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APPLIED SCIENCE DIVISION

THE RESIDENTIAL STANDARDS DEMONSTRATION PROGRAM: MATCHED PAIR COST ANALYSIS

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December 1986

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DIVISION

Prepared for the U.S. Department of Energy under Contract DE-AC03-76SF00098

LBL-22510

THE RESIDENTIAL STANDARDS DEMONSTRATION PROGRAM:

MATCHED PAIR COST ANALYSIS

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Prepared for the Office of Conservation, Bonneville Power Administration.

This work was supported by the Bonneville Power Administration on Contract No. DE-AI79-84BP20521 through the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

EXECUTIVE SUMMARY

The Pacific Northwest is currently experiencing a dramatic and exciting transformation in the way the region produces and consumes energy. Prompted by federal legislation and local initiative, the region is promoting the conservation of energy as the primary energy resource. In the residential sector, energy efficiency standards (Model Conservation Standards, MCS) for new electrically heated construction have been proposed, and a demonstration program (the Residential Standards Demonstration Program, RSDP) is underway to demonstrate to the homebuilding industry what the MCS are, how to comply with them, and increase the industry's familiarity with them.

Another objective of the RSDP is to document the cost-effectiveness of the MCS by collecting energy use and cost data on the homes participating in the program. In this report, we examined the costs associated with building energy-efficient houses using real data compiled by builders and their sub-contractors. We emphasize the costs of "matched pair" houses, two otherwise identical houses except that one was built to "super" energy-efficient standards while the other one was built to current energy practice.

All four states participating in the RSDP were represented in our analysis of 33 matched pair MCS houses: 8 (24%) from Idaho, 6 (18%) from Montana, 2 (6%) from Oregon, and 17 (52%) from Washington. Three climate zones were represented: 23 (70%) in zone 1 (the fewest number of heating degree days), 4 (12%) in zone 2, and 6 (18%) in zone 3 (the greatest number of heating degree days). The median floor area of matched pair houses was 1392 square feet; the mean floor area was 1464 square feet with a standard deviation of 360 square feet. Most of the houses in our MCS sample were found to be designed to be more energy efficient, on the average, than the standard MCS house.

Several levels of analysis were used in examining the cost data for the entire sample and for each of the three climate zones: absolute, incremental, and normalized (absolute and incremental) costs (standardized by floor area and/or component area); and component (e.g., ceiling), sub-component (e.g., attic insulation), and total costs. The discussion emphasizes median costs for they are less susceptible to the positive skew of outliers and, therefore, better represent the central tendency of the sample. We also present other statistical descriptors in our analysis: mean, standard deviation, range, and sample size.

Upon examining total incremental building costs normalized by **floor area**, we found the median cost for matched pair houses was $2.41/ft^2 (see Chapter 7 for more summary information). For a house with a median floor area of 1392 square feet, the total incremental cost would be $3,355. It is important to note that these costs include labor and materials, but exclude builder overhead, fees, and profit, and, therefore, the actual incremental costs would be somewhat larger.

Using incremental building component costs normalized by **component area** as a guide, we found that the largest median incremental component cost per square foot for matched pair houses was glazing ($3.56/ft^2). All other median component costs were below $0.50/ft^2: floor ($0.43/ft^2), walls ($0.42/ft^2), ceiling ($0.23/ft^2), vapor barrier ($0.08/ft^2), doors ($0.00/ft^2), and basement walls ($0.00/ft^2) (see Chapter 5 for more component summary information, and Chapter 6 for detailed analysis of selected component groups).

The matched pair sample did differ from the rest of the MCS houses by having smaller floor areas, more energy-efficient design, greater use of non-central heating systems, and different state and climate representation. The incremental component costs of matched pair houses were generally smaller than those for unmatched houses, and the standard deviations and ranges were smaller for the former than for the latter. The total hard costs for matched pairs were 14% smaller than for the rest of the RSDP houses.

The RSDP findings from this cost analysis should be regarded as only indicative for MCS houses for the following reasons. First, due to different types of building codes and code enforcement among the states, the concept of "current practice" is very loosely defined and variable, and, therefore, the calculation of incremental costs, in which current practice costs are subtracted from energy efficient house costs, is subject to an unknown error. Second, the findings from this demonstration program are not generalizable due to the problem of self-selection in program participation. Third, this was the first time many of the builders ever attempted to build to this level of energy efficiency using innovative building materials and techniques. And fourth, the incremental costs calculated in this report are for energy efficient houses that, in general, achieve or go beyond the Model Conservation Standards (MCS) proposed by the Northwest Power Planning Council.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1. INTRODUCTION

The Pacific Northwest is currently experiencing a dramatic and exciting transformation in the way the region produces and consumes energy. Prompted by federal legislation and local initiative, the region is promoting the conservation of energy as the primary new energy resource. In the residential sector, energy efficiency standards for new electrically heated construction have been proposed, and a demonstration program is underway to examine the costs and energy savings associated with building houses to levels of higher energy efficiency. In this report, we examine the energy-efficient construction costs, reported by builders in this program, of a select group of recently built "matched pair" houses (these were two otherwise identical houses except that one was built to "super" energy-efficient standards while the other one was built to current energy codes). Our findings will be of interest not only to the building industry, government officials, and the general public in the Pacific Northwest, but also to those individuals and organizations outside this region who want to learn from this experience.

Prior to examining the cost data itself, we present an overview on the enabling federal legislation, the proposed residential conservation standards, the demonstration program, and the objectives of this investigation.

THE NORTHWEST POWER ACT

The Pacific Northwest Electric Power Planning and Conservation Act of 1980 (P.L. 96-501) (the "Northwest Power Act") was the federal legislation that directed that priority be given to the lowest cost sources of energy for meeting the electric energy needs in the Pacific Northwest, and, if all else was equal, then energy conservation was to have priority over all other resources. The Northwest Power Act also called for the establishment of the Northwest Power Planning Council (the Council), and specifically identified the development of energy-efficient building standards (Model Conservation Standards) as one of the elements to be contained in the Council's Power Plan.

MODEL CONSERVATION STANDARDS

The Council adopted Model Conservation Standards (MCS) for new residential and commercial buildings in their 1983 Power Plan.[1] The MCS are designed to make new, electrically-heated residential houses more energy efficient by establishing minimum energy use levels ("energy budgets") for space heating. These performance standards vary by climate (there are three climate zones) as seen in Table 1.1. Climate Zone 1 encompasses most of the mild maritime climate west of the Cascades; Climate Zone 2 is the more extreme climate east of the Cascades except for higher elevations; those elevations and most of western Montana are in Climate Zone 3.[2]

Table 1.1. Model Conservation Standards for new residential buildings: space heating targets by climate zone†

	Climate Zones		
	1 Under 6000 HDD*	2 6000-8000 HDD*	3 Over 8000 HDD*
Single-Family	2.0 $kWh/ft^2/yr$	3.2 $kWh/ft^2/yr$	3.2 $kWh/ft^2/yr$
Multi-Family	1.2 $kWh/ft^2/yr$	2.3 $kWh/ft^2/yr$	2.8 $kWh/ft^2/yr$
†These targets are based on specific Council prototypes			
*HDD = Annual heating degree days at a base of 65 °F.			

The MCS also offer a number of options to meet the energy budgets, such as insulation, glazing, heat pumps, solar features, and control of air leakage as shown in Table 1.2. This method of setting standards allows homebuilders wide design flexibility. Houses meeting the MCS are expected to use about one-third of the heating energy of an

[1] While the standards are for both residential and commercial buildings, the discussion and analysis that follow pertain to the residential sector. For a description of the development of the MCS, see Eckman and Watson, 1984.

[2] However, the climate zones associated with a particular building site were determined by the micro-climate heating degree days from the nearest weather station. Thus, Richland, Washington and Boise, Idaho have Climate Zone 1 houses despite being geographically in Climate Zone 2. Moreover, it is important to note that a house with 4001 heating degree days and one with 5999 heating degree days are both in the same climate zone despite a 50% difference in the severity of the weather.

otherwise comparable house built to current standards.

Table 1.2. Types of options for meeting the Model Conservation Standards*

• Relatively high levels of ceiling insulation (R-30 to R-38) • Walls with insulation levels ranging from R-19 to R-31 • Underfloor insulation (over crawl spaces) of R-19 to R-30 • Perimeter insulation for slab-on-grade or basements (R-10 to R-15) • Double or triple-glazed windows with "thermal breaks" (insulating material in the window frames to "break" the thermal path by which heat is lost) • Insulated exterior doors • Control of air infiltration through careful caulking, weatherstripping, and installation of vapor barriers • Use of dehumidifiers to avoid humidity problems • Very low air infiltration designs incorporating continuous vapor barriers and air-to-air heat exchangers • "Sun-tempered" designs (south-oriented windows) • Passive solar designs (south-oriented windows and the inclusion of thermal mass) • Heat pumps as an alternative to high levels of insulation
*This table is derived from Eckman and Watson, 1984.

The Council initially called for state and local governments and utilities to adopt the MCS by January 1986. It was expected that local or state government would adopt the standards in the form of building codes. These entitites would also be responsible for implementing and enforcing the codes. If political jurisdictions failed to adopt and enforce the standards or refused to carry out a program to achieve comparable energy savings, they would be subject to a minimum 10% surcharge on the wholesale power they purchase from the Bonneville Power Administration (BPA) (as stated in the Northwest Power Act).

In December 1985, the Council revised their initial deadline and amended the standards to allow BPA and the utilities to offer marketing and financial assistance to help builders construct MCS houses (the BPA/Utility MCS Program). Utilities not participating in the Program may offer an alternative program so long as it is judged by BPA to produce equivalent savings. BPA has indicated that utilities must declare their option by January 1, 1987: participate in the Program or submit their own equivalent program.

RESIDENTIAL STANDARDS DEMONSTRATION PROGRAM

At the time the standards were adopted, there was no consensus within the building industry about either the additional costs involved in building to the standards or the energy savings which would result. To address these problems, the Council called for BPA to carry out a large-scale demonstration program of houses built to the standards. The result was the Residential Standards Demonstration Program (RSDP). As stated in the final version of the Council's Power Plan (released in late 1983), the RSDP had two basic, interrelated objectives: (1) demonstrate to the homebuilding industry what the MCS are, how to comply with them, and increase the industry's familiarity with them; and (2) obtain more accurate estimates of the average energy savings and incremental costs associated with the MCS. In addition, data regarding the characteristics of the houses (e.g., indoor air quality, solar access, and operation of air-to-air heat exchangers) were also to be collected. The activities designed to meet these objectives were initiated in early 1984 by the energy agencies of the Northwest states (the Washington State Energy Office, the Oregon Department of Energy, the Idaho Department of Water Resources, and the Montana Department of Natural Resources and Conservation) with funding from BPA. Discretion in designing and implementing the RSDP was given to the states, permitting a great amount of flexibility.[3]

To accomplish the first objective, briefings were held in the winter of 1984 throughout the region to inform homebuilders, architects, realtors, lenders, and members of the housing industry about the RSDP. In the spring of 1984, the states conducted builder training workshops which were open to the general public, but were particularly targeted to general contractors, subcontractors, designers, architects, local code officials, and others familiar with standard residential construction. A total of seven workshops were conducted in Washington, Oregon, and Idaho. Since the program was limited to the western portion of Montana, only two workshops were held in that state. Washington also scheduled seven additional sessions throughout the state.

The goal of the two-day workshops was to transfer a working understanding of the "how tos" and "how not tos" of very energy-efficient construction from current practicioners to those otherwise experienced builders who have not yet built super energy-

[3]For more information on the design aspect of the program, see Hart and Selby, 1984.

efficient houses. The contents of the workshops included a description of: the model conservation standards, how to design an energy efficient house, construction documents, inspection procedures, monitoring of the program, available technical assistance, program requirements, and cost accounting procedures. The training materials included slides of on-site applications, hands-on demonstrations, and a detailed manual the builder could use during actual design and construction.

To accomplish the second objective, the RSDP conducted large-scale monitoring of both construction costs and energy use in approximately 400 "super" energy efficient (all-electric) houses. As part of the monitoring program, houses built to the MCS were "triple metered" as were a corresponding number of existing "Control" houses (i.e., houses built in recent years to current practice energy codes). Triple metering involved the placing of separate kilowatt-hour meters on the heating circuit, the domestic hot water circuit, and the total load. Cooperating homeowners were paid to periodically record the meter readings and indoor and outdoor temperatures.

To achieve a more rigorous comparison, approximately 90 houses (a subset of the above 400) were built and monitored using a sophisticated multi-channel remote monitoring system to measure energy use, temperatures and other potentially important parameters every hour. Some of these were "matched pair" houses.

The additional construction cost (i.e., incremental cost) of building a house to the MCS is the focus of this report. Incremental costs associated with the MCS were tracked by participating builders using a cost accounting system developed by the Energy Board of the National Association of Homebuilders in Area 15, state energy agencies, and BPA. The accounting system was taught to the builders during the training sessions through the use of a uniform cost accounting manual (see Appendix A). Using the manual, builders were asked to supply construction cost information on each component of the building to BPA. Those builders who constructed only MCS houses recorded actual material and labor costs for those elements of the house which differed from current code and estimated the costs of building those elements to current code. Those builders who built matched pair houses recorded actual costs for both the model standards and the current code houses. More detail on the types of items included in the accounting system is presented below.

RSDP COST ANALYSIS

Lawrence Berkeley Laboratory (LBL) was selected by BPA to analyze the cost data collected during the RSDP. Using a cost accounting form (see Appendix A), builders and their sub-contractors calculated the cost of building an energy efficient house by determining the costs of the following items: air-to-air heat exchanger, subfloor, framing, insulation, glazing, doors, fireplace, plumbing, electrical, HVAC (heating, ventilation and air conditioning), drywall, painting, vapor barrier (including caulking), passive solar, supervision, design, and loan interest. Also, they provided detailed cost information for the following specific types of building components (identified by insulation value (R-value or U-value), area, and type (e.g., wood or aluminum framed windows)): ceilings, floors, walls, basement walls, glass, air infiltration barriers, and doors. In addition, builders estimated the costs of these components for houses they usually built to current standards ("current practice").[4] Additional information was provided on the cost accounting forms, including floor area, type of heating system, how builders complied with meeting the MCS, and site location.

Builders submitted their cost data to the state energy offices which reviewed the data for mathematical and logical consistencies. The state energy office placed the cost data for each house onto a cost summary form (Appendix B) and submitted the forms to BPA which then placed the data onto their computer system. A cost data tape was sent to LBL for review and analysis. LBL cleaned the data by eliminating data entry errors such as keypunch errors and cost reporting errors (some may remain). In cooperation with BPA, LBL analyzed the cost data using statistical software (SPSS-X).

We have recently completed a cost analysis of all the MCS and Control houses in the RSDP (Vine, 1986).[5] The results presented in the following pages differ from the previous report by their emphasis on matched pair houses. We present the results of unmatched houses for comparative purposes. The discussion in each chapter emphasizes median costs for they are less susceptible to the positive skew of outliers and, therefore, better represent the central tendency of the sample. We also present other statistical descriptors in our analyses: mean, standard deviation, range, and sample size.

[4] A discussion of the problems encountered in estimating these costs is presented in the last chapter of this report.

[5] Two other studies of these groups have recently been completed: a comparison of heating energy use in MCS and Control houses (Meier et al., 1986), and a comparison of the structural and behavioral characteristics of the two samples (Vine and Barnes, 1986). In the near future, the energy and cost data will be examined together by BPA to evaluate the cost-effectiveness of building houses to the MCS.

ORGANIZATION OF REPORT

Chapter 2 briefly summarizes characteristics (e.g., average floor area, type of heating system, and energy efficiency) of the 33 MCS matched pair houses (not control houses) while the remaining chapters deal explicitly with cost. Chapters 3, 4, and 5 analyze examine the incremental costs of building components which are normalized by floor area and component area in the latter two chapters. Chapter 6 contains a detailed analysis of the incremental costs of specific groups of building components. In Chapter 7, we present total incremental building costs for single-family houses, and in the last chapter (Chapter 8), we present our findings and conclusions. Appendices A and B contain the cost accounting form and the cost summary form filled out by the builders, respectively, and Appendices C and D contain the spreadsheets used in Chapters 6 and 7, respectively.

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CHAPTER 2. CHARACTERISTICS OF MATCHED PAIR HOUSES

All four states participating in the Residential Standards Demonstration Program (RSDP) were represented in our analysis of 33 matched pair MCS houses: 8 (24%) from Idaho, 6 (18%) from Montana, 2 (6%) from Oregon, and 17 (52%) from Washington. Three climate zones were represented: 23 (70%) in zone 1 (the fewest number of heating degree days), 4 (12%) in zone 2, and 6 (18%) in zone 3 (the greatest number of heating degree days).[1] In Table 2.1 and in Figure 2.1, we show the relationship between state and climate zone.[2] About 50% of the houses in this sample were from Washington in zone 1.

As seen in Table 2.2, the median floor area of matched pair MCS houses was 1392 square feet, 27% less than that of the unmatched houses; the mean floor area was 1464 square feet with a standard deviation of 360 square feet. The size range of houses was broad: 960 to 2356 square feet.

Five major heating system types were represented in our sample (Table 2.3). Approximately 40% of the matched pair MCS houses were heated by electric baseboard systems, 6% by central forced air, 27% by wall forced air, 18% by heat pumps, and 9% by radiant heat. The matched pair houses differed from the rest of the sample by their use of non-central systems (particularly, radiant heat).

There are four ways a builder can fulfill the requirements of the MCS: one can comply with the prescriptive standard (following a path, or following a path with tradeoffs — a point system) or a performance standard (estimating an energy budget, or meeting an overall thermal integrity (UA)). In complying with the MCS standards, 76% of the matched pair houses used the component prescriptive point path, 24% used the component prescriptive path, and no one used the energy budget path, nor the component performance path (Table 2.3).

We used number of points (based on the prescriptive point system) for characterizing the energy efficiency of houses. Zero points represents a MCS house, and more points indicates increasing energy efficiency. In some cases, upon inspecting a house, a house received negative points because it was found to be deficient in complying with the MCS standards. It is important to note that points are not cost-optimized, i.e., points are not related to cost-effectiveness. Builders are permitted trade-offs to give them flexibility in

[1]See Chapter 1 for a description of the climate zones.

[2]All three climate zones are represented in Idaho, climate zones 1 and 2 are found in Oregon and Washington, and climate zone 3 covers the entire state of Montana.

designing a house. Because the point system allows a substitution for the standard MCS approach, trade-offs usually result in more expensive alternatives.

As seen in Table 2.2, the median number of points in the sample of matched pair MCS houses was 44, 170% more energy-efficient than the rest of the sample; the mean number of points was 35 (similar to that of unmatched houses) with a standard deviation of 23, and the range was -25 to 64 points. Thus, the sample of houses in this study was designed to be more energy efficient, on the average, than the prototypical MCS house.

We combined the houses into five groups based on their energy efficiency (less than 0 points, 0 to 7 points, 8 to 24 points, 25 to 52 points, and 53 or more points) (Table 2.3). The boundaries between groups do not represent any significant changes in energy use, but were constructed only for graphical display. Over 50% of the matched pair MCS houses were located in the next to highest energy-efficiency group (25-52 points), while the unmatched houses were more evenly distributed (Fig 2.2).

Table 2.1. Distribution of matched pair and unmatched houses by state and climate zone.

	Climate Zone 1	Climate Zone 2	Climate Zone 3	Total
All cases				
Matched	23	4	6	33
Unmatched	210	81	71	362
Idaho				
Matched	6	2	0	8
Unmatched	6	20	10	36
Montana				
Matched	0	0	6	6
Unmatched	0	0	61	61
Oregon				
Matched	2	0	0	2
Unmatched	46	11	0	57
Washington				
Matched	15	2	0	17
Unmatched	158	50	0	208

Table 2.2. Size and energy efficiency of matched pair and unmatched houses.					
	Mean	Standard Deviation	Median	Minimum-Maximum	Sample Size
Floor area (ft^2)					
Matched	1464	360	1392	960-2356	33
Unmatched	2100	744	1914	930-5717	362
Energy efficiency (points)*					
Matched	35	23	44	-25-64	26
Unmatched	33	35	26	-78-177	263

*Energy efficiency of houses is indicated by "points", where 0 points represent a MCS house, larger numbers (points) indicate increasing energy efficiency, and negative numbers indicate less efficient houses (see text).

Table 2.3. Characteristics of matched pair and unmatched houses.

	Matched (N=33) (%)	Unmatched (N=362) (%)
Type of heating system		
Baseboard	39	35
Central	6	30
Wall	27	20
Heat pump	18	7
Radiant	9	5
Other	0	2
Compliance path		
Component prescriptive points	76	55
Component prescriptive path	24	32
Energy budget	0	10
Component performance	0	3
Energy-efficiency groups*		
Less than 0 points	4	3
0-7 points	19	22
8-24 points	4	24
25-52 points	58	27
53 points or more	15	25

*Energy efficiency of houses is indicated by "points", where 0 points represent a MCS house, larger numbers (points) indicate increasing energy efficiency, and negative numbers indicate less efficient houses (see text).

Figure 2.1. DISTRIBUTION OF MATCHED PAIRS AND UNMATCHED HOUSES BY CLIMATE AND STATE

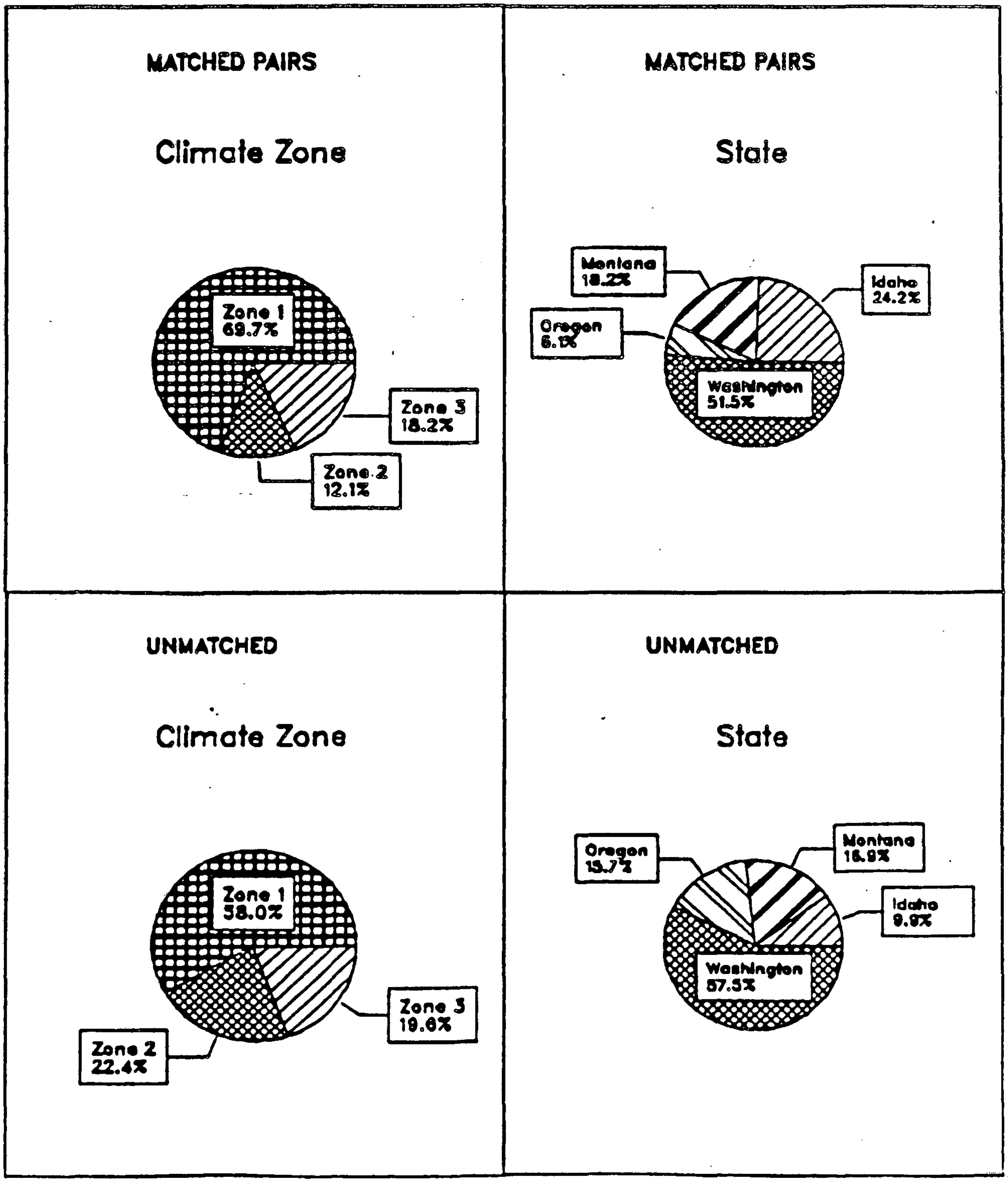
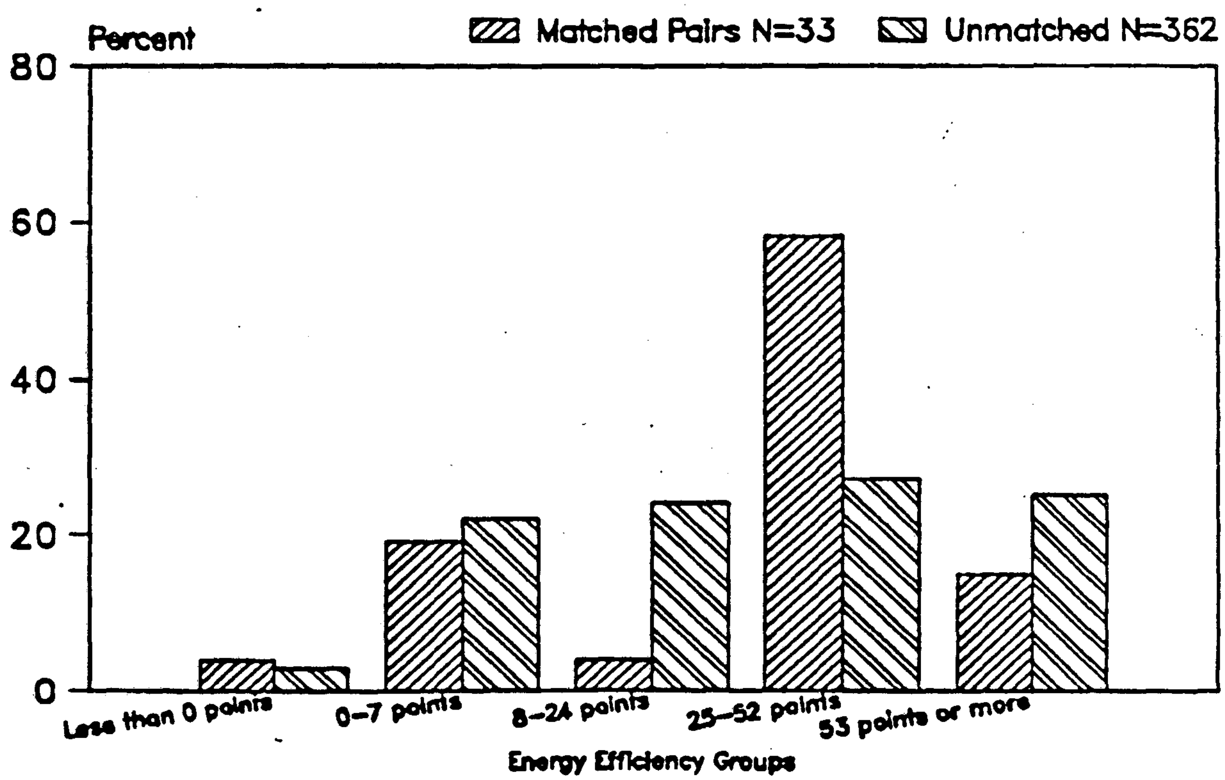


Figure 2.2. ENERGY EFFICIENCY OF MATCHED AND UNMATCHED HOUSES



Energy efficiency of homes is indicated by 'points', where 0 points represent a MCS home, larger numbers (points) indicate increasing energy efficiency, and negative numbers indicate less efficient homes (see text).

CHAPTER 3. COMPONENT COST DEFINITIONS AND INCREMENTAL COSTS

Prior to analyzing the costs discussed in this chapter and those to follow, we first provide definitions of some of the components that are examined in this report.

COMPONENT COST DEFINITIONS

Basement walls: Some states reported areas in linear feet instead of square feet, and these cases are excluded from analysis.

Ceiling: Includes the cost of insulation, but sometimes includes applicable framing (e.g., advanced trusses).

Design: Represents the cost of the architect's time to design the MCS house to include energy features.

Doors: Assumes door areas remain constant; costs of door jambs are included in wall costs.

Drywall: Includes the cost of improved caulking, but does not include Airtight Drywall Approach (ADA) costs which are included in vapor barrier costs.

Electrical: These costs may be less in MCS houses, especially, if kitchen and exhaust fans are no longer needed as a result of the installation of an air-to-air heat exchanger.

Floor: Usually involves only the cost of added insulation.

Framing: Includes floors, walls, and roof trusses.

Glass: Includes the frames, but not the structural framing costs which are included in wall costs.

Heat exchanger (AAHX): Includes duct costs.

HVAC: Heating, ventilation, and air conditioning costs are frequently less in MCS houses due to downsizing furnaces or switching from central to zonal heating.

Insulation: Includes only the cost of insulating materials and labor.

Loan interest: Represents interest costs due to increased house cost, MCS-related construction delays, or extended time in housing market.

Passive solar: Represents the costs of site orientation, thermal mass, insulating materials, and designing or installing extra glazing.

Point system: The point system allows modification of the standard component prescriptive packages given in the Component Prescriptive Standards. Specified variations are given points based upon the impact of the change upon the estimated yearly space heating requirements.

Points: Under the point system, points are calculated as 100 times the change in kWh/yr-ft^2 of heating requirements for the Council's prototype resulting from the modification.

Sub-floor: Represents the costs of insulation and vapor barriers associated with slabs-on-grade, basements, and crawl spaces.

Supervision: Represents the cost of extra time required on-site to supervise workers' or subcontractors' work in order to assure that MCS standards are met.

Walls: Represents the cost of framing, insulation, window jambs, and door jambs.

INCREMENTAL COSTS

In this chapter, we present the "incremental" (extra) building costs of selected components reported by the builders in constructing matched pair houses and unmatched houses. The costs are incremental because they represent the difference between the cost of "MCS/As-built" houses and the cost of houses built to "current practice." Current practice typically refers to existing state or local building standards; however, there are exceptions to this definition (for more discussion, see Chapter 8). For the matched pair houses, the incremental costs are the *actual* construction cost differences reported by the builders. For the unmatched pair houses, the incremental costs are the *estimated* construction cost differences reported by the builders.

We include building components (e.g., walls and ceilings) as well as elements of components (e.g., insulation) in our analysis. Because the costs are examined in two different ways, the categories cannot be added to obtain total incremental costs for the whole house. We provide total incremental costs for single-family houses in Chapter 7.

As noted in Chapter 1, many of the MCS houses contained more energy conservation measures than needed to achieve the Council's Model Conservation Standards. Accordingly, these costs may not represent the costs of building a MCS house, but may stand for the costs of building energy-efficient houses that achieve or go beyond the standards proposed by the Council. All costs are in 1984 dollars and include labor and materials, but exclude builder overhead, fees, and profit.

As shown in Table 3.1, the largest median incremental cost for builders of matched pair houses is the installation of air-to-air heat exchangers ($1299). Because of reduced air infiltration resulting from vapor barriers, the exchangers are required in these houses to provide adequate ventilation; they are not normally found in houses built to current practice. The next most expensive median incremental costs for builders of matched pair houses are glass ($597), vapor barrier ($518), walls ($472), insulation ($404), framing ($403), and ceiling ($232). The remaining median incremental costs are below $200. In general, these costs differ from that for unmatched houses, both in magnitude and in order. Mean costs and their standard deviations are reported in Table 3.1 and displayed in Figure 3.1. There is a large variation in incremental building costs, and, in the next two chapters, we examine two sources of variation: component area and floor area.

In contrast to unmatched houses, the matched pair sample of MCS houses generally has substantially smaller median component costs, smaller standard deviations and ranges in component costs, and median and mean values closer to one another. Furthermore, the components are ordered differently (in terms of mean costs) in the two groups.

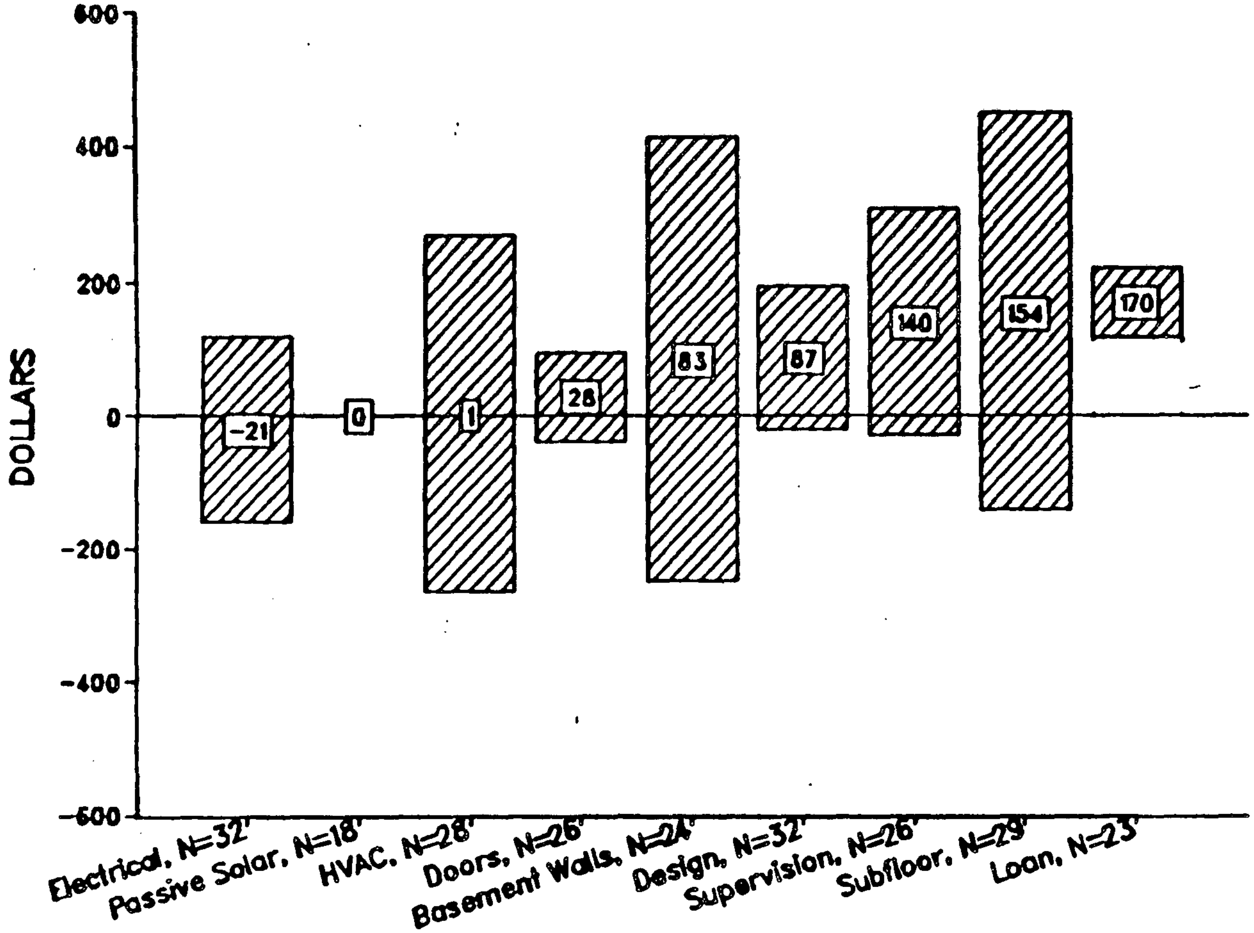
Table 3.1. Incremental costs for matched pair and unmatched houses.					
	Mean ($)	Standard Deviation ($)	Median ($)	Minimum-Maximum ($)	Sample Size
Ceiling					
Matched	320	348	232	-671-1050	31
Unmatched	588	777	425	-547-11795	350
Floor					
Matched	226	195	181	0-722	29
Unmatched	297	281	232	-287-1847	309
Walls					
Matched	584	501	472	-445-2059	27
Unmatched	1180	1085	963	-2562-9998	330
Basement Walls					
Matched	83	330	0	-423-1235	24
Unmatched	238	378	11	-34-3126	280
Glass					
Matched	536	488	597	-424-1779	32
Unmatched	757	678	588	-460-4083	356
Infiltration/ Vapor Barrier					
Matched	516	376	518	80-1760	31
Unmatched	822	626	666	-683-5442	349
Doors					
Matched	28	66	0	-60-230	26
Unmatched	115	223	60	-736-2624	338
Heat Exchanger					
Matched	1298	297	1299	745-2120	26
Unmatched	1308	572	1263	0-4180	340

THE FOLLOWING COMPONENTS MAY CONTAIN COSTS THAT ARE ALSO INCLUDED IN THE COSTS REPORTED ABOVE

	Mean ($)	Standard Deviation ($)	Median ($)	Minimum-Maximum ($)	Sample Size
Subfloor					
Matched	154	294	124	-411-1300	29
Unmatched	296	448	114	-572-3578	331
Framing					
Matched	469	410	403	-374-1621	33
Unmatched	951	1584	732	-2167-24334	353
Insulation					
Matched	518	506	404	-979-1389	33
Unmatched	906	746	758	-980-4544	354
Electrical					
Matched	-21	139	0	-569-300	32
Unmatched	16	447	0	-1030-5708	310
HVAC					
Matched	1	265	0	-755-600	28
Unmatched	-85	938	0	-6000-4509	275
Passive Solar					
Matched	0	0	0	0-0	18
Unmatched	124	564	0	0-5343	235
Supervision					
Matched	140	168	100	0-548	26
Unmatched	356	430	250	0-3500	300

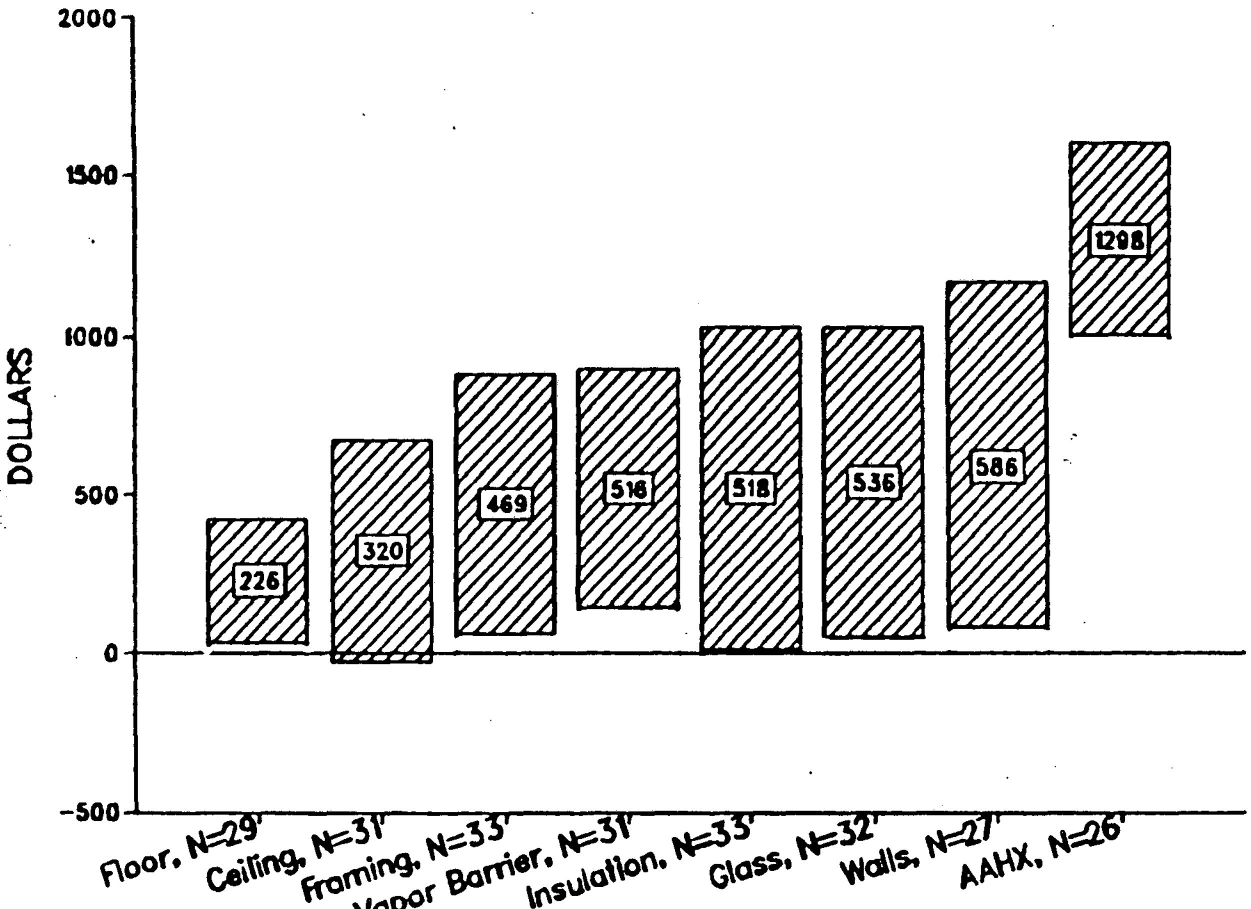
	Mean ($)	Standard Deviation ($)	Median ($)	Minimum-Maximum ($)	Sample Size
Design					
Matched	87	108	60	0-422	32
Unmatched	134	194	100	0-1400	297
Loan Interest					
Matched	170	215	50	-135-637	23
Unmatched	202	337	139	-830-3700	283

Figure 3.1. INCREMENTAL COSTS



Boxed figure is the mean. Shaded area is the mean +/− 1 standard deviation, unless lower limit becomes less than minimum, in which case minimum value is used.

Figure 3.1 continued. INCREMENTAL COSTS



Boxed figure is the mean. Shaded area is the mean +/− standard deviation, unless lower limit becomes less than minimum, in which case minimum is used.

CHAPTER 4. INCREMENTAL COSTS NORMALIZED BY FLOOR AREA

In this chapter, we present incremental building component costs normalized (standardized) by **floor area**. As shown in Table 4.1, the largest median incremental cost per square foot for builders of matched pair houses is the installation of air-to-air heat exchangers ($0.99/ft^2$). The next most expensive median incremental costs per floor area for builders of matched pair houses are glass ($0.44/ft^2$), walls ($0.41/ft^2$), vapor barrier ($0.34/ft^2$), framing ($0.30/ft^2$), and insulation ($0.28/ft^2$). The remaining median incremental costs are below $0.20/ft^2$. Mean costs and their standard deviations are also reported in Table 4.1.

In contrast to the previous chapter, median costs and standard deviations of the costs of the matched pair sample and unmatched houses are similar to one another. As reported in the last chapter, the median and mean values are close to one another, and the ordering of components (by cost) are different in the two groups.

Table 4.1. Incremental costs per floor area for matched pair and unmatched houses					
	Mean ($/ft^2)	Standard Deviation ($/ft^2)	Median ($/ft^2)	Minimum-Maximum ($/ft^2)	Sample Size
Ceiling					
Matched	0.22	0.27	0.19	-0.56-0.88	31
Unmatched	0.29	0.28	0.23	-0.31-2.79	350
Floor					
Matched	0.18	0.16	0.12	0-0.59	29
Unmatched	0.16	0.16	0.12	-0.26-1.22	309
Walls					
Matched	0.41	0.32	0.41	-0.28-1.20	27
Unmatched	0.59	0.57	0.48	-1.90-4.96	330
Basement Walls					
Matched	0.03	0.19	0.00	-0.35-0.68	24
Unmatched	0.10	0.16	0.01	-0.02-1.47	280
Glass					
Matched	0.40	0.37	0.44	-0.18-1.30	32
Unmatched	0.38	0.33	0.30	-0.24-2.12	356
Infiltration/ Vapor Barrier					
Matched	0.37	0.29	0.34	0.05-1.33	31
Unmatched	0.40	0.26	0.35	-0.30-1.54	349
Doors					
Matched	0.02	0.05	0.00	-0.03-0.19	26
Unmatched	0.06	0.10	0.03	-0.52-0.97	338
Heat Exchanger					
Matched	0.95	0.26	0.99	0.52-1.46	26
Unmatched	0.67	0.29	0.67	0-2.08	340

THE FOLLOWING COMPONENTS MAY CONTAIN COSTS THAT ARE ALSO INCLUDED IN THE COSTS REPORTED ABOVE

	Mean ($/ft^2)	Standard Deviation ($/ft^2)	Median ($/ft^2)	Minimum-Maximum ($/ft^2)	Sample Size
Subfloor					
Matched	0.09	0.17	0.07	-0.34-0.65	29
Unmatched	0.13	0.19	0.06	-0.33-1.68	331
Framing					
Matched	0.34	0.31	0.30	-0.19-1.36	33
Unmatched	0.48	0.70	0.36	-0.89-10.06	353
Insulation					
Matched	0.35	0.36	0.28	-0.82-1.12	33
Unmatched	0.46	0.37	0.42	-0.53-3.40	354
Electrical					
Matched	-0.01	0.08	0.00	-0.28-0.13	32
Unmatched	0.01	0.21	0.00	-0.54-2.70	310
HVAC					
Matched	-0.01	0.20	0.00	-0.63-0.50	28
Unmatched	-0.06	0.41	0.00	-1.79-1.78	275
Passive Solar					
Matched	0.00	0.00	0.00	0-0	18
Unmatched	0.06	0.29	0.00	0-2.81	235
Supervision					
Matched	0.10	0.12	0.07	0-0.38	26
Unmatched	0.19	0.25	0.13	0-1.78	300

	Mean ($/ft^2)	Standard Deviation ($/ft^2)	Median ($/ft^2)	Minimum-Maximum ($/ft^2)	Sample Size
Design					
Matched	0.06	0.07	0.05	0-0.26	32
Unmatched	0.07	0.09	0.04	0-0.67	297
Loan Interest					
Matched	0.11	0.15	0.04	-0.12-0.44	23
Unmatched	0.10	0.16	0.07	-0.51-1.53	283

CHAPTER 5. INCREMENTAL COSTS NORMALIZED BY COMPONENT AREA

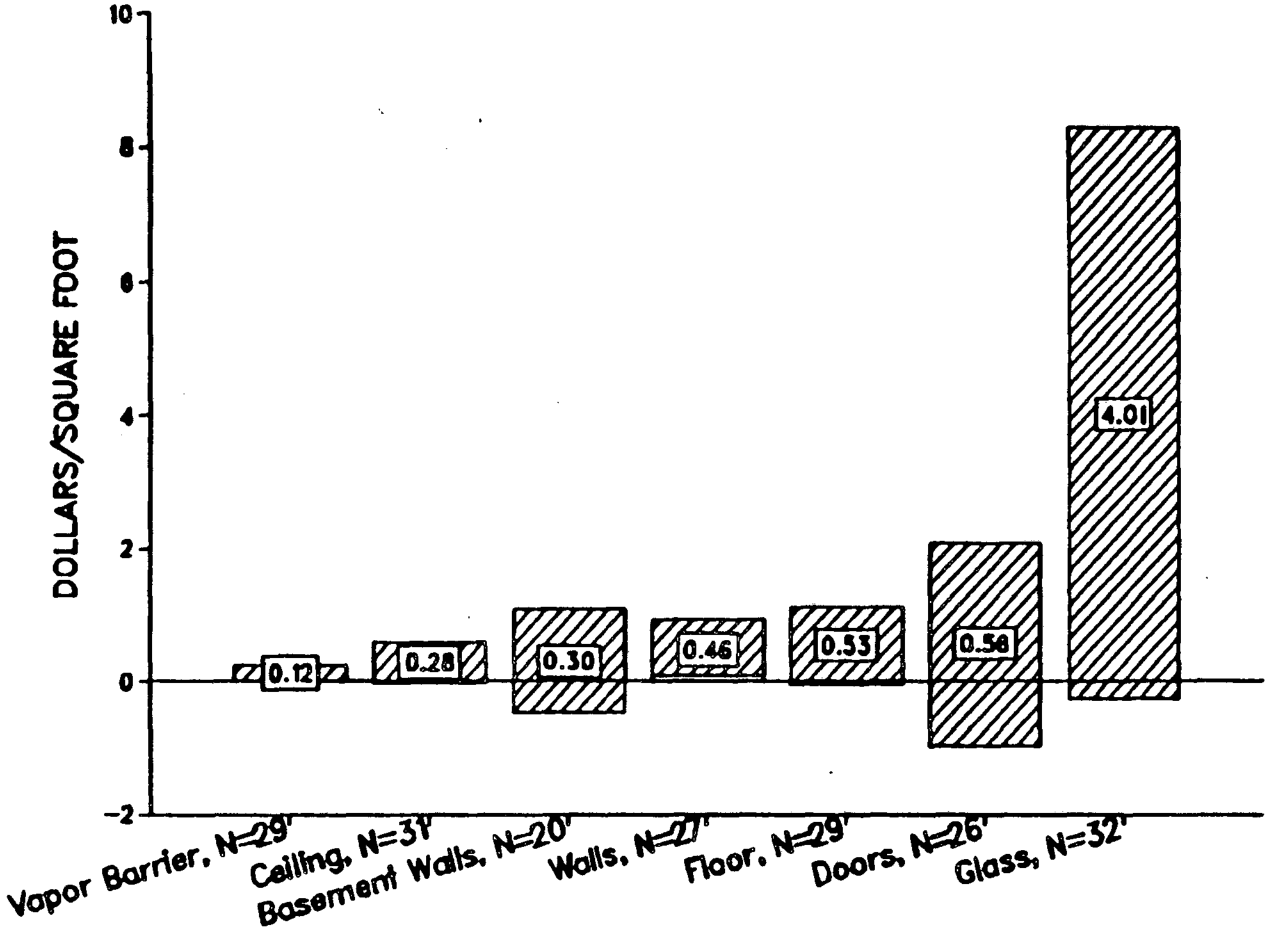
In this chapter, we present incremental building component costs normalized (standardized) by **component area**. As shown in Table 5.1, the largest median incremental cost per square foot of component area for builders of matched pair houses is glazing (\$3.56/ft^2). The next most expensive median incremental costs per component area for builders of matched pair houses are below \$0.50/ft^2: floor (\$0.43/ft^2), walls (\$0.42/ft^2), ceiling (\$0.23/ft^2), vapor barrier (\$0.08/ft^2), doors (\$0.00/ft^2), and basement walls (\$0.00/ft^2). Mean costs and their standard deviations are reported in Table 5.1 and displayed in Figure 5.1.

The results in this chapter are similar to those reported in Chapter 3. In contrast to unmatched houses, the matched pair sample generally has substantially smaller median component costs, smaller standard deviations and ranges in component costs, and median and mean values closer to one another. Furthermore, the components are ordered differently (in terms of mean costs) in the two groups.

Table 5.1. Incremental costs per component area for matched pair and unmatched houses.					
	Mean ($/ft^2)	Standard Deviation ($/ft^2)	Median ($/ft^2)	Minimum-Maximum ($/ft^2)	Sample Size
Ceiling					
Matched	0.28	0.29	0.23	-0.56-0.88	31
Unmatched	0.41	0.40	0.34	-0.96-4.79	350
Floor					
Matched	0.53	0.58	0.43	-0.59-2.38	29
Unmatched	0.37	1.28	0.25	-8.94-16.33	309
Walls					
Matched	0.46	0.38	0.42	-0.42-1.52	27
Unmatched	0.37	6.81	0.64	-122.10-6.36	330
Basement Walls*					
Matched	0.30	0.77	0.00	0-3.25	20
Unmatched	0.23	0.52	0.00	-2.79-2.91	207
Glass					
Matched	4.01	4.26	3.56	-2.89-18.58	32
Unmatched	1.52	27.20	2.57	-508.45-16.72	356
Infiltration/ Vapor Barrier					
Matched	0.12	0.12	0.08	-0.08-0.47	29
Unmatched	0.14	0.16	0.12	-1.48-0.67	298
Doors					
Matched	0.56	1.52	0.00	-1.58-5.75	26
Unmatched	1.93	3.55	1.06	-18.40-21.87	338

*Montana cases are not included in this analysis because component area was reported in linear feet instead of square feet.

Figure 5.1. INCREMENTAL COSTS BY COMPONENT AREA



Boxed figure is the mean. Shaded area is the mean +/− standard deviation, unless lower limit becomes more negative than minimum, in which case minimum is used.

CHAPTER 6. NORMALIZED INCREMENTAL COSTS - GROUP ANALYSIS

In this chapter, we present a detailed analysis of incremental building component costs normalized (standardized) by **component area** for selected groups of components for matched pair and unmatched houses. The building components are ceiling, floor, walls, basement walls, windows, air infiltration barriers, door, and air-to-air heat exchangers. This chapter contains the "cleanest" data because unusual cases are segregated into an "all other" category.

Before each table, we provide component type codes so that the reader can understand the various groups in that particular table. Because there are many approaches builders take in going from Current Practice to MCS practice, we provide descriptive statistics for several groups of approaches that are of particular interest. For example, Group 1 in Table 6.1 contains the incremental cost of increased ceiling insulation (from R-19 to R-30) in vaulted ceilings (with batt insulation but with no foam insulation). In this case, no matched pair houses were represented, but 6 unmatched houses were built this way.

If a case does not belong to the first group, one examines it to see if it belongs to the second group; if it does not belong to the second group, then the third group is examined, etc. Those cases not included in a numbered group are analyzed separately as part of the group "all other cases of increments." There is no overlapping of cases in groups: i.e., a case is placed in only one group. It is important to note that it is not possible to add particular groups in order to compare costs with another group: for example, one should expect different costs for going from R-30 to R-45 than from adding the costs of going from R-30 to R-38 and from R-38 to R-45.

As in the previous tables, we provide the median, mean, standard deviation, range, and sample size. At the end of four tables (ceilings, walls, windows, and air-to-air heat exchangers) in this chapter, we present statistics on "aggregate groups" which represent a series of important and logically consistent aggregations of changes from Current Practice to MCS. It is important to note that these larger groups are inclusive of the previously detailed smaller groups. For those interested in examining individual cases, one should proceed to Appendix C where all the cases are presented in a spreadsheet form and are placed in consecutive order by group number.

CEILING GROUPS

Ceiling Insulation Type Code:

A Attic, advanced truss, loosefill insulation

B Attic, advanced truss, batt insulation

C Attic, standard truss, baffle, compressed batt perimeter

D Attic, standard truss, rigid foam perimeter

E Vaulted, batt, no foam

F Vaulted, batt, foam inside

G Vaulted, compressed batt

H Attic, standard truss, loosefill insulation

I Attic, standard truss, loosefill insulation, compressed batt perimeter

X Missing

Z Other

R-38 includes R-38 to R-41; R-45 includes R-42 to R-46; and R-49 includes R-47 to R-51.

Table 6.1. Ceiling incremental costs per square foot by type of construction for matched pair and unmatched houses.

Group No.	Current Practice	MCS	Mean ($/ft^2)	Standard Deviation ($/ft^2)	Median ($/ft^2)	Min.-Max. ($/ft^2)	Sample Size
1 Matched	R-19	R-30					0
Unmatched	Type E	Type E	0.29	0.13	0.28	0.13-0.47	6
2	R-19	R-38					0
	Type E	Type E,F,G	0.61	0.42	0.54	0.22-1.27	6
3	R-30	R-38					0
	Type C	Type A	0.17	0.00	0.17	0.17-0.17	1
4	R-30	R-38	0.75	0.18	0.75	0.62-0.88	2
	Type C	Type B	0.43	0.16	0.38	0.22-0.73	11
5	R-30	R-38	0.19	0.00	0.19	0.19-0.19	1
	Type C	Type C	0.21	0.14	0.17	0.09-0.56	9
6	R-30	R-35					0
	Type E	Type F	0.40	0.17	0.44	0.08-0.55	6
7	R-30	R-38	0.17	0.20	0.10	0.05-0.61	7
	Type E	Type E	0.36	0.30	0.25	0.05-1.26	23
8	R-30	R-38					0
	Type E	Type F	0.73	0.34	0.64	0.45-1.48	11
9	R-30	R-49					0
	Type E	Type E	1.13	1.02	0.63	0.45-2.30	3
10	R-30	R-38	0.49	0.16	0.48	0.31-0.69	4
	Type H	Type A	0.43	0.25	0.39	0-1.24	86
11	R-30	R-38					0
	Type H	Type B	0.40	0.16	0.41	0.23-0.56	3
12	R-30	R-38					0
	Type H	Type C	0.19	0.26	0.19	0.01-0.37	2
13	R-30	R-38					0
	Type H	Type D	0.41	0.06	0.41	0.37-0.45	2
14	R-30	R-38					0
	Type H	Type H	0.11	0.08	0.09	0.03-0.33	23

Group No.	Current Practice	MCS	Mean ($/ft^2)	Standard Deviation ($/ft^2)	Median ($/ft^2)	Min.-Max. ($/ft^2)	Sample Size
15	R-30	R-45					0
	Type H	Type A	0.32	0.21	0.23	0.09-0.65	10
16	R-30	R-49					0
	Type H	Type A	0.55	0.49	0.46	0.20-2.07	14
17	R-30	R-49	0.16	0.00	0.16	0.16-0.16	1
	Type H	Type H	0.24	0.11	0.21	0.16-0.39	4
18	R-30	R-60					0
	Type H	Type A	0.60	0.19	0.58	0.30-0.83	6
19	R-38	R-38	0.23	0.18	0.17	0.08-0.59	9
	Type H	Type A	0.25	0.28	0.16	0-1.34	27
20	R-38	R-45	0.44	0.06	0.41	0.40-0.50	3
	Type H	Type A	0.21	0.26	0.17	-0.07-0.63	5
21	R-38	R-49					0
	Type H	Type A	0.29	0.08	0.28	0.16-0.44	12
22	R-38	R-60					0
	Type H	Type A	0.50	0.18	0.50	0.21-0.79	15
23	R-30	R-38					0
	Type E,F,G	Type E,F,G	0.47	0.11	0.47	0.39-0.55	2
24	R-30	R-38	0.78	0.00	0.78	0.78-0.78	1
	Type A,B,C, D,H,I	Type A,B,C, D,H,I	0.27	0.31	0.24	-0.31-0.99	16
25	R-30	R-49					0
	Type A,B,C, D,H,I	Type A,B,C, D,H,I	0.19	0.14	0.12	0.10-0.35	3
26	R-30	R-45					0
	Type A,B,C, D,H,I	Type A,B,C, D,H,I	0.42	0.00	0.42	0.42-0.42	1
27	R-38	R-49					0
	Type A,B,C, D,H,I	Type A,B,C, D,H,I	0.18	0.00	0.18	0.18-0.18	1

Group No.	Current Practice	MCS	Mean ($/ft^2)	Standard Deviation ($/ft^2)	Median ($/ft^2)	Min.-Max. ($/ft^2)	Sample Size
28	R-38	R-60					0
	Type A,B, C,D,H,I	Type A,B, C,D,H,I	0.40	0.00	0.40	0.40-0.40	1
29	R-30	R-38					0
	Type E,F, G	Type A,B, C,D,H,I	0.56	0.35	0.56	0.31-0.81	2
30	R-30	R-38					0
	Any type	Any type	0.71	0.58	0.71	0.08-1.72	11
31	R-30	R-49					0
	Any type	Any type	0.82	0.32	0.94	0.21-1.10	6
All other cases of increments			0.02	0.37	0.02	-0.57-0.38	5
			0.58	1.78	0.21	0-12.40	51
AGGREGATE GROUPS (Attics only)							
A	R-30	R-38	0.19	0.00	0.19	0.19-0.19	1
	Any type	Std. Frame	0.16	0.13	0.10	0.01-0.56	36
B	R-30	R-38	0.58	0.20	0.57	0.31-0.88	6
	Any type	Adv. Frame	0.43	0.24	0.39	0-1.24	101
C	R-30	R-49	0.16	0.00	0.16	0.16-0.16	1
	Any type	Any Type	0.44	0.43	0.30	0.10-2.07	21
D	R-30	R-60					0
	Any type	Any Type	0.60	0.19	0.58	0.30-0.83	6
E	R-38	R-49					0
	Any type	Any Type	0.28	0.08	0.27	0.16-0.44	13
F	R-38	R-60					0
	Any type	Any Type	0.49	0.18	0.49	0.21-0.79	16

FLOOR GROUPS

Floor Type Code:

A Crawlspace (insulation under floor or overhangs)

B Slab below grade

C Slab on grade

D Heated crawlspace

E Foam insulation under slab

F Combination of floor and perimeter insulation

X Missing

Z Other

R-0 includes R-0 to R-2; R-5 includes R-3 to R-7; R-10 includes R-8 to R-12; R-15 includes R-13 to R-17; R-19 includes R-18 to R-22; R-25 includes R-23 to R-27; and R-30 includes R-28 to R-32.

Table 6.2. Floor incremental costs per square foot by type of construction for matched pair and unmatched houses.							
Group No.	Current Practice	MCS	Mean ($/ft^2)	Standard Deviation ($/ft^2)	Median ($/ft^2)	Min.-Max. ($/ft^2)	Sample Size
1 Matched	R-0 Type A	R-19 Type A	0.41	0.03	0.39	0.39-0.44	3
Unmatched			0.46	0.05	0.46	0.43-0.50	2
2	R-0 Type B	R-5 Type B					0
			0.42	0.16	0.41	0.19-0.80	11
3	R-0 Type B	R-10 Type B	1.38	0.00	1.38	1.38-1.38	1
			1.49	0.99	1.00	0.34-3.52	12
4	R-0 Type B	R-15 Type B	1.60	0.00	1.60	1.60-1.60	1
			1.61	0.37	1.52	1.22-2.18	5
5	R-0 Type B	R-5 Type E					0
			0.24	0.10	0.25	0.12-0.33	4
6	R-0 Type B	R-10 Type E					0
			0.42	0.46	0.26	0.04-1.32	6
7	R-0 Type B	R-15 Type E					0
			0.81	0.57	1.11	0.16-1.17	3
8	R-0 Type E	R-5 Type E					0
			0.38	0.00	0.38	0.38-0.38	1
9	R-0 Type E	R-10 Type E					0
			0.30	0.06	0.30	0.25-0.34	2
10*	R-0 Type C	R-5 Type C	1.14	1.14	1.14	1.14-1.14	5
			0.78	0.18	0.78	0.65-0.91	2
11*	R-0 Type C	R-10 Type C					0
			1.54	0.75	1.36	0.46-3.12	18
12*	R-0 Type C	R-15 Type C					0
			2.04	0.14	2.04	1.94-2.14	2
13	R-5 Type B	R-10 Type B					0
			0.43	0.33	0.25	0.13-0.91	5

*Costs per linear feet.

Group No.	Current Practice	MCS	Mean ($/ft^2)	Standard Deviation ($/ft^2)	Median ($/ft^2)	Min.-Max. ($/ft^2)	Sample Size
14*	R-5 Type C	R-10 Type C	1.89	0.66	1.89	1.42-2.36	2
			0.87	0.75	0.72	0.09-3.47	23
15*	R-5 Type C	R-15 Type C	2.38	0.00	2.38	2.38-2.38	1
			1.63	1.32	1.18	0.47-3.50	6
16	R-11 Type A	R-19 Type A	0.14	0.09	0.11	0.07-0.31	6
			0.12	0.08	0.12	-0.26-0.54	66
17	R-11 Type A	R-25 Type A	0.48	0.20	0.48	0.34-0.62	2
			0.24	0.10	0.25	0-0.34	9
18	R-11 Type A	R-30 Type A					0
			0.34	0.22	0.30	0.03-1.60	64
19	R-11 Type A	R-38 Type A					0
			0.37	0.11	0.40	0.11-0.47	9
20	R-11 Type D	R-19 Type A	0.17	0.00	0.17	0.17-0.17	1
			0.61	0.45	0.41	0.20-1.22	5
21	R-19 Type A	R-25 Type A					0
			0.17	0.06	0.18	0.10-0.24	4
22	R-19 Type A	R-30 Type A	0.23	0.00	0.23	0.23-0.23	1
			0.27	0.16	0.25	0-0.67	21
All other cases of increments			0.36	0.30	0.49	0-0.81	10
			0.38	0.72	0.16	-0.64-3.78	72

*Costs per linear feet.

WALL GROUPS

Wall Type Code:

A Strapped wall

B Double wall

C 2 X 6, 24" on center, advanced framing

D 2 X 6, 24" on center, standard framing

E 2 X 6, 16" on center, standard framing

F 2 X 6, 24" on center, foam outside

G 2 X 6, 24" on center, foam inside

H 2 X 4, 24" on center, foam outside

I 2 X 4, 24" on center, foam inside

J Foam blocks

K 2 X 8, 24" on center, advanced framing

L 2 X 8, 16" on center, standard framing

M All weather wood foundation

N Cement, foam outside

O Cement, batt inside

P Cement, foam outside, batt inside

Q 2 X 6, 24" on center, mod. advanced framing

R 2 X 6, 24" on center, mod. advanced framing with foam inside

S 2 X 6, 24" on center, mod. advanced framing with foam outside

T Larsen truss, batt insulation

U 2 X 4, 16" on center, standard framing

V No insulation on foundation

X Missing

Z Other

AA 2 X 4, 24" on center, standard framing

BB Cement, no insulation

R-11 includes R-10 to R-13; R-24 includes R-23 to R-26; R-27 includes R-27 to R-28; R-30 includes R-29 to R-32; R-35 includes R-33 to R-36; and R-38 includes R-37 to R-41.

Table 6.3. Wall incremental costs per square foot by type of construction for matched pair and unmatched houses.							
Group No.	Current Practice	MCS	Mean ($/ft²)	Standard Deviation ($/ft²)	Median ($/ft²)	Min.-Max. ($/ft²)	Sample Size
1 Matched	R-11 Type U	R-19 Type C,Q	0.35	0.16	0.42	0.13-0.58	9
Unmatched			0.28	0.15	0.26	0-0.65	46
2	R-11 Type U	R-19 Type D					0
			0.40	0.48	0.30	0.03-1.71	10
3	R-11 Type U	R-19 Type E					0
			0.36	0.17	0.35	0.06-0.65	13
4	R-11 Type U	R-24 Type G	1.20	0.32	1.21	0.87-1.52	3
			0.77	0.29	0.75	0.22-1.54	40
5	R-11 Type U	R-24 Type K					0
			0.29	0.02	0.29	0.27-0.31	3
6	R-11 Type U	R-24 Type L					0
			0.68	0.04	0.70	0.63-0.74	5
7	R-11 Type U	R-27 Type A					0
			0.84	0.39	0.88	0.24-1.57	26
8	R-11 Type U	R-27 Type B					0
			1.12	0.32	1.30	0.75-1.32	3
9	R-11 Type U	R-30 Type B	0.63	0.00	0.63	0.63-0.63	1
			1.24	0.64	1.14	0.51-2.32	6
10	R-11 Type U	R-27 Type F					0
			0.96	0.23	0.99	0.48-1.21	9
11	R-11 Type U	R-27 Type G	0.49	0.00	0.49	0.49-0.49	1
			0.87	0.46	0.81	0-2.18	25
12	R-19 Type D	R-27 Type F					0
			0.73	0.44	0.71	0.22-1.27	4
13	R-19 Type D	R-38 Type B					0
			0.77	0.40	0.68	0.28-1.39	9
14	R-19 Type E	R-24 Type F	-0.15	0.00	-0.15	-0.15--0.15	1
			0.34	0.06	0.34	0.30-0.39	2

Group No.	Current Practice	MCS	Mean ($/ft^2)	Standard Deviation ($/ft^2)	Median ($/ft^2)	Min.-Max. ($/ft^2)	Sample Size
15	R-19 Type E	R-35 Type B					0
			1.18	0.74	1.36	0.13-1.86	4
16	R-19 Type E	R-38 Type B					0
			0.91	0.51	0.88	0.20-1.66	9
17	R-19 Type H	R-27 Type F	0.49	0.00	0.49	0.49-0.49	1
							0
18	R-11 Type U	R-38 Type B					0
			0.84	0.00	0.84	0.84-0.84	1
19	R-19 Type D	R-35 Type B					0
			1.47	0.67	1.24	0.68-2.53	8
20	R-19 Type E	R-27 Type F					0
			0.47	0.34	0.60	0.09-0.72	3
21	R-11 Any type	R-19 Any type	0.32	0.00	0.32	0.32-0.32	1
			0.41	0.24	0.40	0.13-0.71	6
22	R-11 Any type	R-24 Any type	0.57	0.17	0.60	0.37-0.72	4
			1.05	1.25	0.74	0-4.95	28
23	R-19 Any type	R-35 Any type					0
			1.06	0.63	0.82	0.36-2.43	9
24	R-11 Any type	R-30 Any type					0
			1.12	0.46	0.91	0.58-2.08	13
25	R-11 Any type	R-38 Any type					0
			1.22	0.56	1.38	0.23-1.83	6
26	R-19 Any type	R-24 Any type	-0.08	0.31	-0.20	-0.42-0.30	5
			0.32	0.23	0.34	-0.08-0.62	8
27	R-19 Any type	R-27 Any type					0
			0.46	0.49	0.29	0.10-1.17	4
28	R-19 Any type	R-35 Any type	0.70	0.19	0.70	0.56-0.83	2
			0.78	0.40	1.02	0.23-1.22	7
All other cases of increments			0.52	0.04	0.52	0.49-0.54	2
			0.62	0.46	0.56	0-1.74	20

Group No.	Current Practice	MCS	Mean ($/ft^2)	Standard Deviation ($/ft^2)	Median ($/ft^2)	Min.-Max. ($/ft^2)	Sample Size
AGGREGATE GROUPS							
A	R-11	R-19	0.34	0.15	0.42	0.13-0.58	10
	Any type	Any type	0.32	0.23	0.28	0-1.71	75
B	R-11	R-24	0.84	0.40	0.72	0.37-1.52	7
	Any type	Any type	0.85	0.80	0.70	0-4.95	76
C	R-11	R-27	0.49	0.00	0.49	0.49-0.49	1
	Any type	Any type	0.90	0.43	0.86	0-2.43	72
D	R-11	R-30	0.63	0.00	0.63	0.63-0.63	1
	Any type	Any type	1.16	0.50	0.91	0.51-2.32	19
E	R-19	R-24	-0.09	0.28	-0.17	-0.42-0.30	6
	Any type	Any type	0.32	0.20	0.34	-0.08-0.62	10
F	R-19	R-27	0.49	0.00	0.49	0.49-0.49	1
	Any type	Any type	0.56	0.41	0.60	0.09-1.27	11
G	R-19	R-30	0.57	0.32	0.57	0.10-1.11	7
	Any type	Any type	0.57	0.32	0.57	0.10-1.11	7

BASEMENT WALL GROUPS

Basement Wall Type Code:

A Strapped wall

B Double wall

C 2 X 6, 24" on center, advanced framing

D 2 X 6, 24" on center, standard framing

E 2 X 6, 16" on center, standard framing

F 2 X 6, 24" on center, foam outside

G 2 X 6, 24" on center, foam inside

H 2 X 4, 24" on center, foam outside

I 2 X 4, 24" on center, foam inside

J Foam blocks

K 2 X 8, 24" on center, advanced framing

L 2 X 8, 16" on center, standard framing

M All weather wood foundation

N Cement, foam outside

O Cement, batt inside

P Cement, foam outside, batt inside

Q 2 X 6, 24" on center, mod. advanced framing

R 2 X 6, 24" on center, mod. advanced framing with foam inside

S 2 X 6, 24" on center, mod. advanced framing with foam outside

T Larsen truss, batt insulation

U 2 X 4, 16" on center, standard framing

V No insulation on foundation

X Missing

Z Other

AA 2 X 4, 24" on center, standard framing

BB Cement, no insulation

R-0 includes R-0 to R-2; R-5 includes R-4 to R-6; R-11 includes R-10 to R-13; R-15 includes R-14 to R-16; R-19 includes R-17 to R-22; and R-30 includes R-28 to R-32.

Table 6.4. Basement wall incremental costs per square foot by type of construction for matched pair and unmatched houses.							
Group No.	Current Practice	MCS	Mean ($/ft^2)	Standard Deviation ($/ft^2)	Median ($/ft^2)	Min.-Max. ($/ft^2)	Sample Size
1 Matched	R-0	R-11	0.94	0.36	0.94	0.68-1.19	2
Unmatched	Type BB,V	Type O	0.48	0.13	0.48	0.39-0.58	2
2	R-0	R-11					0
	Type BB,V	Type N	0.78	0.46	0.62	0.22-1.98	28
3	R-0	R-19	1.00	0.01	1.00	1.00-1.01	2
	Type BB,V	Type O	0.68	0.35	0.60	0.07-1.17	17
4	R-5	R-10					0
	Type N	Type N	0.64	0.36	0.56	0.23-1.10	5
5	R-11	R-19					0
	Type M	Type M	0.26	0.28	0.14	0.07-0.80	6
6	R-11	R-19					0
	Type O	Type O	0.36	0.51	0.12	-0.03-1.49	14
7	R-0	R-11	3.25	0.00	3.25	3.25-3.25	1
	Any type	Any type	0.55	0.23	0.52	0.30-0.86	4
8	R-0	R-15					0
	Any type	Any type	0.92	0.31	0.89	0.66-1.26	4
9	R-0	R-19	0.16	0.00	0.16	0.16-0.16	1
	Any type	Any type	0.37	1.05	0.47	-1.21-1.35	5
10	R-0	R-30					0
	Any type	Any type	0.62	0.30	0.62	0.25-0.98	4
All other cases of increments			-0.34	0.54	-0.25	-0.94-0.25	5
			0.59	0.74	0.45	-1.35-2.91	48

WINDOW GROUPS

Window Type Code:

A Aluminum slider
B Wood slider
C Aluminum casement
D Wood casement
E Aluminum fixed
F Wood fixed
G Aluminum
H Wood
I Aluminum, thermal break
J Aluminum, heat mirror
K Wood, heat mirror
L Wood, awning
M Aluminum, awning
N Wood, double hung
O Aluminum, double hung
X Missing
Z Other

U-0.34 includes U-0.29 to U-0.36; U-0.38 includes U-0.37 to U-0.40; U-0.48 includes U-0.48 to U-0.50; U-0.70 includes U-0.69 to U-0.71; and U-0.74 includes U-0.74 to U-0.78.

Table 6.5. Window incremental costs per square foot by type of construction for matched pair and unmatched houses.

Group No.	Current Practice	MCS	Mean ($/ft^2)	Standard Deviation ($/ft^2)	Median ($/ft^2)	Min.-Max. ($/ft^2)	Sample Size
1 Matched	U-0.47	Triple Glaz.					0
Unmatched	Any type	Any type	3.43	1.95	2.80	0.92-7.12	9
2	U-0.56	Triple Glaz.	1.49	0.00	1.49	1.49-1.49	1
	Type A	Type I	2.49	2.14	2.58	0-4.79	4
3	U-0.56	Triple Glaz.					0
	Type H	Type H	3.61	1.83	3.06	2.24-7.52	7
4	U-0.56-0.70	Any Glaz.					0
	Type H	Type K	5.24	2.26	5.44	2.28-7.79	4
5	U-0.56	U-0.34					0
	Any Type	Any Type	2.84	1.00	2.76	1.70-4.12	4
6	U-0.56	U-0.38	0.67	0.00	0.67	0.67-0.67	1
	Any Type	Any Type	-3.15	0.00	-3.15	-3.15-3.15	1
7	U-0.56	U-0.48					0
	Any Type	Any Type	1.36	0.75	1.40	0.28-2.50	6
8	U-0.68	U-0.37					0
	Type I	Type J	1.36	0.00	1.36	1.36-1.36	4
9	U-0.70-0.74	Triple Glaz.	3.59	0.00	3.59	3.59-3.59	1
	Type A,C,E, G,M,O	Type A,C,E, G,M,O	3.81	1.84	4.47	0.83-7.30	11

Group No.	Current Practice	MCS	Mean ($/ft^2)	Standard Deviation ($/ft^2)	Median ($/ft^2)	Min.-Max. ($/ft^2)	Sample Size
10	U-0.70-0.74	Double Glaz.					0
	Type A,C,E, G,M,O	Type I	2.76	2.24	2.34	0-10.66	23
11	U-0.70-0.74	Double Glaz.					0
	Type A,C,E, G,M,O	Type J	5.92	4.26	8.22	1.01-8.53	3
12	U-0.70-0.74	Double Glaz.					0
	Type B,D,F, H,L,N	Type B,D,F, H,L,N	1.79	1.44	0.88	0.44-4.66	9
13	U-0.70-0.74	Double Glaz.					0
	Type G	Type H	4.85	3.48	4.05	0-11.25	10
14	U-0.70-0.74	Triple Glaz.	5.38	5.38	5.38	5.38-5.38	5
	Type A,C,E, G,M,O	Type I	3.12	1.56	2.78	0.67-7.32	42
15	U-0.70-0.74	Triple Glaz.	4.02	1.08	4.02	3.25-4.78	2
	Type A,C,E, G,M,O	Type J	4.25	1.53	4.64	0.98-6.14	16
16	U-0.70-0.74	Triple Glaz.					0
	Type G	Type K	10.84	6.51	7.11	7.05-18.35	3
17	U-0.70-0.74	Triple Glaz.					0
	Type G	Type H	7.48	2.11	7.13	5.43-10.25	4
18	U-0.70-0.74	Double Glaz.					0
	Any type	Any type	4.21	2.72	3.94	0-9.30	12

Group No.	Current Practice	MCS	Mean ($/ft^2)	Standard Deviation ($/ft^2)	Median ($/ft^2)	Min.-Max. ($/ft^2)	Sample Size
19	U-0.70-0.74	Triple Glaz.	10.51	0.00	10.51	10.51-10.51	1
	Any type	Any type	3.88	1.28	4.19	2.28-6.01	9
All other cases of increments			1.19	4.11	0.00	0-14.23	12
			1.10	2.06	0.14	-3.44-11.10	46
AGGREGATE GROUPS							
A	> U-0.65	< U-0.41	4.82	0.89	5.38	3.25-5.38	8
	Double Glaz.	Triple Glaz.*	3.30	1.69	3.12	0.67-8.22	74
	Aluminum	Aluminum					
B	> U-0.65	U-0.56-0.64					0
	Double Glaz.	Double Glaz.	3.29	1.77	2.79	1.52-6.91	9
	Aluminum	Aluminum					
C	U-0.56-0.64	< U-0.41	1.49	0.00	1.49	1.49-1.49	1
	Double Glaz.	Triple Glaz.*	2.52	1.85	2.66	0-4.79	5
	Aluminum	Aluminum					
D	U-0.45-0.56	< U-0.41	14.23	0.00	14.23	14.23-14.23	1
	Double Glaz.	Triple Glaz.*	3.93	2.02	3.36	0.92-7.79	19
	Wood	Wood					

*This MCS group also includes double-glaze windows with heat mirror.

AIR INFILTRATION BARRIER GROUPS

Air Infiltration Barrier Type Code:

A Polyethylene under sheetrock

B Foam

C Paint

D Exterior plywood

E Polyethylene between double wall

F Polyethylene between strapped wall

G Polyethylene under slab floor

H A and B

I D and G

J Polyethylene under subfloor

K Airtight drywall

L Craft or foil-faced insulation

M Building paper on exterior

N L and M

O None

X Missing

Z Other

* Any of the above types

Table 6.6. Air infiltration barrier incremental costs per square foot by type of construction for matched pair and unmatched houses

Group No.	Current Practice C/W/F*	MCS C/W/F*	Mean ($/ft^2)	Standard Deviation ($/ft^2)	Median ($/ft^2)	Min.-Max. ($/ft^2)	Sample Size
1 Matched	L,L,L	B,B,B	0.05	0.00	0.05	0.05-0.05	1
Unmatched			0.09	0.05	0.10	0.02-0.15	4
2	B,B,B	B,B,B	0.10	0.00	0.10	0.10-0.10	1
			0.05	0.03	0.05	0.02-0.13	19
3	O,A,G	A,A,G					0
			0.16	0.04	0.16	0.10-0.20	4
4	O,A,O	A,A,J	0.11	0.00	0.11	0.11-0.11	1
			0.19	0.12	0.19	0.03-0.37	6
5	O,A,O	A,A,G	0.12	0.00	0.12	0.12-0.12	1
			0.18	0.09	0.16	0.07-0.33	7
6	O,A,O	A,A,D	0.18	0.00	0.18	0.18-0.18	1
			0.16	0.05	0.19	0.09-0.19	6
7	O,L,O	K,K,K	0.02	0.02	0.02	0.02-0.02	3
			0.05	0.05	0.02	0.02-0.13	5
8	O,L,O	A,E,D					0
			0.18	0.26	0.05	0.02-0.48	3
9	O,L,O	A,B,D					0
			0.12	0.03	0.13	0.09-0.14	3
10	O,L,O	A,A,J					0
			0.03	0.00	0.03	0.03-0.03	4
11	O,L,O	A,A,I					0
			0.26	0.25	0.20	0.05-0.61	4
12	O,L,O	A,A,G	0.08	0.02	0.08	0.06-0.09	2
			0.10	0.11	0.07	0-0.36	9
13	O,L,O	A,A,D	0.09	0.00	0.09	0.09-0.01	1
			0.10	0.07	0.08	0.04-0.22	8
14	O,O,O	H,B,I					0
			0.18	0.05	0.18	0.13-0.22	4

*C=Ceiling, W=Wall, F=Floor

Group No.	Current Practice C/W/F*	MCS C/W/F*	Mean ($/ft^2)	Standard Deviation ($/ft^2)	Median ($/ft^2)	Min.-Max. ($/ft^2)	Sample Size
15	O,O,O	A,F,I					0
			0.11	0.12	0.09	0-0.23	3
16	O,O,O	A,F,D					0
			0.21	0.12	0.16	0.08-0.45	9
17	O,O,O	A,B,I					0
			0.25	0.24	0.15	0.06-0.86	10
18	O,O,O	A,B,G	0.24	0.06	0.24	0.19-0.28	2
			0.22	0.09	0.20	0.07-0.37	14
19	O,O,O	A,B,D	0.29	0.17	0.28	0.14-0.47	4
			0.20	0.09	0.18	0.08-0.40	30
20	O,O,O	A,A,I	0.19	0.00	0.19	0.19-0.19	1
			0.22	0.14	0.19	0.05-0.55	11
21	O,O,O	A,A,G	0.10	0.04	0.08	0.08-0.18	6
			0.19	0.09	0.16	0.07-0.42	23
22	O,O,O	A,A,D					0
			0.16	0.10	0.13	0.02-0.41	31
23	L,L,*	Any type	0.05	0.00	0.05	0.05-0.05	1
			0.09	0.04	0.09	-0.01-0.15	19
24	M,M,*	Any type					0
			0.13	0.07	0.12	0.03-0.20	6
25	N,N,*	Any type					0
			0.10	0.11	0.08	0.01-0.38	10
26	O,A,O	Any type	0.23	0.00	0.23	0.23-0.23	1
			0.20	0.17	0.15	0.07-0.45	4
27	O,L,O	Any type					0
			0.25	0.16	0.25	0.02-0.50	10
28	O,O,*	Any type	0.11	0.11	0.09	0.02-0.24	4
			0.22	0.12	0.24	0.01-0.46	33
All other cases of increments			0.15	0	0.15	0.15-0.15	2
			0.17	0.17	0.15	-0.13-0.67	25

*C=Ceiling, W=Wall, F=Floor

DOOR GROUPS

Door Type Code:

A	Insulated clad foam core
B	Wood solid core
C	Wood hollow core
D	A and B
E	A in both MCS and Current Practice
F	B in both MCS and Current Practice
X	Missing
Z	Other

Table 6.7. Door incremental costs per square foot by type of construction for matched pair and unmatched houses

Group No.	Current Practice	MCS	Mean ($/ft²)	Standard Deviation ($/ft²)	Median ($/ft²)	Min.-Max. ($/ft²)	Sample Size
1	A,E	A,E	0.56	1.25	0.00	0-4.53	18
			1.01	2.18	0.23	-0.57-16.40	161
2	B,F	B,F	0.00	0.00	0.00	0-0	4
			1.86	2.49	0.80	0-7.78	20
3	B	A	-0.87	7.03	-0.10	-8.25-5.75	3
			3.44	4.26	3.21	-18.40-21.87	121
4	A	B	4.13	4.13	4.13	4.13-4.13	1
			2.18	2.18	2.18	2.18-2.18	1
All other cases of increments			0.10	0.68	0.10	-0.38-0.58	2
			2.56	4.02	0.00	-0.38-10.93	14

AIR-TO-AIR HEAT EXCHANGER GROUPS

Air-to-Air Heat Exchanger (AAHX) Code:

A The Air Changer Company

B Airxchange (NuTone)

E Conservation Energy Systems (VanEE)

F Des Champs (79m-4)

G Des Champs (79m-6)

H Des Champs (200 series)

I Des Champs (300 series)

J EER Products (Heat-X-changer)

K Ener-Corp (Enerex 250)

M Mountain Energy and Resources

O Star Heat Exchanger 100A

P Star Heat Exchanger 200A

R Enter Matrix

X Missing

Z Other

Table 6.8. Air-to-air heat exchanger incremental costs per square foot by type of construction for matched pair and unmatched houses

Group No.	AAHX Type	Floor Area	Mean ($/ft^2)	Standard Deviation ($/ft^2)	Median ($/ft^2)	Min.-Max. ($/ft^2)	Sample Size
1 Matched	A	Less than					0
Unmatched		1500 ft^2	1.13	0.22	0.98	0.98-1.54	7
2	B	Less than	0.91	0.19	1.01	0.52-1.01	7
		1500 ft^2	0.69	0.13	0.66	0.52-1.14	23
3	E	Less than	0.91	0.00	0.91	0.91-0.91	1
		1500 ft^2	1.00	0.20	1.06	0.78-1.24	7
4	F	Less than					0
		1500 ft^2	0.82	0.29	0.85	0-1.10	11
5	G	Less than					0
		1500 ft^2	0.96	0.05	0.96	0.93-1.00	2
6	H	Less than	1.37	0.13	1,37	1.28-1.46	2
		1500 ft^2	1.29	0.27	1.32	0.98-1.52	4
7	I	Less than					0
		1500 ft^2	1.67	0.58	1.67	1.26-2.08	2
8	J	Less than	0.97	0.00	0.97	0.97-0.97	1
		1500 ft^2	1.00	0.00	1.00	1.00-1.00	1
9	K	Less than					0
		1500 ft^2	0.89	0.00	0.89	0.89-0.89	1
10	M	Less than	1.37	0.00	1.37	1.37-1.37	1
		1500 ft^2					0
11	O	Less than	1.18	0.08	1.18	1.12-1.23	2
		1500 ft^2	0.84	0.34	0.92	0-1.29	12
12	P	Less than	1.08	0.00	1.08	1.08-1.08	1
		1500 ft^2	1.07	0.31	0.97	0.82-1.42	3
13	R	Less than	1.10	0.00	1.10	1.10-1.10	1
		1500 ft^2	0.93	0.26	0.89	0.70-1.21	3
14	X	Less than	0.71	0.00	0.71	0.71-0.71	1
		1500 ft^2	0.84	0.25	0.87	0.55-1.06	4

Group No.	AAHX Type	Floor Area	Mean ($/ft²)	Standard Deviation ($/ft²)	Median ($/ft²)	Min.-Max. ($/ft²)	Sample Size
15	Z	Less than	1.43	0.00	1.43	1.43-1.43	1
		1500 ft²	0.76	0.18	0.76	0.64-0.89	2
16	A	1500 to					0
		2500 ft²	0.78	0.17	0.75	0.52-1.03	13
17	B	1500 to	0.70	0.07	0.70	0.66-0.75	2
		2500 ft²	0.49	0.19	0.50	0-0.81	32
18	E	1500 to	0.70	0.00	0.70	0.70-0.70	1
		2500 ft²	0.75	0.25	0.83	0-0.99	20
19	F	1500 to					0
		2500 ft²	0.78	0.18	0.74	0.61-1.03	4
20	G	1500 to					0
		2500 ft²	0.79	0.00	0.79	0.79-0.79	1
21	H	1500 to					0
		2500 ft²	0.66	0.16	0.66	0.22-0.94	27
22	I	1500 to	1.33	0.00	1.33	1.33-1.33	1
		2500 ft²	0.74	0.20	0.77	0.29-1.00	12
23	J	1500 to					0
		2500 ft²	0.72	0.00	0.72	0.72-0.72	1
24	K	1500 to					0
		2500 ft²	1.02	0.08	1.02	0.96-1.07	2
25	M	1500 to	0.71	0.10	0.75	0.60-0.78	3
		2500 ft²	0.64	0.36	0.69	0-1.48	23
26	O	1500 to	0.72	0.00	0.72	0.72-0.72	1
		2500 ft²	0.68	0.21	0.72	0.35-1.15	28
27	P	1500 to					0
		2500 ft²	0.62	0.11	0.58	0.50-0.77	8
28	R	1500 to	0.64	0.05	0.64	0.60-0.67	2
		2500 ft²	0.68	0.15	0.72	0.26-0.89	13
29	X	1500 to					0
		2500 ft²	0.35	0.50	0.35	0-0.70	2

Group No.	AAHX Type	Floor Area	Mean ($/ft^2)	Standard Deviation ($/ft^2)	Median ($/ft^2)	Min.-Max. ($/ft^2)	Sample Size
30	Z	1500 to					0
		2500 ft^2	0.62	0.18	0.66	0.42-0.77	3
31	A	More than					0
		2500 ft^2	0.25	0.15	0.27	0-0.45	7
32	B	More than					0
		2500 ft^2	0.49	0.00	0.49	0.49-0.49	1
33	E	More than					0
		2500 ft^2	0.49	0.12	0.50	0.25-0.64	12
34	F	More than					0
		2500 ft^2	0.66	0.38	0.54	0.35-1.09	3
35	G	More than					0
		2500 ft^2	0.56	0.21	0.50	0.40-0.87	4
36	H	More than					0
		2500 ft^2	0.50	0.14	0.47	0.35-0.72	13
37	I	More than					0
		2500 ft^2	0.65	0.21	0.54	0.47-1.00	8
38	J	More than					0
		2500 ft^2	0.43	0.00	0.43	0.43-0.43	1
39	K	More than					0
		2500 ft^2	0.55	0.00	0.55	0.55-0.55	1
40	M	More than					0
		2500 ft^2	0.54	0.35	0.54	0-1.08	6
41	O	More than					0
		2500 ft^2	0.50	0.36	0.49	0-1.22	14
42	P	More than					0
		2500 ft^2	0.47	0.05	0.45	0.41-0.54	6
43	R	More than					0
		2500 ft^2	0.62	0.00	0.62	0.62-0.62	1

Group No.	AAHX Type	Floor Area	Mean ($/ft^2)	Standard Deviation ($/ft^2)	Median ($/ft^2)	Min.-Max. ($/ft^2)	Sample Size
44	X	More than					0
		2500 ft^2	0.60	0.19	0.54	0.46-0.89	4
45	Z	More than					0
		2500 ft^2	0.85	0.72	0.48	0.39-1.68	3
		AGGREGATE GROUPS					
A	All types	Less than 1500 ft^2	1.06	0.24	1.01	0.52-1.46	18
			0.89	0.31	0.89	0-2.08	82
B	All types	1500-2500 ft^2	0.76	0.21	0.71	0.60-1.33	10
			0.66	0.24	0.69	0-1.48	189
C	All types	More than 2500 ft^2					0
			0.52	0.26	0.48	0-1.68	84

CHAPTER 7. SUMMARY ANALYSIS

In this chapter, we present total incremental building costs normalized (standardized) by floor area for single-family houses (Table 7.1). We first present "state calculated total costs" which are the total incremental costs per square foot as reported by the states. We also distinguish between "hard" and "soft" building costs for single-family houses in the following way. "Hard" building costs include air-to-air heat exchanger, subfloor, framing, insulation, glazing, doors, fireplace, plumbing, electrical, HVAC, drywall, painting, vapor barrier and caulking, passive solar, and supervision costs. "Soft" building costs, which are normally part of a builder's overhead, include design, loan, and other costs (including appraisal fees, permit/inspection fees, etc.). It is important to note that the differences, if any, between state calculated total costs and those obtained by adding hard and soft costs are due to recalculations of floor areas by the states to reflect the inclusion of some heated or tempered basements. These revised floor areas are not yet in the data base and, therefore, cannot be replicated. However, it can be assumed that these refinements are probably more accurate than previous data.

The median incremental "state calculated total cost" for building matched pair houses was $\$2.86/ft^2$; the mean incremental cost was $\$2.93/ft^2$ with a standard deviation of $\$1.26/ft^2$. The median incremental "hard" cost for building a matched pair house was $\$2.41/ft^2$; the mean incremental cost was $\$2.59/ft^2$ with a standard deviation of $\$1.11/ft^2$. The range was large: $\$0.34/ft^2$ to $\$4.81/ft^2$. In general, the design, loan, and other costs are relatively minor in comparison to the hard costs. Appendix D contains the spreadsheet of the cases used in this analysis.

The matched pair sample had 14% smaller hard costs than the rest of the RSDP houses, and this difference (in median and mean costs) would be doubled if the cost of the air-to-air heat exchanger (see (Chapter 4) is excluded. There are no substantive differences in design and loan costs between the two groups, however, the matched pair sample incurred more "other costs" than their counterparts.

Table 7.1. Total incremental costs per floor area for matched pair and unmatched houses

	Mean ($/ft^2)	Standard Deviation ($/ft^2)	Median ($/ft^2)	Minimum-Maximum ($/ft^2)	Sample Size
State calculated total costs					
Matched	2.93	1.26	2.86	0.37-5.30	32
Unmatched	3.08	1.37	2.96	0.31-15.90	359
Total hard costs					
Matched	2.59	1.11	2.41	0.34-4.81	32
Unmatched	2.97	1.33	2.79	0.28-13.68	359
Design costs					
Matched	0.06	0.07	0.04	0-0.26	32
Unmatched	0.06	0.09	0.02	0-0.67	359
Loan costs					
Matched	0.08	0.13	0.03	0-0.44	32
Unmatched	0.08	0.14	0.04	0-1.53	359
Other costs					
Matched	0.19	0.16	0.19	0-0.55	32
Unmatched	0.09	0.14	0.00	0-0.78	359

CHAPTER 8. DISCUSSION AND CONCLUSIONS

In this report, we examined the costs associated with building energy efficient houses in the Pacific Northwest as part of the Residential Standards Demonstration Program (RSDP). Several levels of analysis were used in examining the cost data: absolute, incremental, and normalized (absolute and incremental) costs (standardized by floor area and/or component area); and component (e.g., ceiling), sub-component (e.g., attic insulation), and total costs. The focus of this analysis was 33 matched pair houses (these were two otherwise identical houses except that one was built to "super" energy-efficient standards while the other one was built to current energy codes).

Upon examining total incremental building costs normalized by **floor area**, we found the median cost for matched pair houses was $\$2.41/\mathrm{ft}^2$. For the average house in the sample with a median floor area of 1392 square feet, the total incremental cost would be \$3,355. It is important to note that these costs include labor and materials, but exclude builder overhead, fees, and profit, and, therefore, the actual incremental costs would be somewhat larger.

Using incremental building component costs normalized by **component area** as a guide, we found that the largest median incremental component cost per square foot was glazing ($\$3.56/\mathrm{ft}^2$). All other median incremental component costs per square foot were below $\$0.50/\mathrm{ft}^2$: floor ($\$0.43/\mathrm{ft}^2$), walls ($\$0.42/\mathrm{ft}^2$), ceiling ($\$0.23/\mathrm{ft}^2$), vapor barrier ($\$0.08/\mathrm{ft}^2$), doors ($\$0.00/\mathrm{ft}^2$), and basement walls ($\$0.00/\mathrm{ft}^2$).

The matched pair sample did differ from the rest of the MCS houses by having smaller floor areas, more energy-efficient design, greater use of non-central heating systems, and different state and climate representation. The incremental component costs of matched pair houses were generally smaller than those for unmatched houses, and the standard deviations and ranges were smaller for the former than for the latter. The total hard costs for matched pairs are 14% smaller than for the rest of the RSDP houses. These cost differences could be accounted for by the small sample size of matched pair houses and by the different data collection procedures (actual costs for the matched pair houses and estimated costs for the unmatched houses).

A wide range of costs was encountered in all of our analyses. This finding is not unusual for small businesses spread over a large region with different purchasing habits and varying access to suppliers. In interviews with state energy officials, it was reported that some builders were able to take advantage of one-time-only "bargain buys" with local building suppliers. Accordingly, the mean and median values are more representative of the sample than the costs of individual houses. The findings from this cost analysis should be regarded as only indicative for MCS houses for the following reasons. First, in estimating building costs under "current practice" it was hoped that builders would use their current state code as the model for "current practice." However, while Washington and Oregon have statewide energy codes, Idaho and Montana do not have mandatory statewide codes but have local government options.[1]

In 1983 only about 40 percent of Idaho's population was covered by any type of energy efficient building code. While Idaho has produced an energy code, it is considered to be simply a guideline that local governments can enforce, modify, or ignore. Many governments have chosen to ignore it, largely because they lack the funds, staff, or training necessary to enforce it.

Montana's existing energy code is what the building industry calls a "minimum and maximum standard": cities and counties cannot adopt codes that are either less or more strict than the state code, but they can choose not to enforce the code at all. If a town decides not to enforce a code, the state government is responsible for enforcement. However, the state only has authority over dwellings larger than a four-plex and has very few inspectors to cover an extremely large state. This situation has led to uneven enforcement throughout the state.

Oregon also has a "minimum and maximum standard," and cities and counties can choose whether they want to enforce it or leave the responsibility to the state. In general, smaller, less densely populated areas let the state do the enforcement work.

In contrast to the other states, Washington law allows local jurisdictions to pass codes that are stricter than the state's. In addition, all but three percent of the population live in areas that have some type of energy code.

In summary, due to the different types of building codes and code enforcement in the region, the concept of "current practice" is very loosely defined and variable. Hence, the calculation of incremental costs, in which current practice costs are subtracted from energy efficient house costs, is subject to an unknown error.

Second, the cost data itself may be incorrect due to confusion and assumptions made by builders participating in the program. According to some state energy personnel, builders had difficulty in understanding the cost data manual and in completing the cost data forms. In particular, it was very difficult for builders to separate out the costs of building components: for example, separating insulation costs to "walls" for above-

[1]The following discussion on state energy codes is based on an article by Susan Skog, "What happens next: Adoption," *Northwest Energy News* 3(2):18-21 (1984).

grade insulation and to "basement walls" for below-grade insulation. The workshops were helpful for most of the builders in determining this type of calculation. However, some builders didn't construct their houses until several months after the workshops were held, and others didn't complete the cost data forms until several months after they built their houses, leading to poor recall. To ensure high quality data, all the state energy agencies had a cost data review process. Typically, the states contacted individual builders an average of two to three times and for up to two hours at a time to resolve inconsistencies in the data. Thus, we believe that the cost data, on the whole, are good, but some discrepancies in the data may remain.

Third, the findings from this demonstration program are not generalizable. Builders participating in the RSDP are probably not representative of the builders in the Pacific Northwest because they were self-selected: they voluntarily participated in the program. Thus, those with experience in building energy efficient houses are probably over-represented in this program. Hence, we would expect the costs of these builders to be lower than those of less-experienced builders.

Fourth, this was the first time that many of the builders ever attempted to build to this level of energy efficiency using innovative building materials and techniques. For example, most builders had little experience with the sizing and installation of air-to-air heat exchangers and experienced several problems in the installation of this equipment. Consequently, we would expect the cost of building energy efficient houses to decrease over time as the building community becomes more informed and experienced in constructing energy efficient houses. As mentioned previously, one of the major purposes of the RSDP was to educate the building community about the construction techniques and materials involved in building MCS-type houses. The builder training workshops, the cost data manual, and the construction of MCS-type houses provided the resources to develop the skills necessary for constructing energy-efficient houses in a cost-effective manner. Thus, we would expect that these experienced builders would now be able to build these energy efficient houses less expensively than before.

Fifth, the incremental costs calculated in this report are, in many cases, for energy efficient houses that are designed to go beyond the Model Conservation Standards (MCS) proposed by the Northwest Power Planning Council. Initially, it was hoped that incremental costs could be calculated for MCS houses. However, because most of the houses built in the RSDP went beyond the MCS and because of the difficulty experienced by builders in separating out those costs that met the MCS from those costs that exceeded the MCS, the initial objective could not be met.

Sixth, the builders did not try to take the most cost-effective routes in building their energy efficient houses, as assumed in the development of the MCS by the Council:

> "The MCS were developed by the Council in increments of cost-effective measures, and the costs were based on average costs for the most cost-effective techniques and materials. For aesthetic, marketing, or experimental reasons, the RSDP builders could skip the most cost-effective measures, and take more expensive alternatives to reach a comparable level of energy efficiency. Therefore, the RSDP costs can be expected to exceed the typical MCS costs."[2]

Thus, direct comparisons of our findings with the Council's projections should be done cautiously.

Finally, the cost data for the matched pair houses should be regarded as very tentative due to the small sample size (33), and, therefore, comparisons with unmatched houses are tenuous, at best. We would be more confident of the mean and median cost values with larger sample sizes because the impact of one house would have less of an effect on the entire sample.

In summary, we found that builders are able to build energy efficient houses with minimal changes in building materials and techniques without a substantial increase in costs. Moreover, builders learned during this demonstration program: in some cases, builders have changed their usage of materials and building practices after discovering their higher costs in comparison to alternative materials and techniques.[3] Accordingly, as builders gain more experience in building energy efficient houses, and as manufacturers, wholesalers, retailers, and distributors make energy efficient products more available in greater quantities, the costs of building energy efficient houses should decrease.

We would like to thank the following people for their assistance in this project: Ken Keating, Jane Selby, and Phil Thor of the Bonneville Power Administration; Tom Eckman of the Northwest Power Planning Council; Johnny Douglas, Pat Keegan, Dan Silver, and Tony Usibelli of the Washington State Energy Office; Alan Tabachnikov and Jim Maloney of the Oregon Department of Energy; Paul Cartwright and Brian Green of the Montana Department of Natural Resources; Mike McSorley of the Idaho Department of Water Resources; Carole Wright of EDS; Craig Conner of Battelle Pacific Northwest Laboratory; and Barry Barnes, Steve Gold, Alan Meier, and Bruce Nordman of the Lawrence Berkeley Laboratory.

[2] Personal communication, Ken Keating, RSDP Evaluation Group, BPA, September 12, 1985.
[3] Based on interviews with state energy officials.

APPENDIX A

COST DATA

Residential Standards Demonstration Program

HOME I.D. # ______________

Builder:	______________
Address:	______________
Telephone:	______________

State Office:	______________
Contact:	______________
Address:	______________
Telephone:	______________

Prepared By: NAHB AREA XV, 15555 SW Bangy Road, Lake Oswego, OR 97034 (503) 684-1880 in association with NAHB Research Foundation.

Modified By: Bonneville Power Administration 2/29/84

General Instructions

The purpose of this manual is to demonstrate the difference in cost between homes built to meet the Model Conservation Standards (MCS) and homes built to current practice or code. It was designed by builders in the Northwest. Two sets of forms are contained in the manual. One set, with the words "Current Practice" in the upper right hand corner of the page, is to be used to enter the costs to the builder if the homes were built to current standards. The other set, marked "MCS", is to be used to enter the costs for the MCS home. The state will provide a description of the current practice home to the builders. Builders will enter their actual costs for the MCS house and their estimates of what those costs would be for the home built to current standards. Builders who are building a matched pair will enter information on these forms based on the homes they actually build to the MCS and current standards.

Information **only** needs to be entered on these forms if it represents an item whose cost is **different** for the MCS and Current Standards home **because** of the MCS. If no difference in costs occurs, simply check the column labeled NA (not applicable).

The builder will be required to calculate cost information for this manual which would not have to be calculated under normal circumstances. The reason this is necessary is to answer questions about the MCS which are very important to the building community of the region. Please make your best effort to enter accurate, complete information.

Monitor your costs, enter the information as construction progresses, follow the instructions below, and feel free to call the state office listed on the cover if you have any questions.

The instructions below will describe how to fill out the forms in this manual. The state office may ask you for some additional information or copies of some of the forms along the way.

COST FORMS INSTRUCTIONS

ITEM

"Items" are the materials or labor which could have a different cost for the MCS home and the current practice home. If an item is not listed for which cost differs between the two homes, list the information on an extra line.

NA

If an item is not required for a particular house, or if the cost is no different for the MCS and current standards homes, check this column. If NA is checked, no further information needs to be entered on the line.

MATERIALS

Two columns are available for entering costs of materials. Figures entered on these columns should include **all** the materials costs to the builder **and**, if obtainable, the materials cost to the subcontractor. The first column, headed "EST.", is to be used to enter the estimated costs of the materials before construction begins. The builder will be given a materials list of MCS materials taken off by a professional estimator hired by the state. This materials list will show quantities for most of the materials listed in this manual. The builder may use this materials list to obtain cost estimates or he may use a materials list he does himself. These estimated costs should be entered in the "EST." column under "Materials".

The second column, "Actual", is to be used after purchasing the materials to enter the actual costs. If the actual costs were exactly the same as the estimated costs, enter "same" in the "Actual" column.

BUILDER LABOR

This column is to be used to enter the builder's actual own labor cost. The labor cost could be either the cost of paying the builder's employees, and/or the fair market value of the builder's own labor. The costs of paying the builder's employees should include gross wages plus benefits, insurance or social security above the gross wages. In other words, the total cost to the builder of the employee for the particular item. The builder's own labor should be figured as the amount the builder would have to pay someone else for the task.

The builder is not expected to break down "Builder Labor" by every line item listed. But costs should be broken down for each major category. If the builder were to do his own framing, for example, a builder labor figure (or an NA) should be entered for "A. Floor/Crawl Space", "B. Basement", "C. Joists", "D. Exterior Walls", etc.

SUBCONTRACTOR CHARGES

The subcontractor charge information is very important. But it will require some extra communication between the builder and subcontractor. The subcontractor must be persuaded to bid the MCS and current standards homes. If the subcontractor is **unable** to give material costs separately, the total bid, **including materials** should be entered under "BID", and the builder should then write in "L&M" next to the figure, indicating that **both** labor and materials are included. If the subcontractor is **able** to provide material costs separately, they should be entered under "MATERIALS."

The first column, "BID", should represent the subcontractor's bid. The subcontractor should break down the bid into the major categories (A, B, C, etc.) as much as possible. If the subcontractor is unable to do so, categories can be grouped into a single figure.

The second column, "Actual", must be filled in after the subcontractor has completed work. The builder must ask the subcontractor what the bid would have been had he known exactly how much time the job would take. The subcontractor may have little experience with the MCS, and under or overbid the job. This column allows the subcontractor to reflect upon the time and cost of doing the work, and suggest what he feels would be a competitive price in retrospect. Presumably, the subcontractor is familiar with the current standards techniques, so no information needs to be obtained on that form under "Actual".

RELATED COSTS

Many of the items under "Related Costs" will vary depending on the price of the home. The price of the home will be affected by the MCS, so these items could have different costs for the MCS and current practice homes. Please enter costs for all items which vary in cost for the two homes. The costs that have been incurred by the time of the completion of the home (and, therefore, the due date of this accounting manual) are to be entered, even though additional cost may still be incurred.

COST SUMMARY SHEET (Optional)

The totals from each component/task page can be used to fill in the Model Conservation Standards (MCS) and Current Practice Home columns.

ADDITIONAL INFORMATION/QUESTIONS:

Any questions that the builder may have should be directed to the State Office, unless they identify a different source below:

Name: ______________________________

Phone Number: ______________________

COMPONENT: SLAB-ON-GRADE, CRAWL SPACE, BASEMENT **Home I.D.#** ____________

ITEM	NA	MATERIALS EST.	MATERIALS ACTUAL	BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES BID (EST)	SUBCONTRACTOR CHARGES ACTUAL
A. Slab-on grade:		•	•	•	•	•
A.1. vapor barrier						
a.2. perimeter insul.						
a.3. Total labor		•	•			
B. Crawl Space		•	•	•	•	•
B.1. vapor bar., ground		see vapor barrier/calking/sealing				
B.2. vapor bar., perim.						
B.3. insulation-perim.						
B.4. flashing/insul. cover						
B.5. adhesive/fasteners						
C. Basement						
C.1. vapor barrier						
C.2. Insul.-Perimeter						
C.3. flashing/cover						
C.4. Adhesives/fasteners						
TOTALS		$	$	$	$	$

COMPONENT: SLAB-ON-GRADE, CRAWL SPACE, BASEMENT **Home I.D.#** ________________

ITEM	NA	MATERIALS EST.	MATERIALS ACTUAL	BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES BID (EST)	SUBCONTRACTOR CHARGES ACTUAL
A. Slab-on grade:		-	-	-	-	-
A.1. vapor barrier						
a.2. perimeter insul.						
a.3. Total labor		-	-			
B. Crawl Space		-	-	-	-	-
B.1. vapor bar., ground		see vapor barrier/calking/sealing				
B.2. vapor bar., perim.						
B.3. insulation-perim.						
B.4. flashing/insul. cover						
B.5. adhesive/fasteners						
C. Basement						
C.1. vapor barrier						
C.2. Insul.-Perimeter						
C.3. flashing/cover						
C.4. Adhesives/fasteners						
TOTALS		$	$	$	$	$

COMPONENT: FRAMING Home I.D.# ____________

ITEM	NA	MATERIALS EST.	MATERIALS ACTUAL	BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES BID (EST)	SUBCONTRACTOR CHARGES ACTUAL
A. Floor/Crawl Space						
B. Basements						
B.1. Studs						
B.2. Plates						
B.3. Flame spread material-see drywall and paneling						
B.4. Total labor-basement						
C. Joists						
C.1. Rim						
C.2. Support						
C.3. Total labor-Joists						
D. Exterior Walls						
D.1. Studs						
D.2. Plates						
D.3. Headers						
D.4. Sheathing						
D.5. Bracing						
D.6. Blocking/backing						
D.7. Total labor-Walls						
E. Ceilings						
E.1. Trusses						
E.2. Rafters (Vaults)						
E.3. Soffit Enclosures						
E.4. Total labor-Ceilings						
F. Window liners/jambs		See Windows				
G. Doors liners/jambs		See Doors				
TOTALS		$	$	$	$	$

COMPONENT: FRAMING Home I.D.# ____________

ITEM	NA	MATERIALS EST.	MATERIALS ACTUAL	BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES BID (EST)	SUBCONTRACTOR CHARGES ACTUAL
A. Floor/Crawl Space						
B. Basements						
B.1. Studs						
B.2. Plates						
B.3. Flame spread material-see drywall and paneling						
B.4. Total labor-basement						
C. Joists						
C.1. Rim						
C.2. Support						
C.3. Total labor-Joists						
D. Exterior Walls						
D.1. Studs						
D.2. Plates						
D.3. Headers						
D.4. Sheathing						
D.5. Bracing						
D.6. Blocking/backing						
D.7. Total labor-Walls						
E. Ceilings						
E.1. Trusses						
E.2. Rafters (Vaults)						
E.3. Soffit Enclosures						
E.4. Total labor-Ceilings						
F. Window liners/jambs		See Windows				
G. Doors liners/jambs		See Doors				
TOTALS		$	$	$	$	$

COMPONENT: VAPOR BARRIER, CAULKING, SEALING **Home I.D.# ______________**

ITEM	NA	MATERIALS EST.	MATERIALS ACTUAL	BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES BID (EST)	SUBCONTRACTOR CHARGES ACTUAL
A. Vapor Barrier						
A.1. Crawl space ground						
A.2. Floor						
A.3. Walls						
A.4. Ceiling						
A.5. Total V.B. Labor						
B. Caulking/Sealing						
B.1. Rim Joists						
B.2. Sill Plates						
B.3. Sole Plate						
B.4. Framing joints						
B.5. Windows (to frame)						
B.6. Ex. Doors (to frame)						
B.7. Utility Holes						
B.8. All Baseboards						
B.9. Attic Floor						
B.10. Envelope openings						
B.11. Part. Wall Base Mldngs.						
B.12. Elect. Plate. gaskets						
B.13. Total Caulking labor						
C. Air Barrier (tyvek, etc.)						
TOTALS		$	$	$	$	$

COMPONENT: VAPOR BARRIER, CAULKING, SEALING **Home I.D.# ____________**

ITEM	NA	MATERIALS EST.	MATERIALS ACTUAL	BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES BID (EST)	SUBCONTRACTOR CHARGES ACTUAL
A. Vapor Barrier						
A.1. Crawl space ground						
A.2. Floor						
A.3. Walls						
A.4. Ceiling						
A.5. Total V.B. Labor						
B. Caulking/Sealing						
B.1. Rim Joists						
B.2. Sill Plates						
B.3. Sole Plate						
B.4. Framing joints						
B.5. Windows (to frame)						
B.6. Ex. Doors (to frame)						
B.7. Utility Holes						
B.8. All Baseboards						
B.9. Attic Floor						
B.10. Envelope openings						
B.11. Part. Wall Base Mldngs.						
B.12. Elect. Plate. gaskets						
B.13. Total Caulking labor						
C. Air Barrier (tyvek, etc.)						
TOTALS		$	$	$	$	$

COMPONENT: INSULATION Home I.D.# ____________

ITEM	NA	MATERIALS EST.	MATERIALS ACTUAL	BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES BID (EST)	SUBCONTRACTOR CHARGES ACTUAL
A. Perimeter		See Slab-on-Grade, crawl space, Basements				
B. Under Floor						
C. Exterior Wall						
C.1. Sheathing		See Framing				
D. Ceiling						
D.1. Insulation-Ceil.						
D.2. Vents/Baffle						
D.3.						
D.4. Total Ceil. Labor						
E. Pipe Insulation						
F. Heating Syst. Ducts						
F.1. Duct insulation						
F.2. boot insulation						
G. Heat Exchanger Ducts-See Heat Exchangers						
TOTALS		$	$	$	$	$

COMPONENT: INSULATION

Home I.D.# ____________

ITEM	NA	MATERIALS EST.	MATERIALS ACTUAL	BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES BID (EST)	SUBCONTRACTOR CHARGES ACTUAL
A. Perimeter		See Slab-on-Grade, crawl space, Basements				
B. Under Floor						
C. Exterior Wall						
C.1. Sheathing		See Framing				
D. Ceiling						
D.1. Insulation-Ceil.						
D.2. Vents/Baffle						
D.3.						
D.4. Total Ceil. Labor						
E. Pipe Insulation						
F. Heating Syst. Ducts						
F.1. Duct insulation						
F.2. boot insulation						
G. Heat Exchanger Ducts-See Heat Exchangers						
TOTALS		$	$	$	$	$

COMPONENT: WINDOWS Home I.D.# ______

ITEM	NA	MATERIALS EST.	MATERIALS ACTUAL	BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES BID (EST)	SUBCONTRACTOR CHARGES ACTUAL
A. Window Units						
B.						
C.						
D. Liner &/or Ext. Jambs						
E.						
F. Insul. Shades/Shutters						
G.						
H.						
TOTALS		$	$	$	$	$

COMPONENT: DOORS Home I.D.# ______

ITEM	NA	MATERIALS EST.	MATERIALS ACTUAL	BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES BID (EST)	SUBCONTRACTOR CHARGES ACTUAL
A. Door Units						
B. Liners/Extension Jamb						
C.						
D.						
E.						
F.						
TOTALS		$	$	$	$	$

COMPONENT: WINDOWS Home I.D.# ____________

ITEM	NA	MATERIALS		BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES	
		EST.	ACTUAL		BID (EST)	ACTUAL
A. Window Units						
B.						
C.						
D. Liner &/or Ext. Jambs						
E.						
F. Insul. Shades/Shutters						
G.						
H.						
TOTALS		$	$	$	$	$

COMPONENT: DOORS Home I.D.# ____________

ITEM	NA	MATERIALS		BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES	
		EST.	ACTUAL		BID (EST)	ACTUAL
A. Door Units						
B. Liners/Extension Jamb						
C.						
D.						
E.						
F.						
TOTALS		$	$	$	$	$

COMPONENT: Air to Air Heat Exchangers Home I.D.# ____________

ITEM	NA	MATERIALS EST.	MATERIALS ACTUAL	BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES BID (EST)	SUBCONTRACTOR CHARGES ACTUAL
A. Heat Exchanger Unit						
B. Ducting						
C. Duct Insulation						
D. Location						
E. Wiring						
F. Controls						
G.						
H.						
TOTALS		$	$	$	$	$

COMPONENT: HVAC Home I.D.# ____________

ITEM	NA	MATERIALS EST.	MATERIALS ACTUAL	BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES BID (EST)	SUBCONTRACTOR CHARGES ACTUAL
A. HVAC unit						
B. Ducting						
C. Duct Insulation		See Insulation				
D. Duct Sealing						
E.						
F.						
TOTALS		$	$	$	$	$

COMPONENT: Air to Air Heat Exchangers **Home I.D.# ____________**

ITEM	NA	MATERIALS		BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES	
		EST.	ACTUAL		BID (EST)	ACTUAL
A. Heat Exchanger Unit						
B. Ducting						
C. Duct Insulation						
D. Location						
E. Wiring						
F. Controls						
G.						
H.						
TOTALS		$	$	$	$	$

COMPONENT: HVAC **Home I.D.# ____________**

ITEM	NA	MATERIALS		BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES	
		EST.	ACTUAL		BID (EST)	ACTUAL
A. HVAC unit						
B. Ducting						
C. Duct Insulation		See Insulation				
D. Duct Sealing						
E.						
F.						
TOTALS		$	$	$	$	$

COMPONENT: ELECTRICAL

Home I.D.# ____________

ITEM	NA	MATERIALS EST.	MATERIALS ACTUAL	BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES BID (EST)	SUBCONTRACTOR CHARGES ACTUAL
A. Heating Unit Wiring						
B. Bath Fan Wiring						
C. Outlet Gasketing		See Caulking and sealing				
D. Polyethylene pans						
E. Heat Exchanger wiring		See Heat Exchanger				
F.						
G.						
H.						
I.						
J.						
K.						
L.						
M.						
N.						
O.						
P.						
Q.						
R.						
S.						
T.						
U.						
V.						
W.						
X.						
Y.						
Z.						
AA.						
BB.						
CC.						
DD.						
TOTALS		$	$	$	$	$

COMPONENT: ELECTRICAL Home I.D.# ____________

ITEM	NA	MATERIALS		BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES	
		EST.	ACTUAL		BID (EST)	ACTUAL
A. Heating Unit Wiring						
B. Bath Fan Wiring						
C. Outlet Gasketing		See Caulking and sealing				
D. Polyethylene pans						
E. Heat Exchanger wiring		See Heat Exchanger				
F.						
G.						
H.						
I.						
J.						
K.						
L.						
M.						
N.						
O.						
P.						
Q.						
R.						
S.						
T.						
U.						
V.						
W.						
X.						
Y.						
Z.						
AA.						
BB.						
CC.						
DD.						
TOTALS		$	$	$	$	$

COMPONENT: FIREPLACE

Home I.D.# ______________

ITEM	NA	MATERIALS EST.	MATERIALS ACTUAL	BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES BID (EST)	SUBCONTRACTOR CHARGES ACTUAL
A. Combustion Air						
B. Door						
C. Damper						
D.						
E.						
F.						
G.						
H.						
TOTALS		$	$	$	$	$

COMPONENT: PLUMBING

Home I.D.# ______________

ITEM	NA	MATERIALS EST.	MATERIALS ACTUAL	BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES BID (EST)	SUBCONTRACTOR CHARGES ACTUAL
A. Pipe Insulation		see insulation				
B.						
C.						
D.						
E.						
F.						
TOTALS		$	$	$	$	$

COMPONENT: FIREPLACE Home I.D.# ______

ITEM	NA	MATERIALS EST.	MATERIALS ACTUAL	BUILDER ACTUAL LABOR	CHARGES EXCLUDING MATERIAL BID (EST)	CHARGES EXCLUDING MATERIAL ACTUAL
A. Combustion Air						
B. Door						
C. Damper						
D.						
E.						
F.						
G.						
H.						
TOTALS		$	$	$	$	$

COMPONENT: PLUMBING Home I.D.# ______

ITEM	NA	MATERIALS EST.	MATERIALS ACTUAL	BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES BID (EST)	SUBCONTRACTOR CHARGES ACTUAL
A. Pipe Insulation		see insulation				
B.						
C.						
D.						
E.						
F.						
TOTALS		$	$	$	$	$

COMPONENT: DRYWALL & PANELING Home I.D.# ____________

ITEM	NA	MATERIALS EST.	MATERIALS ACTUAL	BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES BID (EST)	SUBCONTRACTOR CHARGES ACTUAL
A. Walls						
B. Ceilings						
C. Clips						
D. Fasteners						
E. Flame spread material						
F.						
G.						
H.						
TOTALS		$	$	$	$	$

COMPONENT: PAINTING Home I.D.# ____________

ITEM	NA	MATERIALS EST.	MATERIALS ACTUAL	BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES BID (EST)	SUBCONTRACTOR CHARGES ACTUAL
A. Jambs						
B. Drywall returns						
C.						
D.						
E.						
F.						
TOTALS		$	$	$	$	$

COMPONENT: DRYWALL & PANELING Home I.D.# ____________

ITEM	NA	MATERIALS EST.	MATERIALS ACTUAL	BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES BID (EST)	SUBCONTRACTOR CHARGES ACTUAL
A. Walls						
B. Ceilings						
C. Clips						
D. Fasteners						
E. Flame spread material						
F.						
G.						
H.						
TOTALS		$	$	$	$	$

COMPONENT: PAINTING Home I.D.# ____________

ITEM	NA	MATERIALS EST.	MATERIALS ACTUAL	BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES BID (EST)	SUBCONTRACTOR CHARGES ACTUAL
A. Jambs						
B. Drywall returns						
C.						
D.						
E.						
F.						
TOTALS		$	$	$	$	$

COMPONENT: PASSIVE SOLAR Home I.D.# ____________

ITEM	NA	MATERIALS		BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES	
		EST.	ACTUAL		BID (EST)	ACTUAL
A. Thermal Mass						
B. mass support						
C. shading devices						
D. venting						
E. drapes/night insul.		See Windows				
F. Glazing		See Windows				
G. Ducting						
H. Equip. & Controls						
I.						
J.						
K.						
L.						
M.						
N.						
O.						
P.						
Q.						
R.						
S.						
T.						
U.						
V.						
W.						
X.						
Y.						
Z.						
AA.						
BB.						
CC.						
DD.						
TOTALS		$	$	$	$	$

COMPONENT: PASSIVE SOLAR

Home I.D.# ______________________

ITEM	NA	MATERIALS		BUILDER ACTUAL LABOR	SUBCONTRACTOR CHARGES	
		EST.	ACTUAL		BID (EST)	ACTUAL
A. Thermal Mass						
B. mass support						
C. shading devices						
D. venting						
E. drapes/night insul.		See Windows				
F. Glazing		See Windows				
G. Ducting						
H. Equip. & Controls						
I.						
J.						
K.						
L.						
M.						
N.						
O.						
P.						
Q.						
R.						
S.						
T.						
U.						
V.						
W.						
X.						
Y.						
Z.						
AA.						
BB.						
CC.						
DD.						
TOTALS		$	$	$	$	$

House Identification NO: ____________________

Component: RELATED COST*

Item	n/a	Cost
a. Supervision		
b. Design		
c. Permit/inspection fees		
d. Hazard insurance		
e. Appraisal fee		
f. H.O.W.		
g. Construction loan interest**		
h. Commission		
i. Discount points		
j. Take-Out title insurance		
k. Transfer tax and/or sales tax		
l. Closing cost		
m. Escrow fee		
n. Estimated monthly, construction interest		
o.		

Total: ______ __________

* Identify all related costs incurred at completion of home and include on this sheet.

** Identify construction loan interest incurred to point of completion.

House Identification NO: ____________________

Component: RELATED COST*

Item	n/a	Cost
a. Supervision		
b. Design		
c. Permit/inspection fees		
d. Hazard insurance		
e. Appraisal fee		
f. H.O.W.		
g. Construction loan interest**		
h. Commission		
i. Discount points		
j. Take-Out title insurance		
k. Transfer tax and/or sales tax		
l. Closing cost		
m. Escrow fee		
n. Estimated monthly, construction interest		
o.		

Total: ______ ____________

* Identify all related costs incurred at completion of home and include on this sheet.

** Identify construction loan interest incurred to point of completion.

COST SUMMARY

	CURRENT PRACTICE	MODEL CONSERVATION STANDARDS (MCS)
Air to Air Heat Exchanger		
Slab, Crawl Space, Basement		
Framing		
Insulation		
Glazing		
Doors		
Fireplace		
Plumbing		
Electrical		
HVAC		
Drywall		
Painting		
Vapor Barriers, Caulking & Sealing		
Passive Solar		
Related Costs		

TOTAL

APPENDIX B

COST SUMMARY FORM

Contract # ______________ Builder ID# ____________

House Data Entered ____________ By ________

Cost Data Entered ____________ By ________

BPA BLDR ID# ______________

Name ______________________________ # Homes ________

Street ______________________________ MCS Exp(Y/N) ________

C/S/Z ______________________________

Phone ______________________________

BPA SITE ID# ______________

Occupant Name ______________________________ MCS(Y/N) ________

Street ______________________________ Sequence # ________

C/S/Z ______________________________ Matched(Y/N) ________

Climate Zone _____ Multi-family(Y/N) ________

House Type	___________	Floor Area	___________	Fuel Type	___________
Compliance	___________	Bsmt Area	___________	Capacity	___________
Path	___________	Glaze Area	___________	Water Heater Gains ?	___________
Points	___________	Solar Area	___________		
Infil. Pkg.	___________	Door Type	___________	Dryer Gains ?	___________
KWH/sq.ft.	___________	Insp. Date	___________	Wthr Flag	___________

COST SUMMARY FORM - 2 BPA Site ID# ____________

ITEM	CURRENT PRACTICE	MCS / AS-BUILT	TO MCS
AAHX			
SubFloor			
Framing			
Insulation			
Glazing			
Doors			
Fireplace			
Plumbing			
Electrical			
HVAC			
Drywall			
Painting			
VB,Caulking			
Passive Solar			
Supervision			
Design			
Loan Interest			
Other Related			
TOTALS			
	INCREMENTAL COST	____________/sqft	____________/sqft

COST SUMMARY FORM - 3 BPA Site ID# : ____________

COMPONENTS	MCS				CURRENT PRACTICE			
	Type	Rval	Area	Cost	Type	Rval	Area	Cost
CEILING 1)	___	___	______	_________	___	___	______	_________
2)	___	___	______	_________	___	___	______	_________
3)	___	___	______	_________	___	___	______	_________
TOTALS				_________				_________
FLOOR 1)	___	___	______	_________	___	___	______	_________
2)	___	___	______	_________	___	___	______	_________
3)	___	___	______	_________	___	___	______	_________
TOTALS				_________				_________
WALLS 1)	___	___	______	_________	___	___	______	_________
2)	___	___	______	_________	___	___	______	_________
3)	___	___	______	_________	___	___	______	_________
TOTALS				_________				_________
BSMT WALLS 1)	___	___	______	_________	___	___	______	_________
2)	___	___	______	_________	___	___	______	_________
3)	___	___	______	_________	___	___	______	_________
TOTALS				_________				_________

COST SUMMARY FORM - 4 BPA Site ID# : ________

		MCS					CURRENT PRACTICE			
		Type	#Gl	Uvl	Area	Cost	Type	Uvl	Area	Cost
GLASS	1)	___	___	___	___	___	___	___	___	___
	2)	___	___	___	___	___	___	___	___	___
	3)	___	___	___	___	___	___	___	___	___
TOTALS						___				___

		MCS			CURRENT PRACTICE		
		C/W/F	Area	Cost	C/W/F	Area	Cost
INFIL. V.B.	1)	__/__/__	___	___	__/__/__	___	___
	2)	__/__/__	___	___	__/__/__	___	___
TOTALS				___			___

APPENDIX C

This appendix contains a listing of homes (spreadsheets) used in the determination of groups of components analyzed in Chapter 6. The following information is provided for each home: identification number, area of component, type of component, R-value (or U-value) of component, cost of component, incremental cost per square foot, and group number (identifying which group the home was placed).[1] The spreadsheets are presented in the same order as in Chapter 6: ceiling, floor, wall, basement wall, window, air infiltration barrier, door, and air-to-air heat exchanger. Column headings are explained in the glossary below.

GLOSSARY

SITEID[2]	Identification of house/builder.
AREA	Area of component.
CPTYPE	Component type - current practice.
MCSTYPE	Component type - MCS.
CPRVAL	Component R-value - current practice.
MCSRVAL	Component R-value - MCS.
CPUVAL	Component U-value - current practice.
MCSUVAL	Component U-value - MCS.
CP$	Component cost - current practice.
MCS$	Component cost - MCS.
INCOST$	Incremental cost/ft^2 = ((MCS$-CP$)/AREA)
GRP	Group number

[1] We have used group number 99 to indicate "all other cases of increments."

[2] SITEID is an eight digit number and is described on the next page.

KEY TO RSDP IDENTIFICATION NUMBERS

Column	Character	Explanation
1		**state**
	1	Idaho
	2	Montana
	3	Oregon
	4	Washington
2		**climate zone**
	1	4,000 - 6,000 degree-days
	2	6,000 - 8,000 degree-days
	3	8,000 + degree-days
3		**sample type**
	1	matched pair
	2	unmatched
	3	unmatched + ELCAP (sort of)
4		**construction type**
	1	MCS
	2	Control
5		**house type**
	1	Single-family
	2	Multifamily
6		house identification number
7		house identification number
8		house identification number

CEILING SPREADSHEET

Ceiling Insulation Type Code:

A Attic, advanced truss, loosefill insulation

B Attic, advanced truss, batt insulation

C Attic, standard truss, baffle, compressed batt perimeter

D Attic, standard truss, rigid foam perimeter

E Vaulted, batt, no foam

F Vaulted, batt, foam inside

G Vaulted, compressed batt

H Attic, standard truss, loosefill insulation

I Attic, standard truss, loosefill insulation, compressed batt perimeter

X Missing

Z Other

19-OCT-86 ceiling spreadsheet - for matched pairs analysis
11:[illegible]6:19 Lawrence Berkeley Laboratory DEC VAX-8600 VMS V4.4

SITEID	AREA	CPTYPE	MCSTYPE	CPRVAL	MCSRVAL	CP$	MCS$	INCOSTS	GRP
31111112	1193	C	B	30	38	3790	4840	.88	4
41111045	1035	C	B	30	38	3078	3718	.62	4
41111151	1422	C	C	30	38	418	684	.19	5
41111209	732	E	E	30	38	430	500	.10	7
41111211	732	E	E	30	38	430	500	.10	7
41111213	732	E	E	30	38	430	500	.10	7
41111215	732	E	E	30	38	430	500	.10	7
41111217	732	E	E	30	38	430	500	.10	7
41111045	236	E	E	30	38	60	204	.61	7
42111021	64	E	E	30	38	32	35	.05	7
41111028	1052	H	A	30	38	1087	1538	.43	10
41111174	1435	H	A	30	38	3044	3791	.52	10
41111176	1299	H	A	30	38	2787	3683	.69	10
42111021	913	H	A	30	38	809	1094	.31	10
42111144	975	H	H	30	49	329	487	.16	17
11111140	1700	H	A	38	38	921	1062	.08	19
11111142	1697	H	A	38	38	904	1062	.09	19
11111143	1196	H	A	38	38	943	1067	.10	19
11111145	1491	H	A	38	38	1221	1349	.09	19
11111153	1348	H	A	38	38	1110	1342	.17	19
23111521	960	H	A	38	38	746	966	.23	19
23111573	960	H	A	38	38	746	966	.23	19
41111235	679	H	A	38	38	1442	1846	.59	19
41111237	1323	H	A	38	38	2390	3018	.47	19
12111117	1002	H	A	38	42	2289	2702	.41	20
23111574	1236	H	A	38	43	1774	2268	.40	20
12111152	1142	H	A	38	44	2805	3371	.50	20
31111218	1038	C	A	30	38	2957	3763	.78	24
41111112	1097	E	E	30	30	536	559	.02	99
11111106	1628	H	A	33	38	2009	2435	.26	99
23111523	1392	A	A	38	38	0	0	.00	99
41111239	866	C	B	38	38	1646	1979	.38	99
23111514	1184	Z	A	38	50	3756	3085	-0.57	99

NUMBER OF CASES READ = 33 NUMBER OF CASES LISTED = 33

FLOOR SPREADSHEET

Floor Type Code:

A Crawlspace (insulation under floor or overhangs)
B Slab below grade
C Slab on grade
D Heated crawlspace
E Foam insulation under slab
F Combination of floor and perimeter insulation
X Missing
Z Other

24-OCT-86 floor spreadsheet - for matched pairs analysis
13:53:42 Lawrence Berkeley Laboratory DEC VAX-8600 VMS V4.4

SITEID	AREA	CPTYPE	MCSTYPE	CPRVAL	MCSRVAL	CP$	MCS$	INCOST$	GRP
23111514	1195	A	A	0	19	1674	2203	.44	1
23111521	960	A	A	0	19	0	376	.39	1
23111573	960	A	A	0	19	0	376	.39	1
41111178	74	B	B	0	10	0	102	1.38	3
23111574	256	B	B	0	15	0	410	1.60	4
41111209	110	C	C	0	6	0	125	1.14	10
41111211	110	C	C	0	6	0	125	1.14	10
41111213	110	C	C	0	6	0	125	1.14	10
41111215	110	C	C	0	6	0	125	1.14	10
41111217	110	C	C	0	6	0	125	1.14	10
41111239	94	C	C	6	10	0	222	2.36	14
41111028	128	C	C	6	10	81	263	1.42	14
41111151	148	C	C	5	15	84	436	2.38	15
41111045	1271	A	A	11	19	278	459	.14	16
41111174	1435	A	A	11	19	0	125	.09	16
41111176	1299	A	A	11	19	0	104	.08	16
42111021	130	A	A	11	19	32	41	.07	16
41111178	553	A	A	11	19	0	169	.31	16
41111239	85	A	A	11	19	16	27	.13	16
41111235	660	A	A	11	25	163	570	.62	17
41111237	1314	A	A	11	25	289	732	.34	17
41111112	1097	D	A	11	19	142	331	.17	20
31111218	1024	A	A	19	30	1357	1591	.23	22
23111512	1144	A	A	0	3	0	674	.59	99
23111523	1392	A	A	0	3	0	722	.52	99
31111112	1193	A	A	19	19	546	546	.00	99
11111145	190	A	D	19	20	76	93	.09	99
31111218	176	C	C	19	19	80	170	.51	99
11111106	598	A	A	20	20	123	123	.00	99
11111140	352	A	D	20	20	86	294	.59	99
11111142	382	D	D	20	20	89	95	.02	99
11111143	288	D	D	20	20	62	294	.81	99
11111153	304	D	D	20	20	65	209	.47	99

NUMBER OF CASES READ = 33 NUMBER OF CASES LISTED = 33

WALL SPREADSHEET

Wall Type Code:

A Strapped wall

B Double wall

C 2 X 6, 24" on center, advanced framing

D 2 X 6, 24" on center, standard framing

E 2 X 6, 16" on center, standard framing

F 2 X 6, 24" on center, foam outside

G 2 X 6, 24" on center, foam inside

H 2 X 4, 24" on center, foam outside

I 2 X 4, 24" on center, foam inside

J Foam blocks

K 2 X 8, 24" on center, advanced framing

L 2 X 8, 16" on center, standard framing

M All weather wood foundation

N Cement, foam outside

O Cement, batt inside

P Cement, foam outside, batt inside

Q 2 X 6, 24" on center, mod. advanced framing

R 2 X 6, 24" on center, mod. advanced framing with foam inside

S 2 X 6, 24" on center, mod. advanced framing with foam outside

T Larsen truss, batt insulation

U 2 X 4, 16" on center, standard framing

V No insulation on foundation

X Missing

Z Other

AA 2 X 4, 24" on center, standard framing

BB Cement, no insulation

24-OCT-86 wall spreadsheet - matched pairs analysis
13:55:20 Lawrence Berkeley Laboratory DEC VAX-8600 VMS V4.4

SITEID	AREA	CPTYPE	MCSTYPE	CPRVAL	MCSRVAL	CP$	MCS$	INCOSTS	GRP
31111112	1168	U	C	11	19	4063	4745	.58	1
41111028	1589	U	C	11	19	4774	4976	.13	1
41111112	868	U	C	11	19	390	527	.16	1
41111209	1126	U	C	11	19	1362	1834	.42	1
41111211	1126	U	C	11	19	1362	1834	.42	1
41111213	1126	U	C	11	19	1362	1834	.42	1
41111215	1126	U	C	11	19	1362	1834	.42	1
41111217	1126	U	C	11	19	1362	1834	.42	1
31111218	1108	U	Q	11	19	3843	4007	.15	1
41111174	1255	U	G	11	25	2700	3790	.87	4
41111176	1295	U	G	11	25	2439	4003	1.21	4
41111178	1356	U	G	11	25	2747	4806	1.52	4
41111045	1361	U	B	11	30	1077	1929	.63	9
42111021	1515	U	G	11	27	1761	2505	.49	11
11111145	796	E	F	19	25	546	424	-0.15	14
23111573	872	H	F	19	27	1024	1447	.49	17
41111151	1209	U	Z	11	19	422	805	.32	21
41111235	1523	U	G	13	24	3652	4214	.37	22
41111237	1085	U	G	13	24	2782	3567	.72	22
41111239	1656	U	G	13	24	2880	3684	.49	22
42111144	1320	U	L	13	26	621	1540	.70	22
11111142	1098	E	S	19	26	800	1022	.20	26
11111140	1098	H	F	19	26	1192	1526	.30	26
11111143	978	H	F	19	26	918	651	-0.27	26
11111153	1577	H	F	19	26	1476	1175	-0.19	26
11111106	1052	D	F	20	25	2312	1867	-0.42	26
12111117	1539	D	F	19	33	3412	4272	.56	28
12111152	1540	E	B	19	34	3315	4594	.83	28
23111521	886	H	F	17	27	1024	1461	.49	99
23111574	1656	Z	Z	25	32	690	1592	.54	99

NUMBER OF CASES READ = 30 NUMBER OF CASES LISTED = 30

BASEMENT WALL SPREADSHEET

Basement Wall Type Code:

A Strapped wall

B Double wall

C 2 X 6, 24" on center, advanced framing

D 2 X 6, 24" on center, standard framing

E 2 X 6, 16" on center, standard framing

F 2 X 6, 24" on center, foam outside

G 2 X 6, 24" on center, foam inside

H 2 X 4, 24" on center, foam outside

I 2 X 4, 24" on center, foam inside

J Foam blocks

K 2 X 8, 24" on center, advanced framing

L 2 X 8, 16" on center, standard framing

M All weather wood foundation

N Cement, foam outside

O Cement, batt inside

P Cement, foam outside, batt inside

Q 2 X 6, 24" on center, mod. advanced framing

R 2 X 6, 24" on center, mod. advanced framing with foam inside

S 2 X 6, 24" on center, mod. advanced framing with foam outside

T Larsen truss, batt insulation

U 2 X 4, 16" on center, standard framing

V No insulation on foundation

X Missing

Z Other

AA 2 X 4, 24" on center, standard framing

BB Cement, no insulation

SITEID	AREA	CPTYPE	MCSTYPE	CPRVAL	MCSRVAL	CP$	MCS$	INCOSTS	GRP
12111117	476	BB	O	0	12	1297	1865	1.19	1
12111152	646	BB	O	0	13	443	883	.68	1
23111574	453	BB	O	0	19	0	451	1.00	3
42111144	506	V	O	0	19	0	511	1.01	3
42111021	380	Z	N	0	10	0	1235	3.25	7
11111106	322	BB	M	0	20	72	123	.16	9
23111512	420	O	B	.	0	103	0	-0.25	99
31111218	352	U	Q	11	19	1006	1093	.25	99
23111514	449	Z	Z	12	10	955	532	-0.94	99
41111178	256	O	Z	13	18	0	21	.08	99
23111523	468	Z	V	15	0	403	0	-0.86	99

NUMBER OF CASES READ = 11 NUMBER OF CASES LISTED = 11

WINDOW SPREADSHEET

Window Type Code:

A Aluminum slider

B Wood slider

C Aluminum casement

D Wood casement

E Aluminum fixed

F Wood fixed

G Aluminum

H Wood

I Aluminum, thermal break

J Aluminum, heat mirror

K Wood, heat mirror

L Wood, awning

M Aluminum, awning

N Wood, double hung

O Aluminum, double hung

X Missing

Z Other

24-OCT-86 window spreadsheet - matched pairs analysis
13:57:22 Lawrence Berkeley Laboratory DEC VAX-8600 VMS V4.4

SITEID	AREA	CPTYPE	MCSTYPE	CPUVAL	MCSUVAL	PANES	CP$	MCS$	INCOST$	GRP
12111152	192	A	I	.560	.370	3	2660	2946	1.49	2
12111117	189	A	F	.560	.370	3	1334	1460	.67	6
41111237	189	A	A	.740	.410	3	874	1553	3.59	9
41111213	111	G	I	.740	.410	3	702	1299	5.38	14
41111209	111	G	I	.740	.480	3	702	1299	5.38	14
41111211	111	G	I	.740	.480	3	702	1299	5.38	14
41111215	111	G	I	.740	.480	3	702	1299	5.38	14
41111217	111	G	I	.740	.480	3	702	1299	5.38	14
41111151	165	G	J	.740	.360	3	687	1475	4.78	15
42111021	171	G	J	.740	.360	3	1034	1590	3.25	15
31111112	148	A	B	.700	.320	3	780	2335	10.51	19
11111145	139	D	D	.450	.450	2	2375	2375	.00	99
11111153	169	D	D	.450	.450	2	1521	1521	.00	99
11111140	192	D	D	.470	.450	2	1728	1728	.00	99
11111143	104	D	D	.470	.450	2	936	936	.00	99
11111106	198	O	D	.470	.470	2	2593	2593	.00	99
11111140	80	A	A	.530	.530	2	220	220	.00	99
11111143	40	A	A	.530	.530	2	291	291	.00	99
11111153	40	A	A	.530	.530	2	262	262	.00	99
11111145	40	E	E	.530	.530	2	474	474	.00	99
11111145	20	L	L	.530	.530	2	250	250	.00	99
23111523	125	B	K	.550	.350	2	1244	3023	14.23	99
11111142	92	A	D	.560	.450	2	3281	3281	.00	99

NUMBER OF CASES READ = 23 NUMBER OF CASES LISTED = 23

AIR INFILTRATION BARRIER SPREADSHEET

Air Infiltration Barrier Type Code:

A Polyethylene under sheetrock
B Foam
C Paint
D Exterior plywood
E Polyethylene between double wall
F Polyethylene between strapped wall
G Polyethylene under slab floor
H A and B
I D and G
J Polyethylene under subfloor
K Airtight drywall
L Craft or foil-faced insulation
M Building paper on exterior
N L and M
O None
X Missing
Z Other

CCPTYPE Ceiling component type - current practice
CMCSTYPE Ceiling component type - MCS
WCPTYPE Window component type - current practice
WMCSTYPE Window component type - MCS
FCPTYPE Floor component type - current practice
FMCSTYPE Floor component type - MCS

SITEID	AREA	CCPTYPE	WCPTYPE	FCPTYPE	CMCSTYPE	WMCSTYPE	FMCSTYPE	CP$	MCS$	INCOSTS	GRP
31111218	2858	L	L	L	B	B	B	278	413	.05	1
31111112	3554	B	B	B	B	B	B	75	430	.10	2
23111521	3350	O	A	O	A	A	J	54	423	.11	4
23111574	4524	O	A	O	A	A	G	107	660	.12	5
41111112	3062	O	A	O	A	A	D	43	585	.18	6
11111140	4498	O	L	O	K	K	K	0	80	.02	7
11111143	3370	O	L	O	K	K	K	0	80	.02	7
11111153	3495	O	L	O	K	K	K	0	80	.02	7
12111117	4019	O	L	O	A	A	G	86	451	.09	12
12111152	4470	O	L	O	A	A	G	120	395	.06	12
11111106	4514	O	L	O	A	A	D	150	553	.09	13
41111239	3314	O	O	O	A	B	G	0	940	.28	18
42111021	3849	O	O	O	A	B	G	43	761	.19	18
41111174	4125	O	O	O	A	B	D	0	574	.14	19
41111176	3893	O	O	O	A	B	D	0	573	.15	19
41111235	2767	O	O	O	A	B	D	0	1111	.40	19
41111237	3722	O	O	O	A	B	D	0	1760	.47	19
41111028	3976	O	O	O	A	A	I	84	823	.19	20
41111151	4053	O	O	O	A	A	G	2890	3636	.18	21
41111209	2590	O	O	O	A	A	G	0	215	.08	21
41111211	2590	O	O	O	A	A	G	0	215	.08	21
41111213	2590	O	O	O	A	A	G	0	215	.08	21
41111215	2590	O	O	O	A	A	G	0	215	.08	21
41111217	2590	O	O	O	A	A	G	0	215	.08	21
31111112	3554	L	L	O	L	L	L	115	278	.05	23
23111514	3816	O	A	O	A	A	Z	434	1304	.23	26
11111142	4492	O	O	O	K	K	K	0	80	.02	28
11111145	3778	O	O	O	K	K	K	0	80	.02	28
42111144	2801	O	O	O	A	A	O	22	681	.24	28
41111045	3903	O	O	O	A	A	J	80	715	.16	28
23111573	2792	X	A	X	A	A	J	54	459	.15	99
41111178	4068	X	X	D	A	B	I	0	598	.15	99

NUMBER OF CASES READ = 32 NUMBER OF CASES LISTED = 32

DOOR SPREADSHEET

Door Type Code:

A Insulated clad foam core

B Wood solid core

C Wood hollow core

D A and B

E A in both MCS and Current Practice

F B in both MCS and Current Practice

X Missing

Z Other

SITEID	AREA	CPTYPE	MCSTYPE	CPUVAL	MCSUVAL	CP$	MCS$	INCOSTS	GRP
23111574	40	A	A	0	0	70	84	.35	1
41111028	40	A	A	0	0	490	491	.03	1
41111151	38	A	A	0	0	76	175	2.61	1
41111174	20	A	A	0	0	0	0	.00	1
41111176	20	A	A	0	0	0	0	.00	1
41111178	40	A	A	0	0	0	0	.00	1
41111239	20	A	A	0	0	0	0	.00	1
42111144	60	A	A	0	0	146	172	.43	1
23111521	60	A	A	0	0	0	0	.00	1
11111106	38	A	A	1	1	266	266	.00	1
11111140	38	A	A	1	1	291	291	.00	1
11111143	38	A	A	1	1	226	226	.00	1
11111153	38	A	A	1	1	242	242	.00	1
12111117	40	A	A	1	1	916	1097	4.53	1
23111523	40	E	E	0	0	0	0	.00	1
23111512	42	E	E	0	0	0	0	.00	1
23111514	72	E	E	0	0	469	625	2.17	1
23111573	58	E	E	0	0	0	0	.00	1
41111174	20	B	B	1	1	0	0	.00	2
41111176	20	B	B	1	1	0	0	.00	2
41111178	20	B	B	1	1	0	0	.00	2
41111239	18	B	B	1	1	0	0	.00	2
31111112	40	B	A	0	0	370	600	5.75	3
41111045	40	B	A	1	0	210	206	-0.10	3
11111142	40	B	A	1	1	650	320	-8.25	3
11111142	80	A	B	1	1	320	650	4.13	4
41111112	38	D	D	0	0	0	22	.58	99
42111021	37	Z	A	10	0	527	513	-0.38	99

NUMBER OF CASES READ = 28 NUMBER OF CASES LISTED = 28

AIR-TO-AIR HEAT EXCHANGER SPREADSHEET

AAHX Type Code:

A The Air Changer Company
B Airxchange (NuTone)
E Conservation Energy Systems (VanEE)
F Des Champs (79m-4)
G Des Champs (79m-6)
H Des Champs (200 series)
I Des Champs (300 series)
J EER Products (Heat-X-changer)
K Ener-Corp (Enerex 250)
M Mountain Energy and Resources
O Star Heat Exchanger 100A
P Star Heat Exchanger 200A
R Enter Matrix
X Missing
Z Other

SITEID	AREA	TYPE	COSTS	INCOSTS	GRP
41111209	1143	B	1155	1.01	2
41111211	1143	B	1155	1.01	2
41111213	1143	B	1155	1.01	2
41111215	1143	B	1155	1.01	2
41111217	1143	B	1155	1.01	2
31111112	1193	B	925	.78	2
41111151	1422	B	745	.52	2
23111523	1392	E	1269	.91	3
23111521	960	H	1232	1.28	6
23111573	960	H	1402	1.46	6
41111174	1435	J	1393	.97	8
23111512	1144	M	1568	1.37	10
41111235	1246	O	1528	1.23	11
41111237	1323	O	1486	1.12	11
41111176	1299	P	1406	1.08	12
23111514	1195	R	1310	1.10	13
31111218	1200	X	850	.71	14
41111045	1271	Z	1819	1.43	15
41111028	1505	B	999	.66	17
42111021	1824	B	1370	.75	17
23111574	2356	E	1645	.70	18
11111106	1598	I	2120	1.33	22
41111112	1601	O	963	.60	25
41111239	1658	O	1288	.78	25
41111178	1851	O	1395	.75	25
42111144	1860	P	1331	.72	26
12111117	2004	X	1200	.60	28
12111152	2252	X	1500	.67	28

NUMBER OF CASES READ = 28 NUMBER OF CASES LISTED = 28

APPENDIX D

This appendix contains a listing of homes ordered by "state calculated total cost" (see main text), as discussed in Chapter 7. The following information is provided for each home: identification number, state calculated total cost, total hard building cost, design cost, loan cost, and other cost. Column headings are explained in the glossary below.

GLOSSARY

SITEID[1]	Identification of house/builder
COST094	State calculated total cost
TOTAL	Total hard building cost
DESIGN	Design cost
LOAN	Loan cost
OTHER	Other cost

[1] SITEID is an eight digit number and is described on the next page.

KEY TO RSDP IDENTIFICATION NUMBERS

Column	Character	Explanation
1		**state**
	1	Idaho
	2	Montana
	3	Oregon
	4	Washington
2		**climate zone**
	1	4,000 - 6,000 degree-days
	2	6,000 - 8,000 degree-days
	3	8,000 + degree-days
3		**sample type**
	1	matched pair
	2	unmatched
	3	unmatched + ELCAP (sort of)
4		**construction type**
	1	MCS
	2	Control
5		**house type**
	1	Single-family
	2	Multifamily
6		house identification number
7		house identification number
8		house identification number

COST094	TOTAL	DESIGN	LOAN	OTHER
.37	.33	.02	.00	.02
.49	.44	.04	.00	.01
.73	.60	.12	.00	.01
1.24	1.17	.06	.00	.01
1.36	1.36	.00	.00	.00
2.24	1.96	.26	.00	.02
2.34	2.19	.13	.00	.02
2.42	2.10	.00	.08	.24
2.46	2.40	.06	.00	.00
2.51	2.41	.00	.00	.10
2.59	2.41	.05	.03	.10
2.59	2.41	.05	.03	.10
2.59	2.41	.05	.03	.10
2.59	2.41	.05	.03	.10
2.59	2.41	.05	.03	.10
2.86	1.96	.17	.42	.31
2.87	2.33	.13	.01	.40
2.91	2.33	.15	.11	.26
3.00	2.55	.00	.08	.37
3.06	2.79	.01	.03	.24
3.28	2.90	.02	.00	.36
3.34	3.03	.00	.13	.18
3.42	2.84	.06	.03	.49
3.46	3.11	.02	.00	.34
3.75	3.68	.07	.00	.00
3.91	3.22	.00	.29	.41
4.03	3.20	.00	.40	.43
4.40	3.97	.00	.19	.24
4.85	4.51	.00	.13	.23
4.99	4.58	.00	.18	.23
5.16	4.16	.00	.44	.55
5.30	4.81	.25	.04	.20

NUMBER OF CASES READ = 32 NUMBER OF CASES LISTED = 32

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