The Residential Building Characteristics On-Site Inspection: Summary Report

**S. A. Weakley
R. F. Darwin**

T. L. Howe

June 1990

**Prepared for the
Bonneville Power Administration
under a Related Services Agreement
with the U.S. Department of Energy
Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute**

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor Battelle Memorial Institute, nor any of their employees, makes any warranty, expressed or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or Battelle Memorial Institute. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE MEMORIAL INSTITUTE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America

Available to DOE and DOE contractors from the
Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831;
prices available from (615) 576-8401. FTS 626-8401.

Available to the public from the National Technical Information Service,
U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161.

NTIS Price Codes, Microfiche A01

Printed Copy

Price Code	Page Range	Price Code	Page Range
A02	1- 10	A15	326-350
A03	11- 50	A16	351-375
A04	51- 75	A17	376-400
A05	76-100	A18	401-425
A06	101-125	A19	426-450
A07	126-150	A20	451-475
A08	151-175	A21	476-500
A09	176-200	A22	501-525
A10	201-225	A23	526-550
A11	226-250	A24	551-575
A12	251-275	A25	576-600
A13	276-300	A99	601-Up
A14	301-325		

THE RESIDENTIAL BUILDING CHARACTERISTICS
ON-SITE INSPECTION: SUMMARY REPORT

S. A. Weakley
R. F. Darwin
T. L. Howe

Manuscript Completed: December 1987
Date Published: June 1990

Prepared for
the Bonneville Power Administration
under a Related Services Agreement
with the U.S. Department of Energy
Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Richland, Washington 99352

SUMMARY

The Residential Building Characteristics On-Site Inspection (RI) was sponsored by the Bonneville Power Administration (BPA), and implemented by Energy Counselors, Inc., of Beaverton, Oregon. The purpose of the inspection was to collect detailed information on the structural characteristics and capital equipment of residences participating in BPA's End-Use Load and Conservation Assessment Program (ELCAP).

ELCAP is a long-term program to collect information on the structural characteristics of residences in the Pacific Northwest as well as the attitudinal, behavioral, and demographic characteristics of the residences' occupants. Combined with other data collection efforts, the information obtained by the RI will be used to assess and evaluate energy use and conservation within the region's residential sector.

This report documents the design of the inspection instruments (forms), the implementation of the inspection, and some of the results from the data base. The number of residences inspected was 416 or 93% of the potential sample of 447 residences.

The structural information gathered about each residence included detailed descriptions of each exterior wall, window, exterior door, foundation, ceiling/roof, and floor. The capital equipment information included details on each residence's HVAC system(s), refrigerator, freezer, dishwasher, and hot water heater as well as the total number of other appliances. For residences having an accessible crawl space, a detailed inspection of the crawl space was performed to identify potential moisture and/or insect problems. Other, general information obtained in the inspection included the age of the house, the type of dwelling unit, ventilation information, the number of levels in the house, the occupied area and volume, the number of rooms in the residence, and any modifications and/or additions that had been made to the residence since August 1983. All of the above information has been encoded and entered into the Characteristics Data Base at PNL.

CONTENTS

SUMMARY	iii
1.0 INTRODUCTION.....	1.1
2.0 INSPECTION DESIGN AND IMPLEMENTATION	2.1
2.1 INSPECTION DESIGN	2.1
2.2 INSPECTION IMPLEMENTATION	2.4
3.0 RESULTS.....	3.1
3.1 GENERAL CHARACTERISTICS.....	3.2
3.2 HVAC SYSTEM CHARACTERISTICS.....	3.9
3.3 INSULATION CHARACTERISTICS	3.15
3.4 FOUNDATION CHARACTERISTICS.....	3.21
3.5 APPLIANCE CHARACTERISTICS.....	3.26
3.6 CRAWL SPACE INSPECTION RESULTS.....	3.30
3.7 RECOMMENDATIONS.....	3.32
REFERENCES	R.1
APPENDIX A - QUALITY ASSURANCE OF RESIDENTIAL INSPECTIONS	A.1

FIGURES

2.1	Postcard Sent to ELCAP Residents.....	2.5
3.1	ELCAP Regions	3.4

TARLES

3.1	Number of Inspected Residences by Study Type.....	3.1
3.2	General Characteristics of the 416 Inspected Residences.....	3.3
3.3	Conditioned Area of Dwelling by Year Built.....	3.5
3.4	Geographic Location of Dwellings by year Built.....	3.5
3.5	Type of Residence by Year Built.....	3.6
3.6	Geographic Location of Dwellings by Conditioned Area.....	3.7
3.7	Type of Residence by Conditioned Area.....	3.7
3.8	Type of Residence by Geographic Location of Dwellings.....	3.8
3.9	HVAC System Characterization.....	3.9
3.10	Heating System Type by Year Residence Built.....	3.10
3.11	Heating System Type by Conditioned Area.....	3.11
3.12	Heating System Type by Geographic Zone.....	3.12
4.13	Heating System Type by Type of Residence	3.13
3.14	Heating System Type by Wood Heating System.....	3.14
3.16	Floor Insulation Material and Location	3.16
3.15	Residences with Insulation.....	3.15
3.17	Ceiling Insulation Characteristics.....	3.17
3.18	Ceiling Insulation Material by Year Residence Built.....	3.18
3.19	Ceiling Insulation Material by Conditioned Area	3.19
3.20	Ceiling Insulation by Geographic Zone.....	3.19
3.21	Ceiling Insulation Material by Type of Residence.....	3.20
3.22	Foundation Characteristics.....	3.21
3.23	Foundation Type by Year Residence Built.....	3.22
3.24	Foundation Type by Conditioned Area	3.23

3.25 Foundation Type by Geographic Zone.....	3.24
3.26 Foundation Type by Type of Residence.....	3.25
3.27 Types of Hot Water (HW) Heaters.....	3.26
3.28 Location of Hot Water Heaters.....	3.27
3.29 Capacity of Hot Water Heaters.....	3.27
3.30 Types of Refrigerators.....	3.27
3.31 Location of Refrigerators.....	3.28
3.32 Types of Freezers.....	3.28
3.33 Location of Freezers.....	3.29
3.34 Other Appliances/Equipment Found in RI Houses.....	3.29
3.35 Crawl Space Problems.....	3.30
3.36 Crawl Space Problems by Geographic Zone	3.31
3.37 Crawl Spaces Problems by Presence of Insulation.....	3.31
3.38 Crawl Space Problems by Presence of Vapor Barriers.....	3.31

1.0 INTRODUCTION

Electricity is an important energy resource in the Pacific Northwest. Adequately planning for the region's future electricity needs requires extensive information about how electricity is used by the region's consumers. The End-Use Load and Conservation Assessment Program (ELCAP) was launched by the Bonneville Power Administration (BPA) in September, 1983, to more fully understand the levels and patterns of electrical loads throughout the region, and to determine the size of the conservation resource in the region's residential and commercial sectors.

Under the ELCAP, 447 residences are being monitored with a Field Data Acquisition System (data logger) for hourly electricity consumption by end use. The residences are located throughout BPA's service area of Washington, Oregon, Idaho, western Montana, and Wyoming. The Residential Building Characteristics On-Site Inspection (RI) was developed and managed by the Pacific Northwest Laboratory (PNL) under contract to BPA in order to obtain detailed information on the structural characteristics and capital equipment of the ELCAP residences.

The RI survey was conducted by Energy Counselors, Inc., of Beaverton, Oregon, over a one-year period from September 1985 through August 1986. In the first phase, 368 residences, or 82% of the total, were surveyed in less than four months. In the second phase 48 residences were surveyed over a three-month period. All of the data gathered were checked for accuracy and then entered in the Characteristics Data Base (CDB) at PNL.

The results of the RI will be used in combination with information obtained from other ELCAP surveys, such as the Residential Occupant Survey - Mail (ROSM), the Residential Occupant Survey - Telephone (ROST), and the Residential Occupant Survey - Spring '86 (86ROS). The information obtained from these surveys and the RI has been entered into the Characteristics Data Base (CDB) at PNL. The CDB, in combination with the ELCAP Engineering Data Base, which contains the hourly electricity consumption of each residence by end use, will allow a number of analyses of residential sector electric energy use. Also, combining the data obtained from the RI with other survey results in the

ELCAP Fundamental Residential Characteristics data base will provide the energy analyst with a large data set of structural and appliance information and the attitudinal, behavioral and demographic characteristics of the residences' occupants.

This report provides both information on the development and implementation of the RI and on selected descriptive results. In Section 2.0 the survey's design and implementation are described. Section 3.0 summarizes the information obtained from the survey.

2.0 INSPECTION DESIGN AND IMPLEMENTATION

In this section, the work that went into developing the inspection design is described and the inspection design and implementation of the inspection are reviewed. Problems encountered during the survey's implementation and actions taken to solve them are also discussed.

2.1 INSPECTION DESIGN

Design of the RI began in January 1985. A series of meetings between BPA and PNL personnel were held to determine the type and amount of information needed about each ELCAP residence. These meetings determined that an onsite inspection of each residence was required because of the large amount of structural and appliance information that was desired. A preliminary design for the RI was drawn up at PNL in January and February 1985 using input from PNL and BPA personnel. To aid in computer entry of the data, the answer forms for each inspection were separated from the questions themselves. The questions and the coded list of answers for each question were contained in a code booklet. The coded answers were entered on separate summary sheets that were to be used by data entry personnel to input them into the CDB. Separate floor plan sheets were included for each floor of the residence and were to contain the location of all windows, doors, stairs, HVAC equipment and major appliances.

Due to the detailed nature of the RI and to save cost, the inspectors did not calculate any overall heat-transfer values for the structural parts of the residence, i.e., for walls, floors, ceilings, etc. Instead, the inspectors recorded the areas of each wall, floor, etc., and the type of construction and insulation, if any. The insulation information included the type, material, thickness, and R-value. The R-values for various materials were included as an appendix to the code booklet so that each inspector would use the same values. With this information the analyst can calculate each overall heat-transfer coefficient.

In March and early April 1985, design work focused on refining the questions and the format of the summary sheets. After the code booklet and

associated summary sheets were refined, they were field tested on eight ELCAP base-case residences. During and immediately following the eight inspections, two new versions of the code booklet were made. Small changes that the inspectors noted were then incorporated. However, one major problem remained with the inspection: how to handle multiple heating systems in one residence.

BPA and PNL personnel resolved the problem at an April 15, 1985, meeting by deciding that each major heating system would have an associated zone or area of the house identified with it. This zone was labeled and mapped on the floor plan and identified with a particular heating system on the computer summary sheets. Minor heating systems contained within a major heating system zone were to be identified and labeled as a subzone on the floor plan and the summary sheets. The area and volume of these zones and subzones were also to be included on the summary sheets as conditioned areas. Other additions to the floor plan made at that time included the orientation of the house, the length of all perimeter walls, the average ceiling height, and the square footage of each floor.

Two other changes were also made to the code booklet at the meeting. The first was a change in the location part of several of the questions in the code booklet. After zoning was approved, the codes for conditioned and unconditioned zones could be used to identify the locations of doors, walls, windows, floors, HVAC equipment and appliances in the house. In addition to the zone codes for location questions, the following alphanumeric symbols were adopted for the entire code booklet: A for Attic, CS for crawl space, O for Outside, MF for Multi-Family, and G for Ground. The second change to the code booklet was the addition of an insulation-type question to wall, ceiling/roof, and floor questions. Previously, only the insulation material was requested, not the type or form of the insulation, i.e., batt or blanket, loose or blown-in, loose fill in confined cavity, and board or slab.

At the April 15 meeting, a new section entitled "Modifications and Additions Questions" also was added to the RI. The eight questions in the section related to changes or additions the residents may have made to their houses since the summer of 1983. These questions were designed to update an earlier

BPA study, the 1983 Pacific Northwest Residential Energy Survey. The residents' answers to these questions were recorded on separate sheets rather than on the summary sheets. These data were not entered into the computer data base. All of the changes made to the RI design document resulting from the April 15 meeting were completed by mid-June 1985.

On April 19, 1985, BPA requested a feasibility study of the inspectors using microcomputers in the field to enter the RI results. Using microcomputers would have allowed the data to be directly input to the data base rather than on summary sheets or forms. The study results were sent to BPA on May 15, 1985. BPA recommended that the data be entered on paper by the inspectors in the field and entered on the computer data base by PNL staff. The microcomputer entry from the field was seen as being too expensive and of unknown quality compared with the recommended procedure.

On May 31, 1985, BPA decided that residents being monitored as part of their Residential Standards Demonstration Project (RSDP) would also be inspected. This added 111 more residences to the survey for a total of 447.

In July 1985 the inspection of all accessible crawl spaces was included as part of the residential survey in order to identify crawl spaces that had moisture and/or insect problems. As a result of this addition, questions dealing with the exterior contact of the walls and foundation with shrubs, trees and earth were added to the code booklet because these exterior contacts were seen to be ways that insects may enter the walls or foundation. Another sign of insect presence may be sill decay, which was also included as a window question. A question on the accessibility of the crawl space, if one was present, was also added to the code booklet. If the crawl space was accessible, then four more questions were to be answered dealing with water run off and the crawl space vents, entry and odor. Each accessible crawl space was to be diagrammed on a separate sheet with all problems and their locations identified. If more information were obtained, it was to be recorded on a separate page called Inspector Comments.

The September 1985 version of the code booklet and summary sheets included all of the above crawl space changes as well as some simpler changes. Two

changes were made to the procedures manual, which was to be used by the inspectors in the field. One change was that the floor plan of the kitchen was to be drawn separately from the rest of the house, with the distance between the refrigerator, stove, oven and/or range noted on the diagram. This information was to be used to judge the effect of these appliances use on each other. One other change was the decision not to subzone for wood stoves and fireplaces.

The September 1985 version of the survey was field tested during the first week in October 1985. The 20 pilot surveys were reviewed at a meeting with BPA and PNL staff, and the inspectors. Resulting from this October meeting was an agreement on the final version of the procedure manual, code booklet, and all forms. One change was to include a separate kitchen diagram form in each survey. The crawl space diagram was modified to include some idea of the severity of the problems encountered. Two questions were added to the "Modifications and Additions Questions" section concerning small businesses being run in the house and whether the data logger is labeled properly. The code booklet itself was essentially unchanged after the pilot surveys.

The final revision of the survey was published as an ELCAP document entitled Procedures Manual for ELCAP Residential Building Characteristics Survey (BPA 1986). Included in that report are all forms and the code booklet used by the field inspectors.

2.2 INSPECTION IMPLEMENTATION

In June 1985, eight companies were sent a Request for Proposal (RFP) for collecting field data from the residential ELCAP participants. The RFP consisted of a statement of work, quality assurance requirements, evaluation criteria to be used in evaluating the RFP, and other solicitation and general provisions. Seven of the eight companies submitted proposals in July 1985 and a source evaluation team composed of five PNL researchers reviewed the proposals according to the evaluation criteria sent with each RFP. Energy Counselors, Inc. (ECI), of Beaverton, Oregon, was selected by the evaluation team to perform the onsite data collection. A contract with ECI was finalized in August 1985.

Because an inspection of all accessible crawl spaces was added to the PI, a supplement to the contract with ECI was negotiated and then signed in September 1985. Also in September PNL sent each ELCAP resident a postcard reminding them of the inspection and identifying ECI as the firm that would conduct the inspection. A copy of this postcard is shown in Figure 2.1.

In September two other tasks were also added to the inspection. The first task was to photograph each temperature sensor inside and outside the home and to also photograph the Northern exposure of the house and the meteorological station, if one was present. The second task was to affix a U.S. Government property sticker to the Field Data Acquisition System (FDAS) (ELCAP's electricity monitor) or data logger if one was not present on the unit. The cameras and FDAS stickers were given to ECI with instructions in September.

A training session for the ECI inspectors was held on September 23, 1985, in Portland, Oregon. The survey forms were distributed and discussed line by line; instructions were given on completing the floor plan sheets and zoning set-up; and an overview was given of the ELCAP. A session on how to gather the appliance information was given by BPA personnel, and a special session on identifying insect and moisture problems in crawl spaces was presented by a

A Residential Building Survey (Inspection) for the homes in your region has been scheduled to begin after 10/1/85 and will be performed by:

**Energy Counselors, Inc.
7873 S.W. Cirrus Drive
Beaverton, Oregon**

A representative of the firm will contact you soon to arrange for a specific time to perform the work.

Pacific Northwest Laboratory is operated for the U.S. Department of Energy by
Battelle Memorial Institute

FIGURE 2.1. Postcard Sent to ELCAP Residents

consultant. At the meeting it was decided that the pilot study sample of 20 residences would be done in the Portland, Oregon, area beginning in October 1985.

During the first week in October 1985, 20 residences in the Portland, Oregon, area were inspected by Energy Counselors, Inc., (ECI) personnel. The results were sent to PNL and analyzed over the next two weeks. Minor changes to the survey's design were made. The final survey design changes were completed by October 20, 1985, and the new forms, code booklets, and floor plan sheets were then sent to ECI.

As a result of the pilot study, a brochure describing ELCAP was sent to all ELCAP residences to aid in site relations between ECI and the residents and to describe in more detail the importance of the inspection. The brochure was prepared and sent to the residents at the end of November 1985. The ECI inspectors also were given some of the brochures to hand to any residents who had not yet received theirs.

Phase I of the RI began in the field on October 29, 1985, and lasted until February 15, 1985. Over the 14-week period of Phase I, most of the regions of the ELCAP area were to be visited for inspection only once. During Phase I of the RI, 368 residences were inspected by ECI. Of the remaining 79 residences, only 6 residences refused to admit ECI for the RI.

As Phase II of the RI, ECI attempted to visit the 79 residences that were not inspected in Phase I.

Phase II of the RI began in the field on June 2, 1986, and was completed on August 28, 1986. All surveys from Phase II were received at PNL by September 10, 1986, and entered into the data base by the end of September. As part of Phase II, 48 residences were surveyed. The survey forms and documents were the same as used in Phase I.

By the end of Phase II, 31 residences had not been inspected and 416 had been inspected, representing a success rate of 93%. Of the 31 residences not inspected, 10 residents refused to allow ECI to inspect their house, 9 were unable to schedule a time for ECI to inspect, and 12 residences could not be inspected because PNL had not signed access agreements with the owners and/or renters.

After the surveys were sent to PNL, a Quality Assurance (QA) inspection of the data was performed. Appendix A details the QA procedures followed at PNL. If major problems were encountered with any surveys, they were sent back to ECI with questions for interpretation. In most cases the inspectors, after reviewing the returned survey, were able to resolve any problems encountered.

After passing the QA examination, the surveys were submitted to data processing for entry into the CDB. Any questions that the data entry personnel had were resolved before final entry occurred. To assure that all data were entered into the CDB correctly, a double entry QA process was used. This involved two data entry personnel entering the same data and then checking for any differences.

Most of the computerized data were entered into the main data base (the CDB). Three other data bases, however, also were created and/or changed at PNL as a result of the RI. The crawl space data were entered into a separate data base for later analysis. Also, some of the information on the crawl space diagram was encoded and entered in this data base. All ECI and customer comments recorded on the survey's "Inspector Comments" sheet were entered into a separate data base, ANALNOTES. Finally, the date that ECI inspected the residence was entered into the FIXNOTES subdirectory. The FIXNOTES subdirectory is used to keep track of all site visits to ELCAP residences.

In addition to the above computer data bases, there are also paper copies of much of the above data. The survey forms, floor plan sheets, photographs and comment sheets are stored at PNL in their original form for future reference. All of the QA questions about each survey and changes made to the ECI inspectors' survey forms made at PNL were written down and are also stored at PNL. These written documents also serve as backup to the CDB as well as original documents of the RI.

The residents' comments that were recorded by the ECI inspectors primarily dealt with structural details about the house, such as insulation type and thickness, heating systems most often used, etc. The most common nonstructural comments were requests for results or information about the energy uses in the house and questions about when the ELCAP metering would be finished. Some

complaints were also received that there were too many visits from ELCAP-related personnel. This was also the primary reason given by the 10 residents who refused to allow ECI to inspect their houses. Other than this complaint, most of the residents were very cooperative and helpful to the ECI inspectors.

3.0 RESULTS

This chapter summarizes the information obtained from the RI and contained in the CDB. The intent of this discussion is to give a brief description of the inspected dwellings' structural and appliance characteristics.

The residences that participated in the RI are from seven different samples or studies, and the following results cannot be generalized to other populations. Table 3.1 shows the seven studies and the number of inspected residences in each study. The ELCAP base case comprises 64% of the total residences inspected. The Current Code (CC) Study residences are new houses built to their state's existing codes. The Model Conservation Standard (MCS) Study residences are new homes built to meet new, stricter codes for residential construction in the Pacific Northwest. The residences from the CC and MCS studies comprise 25% of the total residences in the RI. The other studies each make up less than 10% of the total residences inspected. The final subcategory shown is not a study but is the total number of residences that have dropped from the ELCAP.

Section 3.1 reviews and summarizes the following general characteristics of all the inspected residences in the CDB: the ages of the residences, the conditioned square footage of the residences, the geographic dispersion of the dwellings, and the types of residences. Sections 3.2 through 3.5 present

TABLE 3.1. Number of Inspected Residences by Study Type

<u>Study Type</u>	<u>Number of Residences</u>	<u>Percentage of Residences</u>
ELCAP Base Case	267	64
Condominiums	2	0.5
Renter Occupied	10	2
Mobile Home	10	2
Gas/Oil Heat	20	5
Current Code	30	7
Model Conservation Standard	72	18
Dropped from ELCAP	5	1

information about the residences, HVAC systems, insulation, foundations, and appliances. In addition, the structural and HVAC information is related to the general characteristics defined in Section 3.2. Section (3.6) discusses the crawl space survey results, and a recommendation's section ends the chapter.

3.1 GENERAL CHARACTERISTICS

Table 3.2 shows 5 general characteristics categories for the 416 inspected residences: year the residences were built, the conditioned area of the residences, the geographic regions and zones where the residences are located, and the type of residences. Each of these general characteristics categories is broken into several subcategories that show the number of residences and the corresponding percentage of residences within each subcategory.

As the year built category shows, the number of residences inspected was almost evenly divided among the three time periods; the pre-1960 subcategory had slightly fewer residences than the other two subcategories. In the conditioned area category, smaller houses, $<1000 \text{ ft}^2$, accounted for only 12% of the residences inspected, whereas the other three subcategories were evenly divided at ~30% of the population each.

The 22 geographic regions listed in Table 3.2 are mapped in Figure 3.1 and can be grouped into three zones. Zone #1 consists of western Washington and western Oregon and encompasses Regions 11-18. Zone #2 consists of eastern Washington, eastern Oregon, Idaho, and a small part of Wyoming and encompasses Regions 3-10, 19, 20, 21 and 22. Geographic zone #3 is western Montana and is made up of residences in Regions 1 and 2. Geographic zone #3 contains only 10% of the residences, but the remaining 90% is almost evenly split between zones 1 and 2.

The type of residences which responded to the RI are also shown in Table 3.2. The types are divided into single-family dwellings, split further by the number of stories, including split level and mobile homes, and multi-family dwellings, further split by the number of units in the complex. One-story single-family dwellings make up 56% of the residences in the inspection. The 1-1/2 and 2-story single-family dwellings make up 31% of the residences

TABLE 3.2. General Characteristics of the 416 Inspected Residences

Year Built	Number of Residences	Percentage of Residences
Before 1960	111	27
1960 to 1978	160	38
After 1978	145	35
Conditioned Area		
<1000 ft ²	49	12
1000 to 1500 ft ²	129	31
1501 to 2000 ft ²	111	27
2000 ft ²	127	30
Geographic Region(a)		
1	31	7
2	13	3
3	18	4
4	25	6
5	21	5
6	5	1
7	32	8
8	1	0.2
9	7	2
10	11	3
11	11	3
12	12	3
13	46	11
14	36	9
15	39	9
16	7	2
17	25	6
18	14	3
19	8	2
20	15	4
21	11	3
22	28	6
Geographic Zone		
#1 = Western Oregon + western Washington	190	46
#2 = Eastern Oregon + eastern Washington + Idaho + Wyoming	182	44
#3 = Western Montana	44	10

(a) See Figure 4.1 for map regions.

TABLE 3.2. (contd)

Type of Residence	Number of Residences	Percentage of Residences
Single Family:		
1 Story	233	56
1 1/2 Story	51	12
2 Story	78	19
2 1/2 Story	3	0.7
3 Story	4	1.7
Split Level	24	6
Mobile Home	10	2
Multi-Family:		
2 Unit (duplex)	3	0.7
4 Unit	9	2
5 or More Unit	1	0.2

FIGURE 3.1. ELCAP Regions

inspected. The remaining 13% is divided among the other 7 subcategories, with only 3% of the residences being multi-family dwellings.

The rest of this section shows how the characteristic categories listed in Table 3.2 interrelate with each other. Table 3.3 shows that the smaller houses, those with $<1000 \text{ ft}^2$ of conditioned space, make up a larger percentage of older homes than of newer ones. The other three subcategories of conditioned area are about the same over time, with only a slight increase in larger houses, $>2000 \text{ ft}^2$, being built in the 1960 to 1978 time span.

Table 3.4 examines the residences' geographic distribution by year built. In geographic zone #3, the proportion of houses built after 1978 is much larger than for the other two earlier time spans. The remainder of the residences are evenly split in each time span between geographic zones 1 and 2, although there are slightly more residences in geographic zone #1 than in #2 for the 1960 to 1978 time span.

TABLE 3.3. Conditioned Area of Dwelling by Year Built

Conditioned Area	Year Built		
	Before 1960 (n=111)	1960 to 1978 (n=160)	After 1978 (n=145)
$<1000 \text{ ft}^2$	21%	6%	12%
1000 to 1500 ft^2	29%	33%	30%
1501 to 2000 ft^2	25%	26%	29%
$>2000 \text{ ft}^2$	25%	35%	29%

TABLE 3.4. Geographic Location of Dwellings by Year Built

Geographic Zone	Year Built		
	Before 1960 (n=111)	1960 to 1978 (n=160)	After 1978 (n=145)
#1	45%	50%	41%
#2	49%	42%	42%
#3	6%	8%	17%

As Table 3.5 shows, the 1-story single-family residences make up 65% of the older, pre-1960 built houses in the RI. Of the remaining older homes, the 1-1/2 and 2-story houses account for all but 4% of the total. In the 1960 to 1978 time span, the one-story single-family house still dominates with 62% of the total residences in this subcategory. Two-story houses still comprise 18% of the total but now the 1-1/2 story, mobile homes, and split-level houses each make up ~6% of the total. Finally in the new houses, post 1978, the single-family houses represent 43% of the total, with the 1-1/2 and 2-story homes each comprising ~20%. The split-level houses increased in this time span to 9% of the total, while the multi-family, 4-unit complex represented 5% of the residences.

As shown in Table 3.6, more of the smaller homes (<1000 ft²) are in geographic zone #2 than in the other two zones. In the 1000 to 1500 ft² conditioned area subcategory, 60% of the houses are in geographic zone #1, while in the 1501 to 2000 ft² subcategory the number of residences is evenly split

TABLE 3.5. Type of Residence by Year Built

<u>Type of Residence</u>	<u>Year Built</u>		
	<u>Before 1960 (n=111)</u>	<u>1960 to 1978 (n=160)</u>	<u>After 1978 (n=145)</u>
Single Family:			
One-Story	65%	62%	43%
1-1/2 Story	16%	6%	16%
Two Story	15%	13%	22%
2-1/2 Story	1%	1%	1%
Three Story	1%	0%	2%
Split Level	1%	6%	9%
Mobile Home	0%	5%	1%
Multi-Family:			
2-Unit (Duplex)	1%	1%	0%
4-Unit	0%	1%	5%
5 or More Unit	0%	0%	1%

TABLE 3.6. Geographic Location of Dwellings by Conditioned Area

Geographic Zone	Conditioned Area			
	<1000 ft ² (n=49)	1000-1500 ft ² (n=129)	1501-2000 ft ² (n=111)	>2000 ft ² (n=127)
#1	37%	60%	46%	34%
#2	53%	30%	50%	49%
#3	10%	10%	4%	17%

between geographic zones #1 and #2. More of the residences in geographic zone #3 are larger houses (>2000 ft²), as evidenced by the fact that 17% of that subcategory is in geographic zone #3.

Table 3.7 examines the relationship between house type and size of conditioned area. In all size subcategories, the single-family, 1-story residence predominates, but the percentage of 1-story houses falls from 70% in the smaller houses (<1000 ft²) to 44% in the larger homes (>2000 ft²). As

TABLE 3.7. Type of Residence by Conditioned Area

Type of Residence	Conditioned Area			
	<1000 ft ² (n=49)	1000-1500 ft ² (n=129)	1501-2000 ft ² (n=111)	>2000 ft ² (n=127)
Single-Family:				
One-Story	76%	70%	45%	44%
1-1/2 Story	0%	15%	13%	14%
Two-Story	0%	9%	27%	28%
2-1/2 Story	0%	0%	0%	2%
Three-Story	0%	0%	0%	3%
Split-Level	0%	3%	10%	7%
Mobile Home	6%	3%	3%	0%
Multi-Family:				
2-Unit (Duplex)	2%	0%	1%	1%
4-Unit	16%	0%	0%	1%
5 or More Unit	0%	0%	1%	0%

expected, the 2, 2-1/2 and 3-story residences are more prevalent in the largest subcategory ($>2000 \text{ ft}^2$). The 1-1/2 story houses make up ~14% of the three subcategories above 1000 ft^2 , while the split level homes are more prevalent in the 1501 to 2000 ft^2 subcategory. Mobile homes and all of the smaller multi-family complexes (<4 units) are more common in the smaller residences ($<1000 \text{ ft}^2$) subcategory.

The single-family, 1-story building, as shown in Table 3.8, is the predominant type of residence in all three geographic zones, comprising ~55% of the total houses in each. The single-family, 2-story building represents ~18% of all houses in each geographic zone. Percentage-wise there are fewer 1-1/2 story buildings but more multi-family dwellings in geographic zone #2. Also, geographic zone #3 has no 2-1/2 or 3 story houses, mobile homes, or multi-family dwellings in the RI.

TABLE 3.8. Type of Residence by Geographic Location of Dwellings

Type of Residence	Geographic Zone		
	#1 (n=190)	#2 (n=182)	#3 (n=44)
Single-Family:			
One-Story	56%	54%	54%
1-1/2 Story	15%	8%	20%
Two-Story	17%	19%	18%
2-1/2 Story	2%	0%	0%
Three-Story	1%	2%	0%
Split-Level	5%	7%	8%
Mobile Home	3%	3%	0%
Multi-Family:			
2-Unit (Duplex)	1%	1%	0%
4-Unit	0%	5%	0%
5 or More Unit	0%	1%	0%

3.2 HVAC SYSTEM CHARACTERISTICS

All of the 416 ELCAP residences surveyed in the RI contain at least one of the following heating systems: electric forced air, heat pump, radiant heat, gas heat, oil heat, or electric resistance heat. Table 3.9 shows the number of residences that contain each of these heating systems. As the table shows, 71 residences contain two heating systems, while the remaining 345 residences contain only one system. The most common heating system is electric resistance heating, with 44% of the RI sample having only this source of heat in the dwelling. Electric resistance heat also is the secondary heat source for 64 residences (15%).

Of the other heating systems, electric forced air is used by 89 residences as the only heat source and in combination with radiant heat in 2 residences. Sixteen residences have an electric forced air system and also electric resistance heat. Heat pump systems for heating and cooling are used by 36 residences as the only heat source and by 6 residences in combination with another

TABLE 3.9. HVAC System Characterization

Heating System	Number of Residences (n=416)	Number with Air Conditioning (n=118)
Electric Forced Air (only)	89 (21%)	37 (31%)
Electric w/Electric Resistance Heat	16 (4%)	5 (4%)
Electric w/Radiant Heat	2 (0.5%)	1 (1%)
Heat Pump (only)	36 (9%)	36 (31%)
Heat w/Electric Resistance Heat	3 (1%)	3 (3%)
Heat w/Oil Heat	2 (0.5%)	2 (2%)
Heat w/Radiant Heat	1 (0.25%)	1 (1%)
Radiant Heat (only)	18 (4%)	1 (1%)
Radiant w/Electric Resistance Heat	28 (7%)	5 (4%)
Radiant w/Oil Heat	1 (0.25%)	0 (0%)
Gas Heat (only)	14 (3%)	3 (2%)
Gas w/Electric Resistance Heat	11 (3%)	3 (2%)
Oil Heat (only)	4 (1%)	1 (1%)
Oil w/Electric Resistance Heat	6 (1%)	1 (1%)
Electric Resistance Heat (only)	184 (44%)	19 (16%)
Electric w/Propane Stove	1 (0.25%)	0 (0%)

heating system. Radiant heat, as shown in Table 3.9, is most often combined with electric resistance heat (28 residences), rather than used as the only heating system (18 residences). Oil heat is also used in combination with another heating system more often (9 residences) than as the only heating system (4 residences). Gas heating systems are used by 6% of the residences surveyed, with approximately half of the houses having electric resistance heat as a secondary source.

Table 3.9 also shows the number of residences with air conditioning (118) associated with the heating system(s) contained in the residence. All heat pump systems are assumed to have air-conditioning capability and represent 37% of the air conditioned residences. Of the remaining air-conditioned houses, 43 have electric forced air heating systems, 19 have only electric resistance heating systems, and the other 14 residences have a variety of heating systems.

Table 3.10 shows that in the older houses built before 1960, 44% use only electric resistance heat while 24% use some gas or oil heating. Only 17% of

TABLE 3.10. Heating System Type by Year Residence Built

Heating System	Before 1960 (n=111)	1960 to 1978 (n=160)	After 1978 (n=145)
Electric Forced Air (only)	11%	28%	23%
Electric w/Electric Resistance Heat	6%	6%	0%
Electric w/Radiant Heat	0%	1%	0%
Heat Pump (only)	5%	9%	11%
Heat w/Electric Resistance Heat	1%	1%	1%
Heat w/Oil Heat	1%	1%	0%
Heat w/Radiant Heat	0%	1%	0%
Radiant Heat (only)	4%	5%	4%
Radiant w/Electric Resistance Heat	5%	10%	5%
Radiant w/Oil Heat	1%	0%	0%
Gas Heat (only)	5%	5%	1%
Gas w/Electric Resistance Heat	8%	1%	0%
Oil Heat (only)	4%	0%	0%
Oil w/Electric Resistance Heat	5%	0%	0%
Electric Resistance Heat (only)	44%	31%	55%
Electric w/Propane Stove	0%	1%	0%

these older houses use an electric forced air system. This percentage more than doubles to 35% for residences built between 1960 and 1978. For houses built from 1960 to 1978, 31% are heated only by electric resistance heat and 12% by heat pump systems. In the newer homes, built after 1978, 55% of the houses are heated only by electric resistance heat and 23% by electric forced air systems. Heat pump systems still represent 12% of the heating systems, while oil and gas heating systems have fallen to 1% of the total.

Residences with less than 1000 ft² of conditioned space are primarily heated with electric resistance heat only (66%), as shown Table 3.11. No heat pump systems are present in any of these smaller houses. The proportion of residences heated with electric forced air systems increases as the conditioned

TABLE 3.11. Heating System Type by Conditioned Area

Heating System	Conditioned Area			
	<1000 ft ² (n=49)	1000-1500 ft ² (n=129)	1501-2000 ft ² (n=111)	>2000 ft ² (n=127)
Electric Forced Air (only)	10%	14%	26%	29%
Electric w/Electric Resistance Heat	2%	2%	4%	6%
Electric w/Radiant Heat	0%	1%	0%	1%
Heat Pump (only)	0%	5%	16%	9%
Heat w/Electric Resistance Heat	0%	0%	0%	2%
Heat w/Oil Heat	0%	1%	0%	1%
Heat w/Radiant Heat	0%	0%	0%	1%
Radiant Heat (only)	6%	7%	5%	1%
Radiant w/Electric Resistance Heat	2%	7%	8%	7%
Radiant w/Oil Heat	0%	0%	0%	1%
Gas Heat (only)	6%	2%	3%	4%
Gas w/Electric Resistance Heat	4%	2%	2%	4%
Oil Heat (only)	2%	0%	2%	1%
Oil w/Electric Resistance Heat	2%	2%	1%	2%
Electric Resistance Heat (only)	66%	57%	32%	30%
Electric w/Propane Stove	0%	0%	0%	1%

area increases from a low of 12% in the smaller houses to a high of 36% in the larger ($>2000 \text{ ft}^2$) houses. The proportion of houses with only electric resistance heat declines from 66% in the smaller houses to a low of 31% in the larger houses. Heat pump systems are more prevalent in the upper two conditioned area categories ($>1500 \text{ ft}^2$), while the other three categories--radiant, oil and gas heat--are spread among all sizes of dwellings.

Table 3.12 shows the geographic dispersion of the heating systems among the three geographic zones previously defined. Zone 1 contains more houses heated only by electric resistance (48%) than does zone 2 (37.5%), while zone 1 has fewer electric forced air systems (20%) than zone 2 (34%). Geographic zone 3 has more electric resistance heated only houses (67%) than the other two zones and less electric forced air systems (14%). Also, no RI houses use gas heat in geographic zone 3.

The distribution of heating systems across types of single-family and multi-family dwellings is shown in Table 3.13. The proportion of houses

TABLE 3.12. Heating System Type by Geographic Zone

Heating System	#1 (n=190)	#2 (n=182)	#3 (n=44)
Electric Forced Air (only)	17%	29%	9%
Electric w/Electric Resistance Heat	3%	4%	5%
Electric w/Radiant Heat	0%	1%	0%
Heat Pump (only)	9%	9%	2%
Heat w/Electric Resistance Heat	0.5%	1%	0%
Heat w/Oil Heat	0.5%	0%	2%
Heat w/Radiant Heat	0%	0%	2%
Radiant Heat (only)	7%	2%	2%
Radiant w/Electric Resistance Heat	4%	9%	9%
Radiant w/Oil Heat	0.5%	0%	0%
Gas Heat (only)	4%	3%	0%
Oil w/Electric Resistance Heat	4%	2%	0%
Oil Heat (only)	2%	0.5%	0%
Gas w/Electric Resistance Heat	0.2	2%	2%
Electric Resistance Heat (only)	48%	37.5%	65%
Electric w/Propane Stove	0%	0%	2%

TABLE 3.13. Heating System Type by Type of Residence

Heating	Single Family							Multi-Family		
	1-Story (n=233)	1-1/2 Story (n=51)	2-Story (n=78)	2-1/2 Story (n=3)	3-Story (n=4)	Split Level (n=24)	Mobile Home (n=10)	2-unit (Duplex) (n=3)	4-unit (n=9)	5 or More Unit (n=1)
Electric Forced Air (only)	19%	20%	22%	33%	25%	25%	80%	0%	11%	100%
Electric w/Electric Resistance Heat	3%	8%	4%	0%	0%	4%	0%	33%	0%	0%
Electric w/Radiant Heat	0.5%	0%	1%	0%	0%	0%	0%	0%	0%	0%
Heat Pump (only)	9%	12%	6%	33%	0%	13%	10%	0%	0%	0%
Heat w/Electric Resistance Heat	1%	2%	0%	0%	0%	0%	0%	0%	0%	0%
Heat w/Oil Heat	0.5%	0%	0%	0%	0%	4%	0%	0%	0%	0%
Heat w/Radiant Heat	0.5%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Radiant Heat (only)	7%	4%	0%	0%	0%	0%	0%	0%	0%	0%
Radiant w/Electric Resistance Heat	7%	4%	8%	0%	0%	12%	0%	0%	0%	0%
Radiant w/Oil Heat	0.5%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Gas Heat (only)	3%	4%	3%	0%	0%	0%	10%	33%	0%	0%
Gas w/Electric Resistance Heat	2%	4%	3%	33%	0%	4%	0%	0%	0%	0%
Oil Heat (only)	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Oil w/Electric Resistance Heat	1%	2%	3%	0%	0%	0%	0%	0%	0%	0%
Electric Resistance Heat (only)	44%	40%	49%	0%	75%	38%	0%	33%	89%	0%
Electric w/Propane Stove	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%

heated only by electric resistance does not change much across the single-family dwelling types, staying at ~45%. Likewise, the electric forced air system proportion stays at ~25% across the single-family dwelling types. The major exception is that 80% of mobile homes in the survey have an electric forced air system.

In addition to the heating systems examined thus far, many residences had wood heating systems, fireplaces or stoves. The number of dwellings with at least one woodstove is 139 or 33% of the total number of residences. The distribution of these woodstoves by the heating system type previously defined is shown in Table 3.14. The table shows that 49% of the woodstoves are present in electric-resistance-heated residences. The residences with fireplaces number 199 or 48% of the total number of residences.

The number of residences without any wood heating system is 118 or 28% of the total. Table 3.14 shows that 54% of these residences also have electric

TABLE 3.14. Heating System Type by Wood Heating System

	With Wood Stove (n=139)	With Fireplace (n=199)	Without Wood Heating (n=118)
Electric Forced Air (only)	22%	24%	17%
Electric w/Electric Resistance Heat	6%	5%	2%
Electric w/Radiant Heat	1%	0%	0%
Heat Pump (only)	6%	12%	7%
Heat w/Electric Resistance Heat	0%	1%	1%
Heat w/Oil Heat	0%	0.5%	1%
Heat w/Radiant Heat	1%	0.5%	0%
Radiant Heat (only)	2%	7%	3%
Radiant w/Electric Resistance Heat	7%	7%	8%
Radiant w/Oil Heat	0%	0.5%	0%
Gas Heat (only)	1%	4%	4%
Gas w/Electric Resistance Heat	2%	4%	1%
Oil Heat (only)	1%	1%	0%
Oil w/Electric Resistance Heat	1%	1%	2%
Electric Resistance Heat (only)	49%	32%	54%
Electric w/Propane Stove	1%	0.5%	0%

resistance heating. Given the totals shown in Table 3.14, 298 dwellings (72%) have some type of wood heating system (416-118) and 40 residences (10%) have both a woodstove and a fireplace (139+199-298).

4.3 INSULATION CHARACTERISTICS

As part of the RI, the insulation material and type of insulation contained on or in the outside walls, under floors, and above the ceiling of the 416 houses in the survey were noted and entered into the CDB. The insulation materials specifically coded for were fiberglass, rock wool, synthetic, cellulose, and foam/polystyrene. Any other materials were noted as well. The insulation types that were specifically coded for in the RI were batt or blanket, loose or blown-in, board or slab, and multiple types. As with insulation materials, any other types were also noted. In addition, for floor insulation, an entry for perimeter insulation was allowed.

Table 3.15 presents the number of residences and the number of records in the CDB for wall, floor, and ceiling insulation. As the table shows, 390 residences (94%) have an some insulation in at least some of the outside walls. These residences have an average of 7-1/2 records per residence because the wall records are separated for each residence by the orientation of the wall, the wall construction type, insulation type, and location of the wall with respect to the various zones in the building. As shown in Table 3.15, 293 of the residences have floor insulation (70%). Of these residences, ~48% or 142 houses have more than one material or type of insulation under the floor. The number of residences with ceiling insulation is 383 (92%), of which 83 have two materials or types of insulation while 4 residences have more than two

TABLE 3.15. Residences with Insulation

<u>Insulation Location</u>	<u>Number of Residences</u>	<u>Number of Records</u>
Wall Insulation	390	2996
Floor Insulation	293	435
Ceiling Insulation	383	672

materials or types in the ceiling. In most cases these represented ceilings above separate conditioned zones with different insulation materials for each ceiling.

Table 3.15 shows 435 records or instances of floor insulation in the CDB. Table 3.16 lists these 435 instances of floor insulation by material and location of the insulation. The most common material and location combination was fiberglass insulation in a crawl space (31%). The 100 entries for unknown materials on the ground are not surprising because slab insulation is difficult to inspect. Likewise, the 51 entries for unknown materials under an overhang are not surprising because in many cases it was difficult to inspect a second story or higher insulation installation.

TABLE 3.16 Floor Insulation Material and Location

<u>Floor Insulation Material</u>	<u>Location</u>	<u>Number of Residences</u>
Fiberglass	In Crawl Space	137
	On Ground	2
	Under Overhang	37
	In Unheated Basement	38
Rock Wool	In Crawl Space	4
	In Unheated Basement	2
Foam/Polystyrene	On Ground	5
	Under Overhang	1
	On Perimeter	8
Other Materials	In Crawl Space	4
	In Unheated Basement	4
	Under Overhang	1
	On Perimeter	1
Unknown Material	In Crawl Space	18
	On Ground	100
	Under Overhang	51
	In Unheated Basement	22

The 383 residences with ceiling insulation are divided into insulation material and type in Table 3.17. As noted above, 87 residences had more than one material or type of insulation present in the ceiling. For these 87 residences the insulation category chosen for the residence was determined by examining the net area covered by each ceiling and then choosing the insulation covering the largest area. The multiple materials and multiple-type category represents 15% of the total. An example of this would be loose-fill rock wool over a fiberglass blanket. The largest category in Table 3.17 is fiberglass batt or blanket and the next most common is cellulose that is loose-fill or blown in.

TABLE 3.17. Ceiling Insulation Characteristics

<u>Insulation Material</u>	<u>Insulation Type</u>	<u>Number</u>	<u>Percent of Total (n=383)</u>
Fiberglass	Batt/Blanket	90	24%
	Loose/Blown-in	57	15%
	Multiple Types	2	0.5%
Rock Wool	Batt/Blanket	3	1%
	Loose/Blown-in	65	17%
Synthetic	Loose/Blown-in	6	2%
	Board/Slab	1	0.5%
Cellulose	Batt/Blanket	4	1%
	Loose/Blown-in	73	19%
Foam/Polystyrene	Board/Slab	3	1%
Multiple Materials	Loose/Blown-in	5	1%
	Multiple Types	59	15%
Other Materials	Batt/Blanket	1	0.5%
	Loose/Blown-in	5	1%
	Board/Slab	4	1%
	Other Types	1	0.5%

The remaining tables dealing with ceiling insulation (Tables 3.18 through 3.21) are divided into the seven ceiling insulation material categories only, along with an entry for no insulation. Table 3.18 shows that the newer homes (constructed after 1978) have a higher percentage of residences with cellulose ceiling insulation (31%) and a lower percentage with multiple materials (1%) than the other two age groups. The percentage of houses with fiberglass and rock wool is not much different across the age categories.

In Table 3.19 the size category that differs the most from the other three is the smaller residence category (<1000 ft²). The percentage of residences with uninsulated ceilings in this category is 20%, while in the larger houses it is 5% to 9%. Also in this category, the percentage of residences with cellulose ceiling insulation is 34%, while in the larger houses this ranges from 13% to 22%. The other three categories have more fiberglass (31% to 41%) and rock wool (16% to 18%) ceiling insulation.

Table 3.20 examines the breakdown of ceiling insulation material by geographic zone. Geographic zone 3 (western Montana) has no residences with uninsulated ceilings and has a higher percentage of "other materials" (12%) and

TABLE 3.18. Ceiling Insulation Material by Year Residence Built

Ceiling Insulation Material	Year Built		
	Before 1960 (n=111)	1960 1968 (n=160)	After 1978 (n=145)
Fiberglass	29%	40%	37%
Rock Wool	14%	18%	16%
Synthetic	5%	1%	1%
Cellulose	14%	10%	31%
Foam/Polystyrene	0%	1%	1%
Multiple Materials	29%	21%	1%
Other Materials	3%	3%	5%
No Insulation	10%	6%	8%

TABLE 3.19. Ceiling Insulation Material by Conditioned Area

Ceiling Insulation Material	Conditioned Area			
	<1000 ft ² (n=49)	1000 - 1500 ft ² (n=129)	1501 - 2000 ft ² (n=111)	>2000 ft ² (n=127)
Fiberglass	18%	41%	31%	41%
Rock Wool	6%	18%	18%	16%
Synthetic	0%	2%	1%	2%
Cellulose	34%	13%	22%	16%
Foam Polystyrene	0%	2%	0%	1%
Multiple Materials	16%	16%	17%	13%
Other Materials	6%	3%	2%	6%
No Insulation	20%	5%	9%	5%

TABLE 3.20. Ceiling Insulation by Geographic Zone

Ceiling Insulation Material	Geographic Zone		
	#1 (n=190)	#2 (n=183)	#3 (n=44)
Fiberglass	43%	30%	27%
Rock Wool	16%	15%	25%
Synthetic	1%	3%	0%
Cellulose	11%	25%	25%
Foam/Polystyrene	1%	0.5%	0%
Multiple Materials	18%	14%	11%
Other Materials	3%	3%	12%
No Insulation	7%	10%	0%

rock wool (25%) used for ceiling insulation than the other two geographic zones. Residences in geographic zone 1 have more fiberglass (43%) and less cellulose (11%) than residences in the other two zones.

As shown in Table 3.21, fiberglass ceiling insulation is the predominant insulation material used in all the single-family dwellings except split-level houses. For the split-level houses in the sample, cellulose ceiling insulation is more common than fiberglass or any other material. For the multi-family

TABLE 3.21. Ceiling Insulation Material by Type of Residence

Ceiling Insulation Material	Single Family							Multi-Family		
	One-Story (n=233)	1-1/2 Story (n=51)	2-Story (n=78)	2-1/2 Story (n=3)	3-Story (n=4)	Split Level (n=24)	Mobile Home (n=10)	2-Unit (Duplex) (n=3)	4-Unit (n=9)	5 or More Units (n=1)
Fiberglass	30%	49%	44%	67%	75%	33%	60%	0%	0%	0%
Rock Wool	17%	10%	21%	0%	0%	13%	0%	100%	0%	100%
Synthetic	2%	0%	1%	0%	0%	4%	0%	0%	0%	0%
Cellulose	20%	16%	14%	33%	0%	38%	0%	0%	22%	0%
Foam/Polystyrene	0.5%	2%	0%	0%	0%	4%	0%	0%	0%	0%
Multiple Materials	21%	10%	9%	0%	0%	4%	10%	0%	0%	0%
Other Materials	4%	6%	4%	0%	0%	0%	0%	0%	0%	0%
No Insulation	5%	7%	7%	0%	25%	4%	30%	0%	78%	0%

dwellings, rock wool is the only ceiling insulation material for the duplexes and the five-unit or larger complex. Among the 4-unit multi-family dwellings, 78% have no ceiling insulation.

3.4 FOUNDATION CHARACTERISTICS

The foundation is the structure that supports and couples a building with the ground. Three types of foundations are identified in the RI: crawl spaces, slab-on-grades, and basements. Four of the 416 residences had no foundation because they were upstairs units of a multi-family (apartment) structure. The other 412 residences had at least one foundation type. Table 3.22 details the seven combinations of foundation type found in residences surveyed by the RI. Overall, the most common foundation type is the crawl space (67% of the houses), followed by the basement (42%), and the slab-on-grade (25%).^(a) As the table shows, 287 or 70% had only one foundation type while 104 (25%) had two types, and 21 (5%) had all three foundation types. The remainder of this section shows how these foundation types are represented across the five general characteristics discussed in Section 3.1.

TABLE 3.22. Foundation Characteristics

<u>Foundation Type</u>	<u>Number of Residences (n=416)</u>	<u>Residences (percentage)</u>
Crawl Space (only)	173	42
Crawl Space w/Basement	49	12
Crawl Space w/Slab	34	8
Crawl Space w/Basement and Slab	21	5
Slab-on-Grade (only)	30	7
Slab w/Basement	21	5
Basement (only)	84	20
No Foundation	4	1

(a) Due to the multiple foundation types in Table 3.22, figures are not additive.

Table 3.23 presents the distribution of foundation types by the year the residence was built. The results indicate that more residences have crawl spaces with basements in the older (before 1960) category (23%) than in the newer (after 1978) category (6%). There are no residences with only slab-on-grade foundations in the older category, while 18% of the residences in the newer category have this foundation type. Also of note is that the percentage of residences with only crawl space and only basement foundations remains fairly constant in all three categories.

The distribution of foundation types across size or conditioned-area categories is shown in Table 3.24. For residences with less than 1500 ft², ~60% have only crawl spaces. The percentage of crawl-space-only residences declines to 19% for the largest-area category. Similarly, the slab-on-grade-only houses make up ~13% of the smaller area categories and only 3% of the larger-area category. In the largest-size category, 32% of the houses have a basement only, while in the smallest-size category 8% of the residences have a basement only. Combining all basement entries, including those with a basement as part of a multiple foundation type, Table 3.24 shows that the largest-size category has 72% of its residences with a basement compared with 18% of the smallest-size category.

TABLE 3.23. Foundation Type by Year Residence Built

Foundation Type	Before 1960 (n=111)	1960 to 1978 (n=160)	After 1978 (n=145)
Crawl Space (only)	41%	44%	39%
Crawl Space w/Basement	23%	9%	6%
Crawl Space w/Slab	5%	12%	6%
Crawl Space w/Basement and Slab	8%	5%	3%
Slab-on-Grade (only)	0%	3%	18%
Slab w/Basement	2%	4%	8%
Basement (only)	21%	23%	17%
No Foundation	0%	0%	3%

TABLE 3.24. Foundation Type by Conditioned Area

Foundation Type	Conditioned Area			
	<1000 ft ² (n=49)	1000 - 1500 ft ² (n=129)	1501 - 2000 ft ² (n=111)	>2000 ft ² (n=127)
Crawl Space (only)	59%	60%	38%	19%
Crawl Space w/Basement	4%	9%	12%	18%
Crawl Space w/Slab	2%	7%	15%	6%
Crawl Space w/Basement and Slab	4%	2%	4%	9%
Slab-on-Grade (only)	13%	12%	5%	3%
Slab w/Basement	2%	1%	2%	13%
Basement (only)	8%	9%	24%	32%
No Foundation	8%	0%	0%	0%

The distribution of foundation types within the three geographic zones is shown in Table 3.25. On a percentage basis for each foundation type, geographic zone 2 is intermediate between zone 1 and 3 and is more like geographic zone 3 than 1. In geographic zone 1, the region west of the Cascades, 54% of the residences have only crawl spaces for foundations while in geographic zones 2 and 3, ~30% of the residences have only crawl spaces. Also in zone 1, 11% of the houses have only slab-on-grade foundations while no residences with this foundation type were found in zone 3, Western Montana. On the other hand, in zone 3, 34% of the residences had a basement only while in zone 1, 9% had basements only.

Table 3.26 displays the type of foundations within each dwelling type. Among the 1-story, single-family dwellings the most prevalent foundation type is the crawl space only (54%). The crawl-space-only foundation also makes up 90% of the mobile home foundations inspected. For the rest of the single-family dwelling types, the most common foundation is the basement, either alone or in combination with another type. All of these dwelling types have at least 49% of their total with a basement. In the large, 4-unit or more, multi-family dwelling categories the major foundation type is the slab-on-grade only. All of the duplexes surveyed have a crawl space for a foundation.

TABLE 3.25. Foundation Type by Geographic Zone

<u>Foundation Type</u>	<u>#1 (n=190)</u>	<u>#2 (n=182)</u>	<u>#3 (n=44)</u>
Crawl Space (only)	54%	32%	27%
Crawl Space w/Basement	8%	14%	16%
Crawl Space w/Slab	11%	7%	2%
Crawl Space w/Basement and Slab	4%	6%	7%
Slab-on-Grade (only)	11%	5%	0%
Slab w/Basement	3%	6%	14%
Basement (only)	9%	28%	34%
No Foundation	0%	2%	0%

TABLE 3.26. Foundation Type by Type of Residence

[illegible]

3.5 APPLIANCE CHARACTERISTICS

In addition to the structural and HVAC data gathered on each residence, information about the appliances was also collected. For most appliances, only the number present in each dwelling was recorded but for the following major appliances more information was requested: refrigerators, freezers, dishwashers and hot water heaters. This section discusses each major appliance and presents the total number of the other appliances.

All residences in the RI had at least one hot water heater. Twenty residences had two hot water heaters and one residence had three for a total of 438 hot water heaters in the RI. The types of hot water heaters in the RI are shown in Table 3.27. Not surprisingly, 95% of the total are electric hot water heaters and 3% are gas heaters.

Table 3.28 shows the location of the hot water heaters at each house. Conditioned areas contain 64% of the hot water heaters and unconditioned areas contain 35%. The hot water heaters can also be divided into seven groups by their capacity, in gallons, as shown in Table 3.29. The most common size of hot water heater found in the RI was 52 gallons (57%). Of the 438 hot water heaters inspected, 184 (42%) were insulated by a blanket or wrap on the tank, while 71 (16%) were efficient unwrapped tanks with R-values greater than 3. Also, 41 hot water heaters (9%) had bottom boards, which are used to prevent heat loss into the floor. Only 9 hot water heaters were solar-assisted and only 8 had thermal traps to prevent heat losses into the connecting pipes.

TABLE 3.27. Types of Hot Water (HW) Heaters

<u>Type</u>	<u>Number of HW Heaters</u>	<u>Percentage of HW Heaters</u>
Electric	418	95
Natural Gas	15	3
Propane	1	0.25
Heat Pump-Add On	1	0.25
Wood	2	0.50
Unknown	1	0.25

TABLE 3.28. Location of Hot Water Heaters

<u>Location</u>	<u>Number of HW Heaters</u>	<u>Percentage of HW Heaters</u>
In Conditioned Area	280	64
In Unconditioned Area	129	29
In Crawl Space	27	6
Outside	1	0.25
Unknown	1	0.25

TABLE 3.29. Capacity of Hot Water Heaters

<u>Capacity (gallons)</u>	<u>Number of HW Heaters</u>	<u>Percentage of HW Heaters</u>
1 to 10	4	1
11 to 40	25	6
41 to 51	42	10
52	250	57
53 to 70	28	6
Greater than 70	22	5
Unknown	67	15

A total of 503 refrigerators are in the RI study. Of the 416 residences inspected, 333 (80%) have one refrigerator, 82 (20%) have more than one refrigerator, and one house, which was vacant, has no refrigerator. Table 3.30 details the various types or configurations of these refrigerators. Most of

TABLE 3.30. Types of Refrigerators

<u>Type</u>	<u>Number of Refrigerators</u>	<u>Percentage of Refrigerators</u>
No Freezer Unit	11	2
Side Freezer Unit	91	18
Top Freezer Unit	329	65
Bottom Freezer Unit	23	5
Inside Freezer Unit	49	10

the refrigerators (65%) have freezing compartments on the top of the unit. Table 3.31 lists the locations of these refrigerators. Most (89%) are located in conditioned areas of the residences.

A total of 320 freezers are in the RI study. Of the 416 residences inspected, 218 (52%) have one freezer, 44 (11%) have two freezers, 4 (1%) have more than two freezers, and 150 (36%) do not have any freezers. Table 3.32 shows that 64% are upright freezers with the remainder being chest freezers. The freezers' locations are shown in Table 3.33. Unlike the refrigerators, most freezers (62%) are located in unconditioned areas.

A total of 342 dishwashers were present in the RI houses. One feature recorded about these dishwashers was the presence of an energy-saver switch. For 170 dishwashers an air-dry/cool-dry switch was present, and for 7 dishwashers a water miser switch was found. A total of 84 dishwashers have both switches on them. Thus, an energy-saver switch was present on 76% of the dishwashers. Also, 94 dishwashers (27%) have a separate water heater element within the dishwasher. The other 73% either do not have this element or it could not be determined whether the dishwasher had the separate element.

Table 3.34 lists other appliances and pieces of equipment found in the inspected residences. The number of residences containing at least one of the

TABLE 3.31. Location of Refrigerators

<u>Location</u>	<u>Number of Refrigerators</u>	<u>Percentage of Refrigerators</u>
Conditioned Area	446	89
Unconditioned Space	51	10
Outside	6	1

TABLE 3.32 Types of Freezers

<u>Type</u>	<u>Number of Freezers</u>	<u>Percentage of Freezers</u>
Upright Freezer	205	64
Chest Freezer	115	36

TABLE 3.33. Location of Freezers

Type	Number of Freezers	Percentage of Freezers
Conditioned Area	123	38
Unconditioned Space	178	56
Outside	17	5
Crawl Space	2	1

TABLE 3.34. Other Appliances/Equipment Found in RI Houses

APPLIANCE/EQUIPMENT	Number of Residences	APPLIANCE/EQUIPMENT	Number of Residences
Electric Stove Top Burner Unit	64	Electrostatic Precipitator	19
Gas Stove Top Burner Unit	3	Well Pump	94
Electric Range and Oven	342	Irrigation Pump	26
Gas Range and Oven	10	Power Saw/Wood Work Equip.	151
Electric Oven	70	Arc Welder	26
Gas Oven	1	Electric Ceramic Kiln	3
Microwave Oven	306	Portable Heater	24
Clothes Washer	396	Electric Pool Heater	5
Electric Clothes Dryer	391	Gas Pool Heater	4
Gas Clothes Dryer	7	Outdoor Light Fixtures	357
Water Softener	43	Greenhouse Light Fixtures	7
Stereo	362	Greenhouse Heater - Electric	4
Black and White T.V.	142	Toaster Oven	6
Color T.V.	390	Instant Hot Wax	6
Home Computer	79	Convection Oven	5
Copy Machine	6	VCR	19
Hot Tub/Jacuzzi	27	Electric Blanket	6
Water Bed Heater	114	Mercury Vapor Light	3
Health or Medical Equip.	6	Fan	11
Humidifier	50	Garbage Disposal	13
Dehumidifier	2	Air Compressor	8
Bathtub/Jacuzzi	2		

listed appliances is shown. The most common appliances found in the 416 houses are color television sets (94%), clothes washers (95%), and electric clothes dryers (97%). Some residences contain more than one of the appliances. For example, 173 houses have more than one color T.V., 83 have more than one stereo, and 98 have more than one piece of wood working equipment.

3.6 CRAWL SPACE INSPECTION RESULTS

As discussed in Section 3.4, 277 houses have a crawl space in the RI. Of these 277 crawl spaces, 253 of them (91%) were accessible and received a crawl-space inspection to identify moisture and/or insect problems. One hundred accessible crawl spaces had problems while 153 had no problems. Table 3.35 lists the number of times each problem was recorded by an inspector and the number of times each problem occurred in combination with a moisture problem. As the table shows, moisture was the most common problem noted (75 times); 80 instances of other problems were recorded. Of these 80 problems, 50 (62%) occurred in combination with a moisture problem.

The geographical dispersion of crawl space problems is shown in Table 3.36. Geographic zone 1 has the most accessible crawl spaces in the RI, 174 out of 253 (69%). Geographic zone 2 has an equal number of accessible crawl spaces with and without problems, while the other two zones have more crawl spaces without problems.

TABLE 3.35. Crawl Space Problems

	Types of Problems ^(a)					
	M	F	R	S	T	A
Total Number	75	15	27	16	16	6
In Combination With Moisture		11	15	11	11	2

(a) M = moisture/condensation F = fungus growth on wood
 R = rot S = soft-stained wood
 T = termites/mud tunnels A = ants, beetles/sawdust

TABLE 3.36. Crawl Space Problems by Geographic Zone

<u>Accessible Crawl Spaces</u>	<u>#1 (n=174)</u>	<u>#2 (n=58)</u>	<u>#3 (n=21)</u>
With Problems	37%	50%	29%
Without Problems	63%	50%	71%

In the accessible crawl spaces, the presence of insulation and of some type of vapor barrier was also recorded. As Table 3.37 shows, the smallest percentage is accessible crawl spaces with insulation and problems. The largest percentage is accessible crawl spaces with insulation and without problems. More problems were found in crawl spaces without insulation than in the crawl spaces with insulation.

Table 3.38 presents the percentage of crawl spaces with and without problems for those crawl spaces with and without vapor barriers. For those crawl spaces with a vapor barrier, most (64%) have no problems. Crawl spaces without a vapor barrier had more problems (46%) than those with a vapor barrier (36%).

TABLE 3.37. Crawl Spaces Problems by Presence of Insulation

<u>Accessible Crawl Spaces</u>	<u>With Insulation (n=137)</u>	<u>Without Insulation (n=116)</u>
With Problems	36%	43%
Without Problems	64%	57%

TABLE 3.38. Crawl Space Problems by Presence of Vapor Barriers

<u>Accessible Crawl Spaces</u>	<u>With Vapor Barrier (n=163)</u>	<u>Without Vapor Barrier (n=90)</u>
With Problems	36%	46%
Without Problems	64%	54%

3.7 RECOMMENDATIONS

If an attempt is made either to inspect the 31 residences that were not inspected or to update any RI data in the CDB, the data should be obtained during maintenance visits to minimize visits to the residences.

Due to the large amount of RI data stored in the CDB, a code booklet or guide to these data should be written to aid any analysts attempting to use the information. Making the RI data more accessible to the analyst should be a high priority concern to all in the ELCAP. Without knowing the structural features of the residences or the appliances being used in the house, an analyst does not have the complete energy use picture. Thus, dissemination and ease of use of the RI data are very important.

REFERENCES

Bonneville Power Administration (BPA). 1986. Procedures Manual for ELCAP Residential Building Characteristics Survey. DOE/BP-13795-9, BPA, Portland, Oregon.

APPENDIX A

QUALITY ASSURANCE OF RESIDENTIAL INSPECTIONS

APPENDIX A

QUALITY ASSURANCE OF RESIDENTIAL INSPECTIONS

The following is a list of the major quality assurance (QA) tasks performed at PNL on each inspection:

- Look at cover sheet and check the PX# on inspection with that in the status reports. Note any discrepancies and resolve them.
- Note receipt of inspection on list of outstanding inspections, and check to see if all floor plans and forms are present in incoming inspections.
- Note date of site visit by ECI and the PX# on list for FIXNOTES computer data base update.
- Examine floor plan(s) to become familiar with the layout scheme and zoning of residence.
- Check questions 17-20 (heating systems) on forms to verify that the correct zoning scheme was used and that all systems are correctly marked on the floor plan(s).
- Given floor plan(s) and pictures, verify that the first 4 questions (type of house or multi-family unit, garage type, and year built) were answered correctly.
- Check floor plan(s) to see that answers to the following parts of question 5 (windows) were entered correctly on the forms: orientation, location, and gross area. The gross area can be calculated from the floor plan for each entry on the form. Any discrepancies should be noted on a separate QA list; if the solution is obvious, the original entry should be changed and documented accordingly. The floor plan(s), according to ECI, are the original and correct representation of the residence, and if any discrepancies occur between the forms and the floor plan(s), the floor plan(s) information overrides the form entry.

- Check floor plan(s) to see that the information for question 6 (doors) on location, orientation, and gross area agrees with the entries on survey form. The same procedure is used here as for question 5 (windows) above. In addition, the entry for glass area for doors should agree with an entry in question 5 (windows). If not, add it to question 5 after determining correctness of glass area from floor plan.
- The entries for question 7 (walls) are very important for calculating the residence's U-value and usually were the hardest to analyze. The entries checked for each wall listed are construction (if possible to tell from floor plan), location, gross area, window/door area, and net area. The gross area, given the location of the wall, is the key data point in the QA check of the walls. In some cases, the height of the walls was not noted on the floor plan or forms, in which case an attempt was made to use common heights (8', 7 1/2', 7') to arrive at the gross area using the lengths shown on the floor plan. If the wall gross area could not be determined, it was noted on the QA list and an attempt was made to figure it out using logical assumptions.

The most difficult buildings in which to check all gross areas are those with vaulted ceilings, partial attics with kneewalls, and very complex floor plans. If information critical to determining the gross wall area is missing, then the inspection is returned to ECI along with the QA list noting the missing information. After return of these from ECI, another attempt to determine the correct figure for gross wall area is made. The inspectors' numbers for gross wall area are accepted at this point unless a more logical value can be obtained from the floor plan.

In addition to the gross area, the window/door area entry is checked to make sure it is correct given the gross area data in questions 5 and 6. A check is also made to see that the net area equals the gross area minus the window/door area. The wall entry for gross area consumes the most QA time and is the most thoroughly checked figure in the form.

- The entries for question 8 (ceiling/roof) that are checked are type, location, and net area. If the residence has a vaulted ceiling, the vault height is needed to check the ceiling net area entry. If it is not noted, the inspection is returned to ECI for clarification.
- Question 9 (attic ventilation) is simply checked to see if entries are made.
- Question 10 (number of conditioned levels) is checked for accuracy using the floor plans.
- Question 11 (area) is checked against the floor plan for both conditioned and unconditioned zones and subzones.
- Question 12 (volume) is checked using the areas in question 11 and the wall heights used in determining the gross wall areas in question 7.
- Question 13 (rooms) is checked to make sure all unconditioned areas on the floor plan (and noted in questions 11 and 12) are included in the correct place on this form.
- Questions 14 (interior air circulation) and 15 (mechanical ventilation to outside) are simply checked to make sure they are filled out.
- Question 16 (floors) has three entries that are checked: type, location, and floor area/perimeter. Again, the floor plan is used to judge the validity of these entries with the floor area also being checked with question 11 (area). In some cases, the area is needed and in other cases the perimeter is needed. If the wrong one is on the form, it is changed; if the perimeter was figured incorrectly, it is also corrected, if possible. A common mistake for the perimeter entry is that an unconditioned zone perimeter for a garage or other space is included when it is not supposed to be.
- Questions 17-20 (heating systems) and question 21 (AC systems) are examined to make sure the correct system code, location, and zone served are recorded. The floor plan is examined to note the location

and zone served. The fuel type and system type for heating systems is examined to understand the nature of the system and the zoning breakdown of the residence.

- Question 22 (duct/piping) is checked to make sure the associated system entry is in agreement with the heating and/or cooling system listed in questions 17-21.
- For questions 23-25 (hot water heater, refrigerators/freezers and dishwashers) the location entry is examined to ensure consistency with the floor plan and the zoning set up for the residence.
- Question 26 (appliances) is examined to ensure that an entry was made to all fields on the summary sheet.
- Question 27 (foundation) has four entries that are checked: type, material, below grade depth, and perimeter length. The type and material has to make sense with the location of the foundation and entries for the floors. The below-grade-depth entry is very useful in the wall gross area calculations and should be consistent with those figures. The perimeter length in some cases, such as basements and slab-on-grade houses, should be similar to the entry for the perimeter in the floor question. All differences should be logical and discrepancies noted on the QA list. Corrections are made from the floor plan if possible.
- Questions 28-32 (crawl space) are glanced at to make sure they are filled in for residences with crawl spaces, as noted in question 27, and to make sure they are not answered for those residences without any crawl space.
- The modification and addition questions are glanced at to ensure that an entry was made to all fields on the summary sheets.
- All pictures and comments are examined to make sure that information that could aid in determining any questionable entries is not overlooked.

These procedures are applied to each inspection as it is examined, and any discrepancies are noted on the QA list. If any major problems are found, the inspection and QA list are returned to ECI in hopes of clearing them up. The inspections returned to ECI are so noted on the list of outstanding inspections. Those taken to data processing are marked off this list. If the data processing team has any questions, the inspection is re-examined to determine the correct entry into the CDB.

DISTRIBUTION

No. of
Copies

No. of
Copies

OFFSITE

2 DOE/Office of Scientific and
Technical Information

2 R. A. Gillman
Bonneville Power Administration
End-Use Research Section
P.O. Box 3621-RPEE
Portland, OR 97208

M. E. Taylor
Bonneville Power Administration
End-Use Research Section
P.O. Box 3621-RPEE
Portland, OR 97208

S. G. Hauser
Battelle Portland Office
500 NE Multnomah, Suite 650
Portland, OR 97232

W. M. Warwick
Battelle Portland Office
500 NE Multnomah, Suite 650
Portland, OR 97232

ONSITE

12 Pacific Northwest Laboratory

C. C. Connor
R. G. Pratt
W. F. Sandusky (4)
G. M. Stokes
Publishing Coordination
Technical Report Files (5)