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P. Albrand, I. Turiel, R. Ritschard, and
D. Wilson

November 1985

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LOW RISE MULTI-FAMILY HOUSING: A PRELIMINARY SURVEY OF BUILDING CHARACTERISTICS AND PROTOTYPE DEVELOPMENT.*

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ABSTRACT

In order to develop a prototypical building with which computer simulations on energy use will be performed and to identify several major research issues, we sampled a group of U.S. builders to gather data on construction characteristics and space conditioning systems in new multi-family buildings. We obtained useful data on insulation levels, building materials, window types, and space conditioning equipment. Where data are available, we make comparisons with other studies.

INTRODUCTION

The Building Energy Analysis Group at Lawrence Berkeley Laboratory (LBL), has been studying energy use in new low-rise multi-family buildings. The major objectives of this research are to: 1) gain a better understanding of the major determinants of energy use and power demand in multi-family residences, 2) evaluate the cost-effectiveness of conservation measures in various climates, and 3) transfer this information to builders of such housing and other interested parties. The research includes collection of data on energy use and building characteristics of new multi-family buildings, development of prototypical buildings, computer simulation, and energy and economic analysis.

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Although multi-family dwellings accounted for about 38% (665,000 units)[1] of all new residential units built in 1984, there is surprisingly little published information on building characteristics available. Therefore, in order to satisfy a need for such data, we organized and convened a panel of builders of multi-family residences from across the country. With guidance provided by panel members, we produced a survey instrument especially designed to collect information on multi-family building characteristics.

First, this paper discusses the multi-family sector from a national perspective using sources other than our survey. We then provide an analysis of the responses received to date. Our preliminary findings cover a small number of multi-family buildings. Thus, the results can not be generalized nor be considered as statistically representative of new multi-family housing. However, we compare our survey results to previous studies, and to previous assumptions about multi-family prototypes given in Appendix A, and identify several major research issues for the multi-family sector, such as developing new prototypical buildings and performing energy and economic analyses.

PUBLISHED DATA ON MULTI-FAMILY HOUSING CHARACTERISTICS

We collected data on multi-family buildings from four major sources of information. These sources are : "Residential Energy Consumption Survey on Housing Characteristics-1982"[1] and "Consumption & Expenditures" survey[2] conducted by the Energy Information Administration, "Characteristics of New Housing-1983"[3] survey conducted by the U.S Department of Housing and Urban Development (HUD) and "National Council of the Multi-Family Housing Industry-1985"[4] survey* conducted by National Association of Home Builders (NAHB). For the purpose of this study, multi-family housing is defined to include all buildings with two or more living units. For the existing U.S. housing stock, multi-family buildings make up more than 26% of all residential units (see Table 1)[2].

*This survey is based on 39 U.S. respondents.

Table 1.
Existing Housing Stock*

	No. of units (millions)	% of Total Units	Average Heated Floor Space (ft^2)
Single family detached	53.8	64.2	1717
Single family attached	3.9	4.6	1535
2 - 4 units	10.1	12.1	1137
> 4 units	12.2	14.6	795
Mobile homes	3.8	4.5	860
Total Residential	83.8	-	-

*1982 Residential Energy Consumption Survey: Housing Characteristics DOE/EIA-0314 (82), August 1984.

Multi-family buildings consume more than 20% of the energy used by residential buildings, or more than 1.9 Quads out of a total of 9.5 Quads for all residential buildings[2] (see Table 2). The majority of respondents to the NAHB[4] survey expect the average size of apartment units to decrease in the near future. They also mentioned that the four most significant ways in which multi-family housing would change in the next 3-5 years are: 1) more conveniences, luxury items, amenities, 2) energy saving construction materials and energy efficient appliances, 3) security features and 4) smaller size units in each category.

Table 2.
Energy Consumed as a Percentage of Total in Existing Residential Buildings (1982 - 1983)

Housing Type	Annual Energy (Quads)	% of Total
Single family detached	6.04	70.0
Single family attached	0.43	5.0
2 - 4 units	1.00	11.6
5 or more	0.89	10.3
Mobile homes	0.27	3.1
Total energy use	8.63	

Source: DOE/EIA/0321 September 1984, Washington D.C. Consumption & Expenditures, April 1981 through March 1982.

Presently, about one third of all new residential units built each year are in multi-family buildings[3]. Although a major decrease in construction occurred in the residential sector between 1979 and 1982, this did not affect the construction of multi-family units to the same extent as single-family units (see Fig. 1).

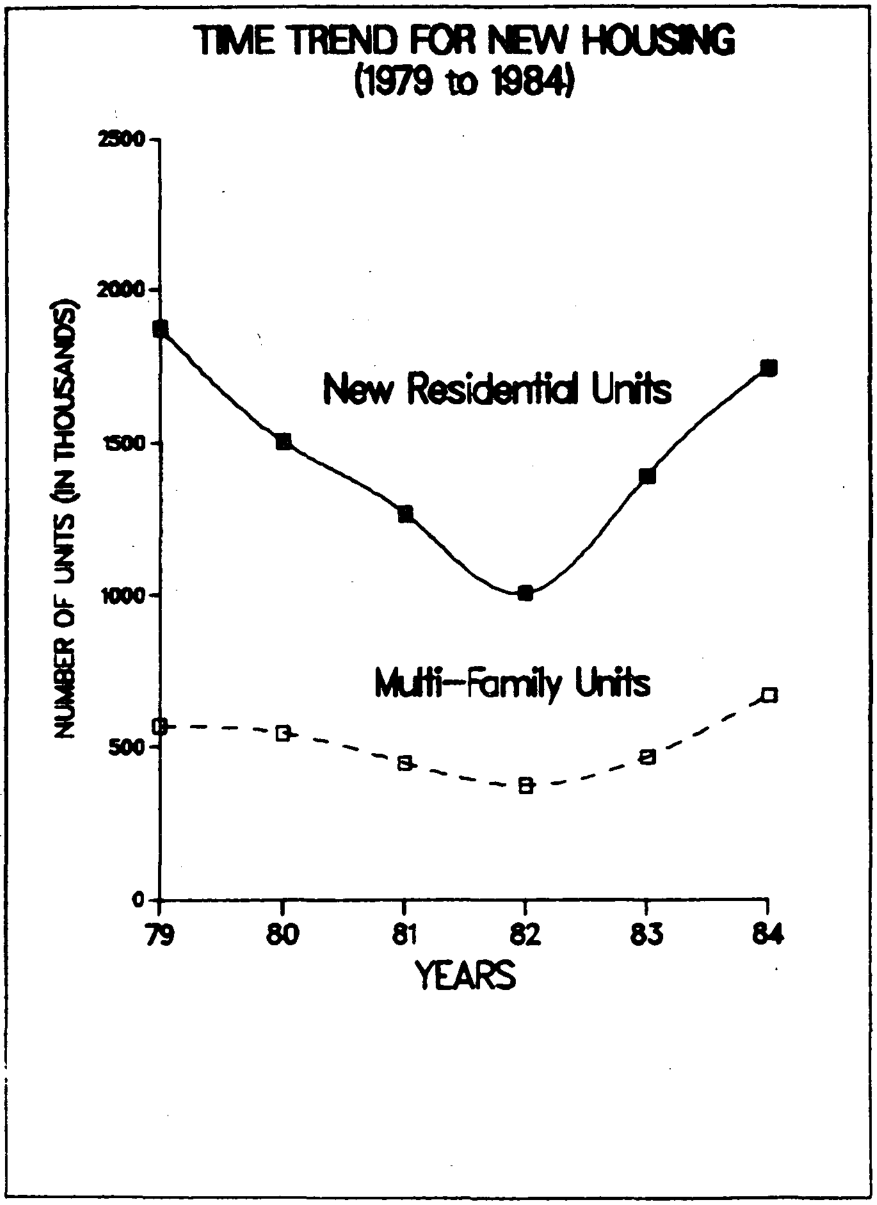


Fig. 1: Time Trend for New Residential Buildings.*(1979-1984)

*Source: Characteristics of New Housing: 1983
U.S. Department of Housing & Urban Development. /C 25-83-13 84/06.

Table 3 shows that in 1983[3] most new multi-family units were built in the South and West. Three states (California, Florida and Texas) account for approximately 45% of all new units in buildings with five or more units, and most multi-family buildings have more than five units.

Table 3.
1983 Multi-family Building Construction as a Percentage of New Units*

Location	*% of New units*
Northeast	7
North Central	13
South	58
West	22

*HUD Construction Reports (25-83-13) June 1984

Electricity is the dominant heating source for newly constructed multi-family housing units (see Fig. 2). More than twice as many new units use electric heat as all the other fuels combined. During the last decade, the use of natural gas and oil somewhat has decreased as heating sources. In 1983, 89% of newly constructed multi-family units were air-conditioned[3]. In that same year, electric heat pumps were installed in 28% of new multi-family units[3].

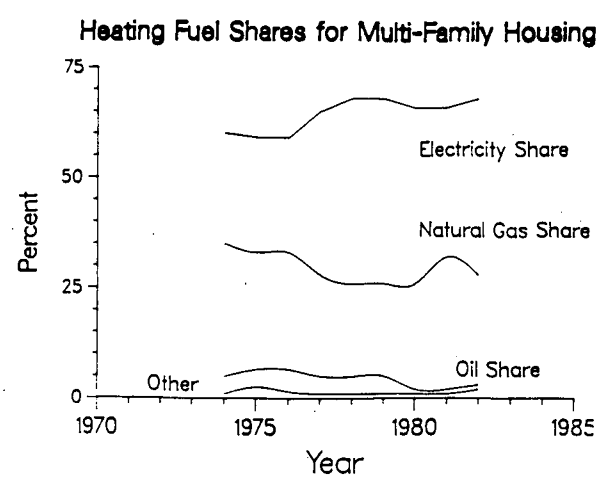


Fig. 2: Heating Fuel Mix in Multi-Family Units.

*Source: Characteristics of New Housing: 1983
U.S. Department of Housing & Urban Development. /C 25-83-13 84/06.

Thirty-three of the 39 respondents in the NAHB survey[4] stated that individual heating ventilation and air conditioning systems (rather than central systems), would be chosen for new garden apartment projects over the next 3-5 years. Most of these buildings will be individually metered.

Seventy-five percent of all multi-family units built each year are in buildings with more than four units. Low-rise buildings (1-3 stories) account for 86% of all new multi-family units[3] and thus represent most new multi-family housing. This is the sector that we emphasize in our research. The average size of new multi-family units has varied between 900 and 1000 square feet over the last few years. This is a little more than half the size of average single family units. Approximately two-thirds of these units are occupied by renters and the majority of those are individually metered[3]. Thus, there is little financial incentive for builders of such units to implement energy conservation measures.

Fig. 3: Typical Low-Rise Multi-Family Housing.

SURVEY OF MULTI-FAMILY BUILDERS

In this section, we describe the results of our survey. We decided not to weight our results (for percentage of builders and percentage of units), for two major reasons: 1) the respondents are very consistent in their answers and 2) 80% of the respondents build their units in the Sun Belt, therefore, a weighted answer would not lead to any climate breakdown.

At the beginning of the study, we could find few data available on construction characteristics and equipment use in newly built multi-family buildings. To guide our research on multi-family buildings, we organized a panel composed of specialists in the building sector. We met with the panel members to seek their assistance in gathering data. The panel recommended that we conduct a formal survey to gather data on new multi-family construction. Thus, we developed a detailed 50-item survey instrument (see Appendix B), and sent it to various builders across the U.S. The questions focused on building components, construction elements, typical architectural features, and the space conditioning systems of the building (heating and cooling). There were two purposes in gathering these data: 1) to identify trends in multi-family construction characteristics and equipment use, 2) to use these data to develop input to a building computer simulation program (DOE-2).

The 28 builders who received the survey ranged from the largest multi-family builder, U.S Home Corporation, to a typical local California builder. We achieved an overall 50% response rate, with 7 responses out of the top 20 US builders* (see list in Appendix C). We attempted to contact builders in all typical U.S. climate regions, but concentrated our efforts in California, Texas and Florida (which account for approximately 45% of all new units built in buildings with five units and more).

*"Building Design & Construction" December, 1983.

MULTI-FAMILY BUILDING SURVEY RESULTS

The survey respondents indicated that most of the buildings they constructed ranged from one story to four stories. Two and three stories buildings represent almost 70% of the total, and over 80% are three stories and less (see Table 4). This corresponds closely to HUD's 1983 survey[3].

Table 4.
Height of buildings constructed

Building Height	Survey Results (%)	HUD Study (%)
One story	14.3	
Two stories	41.9	
Three stories	26.3	
Total 1-3 stories	82.5	86
Four stories	2.3	
Over	14.9	
Total >3 stories	17.2	14

Survey respondents indicated that the overwhelming majority of the buildings built are rectangular (89%) in shape, although a few are L-shaped (8.2%). The average floor area indicated by the survey is 964 ft^2 (see Table 5). For comparison, the average floor area for multifamily units as determined by the 1983 HUD survey was 942 ft^2 (see ref. 3).

Table 5. Apartment Floor Area
(Survey Results)

Type of Apt.	% of units	Average ft^2
Studio	13.1	390
1 Bedroom	22.17	750
2 Bedrooms	50.6	1076
3 Bedrooms	14.1	1442

With regard to building orientation, the primary determinant for 60% of the survey respondents remains the street layout and the need to get maximum housing density. Minor consideration is given to views or solar access.

Building Envelope

Exterior and interior walls:

Ninety-percent of the builders surveyed, report using wood frame roof and wall construction, the rest use steel frame or masonry construction. Wall framing is generally 2x4 studs 16" on center (O.C.), with plywood sheathing and interior drywall. The exterior wall is generally insulated (95%), with either fiberglass and a polyethylene vapor barrier, or rigid polyurethane insulation. The level of wall insulation varies from R-11 to R-19.

Eighty percent of the survey respondents reported that the interior walls are constructed of 2x4 studs with either drywall or gypsumboard. For sixty-percent of them, party walls are insulated, with R-values ranging from R-8 to R-13. Ten-percent of the respondents report placing radiant barriers in the attic walls.

Roof construction and ceilings:

Ninety-five percent of the time, roofs are reported to be wood-frame, using wood rafters, with 1/2" plywood sheathing covered by 1/8" asphalt shingles or spanish tiles. Some of the builders use prefabricated roof structure such as trusses, and panels. Roofs are reported peaked 90% of the time, and of a medium-light color. In most cases, radiant barriers are not used to increase the effectiveness of ceiling insulation. All ceilings are reported insulated ; either with fiberglass or rigid batts, and usually have R-values varying from R-19 to R-30 (and sometimes greater). Seventy-percent of the respondents report a 12" to 24" roof overhang around the perimeter of the roof.

Floors and Foundations:

The most prevalent type of floor between units, reported in 45% of the survey responces, consists of 2x10 joists with 5/8" tongue and groove subfloors. The two other cases mentioned in our survey are: 1) a floor built with a standard wood frame construction some insulation (fiberglass), and a lightweight concrete poured on the surface; and 2) for 25% of the respondents a typical 4" concrete slab usually covered with pad and carpet. Forty-percent of these floors are insulated with a R-value ranging from R-8 to R-19 using different types of insulation (fiberglass,thermocon,batt).

Our survey found three different types of foundation: slab-on-grade, basement and crawl space. The prevalence of slab foundations (see Table 6), is due to the extensive coverage of warm regions of the country (California,Texas and Florida).

Table 6. Foundations
(Survey Results)

Type of foundations	%	Ventilated (%)	Insulated (%)
Basement	6	-	-
Crawl Space	25	75	60
Slab	69	-	13

The slabs, when they are insulated (see Table 6), have either insulation under the slab, or more commonly, perimeter insulation with an R-8 to R-10 value. The crawl spaces usually have insulation both under the floor and on the walls (R-19) and a polyethylene vapor barrier on the ground. Basement foundations appear to be generally used as garage space.

Windows

Builders in our survey reported an equal number of single and doubled-glazed windows in new construction. Window sash type were reported as: 80% aluminium, 15% wood and 5% aluminium with thermal break. Eighty percent of the respondents reported the use regular window glass, with only 20% of them using tinted glass, (typically in luxurious condominiums). No builders in the survey incorporated movable window insulation.

The windows are generally equally distributed among the different orientations of the building, with an average window area of 10-12% of the floor area. Windows are rarely recessed from the plane of the exterior wall and rarely have solar film (8%). No respondents reported the use of attached sunspaces or sun-tempered designs. The use of direct solar gain with an increase of the south window area and an addition of interior thermal mass was not mentioned by any respondents, (the majority of whom build in warm climates). While passive solar strategies are not a prime consideration, 90% of the respondents in our survey are employing insulation and infiltration reduction (weatherstripping, caulking) and 20% are reported to use vapor barriers as a means to reduce energy consumption.

Space Conditioning Systems

Our survey found that 95% of the apartments are reported to have individual heating and cooling systems. While 30% of the builders surveyed used ceilings fans, only 5% of them installed whole house fans. Natural ventilation (when the outdoor temperature allows it), and air conditioning remain the two major methods of cooling. Thirty percent of the respondents use a thermostat with a setback provision to control the temperature in the living space of the unit.

Heating and Cooling Equipment

Most of the builders surveyed install individual heating systems, located within each unit in either the utility area, the attic, or the bathroom. The type of installed equipment varies (see Table 7), but it should be noted that 57% are electrically heated.

Table 7.
Heating Equipment

Type of equipment	Survey results (%)	H.U.D. study (%)*
Electric Resistance	30.9	41
Heat Pump	25.8	27
Gas Furnace	42.0	31
Oil Furnace	1.2	

* Source: Characteristics of New Housing: 1983
U.S. Department of Housing & Urban Development. /C 25-83-13 84/06.

Our respondents reported that individual cooling systems are installed 90% of the time, and these are generally located within the unit or sometimes in the basement or on the patio of each unit. The average seasonal energy efficiency ratio (SEER) of the air conditioners is 8.25. The types of cooling equipment reported in the survey are shown in Table 8. "Other" was not specified by the respondents.

Table 8. Cooling Equipment

Type of equipment	Survey Results (%)
Heat Pump	22.9
Air Conditioner	45.4
Other	31.6

Heating and cooling ductwork is usually located in concealed locations within the conditioned spaces, but it is sometimes also found in unconditioned spaces. When located in unconditioned spaces, the ducts are often in the attic spaces above the ceiling insulation. The R-value of the insulation around the ducts varies from R-11 to R-30.

Typical appliances purchased and installed in the final installation of a typical multifamily building as reported in our survey are: ranges, electrical dishwashers, furnaces, water heaters, refrigerators, and garbage disposers. The major results of our survey respondents are summarized in Table 9.

Table 9.
Summary of Survey Results

GENERAL CHARACTERISTICS
Low-rise (1-3 stories) account for most new construction (75% are 2-3 stories). Almost 90% of the buildings are rectangular in shape. Average unit floor area equals 964 ft^2. Typically, there are 12" to 24" overhangs on the eaves.
CONSTRUCTION CHARACTERISTICS
Walls • 90% of the buildings have wood frame roof and wall construction. • Wall insulation in 90% of the buildings varies from R-11 to R-19. • Party wall insulation in 60% of the building varies from R-8 to R-13.
Floors/Ceilings • Three types of floors are used: Slab-on-grade (70%) crawl-space (25%), basement (5%) • Floor insulation in 42% of the buildings varies from R-8 to R-19. • Ceiling insulation in the buildings varies from R-19 to R-33.
Windows • Equal number of single and double glazing. • Use of aluminium sash (53%) and wood sash 947%). • Few special features: Reflective glazing, Movable insulation, Solar film. • Window areas average 10 to 15% of the floor area of the building.
Infiltration • Use of weatherstripping and caulk (90%).
Systems • Individual heating and cooling systems (90-100%). • Increasing use of heat pump (25.8%) • Important use of air conditioner (46%) • Use of temperature thermostat (20%)

CONCLUSIONS

The results of the survey, where data were available for comparison, were generally consistent with national data obtained from the Department of Housing and Urban Development. However, they are preliminary findings that cover a small percentage of the multi-family sector. It should be noted that for most questions for which we gathered data, there were no data available in the literature or surveys for comparison. Locations with warm climates (California, Florida, Texas) were well represented by our respondents. Because of our small sample size, and also because of the present lack of data on construction characteristics of new low-rise multi-family buildings, we feel that an expanded survey is necessary to increase our knowledge of multi-family construction in various climate regions. In particular, we need data on appliance saturations and occupancy patterns in new low-rise multi-family housing.

The data obtained from both LBL and HUD surveys showed that the overwhelming majority of new units are in buildings with three or fewer stories. This reinforces our decision to study low-rise multifamily buildings. Our initial assumptions used to model a two-story apartment building prototype appear to be valid. However, our survey results identified a need for a new 3-story prototype, (26% of the respondents in our survey are building 3-story garden apartments). From the survey results, we also identified three major research topics that warrant further attention. They are internal loads patterns of multi-family buildings, building peak loads and space conditioning system type selection.

From our survey (and other studies), we found that most new low-rise multi-family construction is in warm locations and that almost all units in these areas use air conditioners for cooling. Therefore, it is important to study methods of reducing cooling energy use and peak demand in such buildings. The total building peak load in low-rise multi-family buildings could be lowered through improved design of a multi-zone building, by understanding the effect of orientation, by the use of thermal mass, by the optimum location of windows and the use of shading. Peak load reductions or shifts in loads to off-peak time, could lead to both consumer and utility company savings, if the utility company concerned uses off-peak rates. For example, San Diego

Gas & Electricity electricity costs drop from 11 cents/kWh during peak time to 7 cents/kWh. during off-peak time. Utility company savings result from a lessened need to generate costly peak energy.

In order to study methods of reducing cooling energy use and peak power demand, we first need to improve our understanding of internal loads in multi-family buildings. The number of persons occupying a zone, the appliances used and the lighting schedules determine the daily profile of internal loads within that zone. These load profiles for each zone are more difficult to determine in a multi-zone building such as a multi-family building, because the different zones are occupied independently of each other. By monitoring an existing building, and by changing the internal loads schedule in the simulation model, we could gain a better understanding of the behaviour of an average zone regarding its occupancy and use of appliances.

Our survey results show that almost all space conditioning systems in new low-rise multi-family buildings are individual in nature. However, it may be more energy efficient to use central systems in some climates. The differences in heating and cooling loads for individual zones at any given moment of time can significantly affect the energy efficiency of a central HVAC system. We plan to study the use of individual space conditioning systems versus central or multi-zone systems, the use of new systems such as heat pumps, and the size and efficiency of the equipment versus the energy use.

Although our preliminary survey results are consistent with the earlier assumptions we made concerning low-rise multi-family construction characteristics, we need to determine whether these results hold for a larger data base of new multi-family buildings and how construction characteristics vary with climate. Additionally, it is important to gather data on appliance saturations and use and occupancy patterns in order to determine better internal loads schedules. This will allow us to study more accurately strategies for reduction of cooling energy use and peak power demand in low-rise multi-family buildings.

REFERENCES

1. "1982 Residential Energy Consumption Survey", DOE/EIA-0314 (82), August 1984, Energy Information Administration, Washington D.C.

2. "Consumption and Expenditures", April 1981 through March 1982, DOE/EIA/0321, September 1983, Energy Information Administration, Washington D.C.

3. "Characteristics of New Housing", 1983, C25-83-13, June 1984, Department of Housing and Urban Development, Washington D.C.

4. "National Council of the Multi-family Housing Industry", February 1985, National Housing Development, Houston.

Appendix A

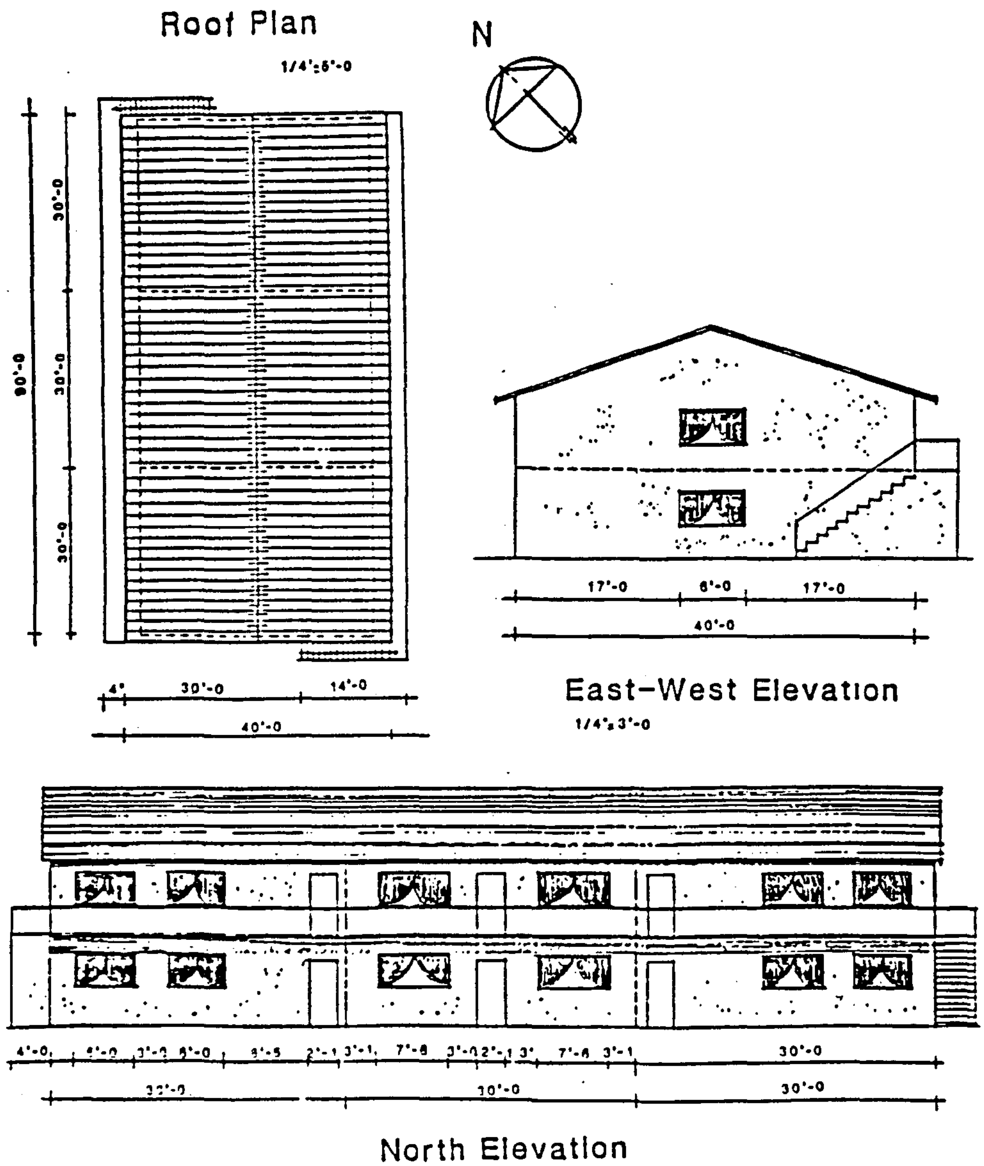
PRELIMINARY ANALYSIS OF A GARDEN APARTMENT PROTOTYPE

Prior to our survey, we first performed a computer analysis, on a two-story garden apartment building, using the best available input data. These data were obtained from typical building plans and a survey for single-family construction conducted by NAHB.

This section describes the modeling assumptions used in our analysis and compares them to the builders survey. The results from our survey confirmed most of the earlier modeling assumptions, and provided new information that will be used in any further energy analyses of new multi-family buildings.

The prototype in our initial study is a two-story building consisting of six 1200 ft^2 apartment units (see A.1), which size is representative of most two-story buildings. For this prototype, we simulated energy use with a computer model (DOE-2), for 45 different locations selected to be representative of most U.S. climates.

A.1: Roof plan and elevations of prototypical multi-family building



The specific construction details for the building envelope are listed below:

WALLS

Exterior Walls: The exterior walls are of the same construction for all six apartment units. We assumed wood frame construction. The wall exterior section consists of: aluminum siding, 1/2" plywood sheathing, wood stud or insulation, and 1/2" drywall. The size of the wood stud varies with the wall insulation. The total insulation R-value varies from R-0 to R-27.

Party Walls: The layer of materials comprising the party walls, i.e., the walls separating the units, are assumed to be constructed as follows: 2 layers of 5/8" gypsum board, R-11 insulation, and 2 layers of 5/8" gypsum board.

FLOORS

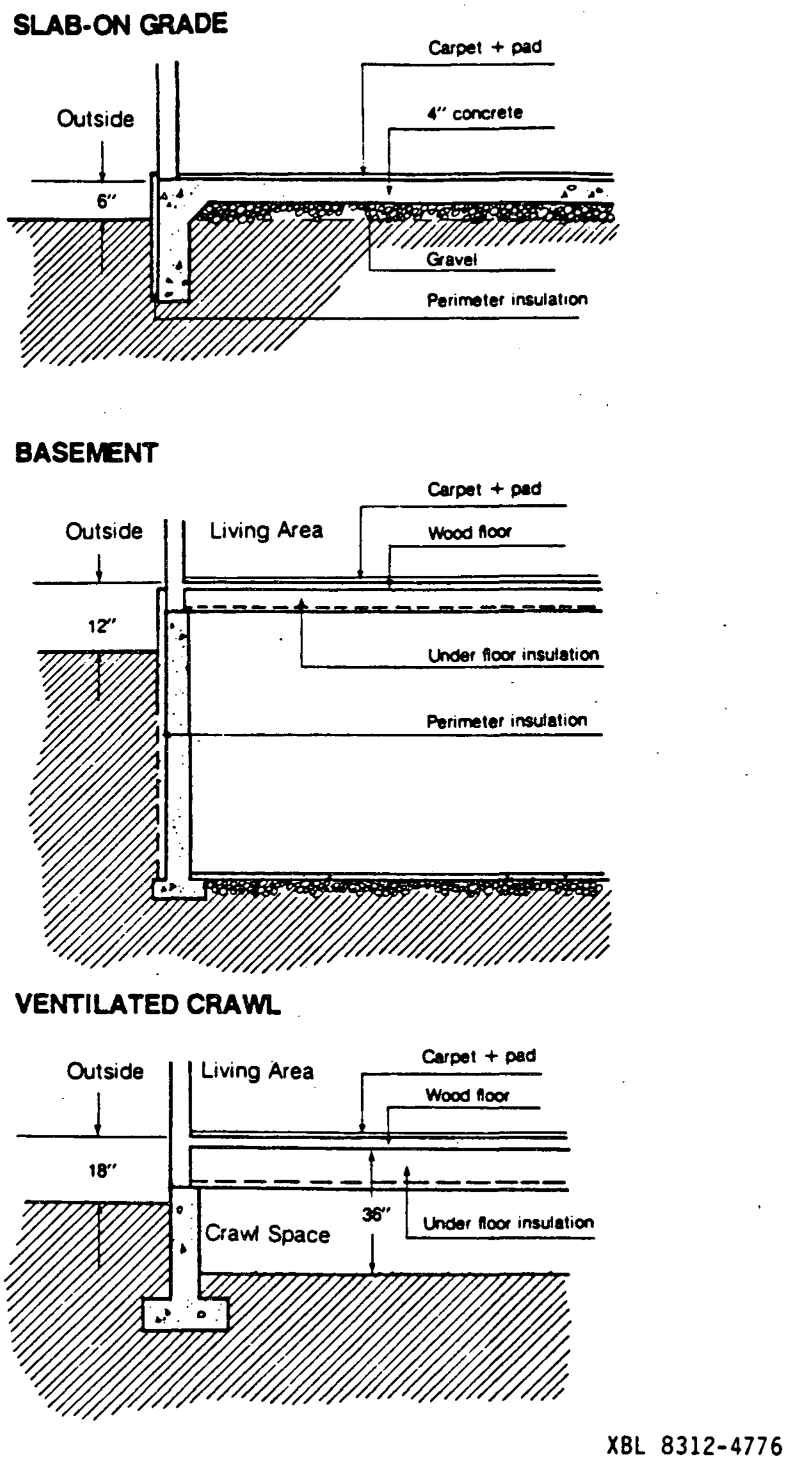
Foundations: We modeled three foundation types: a ventilated crawl space, a slab-on-grade and a basement, with varying insulation levels. We selected the foundation types (see A.2) for each location on the basis of the climate. They are as follows:

- The slab-on-grade is assumed to be a 4 inch concrete slab resting on a gravel bed, with a polyethylene film on the bottom. The top of the slab is covered with pad and carpet. Insulation on the perimeter of the slab extends down from one to two feet.

- The basement is assumed to be unheated. It has 8 feet high walls, extending 6 inches above the ground level. Batts placed between the floor joists are used for insulation.

- The crawl space is assumed to be ventilated. Its insulation is batts between the floor joists.

Ceiling/Floor: We assume the floor separating the upper from the lower level apartment units to include the following materials: Rug and pad, 1" plywood, 2"x10" wood stud (or R-11 insulation), 1/2" gypsum board.



A.2: Schematic Drawing of Foundation Model

ROOF/CEILING

We assume a pitch roof design with overhangs of 2 feet on the eaves and 1 1/2 feet on the gable sides. The roof absorptance has a default value of 0.7 corresponding to a dark colored paint or shingles. The layer of materials that comprise the roof are as follows:

Roof: asphalt shingles, 1/2" plywood finish, wood rafters (the sizing of the rafters varies with the thickness of the insulation), attic air space and 1/2" plywood and 1/2" drywall as a finishing material for the ceiling. The insulation varies from R-0 to R-38.

Roof/Ceiling: The ceiling is assumed to be 2x6" ceiling joists, 24" O.C wood framing with 1/2" drywall and 1/2" plywood. The insulation is fiberglass batts placed both between and on top of the ceiling joists.

WINDOWS

In our previous analysis, we used the assumption that window area was equal to 8% to 10% of the floor area. In that analysis, we assumed windows to be equally distributed on all exterior walls. The number of window panes ranged from one to three with an 0.5 inch air gap between the panes. Our survey confirmed the assumption that window area is equally distributed on all four sides. We also found that window area was equal to 10% to 12% of the floor area which is consistent with the lower window area simulated (10% of the floor area).

SPACE CONDITIONING SYSTEMS & APPLIANCES

Part of our research focused on methods of reducing building heating and cooling energy use. Thus, it was necessary to assume the type of equipment used and its efficiency. In our modeling assumptions, we decided to simulate three types of space conditioning systems: a gas or oil furnace (heating), an electric air conditioner (cooling) and an electric heat pump (heating & cooling.)

These systems types correspond to the type of equipment found in our survey. It should be noted that individual systems are found in 95% of all units.

Our energy use analyses assumed internal loads due to heat gain from the following appliances: range, refrigerator, freezer, clothes dryer, water heater, and television and from lights and occupants. We assumed the house occupancy to be 3.2 persons, reflecting an average single-family household in the United States. A recent estimate of the average single-family building occupancy indicated a value of 3.05 persons per household based on 1980-1981 census data. The impact of 3.05 persons in comparison to 3.2 persons on heating and cooling loads is less than 1%, which is negligible for analytical purposes[1]. These internal loads schedules are described in more detail in another report[2]. We did not gather sufficient information on appliances or occupancy from this survey to make comparisons to our earlier assumptions.

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1. "Affordable Housing through Energy Conservation, Technical Support Document", Y. J. Huang, et al., Lawrence Berkeley Laboratory, LBL report 16342, July 1985.

2. "Low Rise Multi-Family Housing: Prototype Development and Preliminary Energy Analysis", Isaac Turiel et al., Lawrence Berkeley Laboratory, LBL-18823, April 1985.

Appendix B

PRELIMINARY SURVEY OF FOR MULTIFAMILY HOMEBUILDERS

Please answer the following questions to the best of your ability considering low-rise multifamily buildings designed and constructed during the past twelve months or still in the design stage. Low-rise multifamily buildings for the purpose of this study are defined to be buildings with five or more units on four or less floors. Rule of thumb estimates are adequate for the purposes of this study. If you have any questions please contact Isaac Turiel at (415) 486-6493.

1. Most of the multifamily buildings we build are located in the following state or states

____

1a. We construct approximately ____________ multi-family units per year

2. The responses on this questionnaire are relevant to construction in the following states.

____

3. The percentage of buildings we construct of the following types are

   a) one-story ___% b) two-story ___% c) three-story ___%

   d) four-story___% e) > four stories ___%

4. The buildings we construct (%) are shaped as follows:

   a) rectangular ___% b) L-shaped ___% c) U-shaped ___%

   d) other insert answer ___%.

5. The average floor area per unit, ceiling to floor height, and the approximate percentage of each type of unit are as follows:

% units   Average ft^2 Floor to ceiling height

Studio

One Bedroom

Two Bedroom

3 or more

6. What determines building orientation

a) street layout ___ b) solar access ___ c) views ___ d) other ___

please specify ____

7a. Our most typical roof construction is

a) wood frame ___ b) steel ___ c) masonry ___ d) other ___

7b. Give details on construction materials used.

____

____

8. Our roofs are usually a) flat ___ b) peaked ___ c) other ___

9. We usually install ceiling insulation. a) Yes ___ b) No ___

10. If yes, What is the usual type and R-value?

____

____

11a. Our most typical exterior wall construction is

a) wood frame ___ b) steel ___ c) masonary ___ d) other ___

11b. Give details on construction materials used.

____

____

12. We usually install insulation in the exterior wall a) Yes ___ b) No ___

13. If yes, What is the typical type and R-value?

____

14. Our most typical interior wall construction is

____

15. Party walls are typically insulated. a) Yes ___ b) No ___

16. If insulated, What is the usual type and R-value?

____

17. Floors between units are usually constructed as follows:

____

18. Floors between units are usually insulated a) Yes ___ b) No ___

19. If insulated, What is the typical type and R-value?

____

20. Foundations are usually a) basement __ b) crawl-space __ c) slab __ d) other ___

21. If basement, is it heated and insulated? Please provide details.

____

____

22. If crawl-space, is it ventilated and or insulated? Please provide details.

Describe garages underneath as crawl space construction.

____

____

23. If slab, is it insulated? Please provide details.

____

____

24. The typical roof color is a) light ___ b) medium ___ c) dark ___

25. The typicar exterior wall color is a) light ___ b) medium ___ c) dark ___

26. On some buildings we add additional mass to the roof, walls or floors to reduce cooling or heating loads. a) Yes ___ b) No ___

If yes, give details on where mass is added and how much.

____

____

27a. Our windows are usually a) single-glazed ___ b) double-glazed ___ c) triple-glazed ___.

27b. Our typical window sash type is a) aluminum __ b) wood __

c) aluminum with thermal break __

27c. Our window glass type is usually a) regular ___ b) reflective ___ c) absorptive ___

d) tinted ___ e) other ___?

28. Do you install movable window insulation? a) Yes ___ b) No ___

If yes, how often and what kind?

____

____

29. The north-facing window area is typically ___% of the floor area.

30. The south-facing window area is typically ___% of the floor area.

31. The east-facing window area is typically ___% of the floor area.

32. The west-facing window area is typically ___% of the floor area.

33. If you cannot answer above, for each apartment type (studio, etc.), what is total window area as a percentage of the floor area?

a) studio __% b) one bedroom __% c) two bedrooms __% d) 3 or more __%

34a. Are windows recessed from plane of exterior wall? a) Yes __ b) No __

If yes, by how much? a) E-facing ___ b) W-facing ___ c) N-facing ___ d) S-facing ___.

34b. Do windows usually have a solar film attached for reduction of solar gain?

a) Yes ___ b) No ___

35. Is it typical to have external overhangs? a) Yes ___ b) No ___

If yes, please give width, length, and location of overhangs for all four sides of building.

____

36. Sunspaces are built in ___% of units.

37. We usually install weatherstripping around doors and windows to reduce infiltration. a) Yes ___ b) No ___

38. We usually caulk around cracks and openings in building shell and install vapor barriers to reduce infiltration. a) Yes ___ b) No ___

39. We usually install whole house fans. a) Yes ___ b) No ___

40. We usually install ceiling fans (solely for air movement and not for increased infiltration).

a) Yes ___ b) No ___

41a. Heating systems are usually:

a) individual-one for each unit ___ b) central for whole building ___ c) other ___

41b. Heating systems are usually located ___________________.

42. The percentage of units with the following type of heating equipment is as follows:

a) electric resistance ___% b) heat pump ___% c) gas furnace ___%

d) oil furnace ___% e) other ___%.

43a. Cooling units are a) one or more room air conditioners ___

b) one unit for each apartment ___ c) a central unit for each building ___

d) other-explain ___ e) none ___.

43b. Cooling units are usually located ___________________

43c. The percentage of units with the following type of cooling equipment is as follows:

a) heat pump ___% b) regular air conditioner___% c) other-give type ___%.

44. The seasonal energy efficiency ratio (SEER) of average air conditioners we

install is ____

45a. Heating and cooling ductwork is located in

a) conditioned __ b) unconditioned spaces ___?

45b) If located in an unconditioned space, what is the R-value of the insulation, if any?

____

____

46. Thermostats with a setback provision are installed in ___% of units.

47a. Radiant barriers are sometimes used to increase the effectiveness

of insulation. a) Yes ___ b) No ___

47b. If yes, Where is it used?

____

____

47c. If yes, How often is it used?

____

____

____

48. Please list appliances purchased and installed in typical multifamily buildings. If known, please give capacities of equipment, efficiencies, and fuel used. Are energy-efficient appliances ever chosen or are lowest cost appliances usually chosen? Please describe.

____

____

____

49. If you would like to add any information on building characteristics that were not adequately covered, please do so. For example, are energy related characteristics of rental units substantially different than those of owner occupied units.

Appendix C

LIST OF RESPONDENTS TO MULTIFAMILY HOUSING QUESTIONNAIRE

American Diversified Corporation (5)*
Lester G. Day
3200 Park Center Drive
Suite 1500
Costa Mesa, CA 92626

Brabham, Debay and Associates
Lewis Brabham, P.E.
2725 N. Australian Avenue
West Palm Beach, FL 33407

Cardinal Industries (6)*
Broderick Holt
2192 Seville Avenue
Columbus, OH 43232

Cenvill Development Corporation (16)*
Bob Black
13400 South West 10th Street
Tembroke Pines, FL 33027

Empire West Companies (17)*
Dale Cox
5656 E. Grant Road
Suite 100
Tucson, AZ 85712

Jagger Associates (11)*
Mike Weyrand
Construction Department
1201 Spyglass Road
Austin, TX 78746

Krueger Bensen Ziemer
Joe Wilcox, A.I.A.
30 West Arrellaga Street
Santa Barbara, CA 93101

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1156 North Mountain Avenue
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San Francisco, CA 94123

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16901 Dallas Parkway
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Ryan Homes (4)*
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Scottsdale, AZ 85253

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