Appendix G: MCS Cost-effectiveness for Residences

INTRODUCTION

This appendix provides an overview of the method and data used to evaluation the regional cost-effectiveness and consumer economic feasibility of the Council's Model Conservation Standards for New Electrically Heated Residential Buildings. The first section describes the methodology, cost and savings assumptions used to establish the efficiency level that achieves all electricity savings that are cost-effective to the region's power system. The second section describes the methodology and assumptions used to determine whether the regionally cost-effective efficiency levels are economically feasible for new homebuyers in the region.

REGIONAL COST EFFECTIVENESS

Base Case Assumptions

Since the Council first promulgated its model conservation standards for new residential constructions in 1983 all of the states in the region have revised their energy codes. Consequently, many of the conservation measures included in the Council's original standards have now been incorporated into state regulations. In addition, some of the measures identified in prior Council Power Plan's as being regionally cost-effective when installed in new manufactured homes are now required by federal regulation.[1] This analysis assumes that the "base case" construction practices in the region comply with existing state codes and federal standards. However, since not all of the energy codes in the region are equally stringent this analysis uses the less restrictive measure permitted by code for each building component (e.g., walls, windows, doors, etc.). Table G-1 shows the levels of energy efficiency assumed for new site built and manufactured homes built to existing state codes and federal standards.

[1] The energy efficiency of new manufactured homes are regulated under the National Manufactured Housing Construction and Safety Standards Act of 1974. 42 USC §5401 et seq. (1983) which also pre-empts state regulation of their construction.

Table G-1: Base Case Efficiency Level Assumptions

Component	Site Built Homes	Manufactured Homes
Attic	R38 Standard Framing	R38 Intermediate Framing
Door	R5	R5
Floor	R30	R22
Infiltration	0.35 Air changes per hour	0.35 Air changes per hour
Joisted Vault	R30	R19
Slab-on-Grade (F-Value/linear foot of perimeter)	R10	Not Applicable
Trussed Vault	R38	R19
Wall	R19 Standard Framing	R19
Wall Below Grade (Interior)	R21	Not Applicable
Slab-below-Grade (F-Value/lin.ft. perimeter)	R10	Not Applicable
Window	Class 35 (U<0.35)	Class 50 (U<0.50)

Measure Cost Assumptions

The cost data for new site built homes used in the Council's analysis were obtained from a 1994 survey of new residential construction costs prepared for Bonneville and cost estimates provided to the Regional Technical Forum based on program data from the Energy Trust of Oregon and Mission Valley Power.[2] These costs were converted to year 2006 dollars using the GDP Deflator. Costs include a 20 percent markup for builder overhead and profit. Table G-2 provides a summary of the incremental costs used in the analysis for site built homes.

[2] Frankel, Mark, Baylon, D. and M. Lubliner 1995. Residential Energy Conservation Evaluation: Cost-Effectiveness of Energy Conservation Measures in New Residential Construction in Washington State. Washington State Energy Office, Olympia, WA. and the Bonneville Power Administration, Portland, OR.

Table G-2: Incremental Cost of New Site Built Residential Space Heating Conservation Measures

Conservation Measure	Incremental Installed Cost (2006$/sq.ft.)
Wall R19 Standard Framing	Base
Wall R21 Advanced Framing	$0.15
Wall R21 Standard Framing + R5 Foam	$0.87
Wall R30 Stressed Skin Panel	$1.19
Wall R38 Double Wall	$0.61
Attic R38 Standard Framing	Base
Attic R49 Advanced Framing	$0.39
Attic R60 Advanced Framing	$0.39
Vault R30 (Joisted)	Base
Vault R38 (Joisted w/High Density Insulation)	$0.62
Vault R50 Stressed Skin Panel	$2.18
Underfloor R30	Base
Underfloor R38 (Truss joist)	$0.41
Window Class 35 (U<0.35)	Base
Window Class 30 (U<0.30)	$0.89
Window Class 25 (U<0.25)	$2.00
Exterior Door R5	Base
Slab-On-Grade R10 Perimeter, down 2 ft	Base
Slab-On-Grade R10 Perimeter, down 4 ft	$.27
Slab-On-Grade R10 Full Under Slab w/R5 TB	$0.81
Below-Grade Wall R21 Interior	Base
Below-Grade Wall R21 Interior + R5 Foam	$0.87

Cost for new manufactured home energy efficiency improvements were obtained from regional manufacturers, insulation and window.[3] Table G-3 summarizes this same information for manufactured homes. These cost assume a manufacturer markup on material costs of 200 percent to cover labor and production cost and profit as well as and a retailer markup of 35 percent.

[3] Davis, Robert, D. Baylon and L. Palmiter, 1995 (draft report). *Impact Evaluation of the Manufactured Housing Acquisition Program (MAP).* Bonneville Power Administration, Portland, OR.

Table G-3: Incremental Cost of New Manufactured Home Residential Space Heating Conservation Measures

Conservation Measure	Incremental Installed Cost (2006$/sq.ft)
Wall R19 Standard Framing	Base
Wall R21 Standard Framing	$0.17
Attic R19	Base
Attic R25	$0.10
Attic R30	$0.10
Attic R38	$0.15
Attic R49	$0.23
Vault R19	Base
Vault R25	$0.10
Vault R30	$0.10
Vault R38	$0.15
Underfloor R22	Base
Underfloor R33	$0.18
Underfloor R44	$0.18
Window Class 35 (U<0.35)	Base
Window Class 30 (U<0.30)	$0.89
Window Class 25 (U<0.25)	$2.00
Exterior Door R5	$4.54

Energy Use Assumptions

The Council used an engineering simulation model, SEEM©, that is an improved version of the SUNDAY© simulation that has been calibrated to end-use metered space heating for electrically heated homes built across the region.[4] Thermal shell savings were computed for each measure based on the "economic" optimum order of application. This was done by first computing the change in heat loss rate (UA) that resulted from the application of each measure. The incremental cost of installing each measure was then divided by this "delta UA" to establish a measure's benefit-to-cost ratio (i.e., dollars/delta UA). The SEEM© simulation model was then used to estimate the space heating and space cooling energy savings that would result from the applying all measures starting with those that had the largest benefit-to-cost ratios. Savings were estimated for three typical site built single family homes and three typical manufactured homes. Table G-4 provides a summary of the component areas for each of these six homes.

[4] Palmiter, L., I. Brown and M. Kennedy 1988. *SUNDAY Calibration*. Bonneville Power Administration, Portland, OR.

Table G-4: Prototypical Home Component Dimensions

	Site Built Homes			Manufactured Homes		
Component	1344 sq.ft.	2200 sq.ft.	2268 sq.ft.	924 sq.ft.	1568 sq.ft.	2352 sq.ft.
Attic	1344	1784	1344	924	1568	2352
Door	40	40	40	40	40	40
Floor over Crawlspace	1,344	1,784	0	924	1,568	2,352
Volume	10,752	18,700	22,848	7,392	12,544	18,816
Slab-on-Grade (F-Value/lin.ft. perimeter)	-	-	140	-	-	-
Wall (Above Grade)	969	1,805	1,064	1,125	1,108	1,234
Wall Below Grade (Interior)	-	-	962	-	-	-
Slab-below-Grade (F-Value/lin.ft. perimeter)	-	-	148	-	-	-
Window	175	365	376	116	196	294

Five locations, Seattle, Portland, Boise, Spokane and Kalispell were selected to represent the range of climates found across the region. The SEEM© simulation model was run using the most recent (version 3) Typical Meteorological Year weather files for each of these locations. The savings produced by each measure across all five locations were then weighted together based on the share of new housing built in each location to form the three climate zones used by the Council. Table G-5 shows the weights used.

Table G-5: Location Weights Used to Establish Northwest Heating Zones

Location	Portland	Seattle	Boise	Spokane	Kalispell
Heating Zone 1	20%	50%	15%	15%	0%
Heating Zone 2	0%	0%	10%	85%	5%
Heating Zone 3	0%	0%	0%	0%	100%

In order to determine whether a measure is regionally cost-effective the Council then compared to cost of installing each measure with the value of the energy savings it produced over its lifetime. The value of all conservation savings vary by time of day and season of the year based on the market prices for electricity across the West and the impact of the savings on the need to expand the region's transmission and distribution system.

Tables G-6 through G-8 show the results of the cost-effectiveness analysis for each heating climate zone for site built homes and Tables G-9 through G-11 show the results of the cost-effectiveness analysis for new manufactured homes. All measures with a benefit/cost (B/C) ratio of 1.0 or larger are considered regionally cost-effective.

Table G-6: Regional Cost-Effectiveness Results for Site Built Homes in Heating Zone 1

1344 sq. ft				2200 sq. ft				2688 sq. ft			
Measure	**Savings (kWh/yr)**	**Installed Cost**	**Benefit/ Cost Ratio**	**Measure**	**Savings (kWh/yr)**	**Installed Cost**	**Benefit/ Cost Ratio**	**Measure**	**Savings (kWh/yr)**	**Installed Cost**	**Benefit/ Cost Ratio**
WINDOW CL30	298	156	1.7	WINDOW CL30	644	326	1.7	WINDOW CL30	644	336	1.7
INFILTRATION @ 0.20 ACH w/HRV	1027	672	1.4	INFILTRATION @ 0.20 ACH w/HRV	1784	1100	1.4	INFILTRATION @ 0.20 ACH w/HRV	2281	1344	1.5
ATTIC R49 ADVrh	524	520	0.9	ATTIC R49 ADVrh	723	690	0.9	ATTIC R49 ADVrh	602	520	1.0
WINDOW CL25	321	349	0.8	WINDOW CL25	713	730	0.9	SLAB R10-FULL	1078	1088	0.9
WALL R21 INT+R5	749	988	0.7	WALL R21 INT+R5	1459	1840	0.7	WINDOW CL25	729	753	0.9
FLOOR R38 STD w/12"Truss	335	552	0.5	FLOOR R38 STD w/12"Truss	454	733	0.5	BGWALL R21	117	146	0.7
ATTIC R60 ADVrh	138	520	0.2	ATTIC R60 ADVrh	190	690	0.2	WALL R21 INT+R5	802	1084	0.7
WALL 8" SSPANEL	213	1150	0.2	WALL 8" SSPANEL	382	2142	0.2	ATTIC R60 ADVrh	121	520	0.2
WALL R33 DBL	24	590	0.0	WALL R33 DBL	45	1099	0.0	WALL 8" SSPANEL	199	1262	0.1
								WALL R33 DBL	25	647	0.0

Table G-7: Regional Cost-Effectiveness Results for Site Built Homes in Heating Zone 2

1344 sq. ft				2200 sq. ft				2688 sq. ft			
Measure	**Savings (kWh/yr)**	**Installed Cost**	**Measure**	**Savings (kWh/yr)**	**Installed Cost**	**Measure**	**Savings (kWh/yr)**	**Installed Cost**	**Measure**	**Savings (kWh/yr)**	**Installed Cost**
WINDOW CL30	392	156	2.2	WINDOW CL30	830	326	2.3	WINDOW CL30	836	336	2.2
INFILTRATION @ 0.20 ACH w/HRV	1349	672	1.8	INFILTRATION @ 0.20 ACH w/HRV	2309	1100	1.9	INFILTRATION @ 0.20 ACH w/HRV	2956	1344	1.9
ATTIC R49 ADVrh	692	520	1.2	ATTIC R49 ADVrh	940	690	1.2	ATTIC R49 ADVrh	762	520	1.3
WINDOW CL25	402	349	1.0	WINDOW CL25	878	730	1.1	SLAB R10-FULL	1331	1088	1.1
WALL R21 INT+R5	933	988	0.8	WALL R21 INT+R5	1805	1840	0.9	WINDOW CL25	900	753	1.1
FLOOR R38 STD w/12"Truss	435	552	0.7	FLOOR R38 STD w/12"Truss	594	733	0.7	BGWALL R21	144	146	0.9
ATTIC R60 ADVrh	183	520	0.3	ATTIC R60 ADVrh	251	690	0.3	WALL R21 INT+R5	1025	1084	0.8
WALL 8" SSPANEL	289	1150	0.2	WALL 8" SSPANEL	519	2142	0.2	ATTIC R60 ADVrh	162	520	0.3
WALL R33 DBL	33	590	0.0	WALL R33 DBL	61	1099	0.0	WALL 8" SSPANEL	272	1262	0.2
								WALL R33 DBL	34	647	0.0

Table G-8: Regional Cost-Effectiveness Results for Site Built Homes in Heating Zone 3

1344 sq. ft				2200 sq. ft				2688 sq. ft			
Measure	**Savings (kWh/yr)**	**Installed Cost**	**Benefit/ Cost Ratio**	**Measure**	**Savings (kWh/yr)**	**Installed Cost**	**Benefit/ Cost Ratio**	**Measure**	**Savings (kWh/yr)**	**Installed Cost**	**Benefit/ Cost Ratio**
WINDOW CL30	466	156	2.6	WINDOW CL30	989	326	2.7	WINDOW CL30	1006	336	2.7
INFILTRATION @ 0.20 ACH w/HRV	1610	672	2.1	INFILTRATION @ 0.20 ACH w/HRV	2751	1100	2.2	INFILTRATION @ 0.20 ACH w/HRV	3522	1344	2.3
ATTIC R49 ADVrh	823	520	1.4	ATTIC R49 ADVrh	1115	690	1.4	ATTIC R49 ADVrh	898	520	1.5
WINDOW CL25	473	349	1.2	WINDOW CL25	1019	730	1.2	SLAB R10-FULL	1567	1088	1.3
WALL R21 INT+R5	1096	988	1.0	WALL R21 INT+R5	2100	1840	1.0	WINDOW CL25	1060	753	1.2
FLOOR R38 STD w/12"Truss	523	552	0.8	FLOOR R38 STD w/12"Truss	708	733	0.9	BGWALL R21	170	146	1.0
ATTIC R60 ADVrh	220	520	0.4	ATTIC R60 ADVrh	297	690	0.4	WALL R21 INT+R5	1223	1084	1.0
WALL 8" SSPANEL	356	1150	0.3	WALL 8" SSPANEL	641	2142	0.3	ATTIC R60 ADVrh	198	520	0.3
WALL R33 DBL	41	590	0.1	WALL R33 DBL	76	1099	0.1	WALL 8" SSPANEL	345	1262	0.2
								WALL R33 DBL	43	647	0.1

Table G-9: Regional Cost-Effectiveness Results for Manufactured Homes in Heating Zone 1

924 sq. ft				1568 sq. ft				2352 sq. ft			
Measure	**Savings (kWh/yr)**	**Installed Cost**	**Benefit/ Cost Ratio**	**Measure**	**Savings (kWh/yr)**	**Installed Cost**	**Benefit/ Cost Ratio**	**Measure**	**Savings (kWh/yr)**	**Installed Cost**	**Benefit/ Cost Ratio**
WINDOW CL35	676	135	4.5	WINDOW CL35	1078	228	4.2	WINDOW CL35	1579	343	4.1
FLOOR R33	465	163	2.5	FLOOR R33	806	276	2.6	FLOOR R33	1213	415	2.6
WINDOW CL30	230	103	2.0	WINDOW CL30	406	175	2.1	WINDOW CL30	619	263	2.1
VAULT R30	95	47	1.8	ATTIC R30	171	79	1.9	ATTIC R30	261	118	2.0
ATTIC R30	94	47	1.8	VAULT R30	171	79	1.9	VAULT R30	261	118	2.0
DOOR R5	324	211	1.4	DOOR R5	347	211	1.5	DOOR R5	353	211	1.5
WALL R21 ADV	256	195	1.2	WALL R21 ADV	281	192	1.3	WALL R21 ADV	320	214	1.3
ATTIC R38	66	70	0.8	ATTIC R38	164	118	1.2	ATTIC R38	252	178	1.3
WINDOW CL25	159	231	0.6	WINDOW CL25	394	392	0.9	WINDOW CL25	604	588	0.9
VAULT R38	40	70	0.5	VAULT R38	98	118	0.7	VAULT R38	152	178	0.8
ATTIC R49	53	105	0.5	ATTIC R49	126	178	0.6	ATTIC R49	192	266	0.6
FLOOR R44	53	163	0.3	FLOOR R44	109	276	0.4	FLOOR R44	186	415	0.4

Table G-10: Regional Cost-Effectiveness Results for Manufactured Homes in Heating Zone 2

924 sq. ft				1568 sq. ft				2352 sq. ft			
Measure	**Savings (kWh/yr)**	**Installed Cost**	**Benefit/ Cost Ratio**	**Measure**	**Savings (kWh/yr)**	**Installed Cost**	**Benefit/ Cost Ratio**	**Measure**	**Savings (kWh/yr)**	**Installed Cost**	**Benefit/ Cost Ratio**
WINDOW CL35	894	135	5.9	WINDOW CL35	1367	228	5.3	WINDOW CL35	1969	343	5.1
FLOOR R33	614	163	3.3	FLOOR R33	1065	276	3.4	FLOOR R33	1593	415	3.4
WINDOW CL30	304	103	2.6	WINDOW CL30	532	175	2.7	WINDOW CL30	811	263	2.7
VAULT R30	127	47	2.4	ATTIC R30	224	79	2.5	ATTIC R30	342	118	2.6
ATTIC R30	126	47	2.4	VAULT R30	224	79	2.5	VAULT R30	342	118	2.6
DOOR R5	434	211	1.8	DOOR R5	456	211	1.9	DOOR R5	463	211	1.9
WALL R21 ADV	336	195	1.5	WALL R21 ADV	374	192	1.7	WALL R21 ADV	424	214	1.8
ATTIC R38	93	70	1.2	ATTIC R38	217	118	1.6	ATTIC R38	333	178	1.7
WINDOW CL25	222	231	0.8	WINDOW CL25	524	392	1.2	WINDOW CL25	798	588	1.2
VAULT R38	56	70	0.7	VAULT R38	129	118	1.0	VAULT R38	202	178	1.0
ATTIC R49	74	105	0.6	ATTIC R49	162	178	0.8	ATTIC R49	246	266	0.8
FLOOR R44	74	163	0.4	FLOOR R44	145	276	0.5	FLOOR R44	237	415	0.5

Table G-11: Regional Cost-Effectiveness Results for Manufactured Homes in Heating Zone 3

924 sq. ft				1568 sq. ft				2352 sq. ft			
Measure	**Savings (kWh/yr)**	**Installed Cost**	**Benefit/ Cost Ratio**	**Measure**	**Savings (kWh/yr)**	**Installed Cost**	**Benefit/ Cost Ratio**	**Measure**	**Savings (kWh/yr)**	**Installed Cost**	**Benefit/ Cost Ratio**
WINDOW CL35	1073	135	7.1	WINDOW CL35	1636	228	6.3	WINDOW CL35	2362	343	6.1
FLOOR R33	739	163	4.0	FLOOR R33	1276	276	4.1	FLOOR R33	1908	415	4.1
WINDOW CL30	365	103	3.1	WINDOW CL30	641	175	3.2	WINDOW CL30	975	263	3.3
VAULT R30	151	47	2.9	ATTIC R30	270	79	3.0	ATTIC R30	411	118	3.1
ATTIC R30	151	47	2.9	VAULT R30	270	79	3.0	VAULT R30	411	118	3.1
DOOR R5	523	211	2.2	DOOR R5	549	211	2.3	DOOR R5	556	211	2.3
WALL R21 ADV	407	195	1.9	WALL R21 ADV	448	192	2.1	WALL R21 ADV	508	214	2.1
ATTIC R38	117	70	1.5	ATTIC R38	263	118	2.0	ATTIC R38	402	178	2.0
WINDOW CL25	280	231	1.1	WINDOW CL25	631	392	1.4	WINDOW CL25	962	588	1.5
VAULT R38	70	70	0.9	VAULT R38	154	118	1.2	VAULT R38	241	178	1.2
ATTIC R49	94	105	0.8	ATTIC R49	195	178	1.0	ATTIC R49	296	266	1.0
FLOOR R44	94	163	0.5	FLOOR R44	179	276	0.6	FLOOR R44	286	415	0.6

Once the cost-effective level of the thermal shell was established the Council tested the cost-effectiveness of improving the efficiency of the homes space conditioning system. This was done by applying running the SEEM© model with higher performance heat pumps, improved duct systems, including moving all duct work and HVAC system inside the conditioned space, and carrying out heat pump commissioning and controls to ensure the system operated as designed. The average costs of these measures are shown in Table G-12. All of measures listed in Table G-12 are regionally cost-effectiveness, with total resource cost benefit-to-cost ratio greater than 1.0.

Table G-12: Heating System Efficiency Improvements

HVAC System Efficiency Improvements	Incremental Cost (2006$)
PTCS Heat Pump Commissioning	$225
PTCS - Duct Sealing	$300
PTCS-Interior Ducts & HVAC	$350
Air Source Heat Pump - Baseline (HSPF 7.7/SEER 13)	$3,880
Air Source Heat Pump - (HSPF 8.5/SEER 14)	$5,790
Air Source Heat Pump - Baseline (HSPF 9.0/SEER 14)	$6,900

In addition to space conditioning system efficiency improvements, recent changes to state energy codes have included lighting efficiency improvements. National model codes also include minimum lighting efficiency requirements. Therefore, the Council also analyzed lighting efficiency improvements. Four levels of efficiency, including baseline lighting power densities were reviewed for cost-effectiveness. It was assumed that all of these levels could be achieved with higher efficacy lighting technologies (compact fluorescent, LEDs) without reducing lumen levels. The estimated cost of these improvements is show in Table G-13.

Reduction in lighting power densities interact with the space heating and cooling needs of a home. Therefore, to properly estimate the net savings from these lighting reductions the SEEM© model was run to calculate the space heating and cooling loads after their implementation. All of the lighting levels shown in Table G-13 are regionally cost-effective, with total resource cost benefit-to-cost ratios greater than 1.0.

Table G-13: Lighting System Efficiency Improvements and Cost

Efficiency Level	Lighting Power Density (Watts/sq.ft.)	Cost/sq.ft.
Baseline	1.75	
Energy Star	1.00	$0.11
Advanced	0.75	$0.17
Full	0.60	$0.23

The 5th Plan's Model Conservation Standards did not cover water heating. Higher efficiency tanks have been available for decades and with the anticipated availability of heat pump water heaters, there is now a potentially cost-effective technology to reduce water heating consumption by as much as half. The estimated average cost and savings assumed for improving water heating efficiency are shown in Table G-14. Using these cost and savings, all of the water heating measures shown in Table G-14 are regionally cost-effective, with total resource cost benefit-to-cost ratios greater than 1.0.

Table G-14: Water Heating System Efficiency Improvements and Cost

Water Heating System Type	DHW System Cost (2006$)	DHW Use (kWh/yr)
EF 0.90	$649	3,655
EF 0.92	$669	3,576
EF 0.94	$746	3,500
EF 2.2	$1,450	1,499

The Council's Model Conservation Standards are "performance based" and not prescriptive standards. That is, many different combinations of energy efficiency measures can be used to meet the overall performance levels called for in the standards. In order to translate the regional cost-effectiveness results into "model standards" the Council calculates the total annual space conditioning, water heating and lighting use of a "reference building" that meets the Council's standards so that its efficiency can be compared to the same building built with some other combination of measures. Table G-15 shows the maximum annual energy budget for space conditioning, water heating and lighting use permitted under the draft sixth Plan's model standards "reference" case requirements for site built and manufactured homes for each of the region's three heating climate zones. These "performance budgets" incorporate all of the conservation measures shown in Tables G-6 through G-14 that have a benefit-to-cost ratio of 1.0 or higher on a total resource cost basis.

Table G-15: Draft Sixth Plan Model Conservation Standards Annual Space Conditioning, Water Heating and Lighting Budgets[5]

	Site Built Homes (kWh/sq.ft./yr)	Manufactured Homes (kWh/sq.ft/yr)
Heating Zone 1	2.87	2.54
Heating Zone 2	4.27	3.54
Heating Zone 3	5.15	4.10

The Council compared the requirements underlying the performance shown in Table G-15 for site built homes with the requirements of state energy codes in the region. It also compared the requirements underlying the performance shown in Table G-15 with the requirements of regional Energy Star® site built and manufactured home program specifications. This comparison, revealed that none of the region's energy codes nor the Energy Star® program specifications met the Model Conservation Standards goal of capturing all regionally cost-effective electricity savings. It therefore appears that further strengthening of these codes and program specifications is required. The following section addresses the question of whether these higher levels of efficiency would be economically feasible for consumers.

CONSUMER ECONOMIC FEASIBILITY

The Act requires that the Council's Model Conservation Standards be "economically feasible for consumers" taking into account any financial assistance made available through Bonneville and the region's utilities. In order to determine whether the performance standards set forth in Table G-15 met this test the Council developed a methodology that allowed it to compare the life cycle cost of home ownership, including energy costs, of typical homes with increasing levels of

[5] Annual space conditioning, water heating and lighting use for a typical 2250 sq.ft. site built home and 1750 sq.ft. manufactured home. Both homes are assumed to have air source heat pumps with a minimum HSPF 9.0/SEER 14, heat pump water heater and maximum lighting power density of 0.6 Watts/sq.ft.

energy efficiency built into them. This section describes this methodology and results of this analysis.

The life cycle cost of home ownership is determined by many variables, such as the mortgage rate, downpayment amount, the marginal state and federal income tax rates of the homebuyer, retail electric rates, etc. The value of some of these variables, such as property and state income tax rates are known, but differ across state or utility service areas or differ by income level. For example, homebuyers in Washington state pay no state income tax, while those in Oregon pay upwards of 9% of their income in state taxes. Since home mortgage interest payments are deductible, Oregon homebuyers have a lower "net" interest rate than do Washington buyers. The value of other variables, such as mortgage rates and the fraction of a home's price that the buyer pays as a downpayment are a function of income, credit worthiness, market conditions and other factors. Consequently, it is an extreme oversimplification to attempt to represent the economic feasibility of higher levels of efficiency using the "average" of all of these variables as input assumptions.

In order to better reflect the range of conditions individual new homebuyers might face the Council developed a model that tested over a 1500 different combinations of major variables that determine a specific consumer's life cycle cost of home ownership for each heating climate zone. Table G-16 lists these variables and the data sources used to derive the actual distribution of values used.

Table G-16: Data Sources and Variables Used in Life Cycle Cost Analysis

Variable	Data Source
Average New Home Price	Federal Housing Finance Board
Mortgage Interest Rates	Federal Housing Finance Board & Mortgage Bankers Association
Downpayment	Federal Housing Finance Board
Private Mortgage Insurance Rates	Mortgage Bankers Association
Retail Electric Rates	Energy Information Administration
Retail Gas Rates	Energy Information Administration
Retail Electric and Gas Price Escalation Rates	Council Draft 6th Plan Forecast
Federal Income Tax Rates	Internal Revenue Service
State Income and Property Tax Rates	ID, MT, OR & WA State Departments of Revenue
Adjusted Gross Incomes	Internal Revenue Service
Home owners insurance	Online estimates from Realtor.com

A "Monte Carlo" simulation model add-on to EXCEL© called Crystal Ball© was used to select specific values for each of these variables from the distribution of each variable. Each combination of values was then to use to compute the present value of a 30-year (360 month) stream of mortgage principal and interest payments, insurance premiums, property taxes and energy cost for a new site built or manufactured home built to increasing levels of thermal efficiency. Figures G-1 through G-6 show the distributions used for each of the major financial input assumptions to the life cycle cost analysis.

Figure G-1: Distribution of Nominal Mortgage Rates

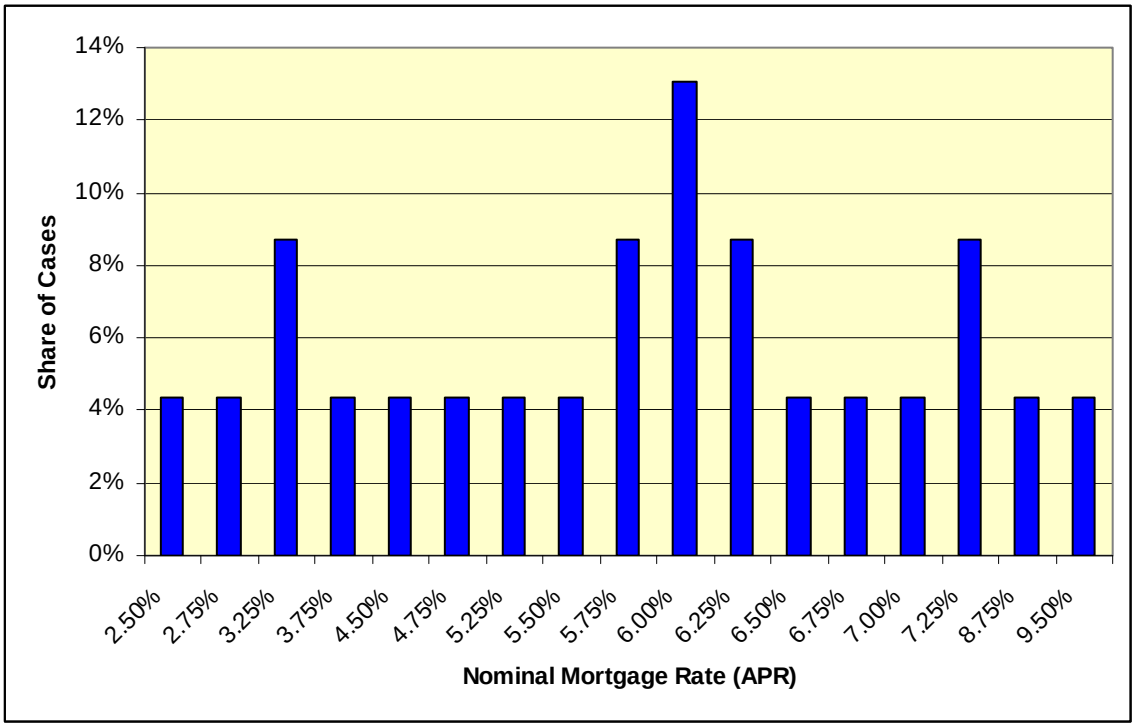


Figure G-2: Distribution of Downpayment Amounts

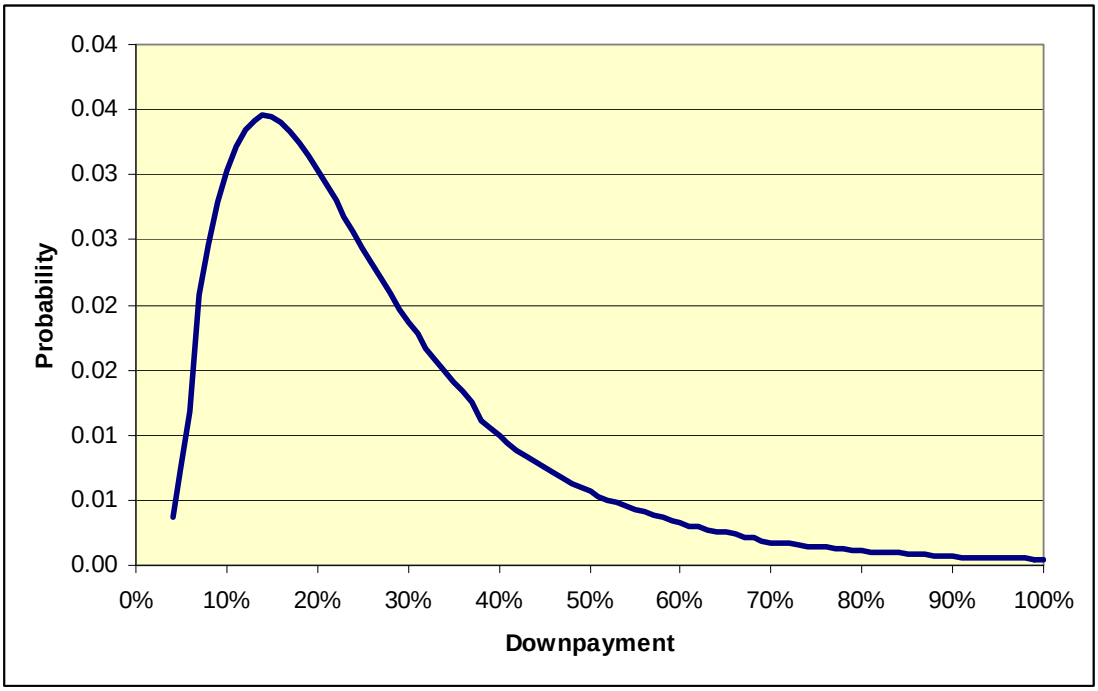


Table G-17: Distribution of Marginal State and Federal Income Tax Rates

	Idaho			Montana			Oregon			Washington		
Adjusted Gross Income	Federal Tax Rate	State Income Tax Rate	Share of Returns	Federal Tax Rate	State Income Tax Rate	Share of Returns	Federal Tax Rate	State Income Tax Rate	Share of Returns	Federal Tax Rate	State Income Tax Rate	Share of Returns
Under $10,000	10%	5.1%	20.0%	10%	3.0%	24.4%	10%	7.0%	18.6%	10%	0.0%	16.8%
$10,000 Under $20,000	15%	7.1%	19.3%	15%	5.0%	20.8%	15%	9.0%	18.1%	15%	0.0%	16.1%
$20,000 Under $30,000	15%	7.8%	15.0%	15%	6.0%	14.2%	15%	9.0%	14.4%	15%	0.0%	13.7%
$30,000 Under $50,000	18%	7.8%	19.6%	18%	8.0%	18.0%	19%	9.0%	19.5%	20%	0.0%	19.8%
$50,000 Under $75,000	25%	7.8%	13.6%	25%	9.0%	12.1%	25%	9.0%	14.1%	25%	0.0%	15.5%
$75,000 Under $100,000	25%	7.8%	5.7%	25%	10.0%	4.6%	25%	9.0%	6.8%	25%	0.0%	8.1%
$100,000 Under $150,000	28%	7.8%	3.2%	28%	11.0%	2.4%	28%	9.0%	4.3%	28%	0.0%	5.5%
$150,000 Under $200,000	28%	7.8%	0.9%	29%	11.0%	0.8%	29%	9.0%	1.3%	29%	0.0%	1.5%
$200,000 Under $500,000	33%	7.8%	0.9%	33%	11.0%	0.8%	33%	9.0%	1.3%	33%	0.0%	1.5%
$500,000 Under $1,000,000	35%	7.8%	0.2%	35%	11.0%	0.1%	35%	9.0%	0.2%	35%	0.0%	0.3%
$1,000,000 and Over	35%	7.8%	0.1%	35%	11.0%	0.0%	35%	9.0%	0.1%	35%	0.0%	0.2%

Figure G-3: Property Tax Rates by State

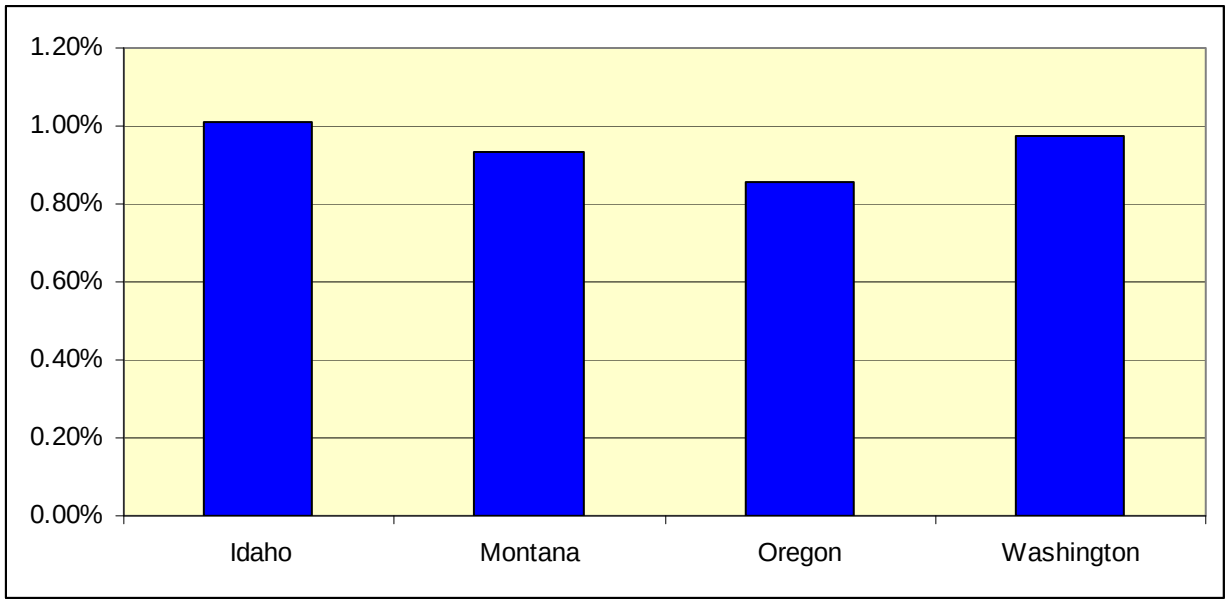


Figure G-4: Base Year Retail Electric Rates by Climate Zone

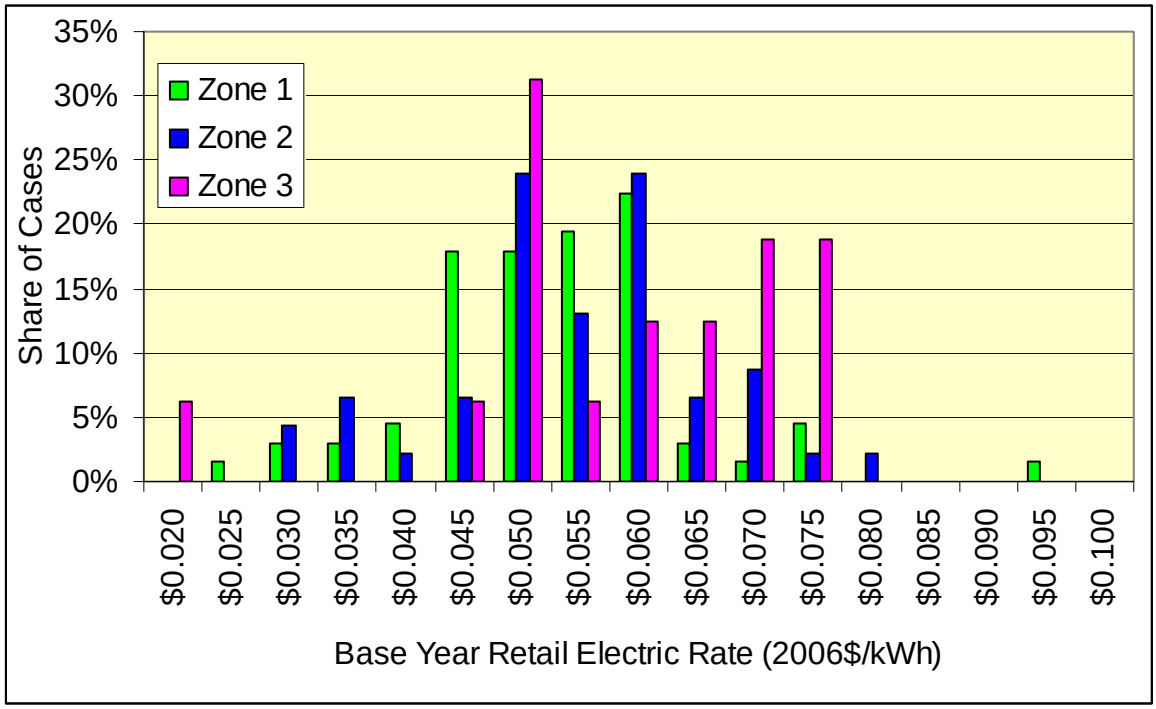
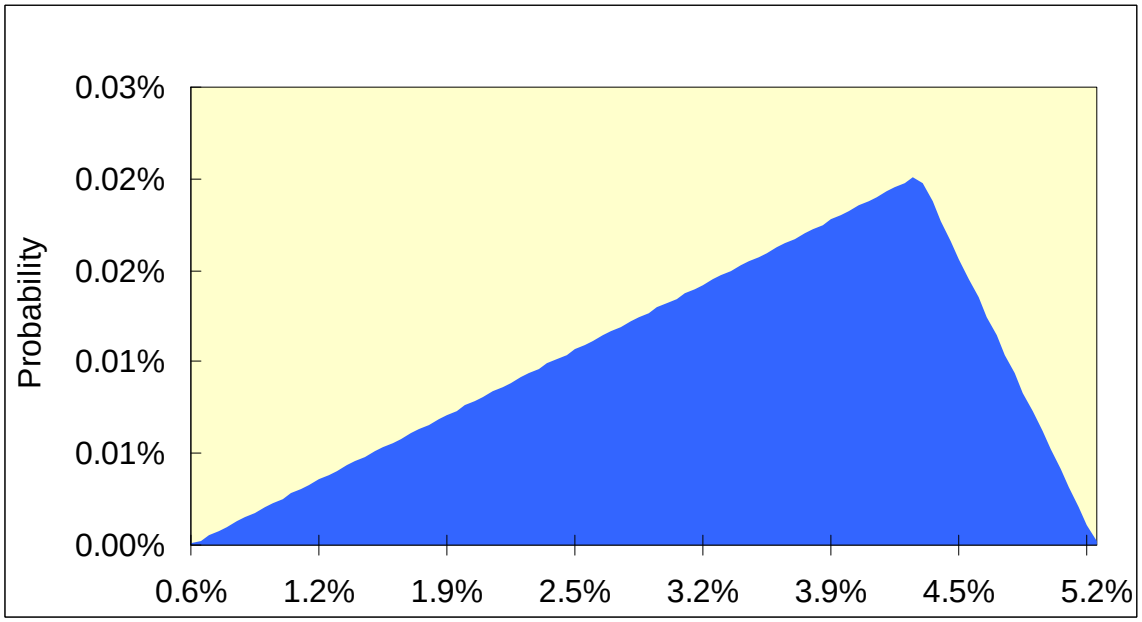


Figure G-5: Nominal Escalation Rates for Retail Electricity Prices - All Climate Zones



The incremental costs of conservation measures described in the prior section on regional cost-effectiveness were used in the life cycle cost calculations. Annual space heating and cooling energy use was computed for four heating system types using the system efficiency assumptions shown in Table G-12 and the water heating and lighting use shown in Tables G13 and G-14.

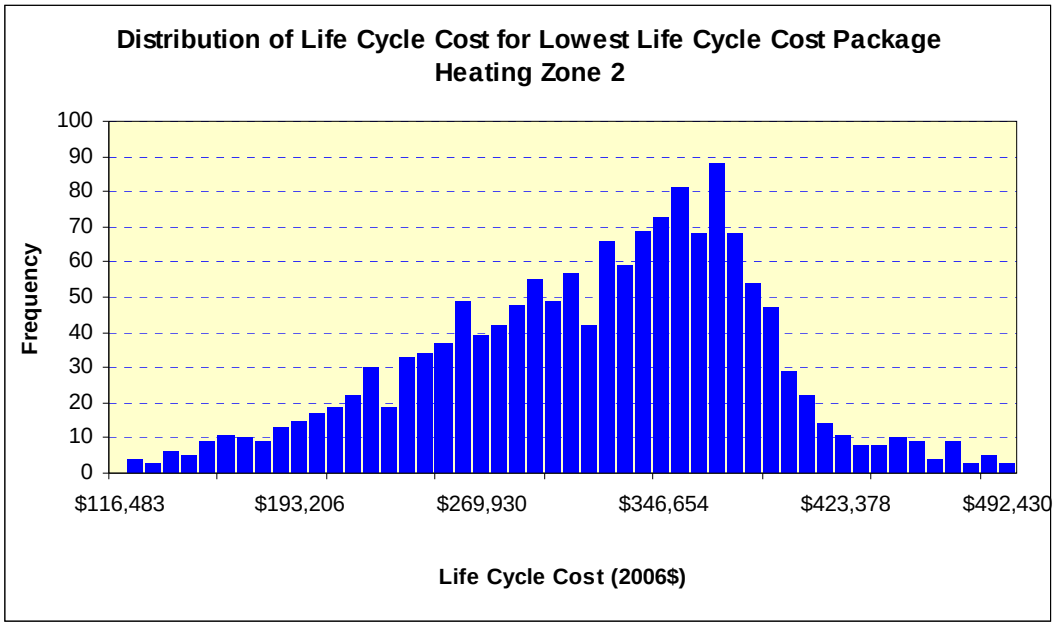
The life cycle cost simulation model used the same 1,500 combinations of input assumptions for each level of energy efficiency tested. As a result, the Council could compare the distribution of 1,500 different life cycle cost results for a home built to incrementally higher levels of efficiency, rather than just single cases. This allowed the Council to consider how "robust" a conclusion one might draw regarding the economic feasibility of each measure.

Figure G-6 illustrates a typical distribution of net present value results for one the lowest life cycle cost package identified for Heating Zone 2. The graph plots the life cycle cost value of a conservation package (i.e., thermal shell, space conditioning system, water heating system and lighting system) costs and energy use over the term of the mortgage on the horizontal (x) axis. The frequency of obtaining a given life cycle cost is plotted on the vertical (y) axis.

The simulation model was set up to seek out the lowest life cycle cost path to comply with current codes. In this case, the model was only permitted to select different electric space conditioning systems. That is, it was not allowed to choose improvements in thermal shell, water heating, lighting or duct system efficiency. Table G-18 shows the mean life cycle cost, first cost and energy use of for each of the regions three heating zones for new single-family homes and for new manufactured homes.

Once the "base case" homes life cycle cost was established the model was set up to seek out the lowest life cycle cost package of measures by selecting various combinations of thermal shell improvements, space conditioning systems, duct system efficiencies and lighting and water heating system efficiency improvements. Table G-19 shows the mean life cycle cost, first cost and annual energy use for the package that performed best across all 1500 different combinations of financial inputs.

Figure G-6: Illustrative Distribution of Life Cycle Cost Results



Finally, the simulation model was run to determine the life cycle cost of the package for each heating zone that includes all measures that were found to regionally cost-effective to the power

system. Table G-20 shows the mean life cycle cost, first cost and annual energy use for these packages for each climate zone.

A comparison of the energy use for the lowest life cycle cost packages shown in Table G-19 with the life cycle cost of the packages containing all regionally cost-effective measures shown in Table G-20 reveals that across all climate zones and building types, life cycle costs are higher for those packages containing all regionally cost-effective measures.

Table G-18: Lowest Life Cycle Minimally Code Compliant Packages (Base Case)

	Life Cycle Cost - 30 yrs		First Cost		Total Use (kWh/yr)	
	Single Family	Manufactured Home	Single Family	Manufactured Home	Single Family	Manufactured Home
Zone 1	$314,247	$99,749	$2,297	$8,732	17,575	10,131
Zone 2	$324,608	$104,167	$2,297	$8,732	19,551	14,528
Zone 3	$255,368	$103,076	$2,297	$8,732	26,752	17,158

Table G-19: Lowest Life Cost Cycle Packages (Economically Feasible)

	Life Cycle Cost - 30 yrs		First Cost		Total Use (kWh/yr)	
	Single Family	Manufactured Home	Single Family	Manufactured Home	Single Family	Manufactured Home
Zone 1	$307,500	$93,705	$10,899	$10,908	9,265	5,431
Zone 2	$315,460	$95,623	$10,899	$10,904	10,462	7,165
Zone 3	$242,302	$91,231	$10,899	$11,107	12,453	8,173

Table G-20: All Regionally Cost-Effective Packages (MCS)

	Life Cycle Cost - 30 yrs		First Cost		Total Use (kWh/yr)	
	Single Family	Manufactured Home	Single Family	Manufactured Home	Single Family	Manufactured Home
Zone 1	$308,254	$94,593	$12,068	$11,617	6,449	4,334
Zone 2	$316,107	$96,303	$12,068	$11,617	9,776	6,204
Zone 3	$242,780	$91,658	$12,068	$11,617	11,714	7,170

Table G-21 shows differences in the buildings shell between the lowest life cycle cost packages and the packages that contain all regionally cost-effective measures. A review of Table G-21 reveals that the only difference in the thermal shell is in the level of attic insulation and air sealing.

Table G-21: Comparison of Thermal Shell Measures in Lowest Life Cycle Cost Packages and All Regionally Cost-Effective Packages

Component	Regionally Cost-Effective (All Zones)	Minimum Life Cycle Cost (All Zones)
Wall – Above Grade	R21 Advanced Framing	R21 Advanced Framing
Wall – Below Grade	R19	R19
Attic	R49 Advanced	R38 STD
Vault	R30	R30
Floor	R30	R30
Window	Class 25	Class 25
Door	R5	R5
Slab	R10 Full Under Slab	R10 Full Under Slab
Wall – Ext. Below grade	R10	R10
Infiltration	Air Sealing w/HRV	Current Practice

Table G-22 shows the differences in the space conditioning, water heating and lighting system efficiency components between the lowest life cycle cost packages and the packages containing all regionally cost-effective measures. As can be seen in Table G-22 the only difference between the lowest life cycle cost package and the package containing all regionally cost-effective measures is the minimum efficiency requirements for the heat pump space conditioning system.

Table G-22: Comparison of Space Conditioning, Water Heating and Lighting Measures in Lowest Life Cycle Cost Packages and All Regionally Cost-Effective Packages

Component	Regionally Cost-Effective	Minimum Life Cycle Cost
HVAC System	HSPF 9.0/SEER 14 Heat Pump	HSPF 7.7/SEER 13 Heat Pump
Duct System	Interior Ducts	Interior Ducts
Water Heater	Heat Pump	Heat Pump
Lighting	0.6 Watts/sq.ft.	0.6 Watts/sq.ft.