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Cost Data Collection for Manufactured Homes in RCDP

Super Good Cents

Residential Construction Demonstration Project

Bonneville
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COST DATA COLLECTION FOR MANUFACTURED HOMES IN RCDP

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DISCLAIMER

SUMMARY

As part of the Residential Construction Demonstration Project (RCDP), Pacific Northwest Laboratory (PNL) gathered technical and cost information on 150 manufactured homes built to Super Good Cents (SGC) specifications by eight manufacturing plants in the Pacific Northwest. This study was sponsored by the Bonneville Power Administration (Bonneville) and took place from December 1987 to July 1989.

The SGC is a marketing program originally designed for site-built homes. In the manufactured housing RCDP, Bonneville provided incentives to regional manufacturers to build manufactured homes to SGC requirements, and manufacturers provided data on the costs of meeting these requirements. Participating manufacturers were interviewed and the data were entered into a database for submission to Bonneville. Combined with energy and infiltration rate data to be collected for each home, the information obtained in this study will be used to assess and evaluate the cost-effectiveness of various energy conservation approaches for manufactured housing.

For the 150 RCDP homes, the following general characteristics and their interrelationship were examined: the presence of a heat pump, the geographic/climate zone in which the homes were sited, the total incremental wholesale cost, and the gross floor area. Information also was gathered on the technical upgrades needed to qualify as an SGC home and the upgrades' incremental costs (the costs above the base-case level for that home) for walls, ceiling, floors, doors, windows, heating equipment, ventilation equipment, and infiltration control measures.

Table S.1 shows the number of RCDP homes where each component was upgraded and the average incremental wholesale cost of that upgrade when compared with the minimum level, or standard equipment, available for each RCDP home. Relative to the minimum levels offered, the average total incremental wholesale cost per home was $3,559; the window component had the largest component incremental cost ($977.00). The average incremental cost of homes that met the requirements by using heat pumps was $5,245. For those that did not use heat pumps, the average incremental cost was $3,102.

TABLE S.1. SGC Upgrades[a]

Component	Number of Homes	Average Incremental Cost Relative to Base Level
Walls	143	$ 439
Ceiling		
Vaulted	144	248
Attic	119	259
Floor	150	632
Door	114	185
Window	140	977
HVAC		
Heating changes	140	658
With Heat Pump	32	2,899
Without Heat Pump	108	-6
Ventilation	150	276
Infiltration	150	65
Vapor/Moisture Control	29	65
Ductwork	140	18
Total Average Cost	150	3,559
With Heat Pump	32	5,245
Without Heat Pump	118	3,102

(a) The costs reported in this table are for all upgrades, across all climate zones. The incremental costs are calculated relative to the lowest energy-efficiency levels offered for each base model and not relative to the levels most commonly purchased. The upgrades represented in this table include all changes that manufacturers reported as part of the upgrade, even minor ones.

The same homes with the upgrades most commonly purchased had an incremental wholesale cost of $889 compared with the minimum levels available. Based on these averages, the average wholesale cost to meet SGC requirements was $2,670 above the cost of homes with the upgrades most commonly purchased. For homes that complied by using heat pumps, the incremental cost was $4,356; and for those that did not use heat pumps, the incremental cost was $2,213.

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1.0 INTRODUCTION

In the Pacific Northwest, a major effort has been made to improve the energy efficiency of new buildings. In the residential building sector, energy-efficient standards for new construction, called Model Conservation Standards (MCS), have been proposed; and demonstration projects are under way to implement MCS features and to explore new conservation possibilities.

Bonneville Power Administration (Bonneville) administers a Pacific Northwest program to promote the construction and marketing of energy-efficient site-built homes. This program, Super Good Cents (SGC), pays incentives for new buildings that meet the MCS energy-efficiency levels. Starting in late 1987, Bonneville began a research and demonstration project to include HUD-code manufactured homes (homes built under the U.S. Department of Housing and Urban Development's standards) in the SGC program.

Under Bonneville's ongoing Residential Construction and Demonstration Project (RCDP), the region's manufacturers were invited to construct 150 manufactured homes meeting the SGC requirements for site-built homes (modified for manufactured home practices). Manufacturers received incentives to construct the homes and agreed to provide Bonneville cost data and other information related to their participation in the project. The goals of the RCDP for manufactured housing are to provide manufacturers and their dealers with technical assistance in producing and selling homes that will qualify as SGC homes, to collect information on the cost-effectiveness and improved thermal performance of manufactured homes, and to develop a process to qualify and certify manufactured homes for the SGC program.

The project is administered by the Washington State Energy Office (WSEO), with local project management provided by the state energy offices in Oregon, Idaho, and Montana. Pacific Northwest Laboratory (PNL)[a] is responsible for gathering cost data specific to upgraded components from the manufacturers and for compiling the information in a database. PNL is also

(a) Pacific Northwest Laboratory is operated by Battelle Memorial Institute for the U.S. Department of Energy under Contract DE-AC06-76RLO 1830.

responsible for gathering information on manufacturers' attitudes and experiences with the program; this effort will result in several case studies describing the manufacturers' responses.[a] PNL will also perform ventilation and infiltration testing to determine the infiltration characteristics of homes in the project. Information gathered by PNL will be used to determine the effectiveness of different elements of the project.

This report provides information on PNL's activities in collecting technical and cost data, and presents selected descriptive results from the cost database. Analysis will be performed under a separate Bonneville contract after energy, ventilation, and infiltration rate data are collected.

In Chapter 2.0 the methodology used to obtain the technical and cost data is described. Chapter 3.0 summarizes the information contained in the cost database. Volume 2 of this report contains the appendices and can be obtained through Sheila Riewer at Bonneville, (503) 230-5473. The appendices contain the data collection forms, a data dictionary, and selected raw data from the three databases. One database contains data for the base case homes, i.e., the homes with the standard levels of energy efficiency measures, such as floor, wall, and ceiling insulation and without any SGC upgrades. The second database contains the data for the 150 homes configured to meet SGC specifications. The third database contains data for the same homes, but with the levels of energy-efficiency measures most commonly purchased.

(a) Lee, A. D. and S. A. Harkreader. 1989 (draft). Case Study of the Regional Manufacturer Participation in the Manufactured Housing RCDP. Pacific Northwest Laboratory, Richland, Washington.

2.0 METHODOLOGY

The RCDP cost data were collected on 150 manufactured homes using standardized forms. The development of the forms began in December 1987 and was completed in March 1988 through a process involving PNL, Bonneville, and representatives from the participating state energy offices (SEOs). After data on the first five homes were gathered, the forms were modified slightly in order to gather more information on windows. This second set of forms was completed in June 1988. All forms used were reviewed by the RCDP Manufactured Housing Work Group, composed of Bonneville personnel, industry representatives, SEO personnel, PNL representatives, and other interested parties.

The forms were designed to collect information on each component (exterior walls, floors, windows, doors, ceilings, and heating and ventilation systems) of the base, RCDP, and most common homes. The base home is defined by describing those components and characteristics that are standard equipment for each model. The RCDP homes are defined by describing those attributes that are added to make the model meet SGC specifications. The most common home is defined by describing those attributes typically added to each base home model by most of the purchasers. Appendix A in Volume 2 of this study contains copies of the three forms that were used to collect cost information for this study. For all homes, general information was collected such as manufacturer name, contact person, address, phone number, SGC number, model number/name, climate zone of the home site, and floor area.

The databases are linked by the SGC number, which is the program number assigned to each RCDP home. For each RCDP home, the plant that manufactured it indicated the standard model (base home) upon which it was based and the most common upgrades sold on that standard model (most common home). Each of these three home configurations has the same SGC number in the databases. Each RCDP home is a separate entry in the databases. Most plants produced several RCDP homes, but several of a manufacturer's RCDP homes may be based on the same standard model.

The forms for gathering information for the base models (or standard homes) were designed to show the home's characteristics before any upgrades were made. The net area, nominal R-value, the UA-value, and lumber dimensions were collected for the exterior walls, ceilings, and floors. The information collected for the doors included manufacturer; model number; type of material used in construction; use of window, thermal break, and storm door; area of all doors; and U-value or R-value. The window information gathered included the type of window, the manufacturer and model number, the area of the windows, the number of windows, the number of panes in each window, the type of frame, the presence of storm windows, and the U-value and its source.

The forms also included heating and ventilation system information. The type of heating equipment, including the manufacturer, and the unit capacity of the equipment were recorded. The type of ventilation systems used and their characteristics were recorded. The measures taken for envelope infiltration control were recorded, as were the vapor/moisture control measures and the insulated ductwork.

The forms for the 150 homes were designed to collect information about each RCDP model to be manufactured after the design was qualified and approved as an SGC home by the responsible state office. In addition to the information gathered for the base homes, more detailed information on the type of insulation in floors, ceilings, and exterior walls was gathered for the RCDP homes. Wholesale costs incremental to the base home cost including material, labor, profit, and overhead costs were recorded for all components of the upgraded homes.

The third form was designed to collect data about the options most commonly selected by buyers of each base home model. The form's design was nearly identical to the RCDP forms. Again, the incremental costs (relative to the base home model) included material, labor, profit, and overhead.

A computerized database system was developed on dBASE III Plus™[a] to organize and maintain the data. The databases were designed using the

(a) Trademark of Ashton-Tate, Torrance, California.

standardized forms as guides. The databases all have format screens, which match the forms, to insure more accurate data entry. A separate database was developed for each component for each of the three types of homes. Therefore, 18 databases were developed. Appendix B in Volume 2 lists every field in each of the 18 databases and briefly describes each field.

An initial visit to each of the eight manufacturers provided a learning session for both the PNL researcher and the manufacturer's representative. The representative needed to understand the project and PNL staff needed to understand how the costs were being reported. The first visit took place in March 1988, and the last manufacturer was visited in March 1989. After the initial visits, the data on the remaining homes were gathered over the telephone. As much data as possible was taken from the WATTSUN™[a] runs provided by the WSEO. The data not provided by the WATTSUN runs were obtained from the manufacturer's representative. If any data seemed to conflict or appeared to be inaccurate, questions were resolved with telephone calls to the manufacturer or WSEO.

Between May and July, 1989, a final telephone call was made to each manufacturer representative to ask about the cost methodology used to determine the incremental costs for the RCDP homes. The following information concerning cost methodology was obtained from each manufacturer:

- the formula used to compute pricing or incremental costs
- the variation of manufacturer markup over time
- the differences, if any, between the standard markup practices and those used for RCDP homes.

All manufacturers used the same general approach, basing prices or incremental costs on increased material costs to which a markup factor(s) was applied. The major variations were as follows:

(a) Trademark of the Washington State Energy Office, Olympia, Washington. WATTSUN is a computer program developed by WSEO, Ecotope, and Bonneville based on The Model Conservation Standard Energy Budget Approach Handbook (WSEO 1984). It calculates the thermal performance, annual energy budget, and economic performance of a home.

- whether pricing or incremental costs were based on whole house or individual component costs
- whether labor costs were included separately or as an element in the markup percentage
- whether the markup varied over time.

Most cases showed no difference between the markup used on RCDP homes and the markup used for any new home.

3.0 RESULTS OF THE DATA COLLECTION

This chapter summarizes the information in the database, obtained from the data collection effort. The intent of this discussion is to briefly describe the data collected. The 150 manufactured RCDP homes that are part of this study were built by eight manufacturing plants in the Pacific Northwest.

Section 3.1 reviews and summarizes the following general characteristics of the 150 RCDP manufactured homes in the database: presence/absence of a heat pump, the climate zone where the home is sited, the total incremental cost for SGC upgrades, and the gross floor area of the home. Sections 3.2 through 3.6 present information about the RCDP manufactured homes' walls, ceilings, floors, doors, and windows, respectively. Section 3.7 presents information concerning characteristics pertaining to, or affecting, the HVAC systems in the RCDP manufactured homes. Section 3.8 briefly describes the information contained in the most common homes database.

3.1 GENERAL CHARACTERISTICS

Table 3.1 shows four general characteristic categories for the 150 RCDP manufactured homes in the interviews and database: the presence of a heat pump, the geographic/MCS climate zone they were built for and sited in, the total gross floor area, and the total incremental cost. Each of these general characteristic categories is broken into several subcategories that show the number of homes and the corresponding percentage of homes within each subcategory.

As the heat pump category shows, 21% of the RCDP homes built had heat pumps. Using a heat pump in a home to qualify it under the SGC specifications allowed for less insulation in the ceiling and walls and did not require the windows to be upgraded in some cases.

The MCS climate zones are determined by heating degree-days. Zone 1 consists of Western Washington and Western Oregon; Zone 2 of Eastern Washington, Eastern Oregon, and Idaho; and Zone 3 of Western Montana. Zone 1 was the mildest and Zone 3 was the coldest. Because Zone 3 is the coldest zone,

TABLE 3.1. General Characteristics of the 150 RCDP Manufactured Homes

	Number of homes	Percentage of homes
HEAT PUMPS		
With Heat Pumps	32	21
Without Heat Pumps	118	79
MCS CLIMATE ZONE		
In Zone 1 - W. Washington and W. Oregon	86	57
In Zone 2 - E. Washington, and E. Oregon and Idaho	62	42
In Zone 3 - W. Montana	2	1
GROSS AREA (ft^2)		
less than 1,200	22	15
1,201 - 1,500	53	35
1,501 - 1,800	70	47
1,801 or greater	5	3
TOTAL INCREMENTAL COST		
$ 0 - 3,000	52	35
$ 3,000 - 4,000	59	39
$ 4,000 - 5,000	19	13
$ 5,000 or greater	20	13

the SGC requirements are the most stringent in this zone. Table 3.1 points out the relative lack of Zone 3 homes in the study. Compared with the recent siting statistics for manufactured homes in each zone, the percentages in this project were higher in Zone 2 (41.3% vs. 25%) and lower in Zone 3 (1.4% vs. 11%) (Lee et al. 1988, Table 7.4). However, this is not expected to substantially affect the information presented here.

The gross floor areas of the RCDP homes built are divided into four subcategories in Table 3.1. The smallest RCDP home built was 1,067 ft^2 and the largest was 2,149 ft^2. The table shows that 50% of the homes built were larger than 1,500 ft^2 and 50% were smaller.

The total incremental cost category in Table 3.1 lists four subcategories. The lowest total incremental cost in the database was $1,989 and the highest was $6,614. The most common cost subcategory was $3,000 to $4,000, with 35% of the homes below and 26% above this category.

Tables 3.2 through 3.5 show how the characteristic categories listed in Table 3.1 interrelate. Table 3.2 shows that almost all (78%) of the heat pump homes were built for Zone 1. The non-heat pump homes were split fairly evenly between Zones 1 and 2.

Table 3.3 examines the total incremental cost broken down by RCDP homes with and without heat pumps. The table shows that 97% of the homes with a heat pump had an incremental cost greater than $4,000. For non-heat pump homes the opposite was true: 93% had an incremental cost of less than $4,000. Overall, the average incremental cost of homes using heat pumps to meet the SGC requirements was $5,245 and that of homes not using heat pumps was $3,102, relative to the base model. This shows that it was more costly to meet SGC standards using a heat pump and other measures than to meet them using other measures alone.

As shown in Table 3.4, more of the Zone 1 homes are in the $0 to $3,000 incremental cost subcategory than any other. For Zone 2 homes, the incremental cost subcategory with the most homes is $3,001 to $4,000. Finally both the Zone 3 homes are in the $4,001 to $5,000 incremental cost subcategory. These results are consistent with the more stringent MCS requirements for the increasingly colder geographic zones.

Table 3.5 examines the relationship between the total incremental cost and the floor area of the home. As would be expected, more of the smaller homes are in the lower cost subcategory than are the larger homes. The table shows that as the area increases, the incremental costs increase also, as one would expect.

3.2 EXTERIOR WALL CHARACTERISTICS

All but 7 of the 150 homes upgraded the exterior walls. The 7 homes that did not upgrade had 2 X 6 studding with R-19 insulation in the base home. Table 3.6 shows the 143 homes that had upgraded exterior walls sorted by the stud dimensions and insulation levels in both the base model and RCDP models. The table indicates how many homes fall into each upgrade category, the average cost of that upgrade, and the average area upgraded. Of the

TABLE 3.2. Geographic Location of Homes by Heat Pump Presence

	Heat Pump	No Heat Pump	Totals
Zone 1	25 Homes 17%	61 Homes 41%	86 Homes 57%
Zone 2	7 Homes 5%	55 Homes 37%	62 Homes 41%
Zone 3	0 Homes 0%	2 Homes 1%	2 Homes 1%
Totals	32 Homes 21%	118 Homes 79%	150 Homes 100%

TABLE 3.3. Total Incremental Cost of Homes by Heat Pump Presence

	Heat Pump	No Heat Pump	Totals
$0-3,000	0 homes 0%	52 homes 35%	52 homes 35%
$3,001-4,000	1 home 1%	58 homes 38%	59 homes 39%
$4,001-5,000	12 homes 8%	7 homes 5%	19 homes 13%
$5,001 or greater	19 homes 12%	1 home 1%	20 homes 13%
Average Incremental Cost	$5,245	$3,102	$3,559
Totals	32 homes 21%	118 homes 79%	150 homes 100%

TABLE 3.4. Total Incremental Cost of Homes by Geographic Location

	Zone 1	Zone 2	Zone 3	Totals
$0-3,000	32 homes 21%	20 homes 13%	0 homes 0%	52 homes 35%
$3,001-4,000	26 homes 17%	33 homes 22%	0 homes 0%	59 homes 39%
$4,001-5,000	12 homes 8%	5 homes 4%	2 homes 1%	19 homes 13%
$5,001 or greater	16 homes 11%	4 homes 3%	0 homes 0%	20 homes 14%
Totals	86 homes 57%	62 homes 42%	2 homes 1%	150 homes 100%

TABLE 3.5. Total Incremental Cost of Homes by Gross Floor Area

	<1200	1200-1500	1501-1800	>1800	Totals
$0-3,000	12 homes 8%	23 homes 15%	17 homes 11%	0 homes 0%	52 homes 35%
$3,001-4,000	8 homes 5%	24 homes 16%	26 homes 18%	1 home 1%	59 homes 39%
$4,001-5,000	1 home 1%	4 homes 3%	12 homes 8%	2 homes 1%	19 homes 13%
$5,001 or greater	1 home 1%	2 homes 1%	15 homes 10%	2 homes 1%	20 homes 13%
Totals	22 homes 15%	53 homes 35%	70 homes 47%	5 homes 3%	150 homes 100%

TABLE 3.6. Base Home to RCDP Exterior Wall Upgrades

RCDP Stud Size and Insulation	Base Home Stud Size and Insulation: 2 X 4 R-11	2 X 6 R-11	Totals
2 X 6 R-19	59 Homes $522 1,079 ft^2	7 Homes $92 1,097 ft^2	66 Homes 46%
2 X 6 R-22	34 Homes $545 1,109 ft^2	41 Homes $251 1,107 ft^2	75 Homes 52%
2 X 6 R-25	1 Home $900 1,119 ft^2		1 Home 1%
2 X 8 R-30	1 Home $1,675 1,143 ft^2		1 Home 1%
Totals	95 Homes 66%	48 Homes 34%	143 Homes $439 1,096 ft^2

Note: Areas listed are for upgraded component areas.

143 homes that did upgrade, the average cost of the added insulation and/or stud cost was $439.00 per home. The average wall area upgraded was 1,096 ft^2. All base homes that were upgraded originally had R-11 insulation and all RCDP homes had 2 X 6 or 2 X 8 studs and R-19 or greater insulation levels.

For the 95 homes that had 2 X 4 studs and R-11 insulation in the base home, the most common upgrade (62%) was to 2 X 6 studs and R-19 insulation. All base homes with 2 X 4 studs went to 2 X 6 or 2 X 8 studs to allow space for insulation levels of at least R-19. Of the 48 homes with 2 X 6 studs and R-11 insulation in the base home, the most common upgrade (85%) was to 2 X 6 studs and R-22 insulation. For these homes, only the insulation level had to be increased; no stud changes were needed. Therefore, the average incremental cost for these homes ($251) was less than for those homes that required stud changes.

3.3 CEILING CHARACTERISTICS

Two types of ceilings are common in manufactured homes: vaulted and attic ceilings. Many manufactured homes have a combination of both ceiling types. Of the 150 RCDP homes built, 123 had both a flat and vaulted ceiling in the home, 26 had a vaulted only, and one had a flat ceiling only. Five of the 123 homes with a combination of flat and vaulted ceilings were not upgraded from the base model. Four of these had R-19 insulation throughout the ceiling, while one had R-22 throughout. Grouping the ceilings by type resulted in a total of 144 vaulted ceiling areas that were upgraded and 119 flat ceiling areas upgraded. These ceiling upgrades will be examined separately.

Two basic types of insulation were used to upgrade the ceilings: fiberglass batt and blown-in. Table 3.7 examines the 144 vaulted ceiling upgrades and shows the base home insulation level and the resulting batt or blown-in insulation level in the RCDP home. The number of homes, average cost, and square footage for each type of upgrade are shown. The average incremental cost to upgrade a vaulted ceiling was $248, and the average size of the vaulted ceilings upgraded was 886 ft^2. Table 3.7 shows that 63% of the upgraded homes started with R-14 insulation in the base home, while 32% started with R-19. The most common batt insulation upgrade from an R-14 base case level was R-33, and the most common blown-in insulation upgrade from an R-14 base home was R-38. The majority (87%) of homes that had R-19 insulation in the base home model upgraded to R-38 batt insulation.

TABLE 3.7. Base Home to RCDP Vaulted Ceiling Upgrades

RCDP Insulation		Base Home Insulation R-14	R-19	R-21	R-22	Totals
Batt	R-22	10 Homes $184 813 ft^2				10 Homes 7%
	R-30		6 Homes $114 516 ft^2			6 Homes 4%
	R-33	18 Homes $290 704 ft^2			2 Homes $255 1,178 ft^2	20 Homes 14%
	R-35	1 Home $167 704 ft^2				1 Home 1%
	R-38	12 Homes $242 808 ft^2	40 Homes $216 667 ft^2	4 Homes $240 1156 ft^2		56 Homes 39%
Blown	R-30	2 Homes $183 679 ft^2				2 Homes 1%
	R-33	4 Homes $179 535 ft^2				4 Homes 3%
	R-38	44 Homes $304 1,240 ft^2		1 Home $270 1,742 ft^2		45 Homes 31%
Totals		91 Homes 63%	46 Homes 32%	5 Homes 3%	2 Homes 1%	144 Homes $248 886 ft^2

Note: Areas listed are for upgraded component areas.

Table 3.8 examines the 119 attic ceiling upgrades and shows the base home insulation level and the new batt or blown-in insulation level in the RCDP home. The table shows the number of homes, average cost, and square footage for each type of upgrade. The average incremental cost to upgrade an attic ceiling was $259 and the average size of the attic ceiling upgraded was 775 ft^2. Table 3.8 shows that 66 (55%) of the upgraded homes started with R-14 insulation in the base home, while 47 (39%) started with R-19. The most common batt insulation upgrade from an R-14 base case level was to R-33 and the most common blown-in insulation upgrade from the same base case level was to R-49. The majority (60%) of homes that had R-19 insulation in the base home upgraded to R-38 batt insulation.

A comparison of Tables 3.7 and 3.8 shows that because of space constraints, the vaulted ceiling upgrade levels are limited to insulation levels of R-38 or less, while the attic insulation levels ranged up to R-52. At the same time, the average area of vaulted ceilings upgraded was about 17% larger than the comparable area of attic ceilings. Overall, the average incremental cost of the upgraded ceiling types was within 5% of each other ($259 vs. $248). For all the RCDP homes built, the ceiling insulation levels were R-19 or greater.

3.4 FLOOR CHARACTERISTICS

All of the 150 RCDP homes had upgraded insulation levels under the floor. None of the base homes had any between-joist insulation, and the underbelly of each base home was insulated with an R-7 or R-11 blanket.

Table 3.9 examines the floor insulation upgrades in the RCDP homes. It shows the base home underbelly insulation levels and the new combination joist/underbelly insulation level in each home. In the base homes, 34% had R-7 insulation and 66% had R-11 insulation. The RCDP homes had joist insulation levels ranging from R-11 to R-25 and underbelly insulation levels ranging from R-7 to R-22. The R-22 underbelly insulation consists of two R-11 batts. The combined joist and underbelly R-values in the RCDP homes

TABLE 3.8. Base Home to RCDP Attic Ceiling Upgrades

RCDP Insulation		Base Home Insulation R-14	R-19	R-21	R-22	Totals
Batt	R-22	4 Homes $125 879 ft^2				4 Homes 4%
	R-30		7 Homes $257 1,169 ft^2			7 Homes 6%
	R-33	12 Homes $256 747 ft^2			1 Home $104 589 ft^2	13 Homes 11%
	R-38	9 Homes $201 620 ft^2	28 Homes $371 983 ft^2	2 Homes $122 621 ft^2	1 Home $144 561 ft^2	40 Homes 34%
	R-42	1 Home $258 711 ft^2				1 Home 1%
	R-45	4 Homes $321 726 ft^2				4 Homes 4%
	R-49	10 Homes $280 683 ft^2	12 Homes $199 708 ft^2	2 Homes $139 631 ft^2		24 Homes 20%
	R-52	1 Home $800 999 ft^2				1 Home 1%
Blown	R-30	2 Homes $193 711 ft^2				2 Homes 2%
	R-33	4 Homes $205 612 ft^2				4 Homes 4%
	R-38	2 Homes $251 699 ft^2				2 Homes 2%
	R-49	17 Homes $190 565 ft^2				17 Homes 14%
Totals		66 Homes 55%	47 Homes 39%	4 Homes 4%	2 Homes 2%	119 Homes $259 775 ft^2

Note: Areas listed are for upgraded component areas.

TABLE 3.9. Base Home to RCDP Floor Upgrades

RCDP Floor Insulation — Joist/Underbelly	Base Home Floor Insulation: R-7 (Underbelly)	Base Home Floor Insulation: R-11 (Underbelly)	Totals
R-11/R-11	4 Homes $409 1,387 ft^2	6 Homes $385 1,647 ft^2	10 Homes 7%
R-19/R-7	6 Homes $580 1,721 ft^2	2 Homes $570 1,646 ft^2	8 Homes 5%
R-19/R-11	14 Homes $565 1,399 ft^2	18 Homes $628 1,614 ft^2	32 Homes 21%
R-19/R-22	3 Homes $1,073 1,710 ft^2		3 Homes 2%
R-22/R-11	10 Homes $395 1,632 ft^2	23 Homes $448 1,509 ft^2	33 Homes 22%
R-22/R-14	8 Homes $436 1,268 ft^2		8 Homes 5%
R-25/R-11		8 Homes $875 1,505 ft^2	8 Homes 5%
R-22/R-22	6 Homes $849 1,495 ft^2	42 Homes $810 1,505 ft^2	48 Homes 32%
Totals	51 Homes 34%	99 Homes 66%	150 Homes $632 1,517 ft^2

Note: Areas listed are for upgraded component areas.

ranged from R-22 to R-44. For the 150 RCDP homes, the average incremental cost to upgrade floor insulation was $632, and the average area covered was 1517 ft^2.

The most common upgrade level (32%), as shown in Table 3.9, was to R-22 insulation in both the joist and underbelly blanket. This also was the highest combined floor R-value level installed in any RCDP home. The average incremental cost to upgrade to that level was $815.

3.5 DOOR CHARACTERISTICS

Door upgrades took place in 114 of the RCDP homes built. The average cost of a door upgrade was $185, and the average U-value of the new doors was 0.20 (Btu/hr/°F-ft^2). The most common upgraded door installed (80% of the time) was a metal door with core insulation.

Storm doors were added to 33 homes at an average cost of $287 and the U-value of the door with a storm added fell to 0.18. Only 10% of the upgraded doors had windows in them. These doors had an average incremental cost of $102 and a U-value of 0.25. One of the most common upgrades was to remove a door with a window and simply install one without a window.

3.6 WINDOW CHARACTERISTICS

Window upgrades were recorded for 140 (93%) of the 150 homes in the study. Because some homes had 2 or more types of upgrades, the total number of upgrades recorded was 147. The types of upgrades included adding storm windows, changing the type of frame, and reducing the number of windows in the home. All windows were upgraded to double-pane. Each RCDP home had an average of about 11 windows. Table 3.10 lists the characteristics of the upgraded RCDP windows with emphasis on the 23 homes that added storm windows. The average incremental cost of a window upgrade was $977 per home, or $87 per window. The average U-value of the upgraded windows was 0.49 Btu/hr/°F-ft^2. In contrast, the average U-value of the base home windows was 0.75. The addition of storm windows lowered the U-value to 0.52 at an incremental cost of $448 per home or $45 per window. All storm windows added were interior storms.

TABLE 3.10. Window Characteristics

	Storm Window	No Storm Window	All Windows
Number of Homes	23	120	140
Number of Windows	231	1342	1573
Average Cost/Home	$448	$1,054	$977
Average Cost/Window	$45	$94	$87
Average Area/Home	122 ft^2	155 ft^2	153 ft^2
Average Area/Window	12 ft^2	14 ft^2	14 ft^2
Average U-Value	0.52	0.48	0.49

Of the 147 upgrades recorded in the study, 82 (56%) had vinyl frames, 38 (26%) had metal frames, and 27 (18%) had thermally improved metal frames. The average incremental cost of upgrading to vinyl frame windows was $99 per window, improving the U-value to 0.45. In addition to improving the window frames, 23 RCDP homes also added a low-emissivity coating to the windows. This resulted in an average incremental cost of $139 per window and a decrease to 0.44 in the U-value.

One problem with interpreting the incremental window costs relates to how costs were reported by the manufacturers. In most cases, window areas changed along with the upgrade. For example, if a manufacturer installed vinyl frame windows in an RCDP home, the manufacturer may have also decreased the total window area. Consequently, the incremental cost reported here captured both the effect of the upgrade and the effect of the window area change. Therefore, the incremental costs should not be interpreted as the sole effect of the upgrade.

3.7 HEATING, VENTILATION AND INFILTRATION CONTROL CHARACTERISTICS

All of the 150 RCDP homes had central forced-air electric furnaces. In almost all homes the furnace capacities were smaller than they were in the base model. In some cases the manufacturer gave the customer a small rebate, but in most cases there was no charge or incremental cost associated with downsizing the furnace. Even for the 32 homes that added heat pumps, the furnace was downsized. For the heat pump homes, the average heat pump cost was $2,899. This was the single most expensive upgrade cost observed in the study. According to one manufacturer, the customer viewed adding a heat pump to the home as getting "free air-conditioning" because the added cost of the heat pump was close to the customer rebate for participating in the RCDP monitoring program.

All of the 150 RCDP homes had some improvements to the ventilation systems. Wall or window ports for fresh air were added to all 150 homes. Most of the homes had time-of-day clocks or timers added to one bath fan. Another addition was bath fans in those bathrooms that did not have them in the base home. Some homes added an attic ventilation system, either passive or active. The average incremental cost of the ventilation improvements in RCDP homes was $276 per home.

The most common infiltration control measure to meet SGC requirements was the use of extra caulking and/or taping around windows, doors, joints, and other penetrations. The average incremental cost for infiltration control was $65 per home. In 29 of the 150 RCDP homes, a vapor/moisture ground cover barrier was included as part of the total incremental cost. This average incremental cost was $65 per home. Crossover ductwork insulation was upgraded to R-11 in 140 of the 150 RCDP homes at an average incremental cost of $18 per home. The manufacturer included the extra ductwork insulation with the home when it left the factory, but it had to be properly installed by the dealers onsite.

3.8 CHARACTERISTICS OF THE MOST COMMONLY PURCHASED UPGRADES

Part of the data collection effort for each RCDP home included asking the manufacturers' representatives what efficiency upgrades most of their customers would have ordered for their particular model home if the customer had not agreed to meet the MCS standards. Since few buyers purchase a home with only the base model's features, this was done so the incremental costs of the RCDP home could be compared with the more typical costs of a manufactured home.

The costs of the upgrades were obtained as well. Only upgrades having to do with the thermal integrity or HVAC systems in the home were recorded. This information was entered and stored in the most common databases. Selected raw data from the most common databases are presented in Appendix E, Volume 2. These data were more subjective than the data on the base homes or RCDP homes because each manufacturer's representative had to estimate which upgrades would have been purchased by most of the customers for each base model home. Thus, the data collected are estimates or "judgment calls" by the manufacturer's representative.

Table 3.11 summarizes the most common component upgrades. Included for each component are the number of homes expected to require upgrades and the average cost per home for the upgrade. Of the 150 homes in the study, 74% would have typically upgraded the insulation level in the walls of the base model. All of the walls would have changed to 2 X 6 studs and R-19 insulation. The average incremental cost per home for this wall upgrade would be $369, making it the costliest upgrade most commonly purchased.

Almost all homes (97%) with vaulted ceilings would have upgraded the vaulted ceiling and 98% of the homes with flat or attic ceilings would also have upgraded the ceiling. The ceiling is the most typically upgraded component in the home. In most cases, the vault and/or attic ceiling would have been upgraded to an R-30 insulation level. The average incremental cost for the typical vaulted ceiling upgrade would have been $132. The average incremental cost for the attic ceiling upgrade would have been $142.

Less than half (47%) of the homes would have upgraded the floor insulation level from the base model. Those that would have upgraded would go from R-7 or R-11 to R-11 or R-22 underbelly, blanket insulation levels. None of the homes would have been insulated with between-joist insulation. The average incremental cost of the typical floor insulation upgrade would have been $274 per home.

TABLE 3.11. Most Common Upgrades From Base Level

Component	Number of Homes	Average Incremental Cost
Walls	111	$368.82
Ceiling		
Vaulted	145	$132.08
Attic	121	$141.83
Floor	70	$274.44
Door	58	$167.10
Windows	78	$164.36
HVAC		
Heating	0	$ 0.00
Ventilation	84	$ 72.95
Infiltration	0	$ 0.00
Vapor/Moisture Control	28	$ 46.21
Ductwork	0	$ 0.00
Average Total Cost	150	$888.74

Only 39% of the homes would have upgraded doors. These upgrades most likely would have been a screen door addition or the removal of door windows. The average incremental cost would have been $167 per home. More than half of the homes (52%) would have upgraded the windows. One of the most common typical upgrades would have been the addition of another window to the home, for an average incremental cost of $164 per home. This addition would have reduced the thermal integrity of the home.

As Table 3.11 shows, normally no upgrades would have been made for heating equipment, infiltration control, or ductwork insulation. On the other hand, 56% of the homes would have a ventilation upgrade and 19% would have upgraded the vapor/moisture ground barrier. The ventilation upgrade in most cases would have been the addition of bath fans. The average cost of a ventilation upgrade would have been $73 per home, and the average cost of a vapor/moisture control upgrade would have been $46 per home.

The difference between the incremental cost of homes with the RCDP upgrades and homes with the most common upgrades gives another measure of the RCDP cost. Based on the data collected, RCDP would add $2,670 to homes built with the most common upgrades.

4.0 CONCLUSIONS

PNL has created comprehensive databases of incremental costs for conservation upgrades that can now be used in cost-effectiveness analyses. These databases will not only be useful for this project but also of potential benefit to future projects. The format of the databases is easy to manipulate for analysis purposes.

The data indicated that individual manufacturers used the same cost estimating procedures for their RCDP homes as they used for their regular homes. Although not all manufacturers used identical approaches, the methods all seemed reasonable. Meeting MCS specifications in Zones 1 and 2 seemed to be fairly easy, as evidenced by the large number of SGC qualified homes in those two zones. Zone 3, on the other hand, appeared to be more difficult. It was more costly to meet MCS in Zone 3, and consequently only two RCDP homes were sited there. Lastly, all the manufacturers added floor insulation between the joists to meet the SGC requirements even though this is not a typical practice in the Northwest.

PNL looked at the costs of the upgrades in two different ways. First, the incremental costs of upgrading to MCS relative to the base model were considered; then the MCS upgrade costs incremental to the most commonly purchased upgraded home were considered. The average cost incremental to the base model is $3,559, while the average cost incremental to the most commonly purchased upgraded model is $2,670. For homes where heat pumps were not used to meet the MCS, the average incremental cost relative to the base model was $3,102; where heat pumps were used, the incremental cost was $5,245. Compared with homes with upgrades most commonly purchased, the incremental cost was $2,213 for homes without heat pumps and $4,356 for homes with heat pumps.

PNL wishes to acknowledge the cooperation and support of the manufactured housing industry in the Pacific Northwest and the participating State Energy Offices. Without their assistance, this project would not have been successful.

5.0 REFERENCES

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