | 12 1 | 15.4% |
| Ave KWH/unit $X10^3$ | 9 8 | | 9 3 | | 9 1 | | 8 1 | | 9.1 |

Note: Average per year decline from the 4-year average to the 1974 figure is: -0 38% per year for single family all-electric units added and -0 83% per year for multiple family units

Table 52. Types of heating systems

| | | |
|---|---|---|
| 1. | Individual warm air | 33% |
| 2. | Central boiler with hot water | 15% |
| 3. | Electric baseboard or panes | 45% |
| 4. | Central boiler with fan coils | 37% |
| 5. | Heat pump | 3% |
| 6. | Other | 18% |

In addition, water heating may be done in any one of three ways: (1) individual apartment water heaters (48%); (2) large water heaters, each for several apartments (29%); and (3) water heating from a large central boiler (23%). To delimit a reasonable number of systems and maintain analytic tractability, the complexity of the market was reduced using the following assumptions:

1) If the apartment has space cooling, the HVAC systems favor individual rather than central.
2) No gas-supplied cooling.
3) If central water heating or space heating is used, then that function is assumed to be supplied by gas.
4) If individual rather than central HVAC function, then all-electric is favored.

The multiple family building HVAC mix is further complicated by the variety of HVAC system combinations which are possible for each HVAC function. To represent market penetrations in final form, the data from Tables 48 and 52 were combined to give the types of HVAC system which required solar energy system design. This data is given in Table 53 The data was cross-checked using the data from Tables 43, 48, and 51 to make certain that the overall penetrations for each category were consistent with the data furnished by SCE.

Table 53 Full HVAC mix for multiple family buildings (same for each zone)

| Function and Combination | Fuel | % | % of Total | |
|---|---|---|---|---|
| Water Heating and Space Heating Only | | | 85 | |
| Central-Central | | | | 20 |
| Fan coil | G-G | 100 | | |
| Central-Individual | | | | 50 |
| Forced air | G-E | 10 | | |
| Resistance | G-G | 80 | | |
| | G-E | 10 | | |
| Individual-Central | | | | 15 |
| Fan coil | E-G | 100 | | |
| Individual-Individual | | | | 15 |
| Resistance | E-E | 100 | | |
| Water Heating, Space Heating, and Space Cooling | | | 15 | |
| Central-X-X | | | | 15 |
| Forced air, central | G-G-E | 25 | | |
| Heat pump, individual | G-E-E | 25 | | |
| Warm air, central | G-G-G | 25 | | |
| Fan coil | G-E-E | 15 | | |
| | G-G-G | 10 | | |
| Individual-Individual-Individual | | | | 85 |
| Warm air | G-G-E | 20 | | |
| Resistance | E-G-E | 20 | | |
| Heat pump | E-E-E | 45 | | |
| | E-E- | | | |

See note, Table 31.

Commercial Office Buildings and Department Stores

The HVAC mix for commercial office buildings and department stores is given in Tables 54, 55, and 56.

There are five basic heating and cooling combinations which appear most often in large commercial buildings. The first is the induction system. This is an old system and no longer much used. The second is the fan coil system using either a 4-pipe (the most common) or a 2-pipe arrangement. This is the most common type of system in use. Because water (heated or chilled) is pumped around the building either electric or gas may be used to fire the system. Gas is most commonly used for water heating in this type of system but electricity seems to be preferred for chilling water.

The third system is a single duct with a terminal reheat. This is also very common, appearing about as often as the fan coil. This is an air system which distributes cold air to a mixing box in each room where it can be reheated depending on the individual thermostat setting. Electricity appears to be preferred for this system.

The fourth type of system is a dual duct system. This system, which mixes hot and cold air at each room according to the local thermostat, can be fired by either gas or electricity. It is similar to a single duct system without terminal reheat or with hot and cold mixing boxes.

The fifth system is a single duct, variable volume. This is a relatively new system but becoming very popular. It can be fired using either electricity or gas.

The sixth system is a hydronic heat pump system. This uses water as a sink or source of energy depending on the requirement of each area. Although not a popular system, it is readily compatible with solar energy.

To model the commercial market, we have chosen to examine each of these systems and assume an even split in the market between gas and electricity for each of them.

Table 54. HVAC systems - department stores

Note: All department store HVAC systems are central; all include space cooling

| | % | % of Total |
|---|---|---|
| E-E-E | 50 | |
| Baseboard, forced air | | 50 |
| Fan coil | | 50 |
| G-G-E | 25 | |
| Forced air, forced air | | 50 |
| Fan coil | | 50 |
| G-G-G | 25 | |
| Fan coil | | 50 |
| Forced air | | 50 |
| See Note, Table 31. | | |

Table 55 HVAC systems - office buildings

| | % | % of Total |
|---|---|---|
| CENTRAL HVAC SYSTEM | | |
| G-G-E | 30 | |
| Forced air, forced air | | 25 |
| Fan coil | | 25 |
| Baseboard | | 25 |
| Terminal reheat | | 25 |
| G-HP-HP | 20 | |
| Hydronic heat pump | | 100 |
| E-E-E | 50 | |
| INDIVIDUAL BY FLOORS | | |
| E-E-E | 80 | |
| Forced air | | 50 |
| Fan coil | | 50 |
| E-G-E | 20 | |
| Forced air | | 50 |
| Fan coil | | 50 |
| See Note, Table 31. | | |

Table 56. HVAC mix - commercial office buildings

| | Existing 1975 | New 1975 | New 2000 |
|---|---|---|---|
| G-G-G | | | |
| Variable air volume | 0.0 | 0.08 | 0.04 |
| Fan coil | 0.18 | 0.12 | 0.04 |
| G-G-E | | | |
| Dual duct | 0.25 | 0 0 | 0.0 |
| Variable air volume | 0.0 | 0.08 | 0.04 |
| Fan coil | 0.18 | 0.12 | 0.04 |
| E-E-E | | | |
| Terminal reheat | 0.30 | 0.0 | 0.0* |
| Variable air volume | 0.0 | 0.33 | 0.42* |
| Fan coil | 0.0 | 0.0 | 0 0 |
| E-HP-HP | | | |
| Hydronic heat pump | 0.09 | 0.25 | 0.42 |

*Retrofit feasible for cooling only.

See Note, Table 31

Using these assumptions and the information derived from the SCE penetration survey, Table 57 was created. It shows the market penetration for each of the systems that is a reasonable system. Note all zones are indicated as being the same. Although this is not strictly accurate, it is a reasonable approximation for the BASE analysis.

Table 57. HVAC system penetration of multiple family building market - all zones

| | Existing Systems | |
|---|---|---|
| Water Heating and Space Heating Only | | 85% |
| Central-Central | | |
| Fan coil, baseboard | G-G | 0.30 |
| Central-Individual | | |
| Resistance | G-E | 0.30 |
| Warm air and gas furnace | G-G | 0.20 |
| Individual-Central | E-G | 0.15 |
| Fan coil | | |
| Individual-Individual | E-E | 0.45 |
| Resistance or electric warm air heater | | |
| Water Heating, Space Heating, and Space Cooling | | 15% |
| Central-X-X | | |
| All Central | G-G-E | 0.02 |
| Central-Individual-Individual | G-E-E | 0.04 |
| All Central (fan coil) | G-G-G | 0.02 |
| Heat pump | G-E-E | 0.04 |
| Fan coil | G-E-E | 0.04 |
| Individual-Individual-Individual | | |
| - | G-G-E | 0.10 |
| Warm air | E-G-E | 0.10 |
| Electric resistance | E-E-E | 0.45 |
| Heat pump | E-E-E | 0.19 |

See Note, Table 31.

# SECTION V

# BASE WEATHER ZONE DEFINITION FOR CUSTOMER AND KWH SALES ALLOCATION

## A. INTRODUCTION

Table 58 gives the SCE customer allocation used in this study. There are three weather zones: (1) Beach, represented by the LAX weather station and containing 855,944 customers (or 33%), (2) Inland Valley, represented by the Burbank weather station and containing 1,495,000 customers (or 57%), and (3) High Desert and San Joaquin Valley, represented by Edwards weather station and containing 174,162 customers (or 7%). (About 94,893 (or 3%) of the SCE customers were located in areas deemed to be unassignable. They are either located near the El Toro weather station or are in the mountains (e.g., Mammoth).) The three stations (LAX, Burbank, Edwards) will be used to define the weather for each of the representative buildings specified in Study 2. That is, data from these stations will be used in the thermal analysis program. The market penetration projections will use the fraction of customers in each of the zones as a means of determining the fractional mix of each building type of zone.

Table 59 gives the 1975 KWH solar allocation for all weather zones. As can be seen, the fraction of sales in each weather zone is nearly the same as the fraction of customers in each zone.

## B. WEATHER ZONE DEFINITION PROCEDURE

Figures 4, 5, and 6 show the geographic location of each weather zone and the SCE divisions which the zone contains. The allocations were made by examining the topography of the SCE territory and estimating areas around each of the 13 weather stations which had similar microclimates. The bulk of this work was performed in Study 1. Using the 13 stations defined in Study 1 and the topographic maps the SCE divisions were assigned to each zone. Wherever ambiguities arose, the districts of subdistricts were left unassigned.

Table 58. 1973 SCE customer allocation to BASE weather zones

| Zone | Representative Weather Station | SCE Customers Number | SCE Customers % of Total |
|---|---|---|---|
| I. Beach | LAX | 855, 944 | 33 |
| II. Inland Valley | Burbank | 1, 495, 020 | 57 |
| III. High Desert | Edwards | 174, 162 | 7 |
| IV. Unassigned | None | 94, 893 | 3 |
| Total | | 2, 620, 019 | 100 |

Table 59. 1975 KWH sales for SCE BASE weather zones (source: SCE Division and District Forecasts, Jan. 1974)

| Zone | Electricity Sales KWH x $10^6$ | Electricity Sales % of Total |
|---|---|---|
| I. Beach | 18,260 | 31 |
| II. Inland Valley | 32,990 | 57 |
| III. High Desert | 3,480 | 6 |
| IV. Unassigned | 3,630 | 6 |
| System Total | 58,360 | 100 |
| Summer Peak Demand: 11,762 KW<br>Winter Peak Demand: 10,062 KW | | |

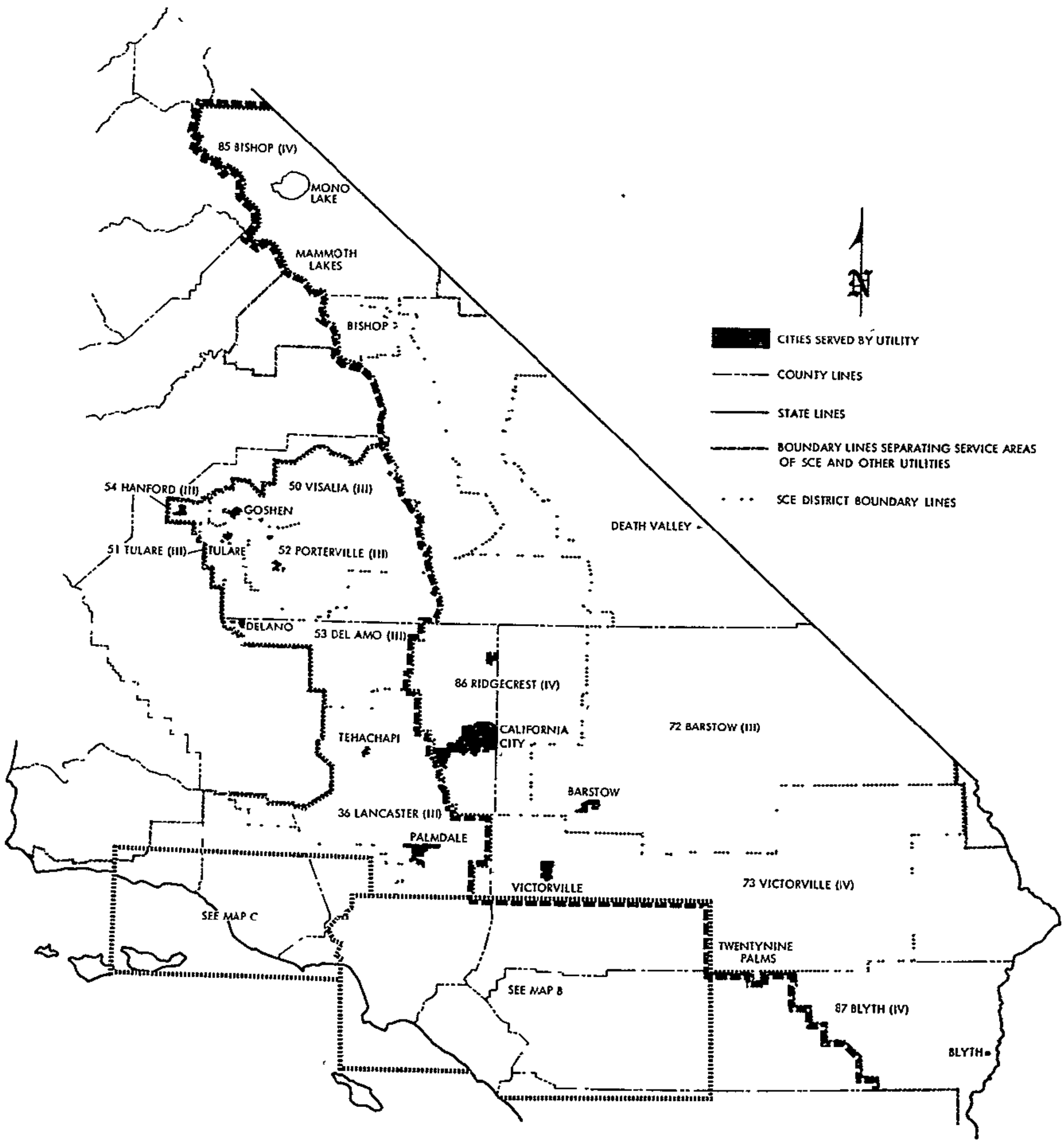


Fig. 4. Area Code Map A

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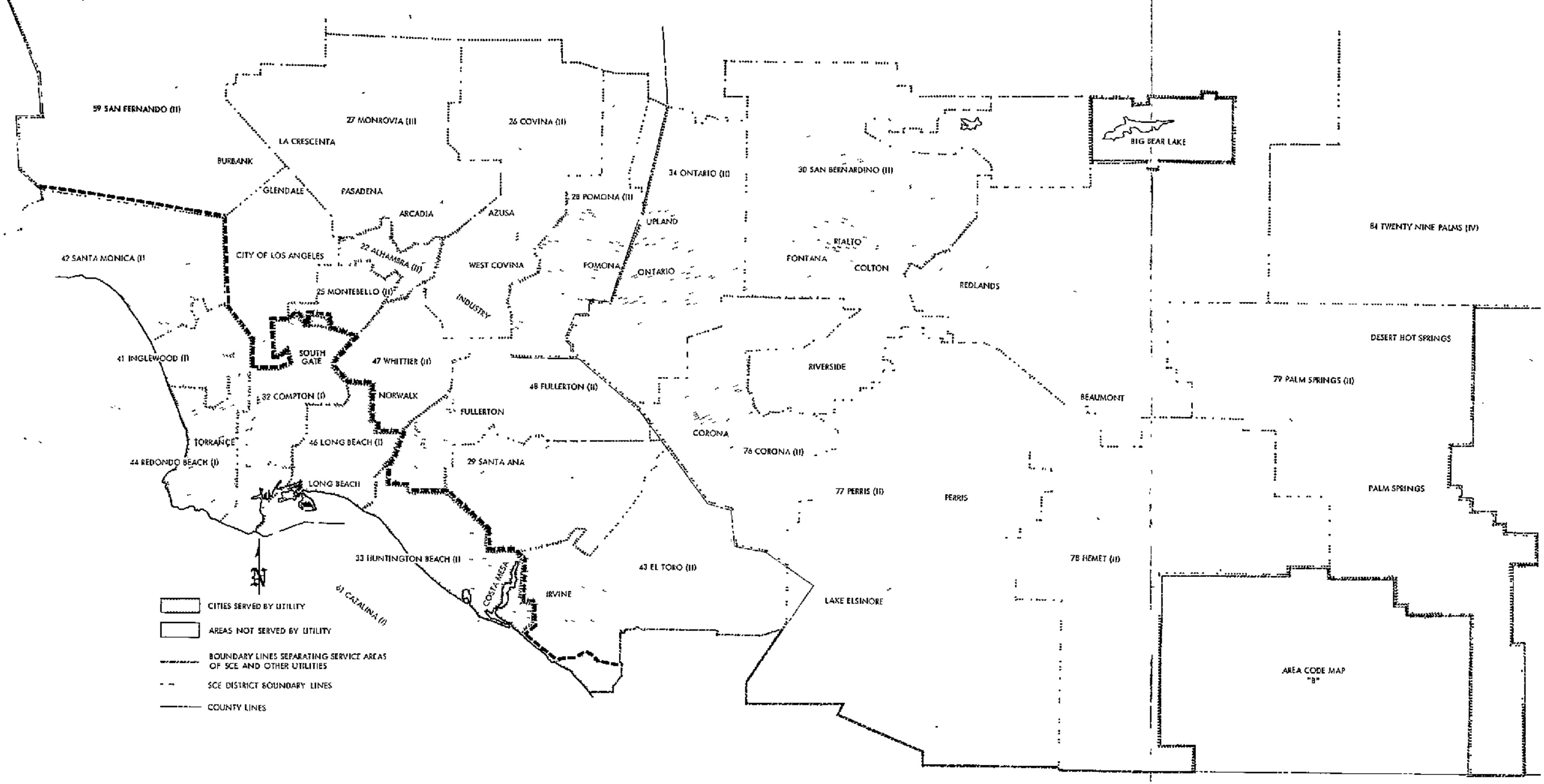


Fig. 5, Area Code Map B

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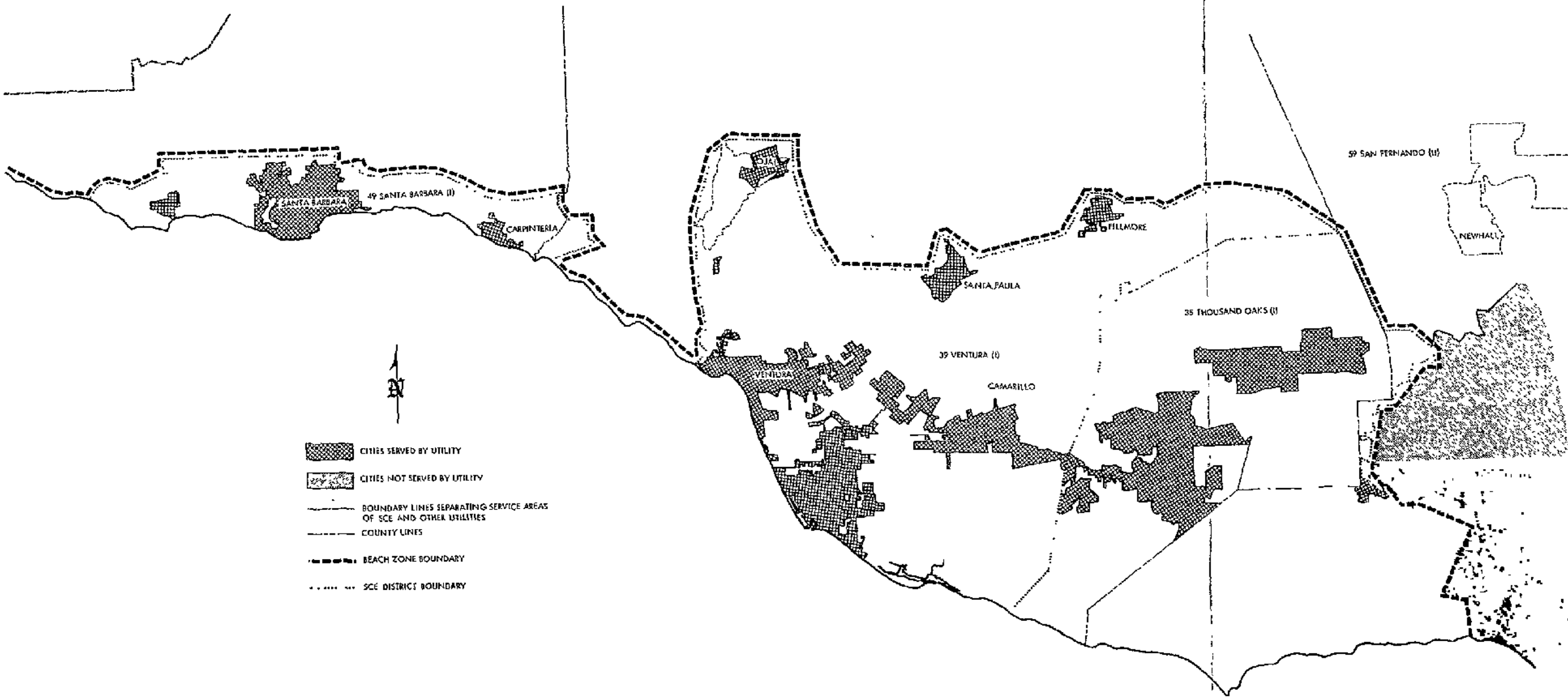


Fig. 6. Area Code Map C

Seven weather zones were then defined combining these stations as suggested by Study 1. Table 60 shows this preliminary allocation of customers by geographical code (district number) to each of the seven weather zones. Unfortunately, this left 54% of the SCE customers unassigned (principally because of the ambiguity of assignment of customers between Burbank and San Bernardino.)

The unassigned customers were eliminated by reassigning as many of the unassigned regions as possible to the nearest weather zone. The bulk of these customers were assigned to either Burbank (Zone 4) or San Bernardino/ Riverside (Zone 5). The thermal differences between zones were examined by running the single family building in each of the seven zones. Following this analysis, the zones were reduced from seven to five. The customer assignments are shown in Table 61.

Further analysis indicated that these zones could be further reduced to the four shown in Table 58 This was done by combining the original Zones 2, 4, and 5 into one zone called "Zone II: Inland Valley" and combining Zones 3 and 6 into one zone called "Zone III: High Desert". This final allocation is shown in Table 62

Electricity sales in the SCE territory, by district and division, are shown in Table 42. This table also shows the assignment of the 42 SCE districts to each weather zone and to the six SCE divisions (Central, Eastern, Southern, Southeastern, Western, and Northern) in addition to the 1975 KWH sales for each district. Table 41 gives the penetration rates for water heating, space heating, and space cooling appliances in each of the six SCE divisions. Column 1 gives the division name, column 2 gives the weather zone assignment of each division based on the districts included within each division (column 3). Column 4 gives the weather zone assignment of each district given in Column 3. Column 5 lists the 7 HVAC function and fuel mixes given in the SCE survey (see Section IV). Columns 6–11 give the penetration rates for each of the HVAC function and fuel mixes for single or multiple family buildings in 1970 and 1973 and the 3-year average growth rate. Column 12 gives the fraction of total SCE electricity sales supplied by each division. Column 13 gives the fraction of the division sales in each of the four weather zones in Column 14.

Table 60. BASE weather zone study: Preliminary allocation of SCE customers to zones

| BASE Weather Station | SCE Districts | SCE Customers Allocated | Fraction of All SCE Customers |
|---|---|---|---|
| Zone 1 | | 729,533 | 0.281 |
| Santa Barbara | 49 | 59,726 | |
| Point Mugu | 35, 39, 49 | 81,826 | |
| LAX | 41, 42, 44 | 237,046 | |
| Long Beach | 29, 33, 43, 46, 47 | 350,046 | |
| Zone 2 | | 32,445 | 0.013 |
| El Centro | 79 | 32,445 | |
| Zone 3 | | 69,512 | 0.027 |
| Bakersfield | 51, 52, 53 | 20,950 | |
| Fresno | 50, 51, 52, 53, 54 | 48,562 | |
| Zone 4 | | 6,403 | 0.002 |
| Burbank | 59 | 6,403 | |
| Zone 5 | | 291,850 | 0.113 |
| Riverside | 26, 27, 28, 30, 34, 76 | 127,889 | |
| San Bernardino | 28, 30, 31, 34, 76, 77, 78, 79 | 163,961 | |
| Zone 6 | | 47,124 | 0.018 |
| Edwards | 36, 72, 73, 86 | 47,124 | |
| Zone 7 | | 33,764 | 0.013 |
| El Toro | 29, 43 | 33,764 | |
| Zone 0 | | 1,410,278 | 0.544 |
| Unknown | | 1,410,278 | |
| Grand Total | | 2,593,556 | 1.009 |

Table 61 BASE weather zone study: Semifinal allocation of customers to zones

| Zone | Representative Weather Station for Zone | Stations in Zone | SCE Districts | SCE Customers Allocated | % Of All SCE Customers |
|---|---|---|---|---|---|
| 1. Beach | LAX | | | 855,944 | 32.7 |
| | | Santa Barbara | 49 | 59,776 | (0.070) |
| | | Pt. Mugu | 35, 39, 49 | 85,490 | (0.100) |
| | | LAX | 41, 42, 44 | 360,679 | (0.421) |
| | | Long Beach | 29, 33, 43, 46, 47 | 350,049 | (0.409) |
| 2. Inland Valleys | Burbank | | | 1,495,020 | 57.1 |
| | | El Toro | 29, 43 | 33,764 | (0.023) |
| | | San Bernadino | 20, 28, 30, 31, 34, 76, 77, 78, 79 | 294,831 | (0.197) |
| | | Riverside | 26, 27, 28, 29, 30, 31, 34, 48, 76, 77, 79 | 427,295 | (0.286) |
| | | Burbank | 22, 25, 27, 32, 33, 35, 39, 46, 47, 59 | 739,130 | (0 494) |
| 3. High Desert | Edwards | | | 66,498 | 2.5 |
| | | Edwards/Inyokern | 36, 72 | 66,498 | (1.000) |
| 4. San Joaquin Valley | Bakersfield | | | 107,684 | 4.1 |
| | | Fresno | 50, 51, 52, 53, 54 | 68,493 | (0.636) |
| | | Bakersfield | 50, 51, 52, 53 | 39,171 | (0.364) |
| 5. Low Desert | El Centro | | | 49,971 | 1.9 |
| | | El Centro | 84, 87 | 49,971 | (1.000) |
| 6. Unassigned (Mountains) | | | 34, 40, 51, 73, 76, 85 | 44,922 | 1.7 |

Table 62 BASE weather zone study: Final allocation of SCE customers to zones

| Final Zone | Representative Weather Station | Weather Stations in Zone | SCE Customers | |
|---|---|---|---|---|
| | | | Number | % of Total |
| I. Beach | LAX | LAX<br>Pt. Mugu<br>Long Beach<br>San Diego | 855,944 | 33 |
| II. Inland Valley | Burbank | Burbank<br>El Toro<br>San Bernardino<br>Riverside | 1,495,020 | 57 |
| III. High Desert (including San Joaquin Valley) | Edwards | Edwards<br>Inyokern<br>Fresno/Bakersfield | 174,162 | 7 |
| IV. Unassigned | None | El Centro<br>Misc. Mountain Areas | 94,893 | 3 |
| Grand Total | | | 2,620,019 | |
| SCE Total | | | 2,620,889 | |

Tables 41 and 42 were used to derive the fraction of electricity sales supplied by each weather zone as given in Table 59. Tables 63, 64, and 65 give the population and sales forecast for SCE and the general Southern California region.

Table 63. SCE data highlights (Source: SCE 1973 System Forecasts)

| | 1960 | 1970 | 1980 | 1990 |
|---|---|---|---|---|
| GNP (1958$ x $10^{12}$) | $488 | $720 | $1,080 | $1,526 |
| SCE Area Population at Year End | 5,406,000 | 7,230,000 | 8,350,000 | 10,250,000 |
| SCE Customers | 1,745,000 | 2,439,000 | 3,149,000 | 3,888,000 |
| Net Sales (KWH x $10^6$) | 18,666 | 44,920 | 90,720 | 166,480 |
| System Net Annual Peak (KW x $10^6$) | 3,714 | 8,274 | 16,830 | 31,160 |
| Growth Rates | | | | |
| Sales (%) | 9.70/8.66 | 7.17/7.39 | 6.30/5.96 | 5.75 |
| Peak (%) | 9.56/7.13 | 7.67/7.05 | 6.65/6.01 | 5.75 |

Table 64. Population of six Southern California counties (Source: SCAG (Southern California Association of Governments) population Growth Analysis - Staff Report, 1972)

| County | 1950 | 1960 | 1970 | 1972 July |
|---|---|---|---|---|
| Imperial | 62,975[1]<br>(1.3%)[2] | 72,105<br>(0.9%) | 74,492<br>(0.7%) | 77,000<br>(0.8%) |
| Los Angeles | 4,151,687<br>(83.17%) | 6,038,771<br>(77.2%) | 7,030,169<br>(68.3%) | 6,966,900<br>(68.3%) |
| Orange | 216,224<br>(4.3%) | 703,925<br>(9.0%) | 1,420,386<br>(14.1%) | 1,565,200<br>(15.3%) |
| Riverside | 170,046<br>(3.4%) | 306,691<br>(3.9%) | 459,074<br>(4.6%) | 485,200<br>(4.8%) |
| San Bernardino | 281,642<br>(5.8%) | 503,591<br>(6.4%) | 684,072<br>(6.8%) | 699,200<br>(6.9%) |
| Ventura | 114,687<br>(2.3%) | 199,138<br>(2.5%) | 376,430<br>(3.6%) | 410,900<br>(4.0%) |
| Total Regional | 4,997,221 | 7,823,721 | 10,044,633 | 10,205,400 |

(1) Population
(2) % of total regional population

Table 65. Population projections for the SCAG region (Source: Ibid.)

| County | 1980 | | 1990 | | 2000 | | 2020 | |
|---|---|---|---|---|---|---|---|---|
| | "High" Series D | "Low" Series E | D | E | D | E | D | E |
| Imperial | 82,900 | 80,000 | 98,000 | 85,600 | 112,500 | 88,100 | 151,710 | 88,600 |
| Los Angeles | 7,653,600 | 7,236,100 | 8,613,700 | 7,667,500 | 9,625,600 | 7,916,860 | 12,006,500 | 8,400,500 |
| Orange | 1,928,700 | 1,774,000 | 2,445,300 | 2,123,500 | 2,907,000 | 2,408,300 | 3,970,000 | 2,976,300 |
| Riverside | 565,900 | 514,500 | 726,200 | 567,300 | 876,700 | 602,800 | 1,175,200 | 647,700 |
| San Bernardino | 832,000 | 766,000 | 1,064,600 | 869,200 | 1,299,000 | 955,600 | 1,843,300 | 112,100 |
| Ventura | 571,200 | 488,400 | 902,100 | 618,500 | 1,241,500 | 741,000 | 2,100,800 | 1,004,500 |
| Totals for SCAG Region: | | | | | | | | |
| Series D | 11,634,300 | | 13,900,000 | | 16,900,000 | | 21,259,000 | |
| Series E | | 10,949,000 | | 11,930,500 | | 12,711,800 | | 14,242,600 |

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