HERS

HOME ENERGY RATING SYSTEM

TOPIC REPORT

CALIFORNIA ENERGY COMMISSION

CONSULTANT REPORT

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ABSTRACT

Public Resources Code (PRC) Section 25942 directs the Energy Commission to adopt a statewide California Home Energy Rating System (HERS) Program for residential dwellings. Phase I of the California HERS Program, which was adopted in 1999, established the basic operating framework of the program, including training and certification procedures for raters, quality assurance procedures, and data collecting and reporting requirements for raters who are performing field verification and diagnostic testing services for demonstrating compliance with Title 24 Building Energy Efficiency Standards.

Phase II of the HERS Program will extend the Phase I HERS Program to cover whole-house home energy ratings of existing (and newly constructed) homes. Phase II will put in place the remaining elements of PRC Section 25942:

- Consistent, accurate, and uniform ratings based on a single statewide rating scale.
- Reasonable estimates of potential utility bill savings, and reliable recommendations on cost-effective measures to improve energy efficiency.
- Labeling procedures that will meet the needs of home buyers, homeowners, renters, the real estate industry, and mortgage lenders with an interest in home energy ratings.

This report will present the results of research and analysis of key issues that relate to Phase II of the HERS program, including, in particular, the following:

- Differences that occur between home energy ratings determined through building energy simulation and actual energy use.
- Proposed modeling assumptions for the California HERS Program.
- Proposed California HERS Program rating scale.
- Proposed Roles, Functions, and Services to be addressed in the California HERS Program, including:
    - California Whole-House Home Energy Rater
    - California Home Energy Auditor
    - California Home Energy Inspector
    - California Home Energy Analyst
    - California Field Verification and Diagnostic Testing Rater
    - Building Performance Contractor
- Proposed approaches for determining measure cost-effectiveness and recommendations for energy efficiency improvements, including cross-checking against utility bills.

Keywords: Whole-House Home Energy Rater, Home Energy Auditor, Home Energy Inspector, Home Energy Analyst, Building Performance Contractor, California Home Energy Rating System Program, HERS, HERS rating scale, utility bills, cost effectiveness, field verification and diagnostic testing

Executive Summary

Purpose

This document reports on research to develop procedures for home energy ratings of existing homes in California.

Discrepancy Between Energy Ratings and Actual Energy Use

The purpose of HERS for existing buildings is to rate the home not the occupants. This can result in a discrepancy between the energy use predicted by the rating and the actual energy use that is reflected on the utility bills. Furthermore, some studies indicate that most existing rating systems tend to overestimate energy use within a building, raising concerns about the merit of efficiency improvement recommendations for the average home. These discrepancies were a source of concern with California Energy Commission (Energy Commission) staff and HERS stakeholders during initial discussions of HERS in the late 1990s.

There are a number of explanations for the discrepancies:

- The data used to generate the rating may be difficult to determine, and specification errors by raters tend to be one-sided, erring on the conservative side (for example, if you can't verify the levels of insulation in an enclosed wall, assume no insulation). These errors could affect:
    - HVAC system type and efficiency.
    - Thermal performance of walls, roofs, and/or floors.
    - Thermal and solar optic performance of windows.
    - Other model inputs.
- Uninsulated building envelope assemblies may perform better than expected by standard assembly U-factor assumptions. See discussion of this issue in Task 2.1.
- The way the home is operated may be different from the assumptions used in the rating.
    - Thermostats may be set higher or lower than assumed for the rating.
    - The heating and cooling equipment may be operated for fewer hours or more hours than assumed for the rating.
    - Internal gains may be higher or lower than assumed for the rating.
    - Hot water consumption may be higher or lower than assumed for the rating.
- Systems in the actual house may be inoperable, malfunctioning, or providing poor air distribution while such equipment may be assumed to be working properly for the calculation of

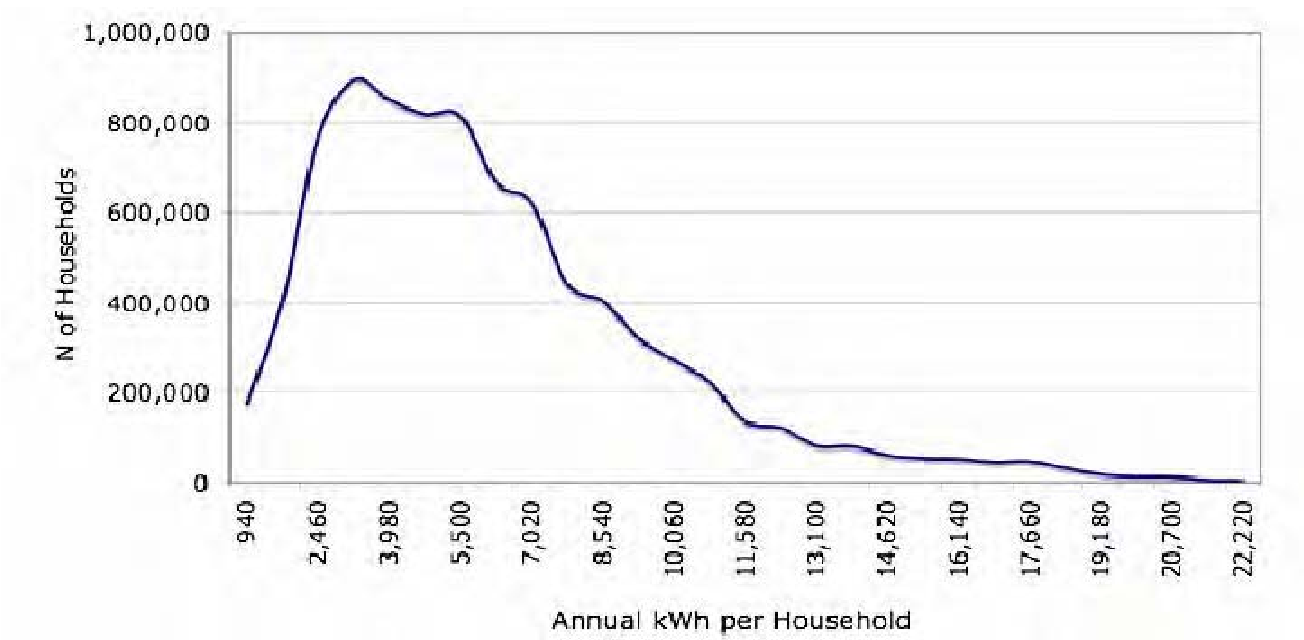
the rating. Also, the model assumes that the HVAC systems will maintain comfort conditions, which may not be achieved in the rated home.

- Major appliances and miscellaneous energy use may be misrepresented in the rating both in terms of the peak power of the devices and the intensity of use. Assumed lighting loads (both hardwired and portable) may be inaccurate. Electronic equipment may be different from that assumed in the rating.

Observed Variation in Energy Use

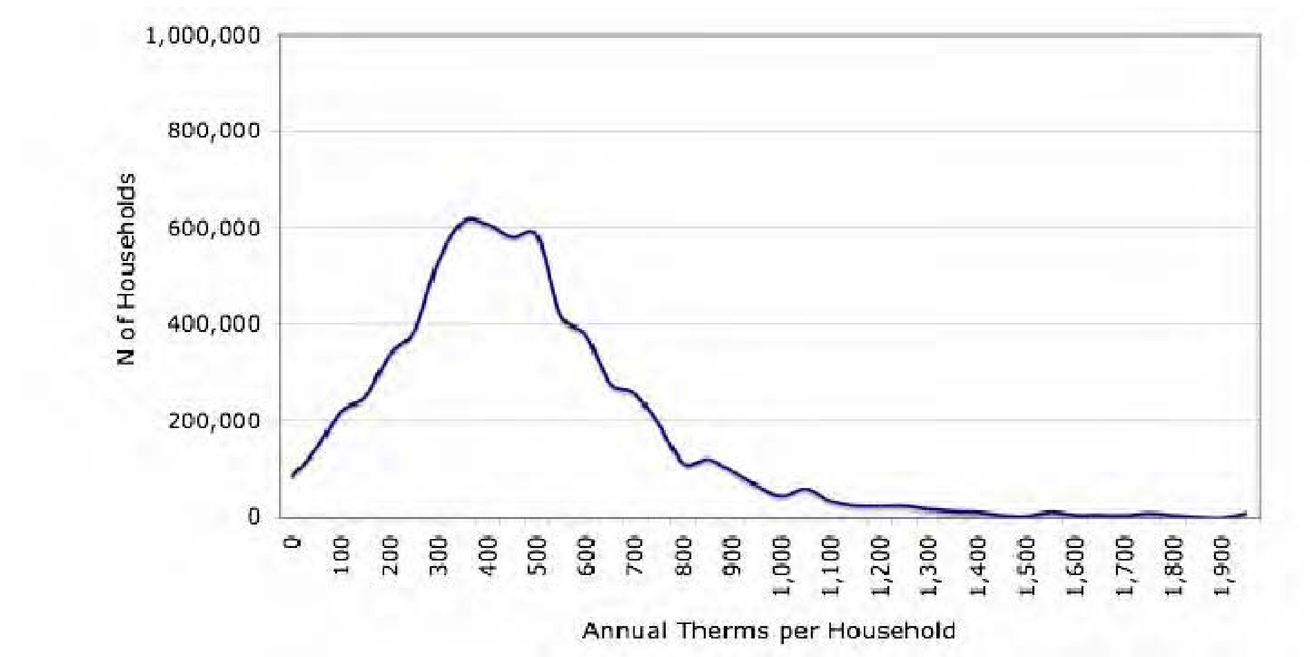
The Energy Commission Residential Appliance Saturation Survey (RASS) indicates large variations among households in both gas and electricity use. Figure 1 and Figure 2 show a frequency distribution for electricity and natural gas consumption. Some of the variation can be explained by factors that are accounted for in a traditional rating, such as house size and energy efficiency features, however, lifestyle factors may be an even larger influence. As shown in Figure 1, the average electricity use is around 6,000 kWh/year, but some homes use more than 20,000 kWh/year and some use as little as 1,000 kWh/year. Similar data for natural gas use is shown in Figure 2.

Figure 1 – Distribution of California Residential Electricity Consumption



Source RASS 2004, Lutzenhiser 2006

Figure 2 – Distribution of California Residential Natural Gas Consumption



Source RASS 2004, Lutzenhiser 2006

Table 1 – Consumption Patterns

Quartile	Electricity Consumption		Natural Gas Consumption	
	Average Usage	Percent of Total	Average Usage	Percent of Total
Mean	6050	n. a.	460	n. a.
First	2350	10	n. a.	10
Second and Third	3200-7500	43	n. a.	50
Fourth	11500	47	n. a.	40

Source RASS 2004, Lutzenhiser 2006

Lifestyle Factors

There is evidence that demographic factors such as lifestyle, income, and ethnicity play an important role in explaining variations in electricity and gas use in homes. Lutzenhiser (2006) presents information derived from the RASS data that shows variations in gas and electricity use as great as three to one. In this study of example groups, households made up of an older, high income, Anglo couple living in a single family home used an average of 9,725 kWh/year while households made up of a young, Hispanic couple with a child living in an apartment used an average of only 3,254 kWh/year. See Table 2 for other reference points.

Table 2 –Consumption Levels of Illustrative Lifestyle Groups

Lifestyle	Type	Income	Ethnicity	kWh	kWh ratio	Therms	Therms Ratio
YY+c	MultFam	$25-50K	Hispanic	3,254	.54	210	.46
S	SnglFam	<$25K	Anglo	4,685	.78	491	1.07
OO	Townhouse	$50-75K	Anglo	5,327	.88	344	.75
MM+c	SnglFam	$100-150K	Asian	5,920	.98	473	1.03
MM+c	SnglFam	$100-150K	Afr Amer	7,936	1.32	792	1.72
OO	SnglFam	$150K+	Anglo	9,725	1.61	522	1.14
Population Averages				6,030		460	

c – child 0-18 years; Y – young adult 19-34 years; M – medium age adult 35-54 years; O – older adult 55-64 years; S – senior 65+ years

Source: Lutzenhiser 2006

House Vintage

The age of the house is also a factor in explaining some of the variation. New homes use an average of 7,451 kWh/year while older homes use only 6,202 kWh/year. See Table 3 for more detail. This may seem counterintuitive since new homes need to meet stringent energy efficiency standards and older homes did not. Factors such as house size (new homes are larger on average than older homes), the saturation of energy using appliances, architectural style and complexity, and the concentration of older homes in the coastal regions – while newer homes are being built in hotter inland climates – are factors that probably contribute to this phenomenon.

Table 3 – Electric UECs by House Age

	New House		Old House	
	UEC	Saturation	UEC	Saturation
All Household	7,451	1,393 homes	6,202	19,760 homes
Conv. Eheat	1,171	0.05	864	0.09
HP Eheat	415	0.01	596	0.02
Aux Eheat	319	0.19	240	0.24
Furnace Fan	167	0.82	136	0.53
Central Air	1,468	0.77	1,264	0.39
Room Air	358	0.06	212	0.17
Evap Cooling	1,114	0.01	677	0.04
Water Heat	2,858	0.04	2,371	0.07
Solar Water Heater	.	0.00	1,345	0.00
Dryer	746	0.33	657	0.29
Clothes Washer	131	0.90	107	0.73
Dish Washer	84	0.92	76	0.60
First Refrigerator	763	1.00	791	1.00
Second Refrigerator	999	0.24	1,193	0.17
Freezer	861	0.19	940	0.18
Pool Pump	2,712	0.13	2,667	0.08
Spa	455	0.14	461	0.08
Outdoor Lighting	418	0.64	253	0.54
Range/Oven	316	0.41	260	0.42
TV	542	0.96	486	0.95
Spa Electric Heat	988	0.06	1,761	0.04
Microwave	137	0.98	133	0.95
Home Office	152	0.23	147	0.18
PC	580	0.84	564	0.68
Water Bed	762	0.03	823	0.01
Well Pump	858	0.04	849	0.04
Miscellaneous	1,820		1,833	

Note: Miscellaneous energy includes interior lighting which is estimated to be 60% of the miscellaneous total.

Source: RASS, including the climate dependent updates

Residence Type

The type of home is also a factor as shown in Table 4. Single family homes use an average of 7,538 kWh/year while town homes use 4,740 kWh/year and apartments use around 4,000 kWh/year. Some of this is related to house size and factors that would be addressed by a HERS rating. Other differences may be related to the demographic profile of occupants.

Table 4 – Electric UECs Calibrated and Normalized, by Residence Type

	Single Family		Town Home		2-4 Unit Apt		5+ Unit Apt		Mobile Home	
	UEC	Sat.	UEC	Sat.	UEC	Sat.	UEC	Sat.	UEC	Sat.
All Household	7,538	13,824 homes	4,740	1,780 homes	4,113	1,608 homes	4,036	3,377 homes	6,014	563 homes
Conv. Eheat	1,498	0.04	726	0.06	589	0.15	660	0.23	1,153	0.10
HP Eheat	1,076	0.01	394	0.01	316	0.02	340	0.05	1,034	0.03
Aux Eheat	296	0.28	114	0.21	85	0.19	74	0.13	298	0.31
Furnace Fan	162	0.68	73	0.54	65	0.32	51	0.26	118	0.58
Central Air	1,480	0.46	742	0.41	1,060	0.28	779	0.32	1,189	0.39
Room Air	270	0.15	176	0.14	143	0.16	125	0.22	270	0.34
Evap Cooling	757	0.05	654	0.02	411	0.02	443	0.02	590	0.27
Water Heat	3,079	0.05	1,723	0.04	1,657	0.09	1,567	0.10	3,258	0.17
Solar Water Heater	1,708	0.00	407	0.00	.	0.00	32	0.00	.	0.00
Dryer	713	0.34	591	0.32	429	0.17	548	0.17	549	0.42
Clothes Washer	127	0.95	63	0.76	62	0.37	14	0.26	11	0.86
Dish Washer	84	0.70	63	0.61	66	0.38	59	0.48	47	0.55
First Refrigerator	824	1.00	769	1.00	722	1.00	721	1.00	809	1.00
Second Refrigerator	1,245	0.25	739	0.11	700	0.06	586	0.04	1,143	0.13
Freezer	937	0.24	877	0.09	964	0.07	908	0.04	951	0.30
Pool Pump	2,671	0.14	.	0.00	.	0.00	.	0.00	.	0.00
Spa	467	0.13	270	0.03	.	0.00	.	0.00	180	0.03
Outdoor Lighting	284	0.67	173	0.56	228	0.32	206	0.25	232	0.56
Range/Oven	301	0.41	240	0.44	191	0.41	207	0.49	208	0.27
TV	519	0.96	465	0.92	439	0.92	436	0.96	457	0.93
Spa Electric Heat	1,719	0.07	694	0.02	.	0.00	.	0.00	3,550	0.02
Microwave	140	0.97	125	0.92	125	0.91	122	0.92	113	0.96
Home Office	148	0.20	158	0.19	145	0.17	144	0.15	121	0.13
PC	578	0.75	591	0.68	521	0.54	532	0.59	458	0.45
Water Bed	840	0.02	748	0.02	732	0.00	757	0.01	773	0.03
Well Pump	862	0.05	842	0.01	911	0.01	816	0.01	724	0.18
Miscellaneous	2,147		1,532		1,339		1,257		1,462	

Source: RASS, includes climate dependent updates

Task 2.1 – Modeling Assumptions

Modeling Assumptions Evaluated

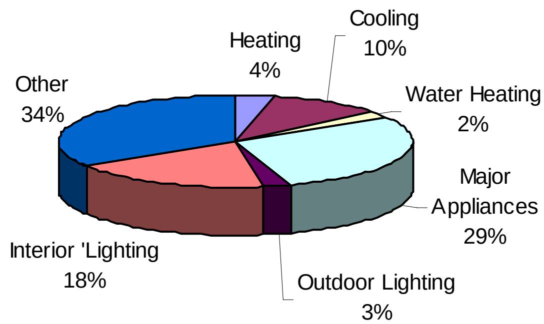
Lighting and Appliance Energy Use

Appliance energy use is not accounted for in California building performance calculations used for Building Energy Efficiency Standards compliance, except indirectly in the internal gain assumption (see below). The Residential Energy Services Network (RESNET), a non-profit industry membership organization, on the other hand considers energy use for major appliances. This section of the report evaluates incorporation of appliance energy use in building energy use modeling for California HERS ratings. For this analysis, lighting is considered separately from appliances.

RESNET includes indoor appliance and lighting energy in its estimate of end use load (EUL_{LA}). Credits are offered for energy efficient refrigerators and dishwashers because these are often provided by the builder and remain with the home when occupants move. Credit is not offered for an energy efficient clothes washer or dryer because they are much less likely to be provided by the builder and are more likely to be taken when occupants move. The RESNET energy use is estimated by an equation that includes a fixed amount of 18,842 Btu/d plus an additional 25.1 Btu/d for each square foot of conditioned floor area. It is not possible to separate the RESNET estimate among end uses or between electricity and gas. The RESNET assumption for internal gains (excluding occupant heat gain) is directly proportional to the energy use estimate (see below).

To put appliance and lighting energy use into perspective, Figure 3 shows the split of average electricity use for existing single family detached homes in California. In this figure, major appliances include the refrigerator, dishwasher, clothes washer, dryer, microwave, range/oven and when applicable a separate freezer or additional refrigerator. Other is everything else, including home offices, TVs, and miscellaneous other uses. Of note in reviewing this figure, the energy uses that are considered in energy efficiency standards performance calculations represent 16% of the total (heating, 4%; cooling, 10%; and water heating, 2%. Keep in mind, however, that the figure only shows electricity use and gas is the principal fuel in California for water heating and space heating. Likewise, the cooling average includes homes in mild climates and in older homes where the saturation of air conditioning is much lower than homes in hot, interior climate zones where central air conditioning is the norm in new homes.

Figure 3 – Average Electricity Consumption for California Single Family Homes



Source: RASS

Accurately considering appliance energy is important for HERS ratings because the energy models will better predict utility bills and it will cover the same energy uses as the RESNET HERS index.

The remainder of this section looks specifically at various types of appliances.

Refrigerator

The estimated annual energy consumption of new refrigerators is reported on the federal EnergyGuide label. Data on energy efficiency models are also reported as part of the EPA EnergySTAR program. Although appliance labeling for refrigerators started around 1980, consistent and comparative data is available primarily for refrigerators manufactured since the late 1980's.

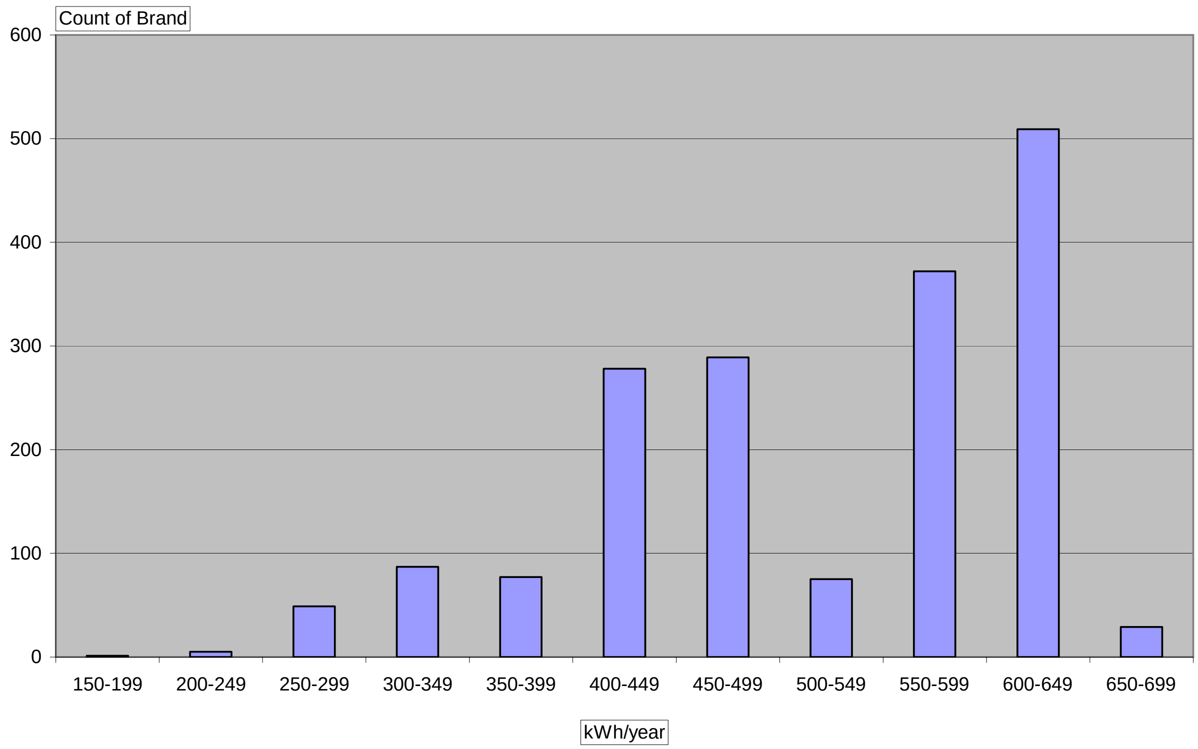
RESNET requires that refrigerator energy be considered in the calculations. The reference house annual consumption is assumed to be 775 kWh/year. Time of use is disregarded by RESNET, so a schedule of refrigerator energy use is not provided (note that refrigerator use is fairly constant over time). If a refrigerator is provided by the builder in the rated home, then the EnergyGuide labeled energy consumption of the installed refrigerator is used as the basis of an adjustment to the estimated annual energy load. All of the refrigerator energy use is assumed to contribute to internal gains and an adjustment to the RESNET internal gains is also made.

For comparison, the average electricity use for refrigerators as reported by the RASS data is 794 kWh/year and consumption tends to increase with house size, which is probably related to the size of the refrigerator. RASS data also indicates that many homes have a second refrigerator that tends to be less efficient. Its average use is 1,051 kWh/year, and about 25% of single family detached homes have a second refrigerator.

EnergySTAR labeled refrigerators are required to exceed federal standards by at least 20%. Figure 4 shows the number of EnergySTAR refrigerators in energy consumption bins ranging from a low of 150-199 kWh/year to 650-699 kWh/year. These products represent a range of sizes and configurations.. As of 12/18/2006, 1,771 refrigerator models were listed by EnergySTAR.

For refrigerators to be included in California HERS calculations, it will be necessary to assume an hourly schedule of operation. A reasonable assumption would be to assume continuous operation.

Figure 4 – Frequency Distribution of EnergySTAR Refrigerators

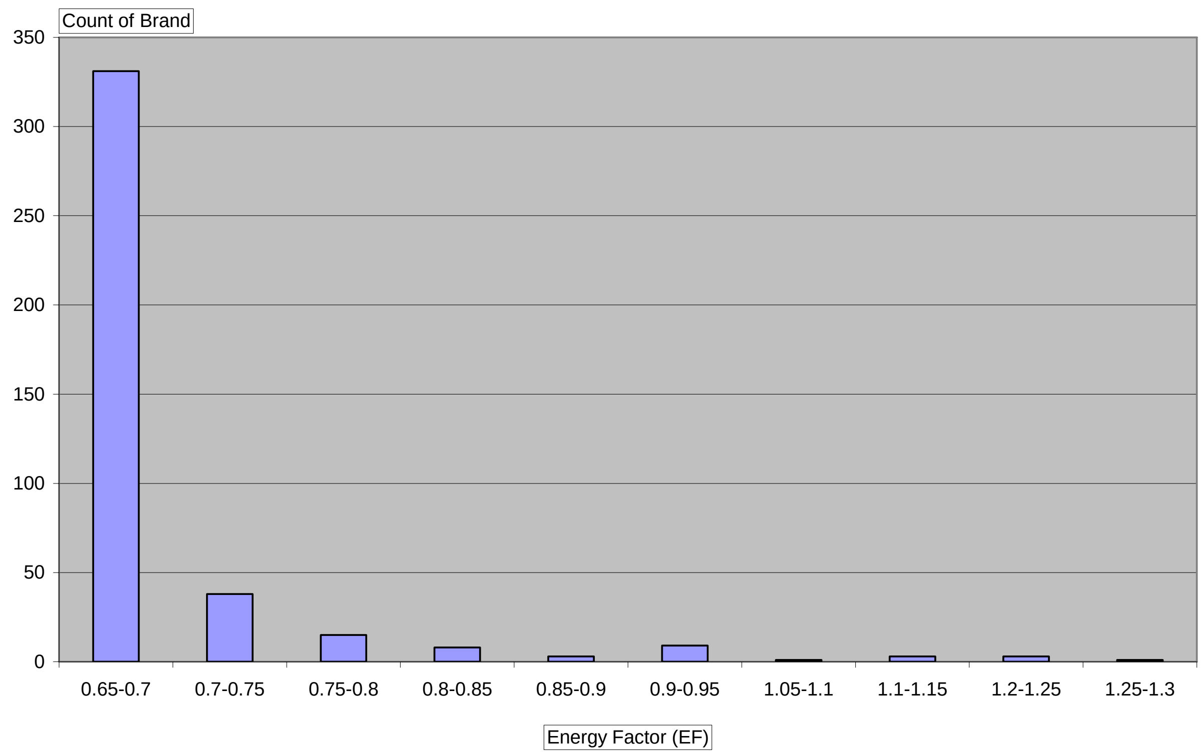


Source: EnergySTAR database December 2006

Dishwasher

Dishwashers are not included in California building standards energy performance calculations, except as a fixed component of the internal gain assumption. Like refrigerators, RESNET has a credit for dishwashers, which is based on the energy factor (EF) of the equipment. The EF, as shown on the EnergyGuide label represents the number of complete cycles that a dishwasher will can perform while using one kilowatt-hour of electricity. EnergySTAR® dishwashers are required to have an energy factor (EF) approximately 25% better than federal standard, which is 0.46. Figure 5 shows a frequency distribution of EnergySTAR dishwashers.

Figure 5 – Frequency Distribution of EnergySTAR Dishwashers



Source: EnergySTAR.gov, December 2006

Most of the energy used by dishwashers is actually the energy required for heating the water they consume. An efficient dishwasher uses less water to do the job. Virtually all dishwashers available today use booster heaters to further heat the water supplied by the water heater to the higher temperatures required for dishwashing. RESNET makes the assumption that 27% of the estimated annual energy for a dishwasher is actually used by the dishwasher motor and its booster heater. The remaining 73% is assumed to be used by the associated water heater.

Using these factors, the RESNET electricity consumption of the dishwasher, excluding the energy used by the associated water heater is given below[1]:

Equation 1

$$\text{EnergyUse(kWh / y)} = 0.27 \times \frac{\text{Cycles / year}}{\text{EnergyFactor}}$$

The assumed energy consumption for the RESNET reference house dishwasher depends on the number of bedrooms and is shown in Table 5 below. RESNET estimated dishwasher energy consumption for the reference home is based on the minimum federal standard energy factor of 0.46.

1 Note that these assumptions of a fixed split between water heater energy and dishwasher energy do not offer any credit for dishwashers that are designed to use less water to do the job. Such a dishwasher would save on the 73% as well as the 27%.

Table 5 – RESNET Reference Home Dishwasher Assumptions

Bedrooms	Cycles/year	Reference Dishwasher kWh/year
1	154	90
2	214	126
3	247	145
4	296	174
5 or more	345	203

When a builder installs a dishwasher, an adjustment is made to the RESNET annual energy use based on the difference between the reference house dishwasher kWh (shown in Table 5). An adjustment is also made to the RESNET internal gains assumption, based on 60% of the electricity use of the dishwasher contributing to internal gains (the remainder would be used to boost the water temperature and would go down the drain).

Average dishwasher consumption as reported by RASS is 77 kWh/year, which is considerably lower than the RESNET estimates shown in Table 5. Considering dishwasher energy use in the California HERS program will require that a schedule of operation be identified. See the discussion later on schedules of operation.

Clothes Washer

RESNET does not offer a credit for energy efficient clothes washers even though they carry the EnergyGuide label and are covered by the EnergySTAR program. The reason for this is that it is assumed that the clothes washer moves with the occupants (i.e., it is not an appliance that is likely to be left with the home when the occupant moves, like the refrigerator and dishwasher).

US EPA Statement on Clothes Washers

Compared to a model manufactured before 1994, an EnergySTAR qualified clothes washer can save up to $110 per year on your utility bills, according to EnergySTAR. Earning the EnergySTAR label means a product meets energy efficiency guidelines set by the US Environmental Protection Agency and the US Department of Energy.

Through superior design and system features, ENERGY STAR qualified clothes washers clean clothes using 50% less energy than standard washers. The Modified Energy Factor (MEF) measures the energy used during the washing process, including machine energy, water heating energy, and dryer energy. The higher the MEF, the more efficient the clothes washer is.

RASS data indicates that the average clothes washer uses about 98 kWh/year. However, there appears to be a relationship between energy use and dwelling unit size reflected in the RASS data.

Clothes Dryer

Like clothes washers, RESNET does not offer a credit for energy efficient clothes dryers, because of the same reasons. .To deal with clothes dryers in the California HERS program, it would be necessary to know if the dryer is gas or electric and to assign a schedule of usage. RASS data indicates that 34% of single family and 32% of town homes have electric clothes dryers. 50% of single family and 32% of town homes have gas dryers. Average use for electric dryers is 653 kWh/year and the single-family average use for gas dryers is 31 therms/year. Gas dryers also use electricity, but it is not possible to determine what this is from the publicly available RASS data. Energy consumption of both electric and gas clothes dryers increases with house size in the RASS database.

Range/Oven

All homes have some type of cooking appliance. However, it can be either gas or electric and this is a factor that needs to be accounted for in the California HERS rating, since the choice affects Time Dependent Value (TDV) energy. RASS data indicates that the average electric oven/range uses 272 kWh/year and the average gas oven/range uses 44 therms/year. 66% of California single family homes have gas oven ranges and 41% have electric. Some homes have both gas and electric and were counted twice in the RASS survey. The energy use of both gas and electric oven/ranges scales with house size but the correlation is not strong.

Ceiling Fans

The energy use from ceiling fans is not included in California Building Energy Efficiency Standards calculations. RESNET includes a procedure for modeling ceiling fans and taking credit for fans that have a Labeled Ceiling Fan Standardized Watts (LCFSW) below that assumed for the reference house. (see RESNET 303.4.1.7.5). RASS does not report specifically on the energy use of ceiling fans, but data indicates that 45% of homes do not have one; 23% have one; 12% have two; and 17% have three or more. There is some variation by climate zone, but no immediate pattern emerges.

Lighting

California residential Building Energy Efficiency performance calculations do not include lighting energy. Lighting is addressed in the California Standards as a mandatory measure in §150(k). Lighting energy, however, is considered as one component in the standard assumption for California internal gains.

RESNET offers a credit for efficient lighting, based on a count of high efficiency luminaires. Annual energy use in the reference house is assumed to be 455 kWh plus 0.80 kWh/ft^2 of conditioned floor area. RESNET assumes that 90% of this is interior lighting and results in internal gain to affect the heater and the air conditioner. The remaining 10% is assumed to be outdoor lighting. RASS data indicates that outdoor lighting is 13% of the total lighting for single family homes and mobile homes. It is 10% for townhouses, 8% for 2-4 unit apartments and 6% for 5+ unit apartments. The RESNET equations are simple to implement, but do not account for installed power of qualifying or non-qualifying lighting fixtures.[2] RESNET does not specify an hourly schedule of lighting operation. Annual RESNET lighting energy estimates for the reference house and the rated house are shown in the Equation 2 below. RESNET offers a credit for savings in interior lighting based on the percent of "qualifying" lighting fixtures. RESNET qualifying lighting fixtures include (1) pin based fluorescent, (2) screw-in fluorescent, or (3) other fixtures controlled by a photocell and motion sensor. Qualifying fixtures must be hardwired (not plug in lamps). Qualifying fixtures exclude fixtures in closets, unfinished basements and landscape lighting.

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2 See the 2006 Mortgage Industry National Home Energy Rating Systems Standards.

Equation 2

$$\text{LightingEnergy}(\text{kWh}/\text{y})_{\text{Reference}} = 455 + 0.8 \times \text{CFA}$$

$$\text{LightingEnergy}(\text{kWh}/\text{y})_{\text{Rated}} = (455 + 0.8 \times \text{CFA}) + (29.5 - 0.5189 \times \text{CFA} \times \text{FL\%} - 295.12 \times \text{FL\%} + 0.0519 \times \text{CFA})$$

The RASS data also provides estimates of residential lighting energy. RASS provides a separate estimate for outdoor lighting, but interior lighting is combined with miscellaneous electricity. The RASS reports, however, indicate that interior lighting represents approximately 60% of the miscellaneous electricity use. Based on this information, Equation 3 may be used to produce estimates consistent with the RASS data.

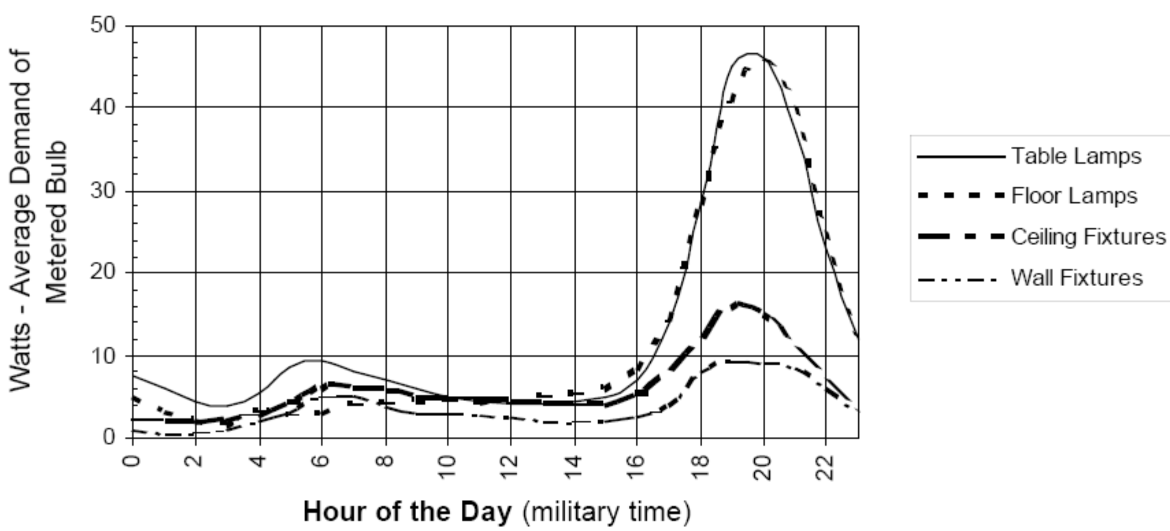
Equation 3

$$\text{LightingEnergy}(\text{kWh}/\text{y})_{\text{Interior}} = 214 + 0.601 \times \text{CFA}$$

$$\text{LightingEnergy}(\text{kWh}/\text{y})_{\text{Exterior}} = -81 + 0.152 \times \text{CFA}$$

A third source of data on residential lighting use is the Lighting Efficiency Technology Report prepared for the Energy Commission in 1999[3]. This document identifies average electricity use of 2,076 kWh/year for single family homes and 1,084 kWh/year for multi-family dwelling units. This report also provides an hourly schedule of residential lighting use, separated by fixture type. See Figure 6. It also has estimated hours of daily lighting use. See Table 6.

Figure 6 – Load Shape for Residential Fixtures



Source Lighting Efficiency Technology Report, September 1999

3 Lighting Efficiency Technology Report, Volume I, California Baseline, CEC, September 1999, HMG.

Table 6 – Lighting Applications from California Lighting Model[4]

ID	Name of Lighting Application	DayHours	AnnualHours	Lumens
1	Ceiling Surface, Utility	2.4	859	1,320
2	Ceiling Surface, Bath	1.8	673	1,499
3	Ceiling Surface, Bedrooms	1.2	447	1,522
4	Ceiling Surface, Garage	2.7	973	3,430
5	Ceiling Surface, Hall	2.2	803	986
6	Ceiling Surface, Kitchen/Dining	3.5	1,277	1,918
7	Ceiling Surface, Living	2.6	959	1,781
8	Ceiling Recessed, Bath	1.7	603	2,920
9	Ceiling Recessed, Hall	1.7	638	1,149
10	Ceiling Recessed, Kitchen	3.7	1,346	4,299
11	Ceiling Recessed, Living	2.0	726	1,875
12	Ceiling Suspended, Bedroom	1.0	376	1,410
13	Ceiling Suspended, Garage	1.8	648	4,629
14	Ceiling Suspended, Kitchen/Dining	3.0	1,087	2,155
15	Ceiling Suspended, Living	1.9	685	1,702
16	Ceiling Suspended, Utility	3.6	1,317	2,231
17	Ceiling, Yard	3.0	1,105	1,385
18	Wall Mounted, Utility	2.8	1,027	1,049
19	Wall Mounted, Bath	2.2	816	1,747
20	Wall Mounted, Bedroom	2.9	1,054	982
21	Wall Mounted, Garage	2.4	889	1,335
22	Wall Mounted, Yard	3.0	1,085	1,309
23	Table Lamp, Bedroom	1.2	441	1,050
24	Table Lamp, Den	1.8	659	1,277
25	Table Lamp, Living	2.8	1,005	1,248
26	Floor Lamp, Bedroom	1.2	428	2,079
27	Floor Lamp, Living	2.6	935	2,122
28	Undercabinet, Kitchen	2.2	798	804
29	All Other, Indoor	2.8	1,034	1,455
30	All Other, Yard	4.2	1,537	1,489

Magnitude of Internal Gains

The Energy Commission modeling rule for internal gains is to assume 20,000 Btu/d plus 15 Btu/d-ft^2 of conditioned floor area[5]. The RESNET modeling rule is to assume 17,900 Btu/d plus 23.8 Btu/d-ft^2

4 Lighting Efficiency Technology Report, Volume I, California Baseline, CEC, September 1999, HMG.

and 4,140 Btu/d-bedroom. The Commission modeling assumption was developed in the late 1980's.[6] These modeling rules are published in the 2005 Residential Alternative Calculation Method (ACM) Approval Manual for the Building Energy Efficiency Standards.

The RESNET modeling assumption is based on monitored data for a set of homes in Florida analyzed by the Florida Solar Energy Center (FSEC) during 1999 and 2000 (See http://www.fsec.ucf.edu/~pfairey/igain/). The RESNET internal gains assumption includes an additional term for number of bedrooms which is intended to represent the heat load from people.[7] The RESNET equation is as follows:

Equation 4

$$InternalGains_{Reference} = 17900 + 23.8 \times CFA + 4140 \times NumberBedrooms$$

For the rated house, the internal gains are adjusted to account for energy efficient refrigerators, dishwashers and/or lighting. See discussion above.

When the Energy Commission and RESNET predictions are compared to each other and to information collected through the RASS, the RESNET estimate is on the order of 15% to 20% higher than what would be indicted by the RASS while the ACM estimate is 20% to 30% lower than RASS based estimates. In comparing RESNET and California, the differences are greatest for homes with many bedrooms and smallest in studio apartments with no bedrooms. This is related to the term in the RESNET equation for number of bedrooms that is not present in the ACM equation. This number of bedrooms term is intended to be a proxy for the number of occupants in the house.

Internal Gains Schedules

The ACM schedules for internal gains are shown in Figure 7. The load curve shows two distinct peaks, one in the morning and one in the evening. This tracks a common pattern in California where most of the activity in the home occurs before and after the workday and the school day, and less activity occurs during the middle of the day. The low is about 3:00 PM and 5:00 AM in the morning. The ACM gives separate schedules for the living and sleeping areas when zonal control is modeled for the house. The ACM also assumes seasonal variations in internal gains as shown in Figure 8. More gains are assumed to occur in the winter and less in the summer.

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5 The technical basis of this assumption is documented in the "Assumptions and Algorithms" report prepared by Eley Associates, June 1988. Prior to 1988, the standard assumption for internal gains was a constant 86,991 Btu/d for single-family and 72,665 Btu/d for multi-family.

6 Algorithms and Assumptions, Volume II, Appendix H, June 1988, Eley Associates

7 The 4,140 Btu/d number is derived by assuming that there is one occupant in the home for each bedroom, that they are present in the house for 18 hours each day and that they generate 230 Btu/h of sensible heat gain.

Figure 7 – ACM Hourly Schedules for Internal Gains – People, Lighting and Equipment

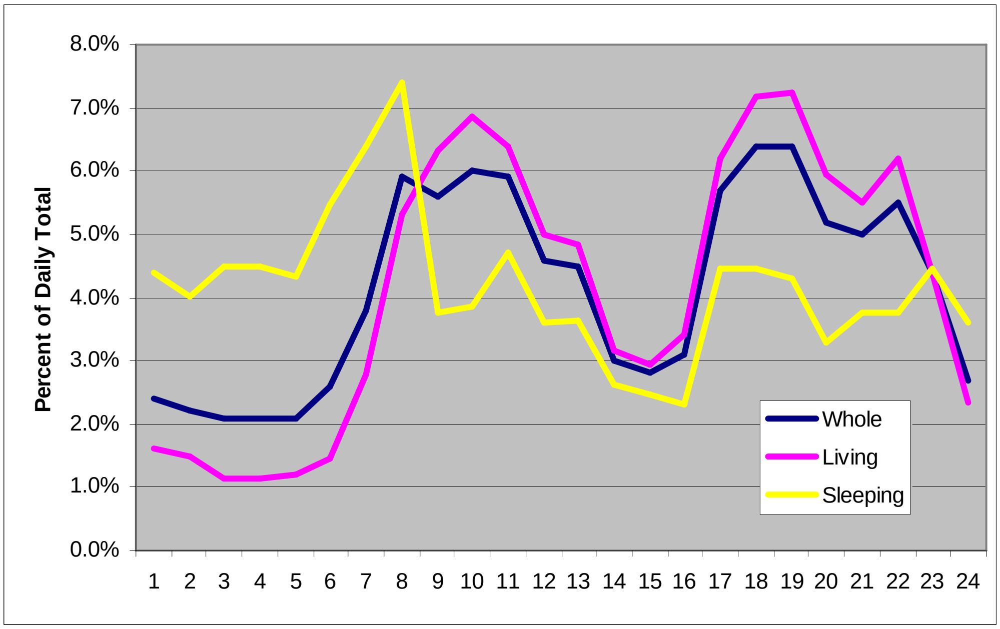
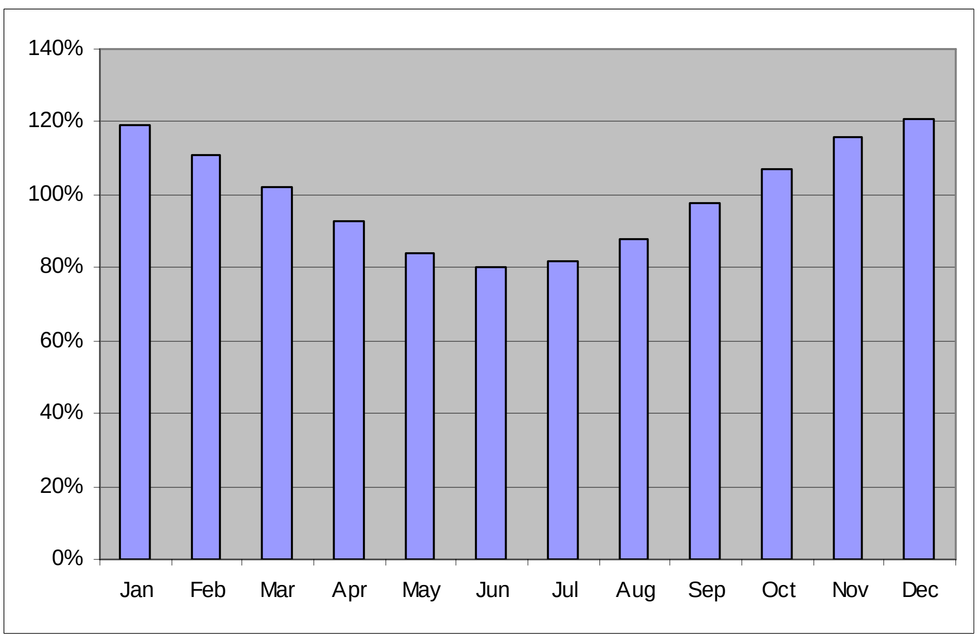
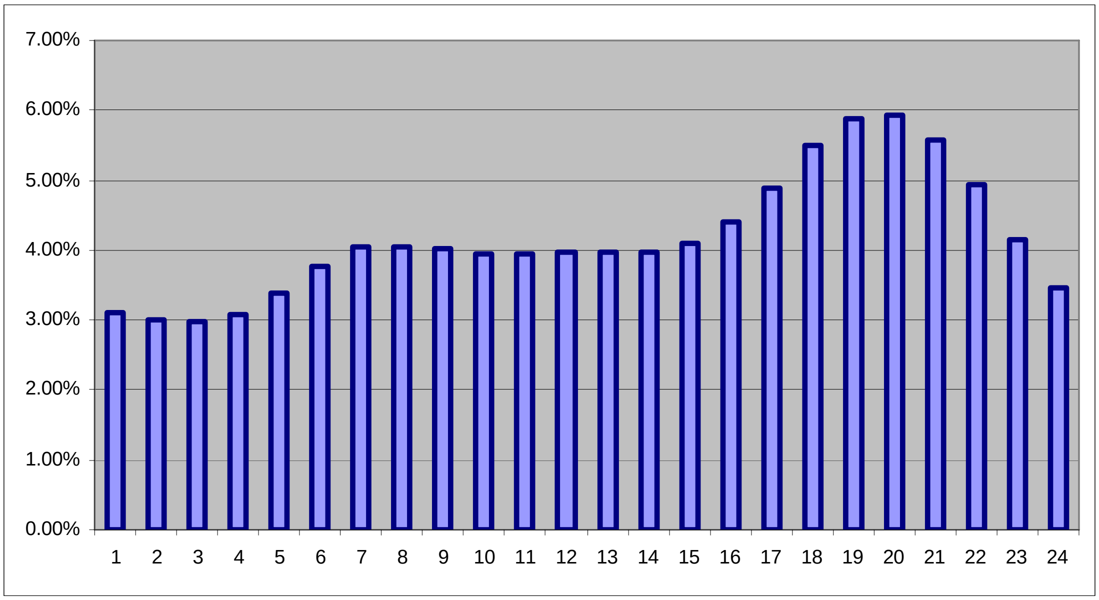


Figure 8 – Seasonal Multipliers for ACM Hourly Internal Gain Schedules – People, Lighting, and Equipment



RESNET does not specify a schedule for internal gains. However, the research paper for the set of Florida homes, which is the basis of the RESNET data, does have a schedule. See Figure 9 and also http://www.fsec.ucf.edu/~pfairey/igain/. This schedule does not include the internal loads for people. It only includes internal loads for equipment, including electricity for refrigerators, lighting, appliances and miscellaneous energy use. The peak is in the evening around 8 PM. Energy use (internal gains) is fairly constant during the day and there is a drop at night. Notice that the equipment use for this set of Florida homes was lowest in the morning, increased to a new level through the middle of the day and then peaked at night. This may be due to a more constant pattern of occupancy for the set of Florida homes than is expected for California.

Figure 9 – Florida Schedule of Internal Gains – Lighting and Equipment Only

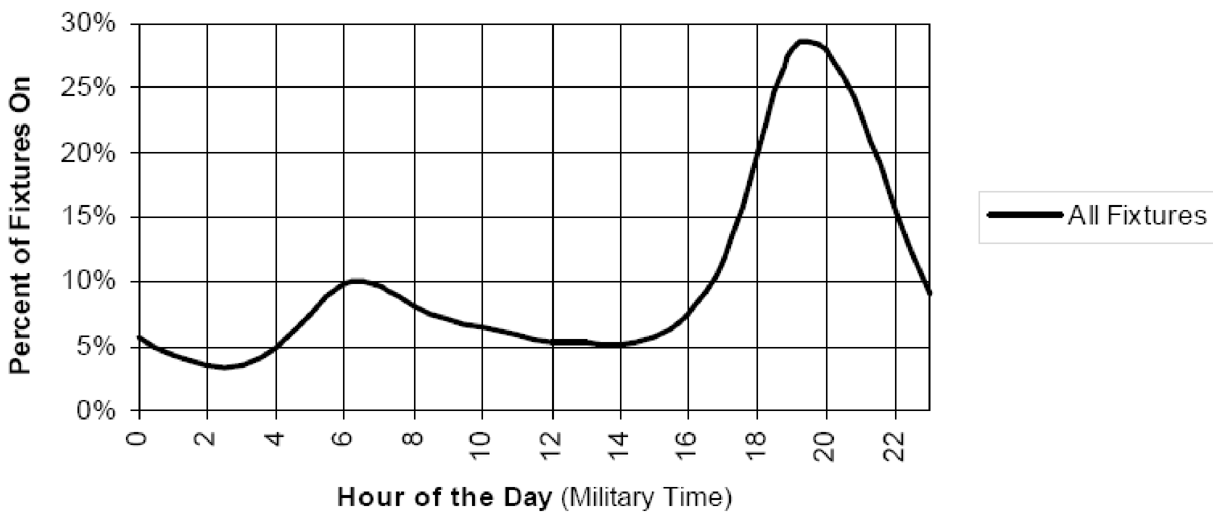


Source: FSEC Research Paper http://www.fsec.ucf.edu/~pfairey/igain/

A third schedule, which applies solely to interior residential lighting, is provided by the Energy Commission Lighting Efficiency Technology Report.[8] The figure shown in Figure 10 combines the curves in Figure 6, which are shown form different fixture types. This curve shows primary use in the early evening, with use tapering off rapidly after about 8 PM. There is also a smaller peak in the morning prior to the beginning of the work/school day.

[8] Lighting Efficiency Technology Report, Volume I, California Baseline, CEC, September 1999, HMG.

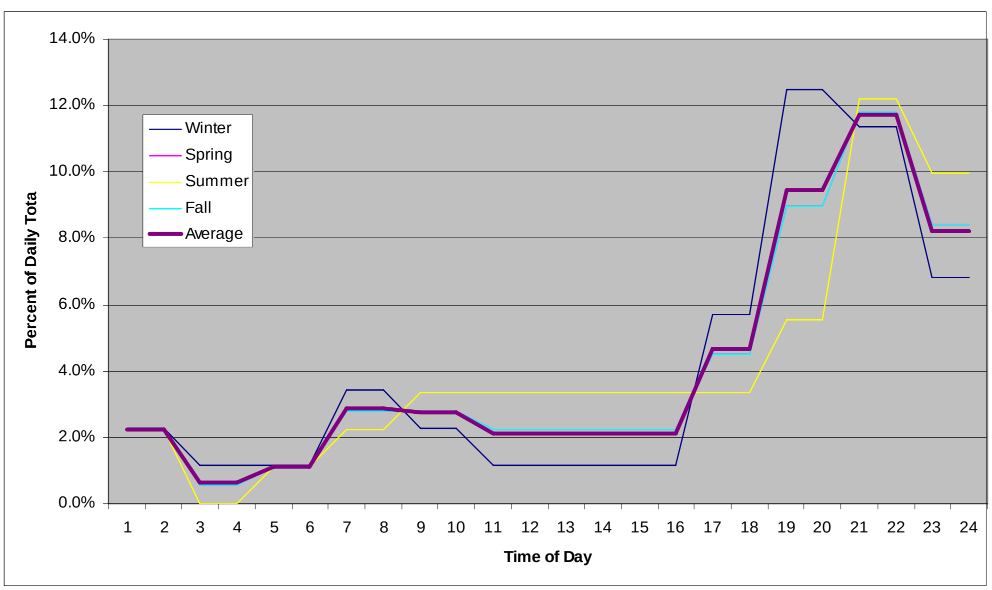
Figure 10 – Diversity Profile of Residential Lighting Fixtures



Source: Lighting Efficiency Technology Report, September 1999

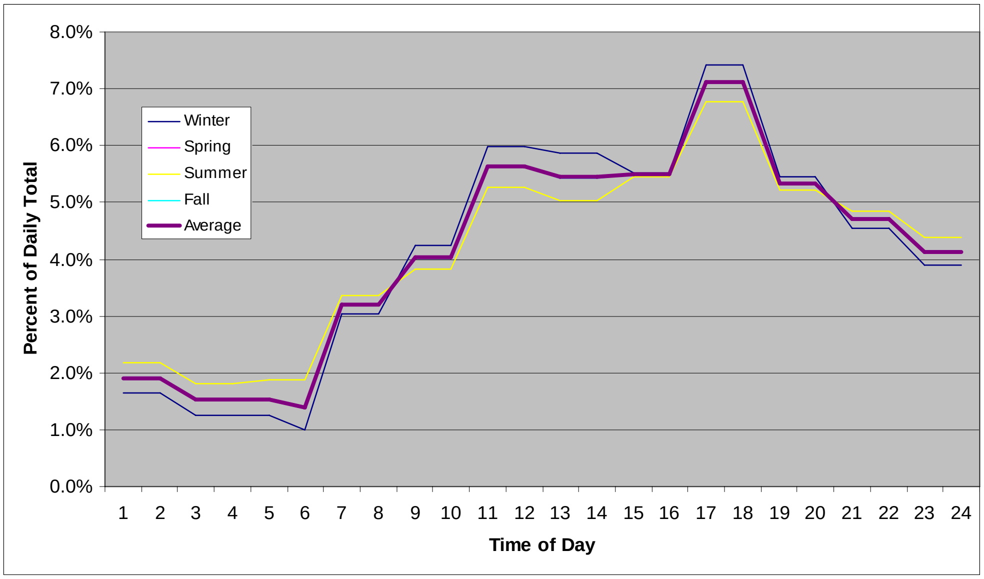
Research supporting Energy Commission standards development activity in 1980 is a final source of schedule information on lighting and miscellaneous equipment schedules. Figure 11 has the schedule for residential lighting. This curve is quite similar to the 1999 California lighting data shown in Figure 10. Figure 12 shows an hourly schedule for non-lighting residential equipment.

Figure 11 – 1980 Energy Commission Residential Lighting Schedule



Source: Assumptions Used with Energy Performance Computer Programs, CEC Project Report No. 7, June 1980

Figure 12 – 1980 Energy Commission Residential Equipment Schedule



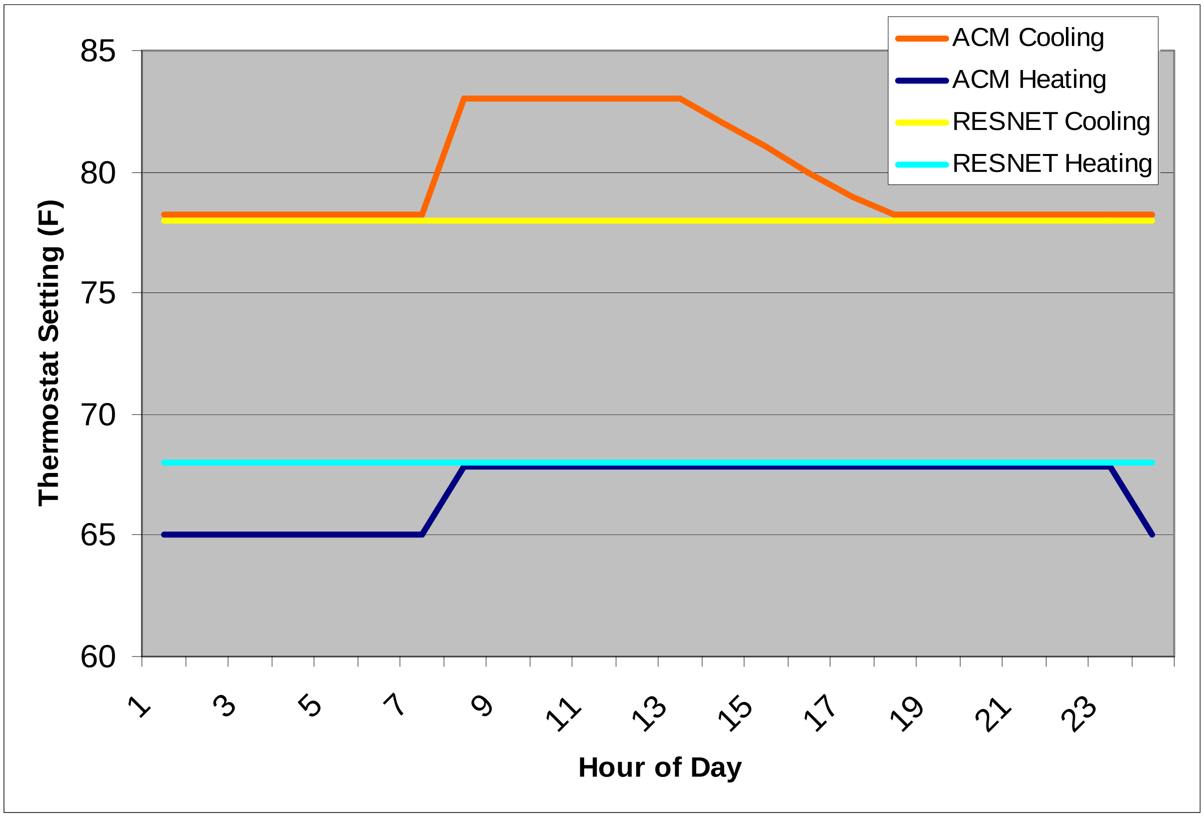
Source: Assumptions Used with Energy Performance Computer Programs, CEC Project Report No. 7, June 1980

Thermostat Settings and Schedules

Figure 13 compares the thermostat settings for California and RESNET. RESNET assumes a constant heating setpoint of 68 F and a constant cooling setpoint of 78 F. California uses the same values except during periods of setup and setback. The cooling setpoint is set up to 83 F during the day and ramps back to 78 F in the early evening. California also sets back the heating setpoint to 65 F at night. The cooling setup schedule was introduced in conjunction with the 2001 update to the California energy efficiency standards to have cooling energy predicted by compliance models in better agreement with utility system use patterns for residential air conditioning.

RESNET section 303.5.1.2 allows the heating setpoint to be setback 2 F between 11 pm and 6 am and the cooling setpoint to be set up 2 F between 9 am and 3 pm when the rated house has a programmable thermostat. Therefore, RESNET gives credit for a programmable thermostat, which is a mandatory measure with the California standards. The RESNET reference house is assumed to have a constant heating setpoint of 68 F and a constant cooling setpoint of 78 F.

Figure 13 – RESNET and California ACM Thermostat Assumptions



Water Heaters

Consumption

The Title 24 assumption for hot water consumption is shown in the equation below (Equation RG-9 of the residential ACM manual).

Equation 5

$$GPD = 21.5 + 0.014 \times CFA$$

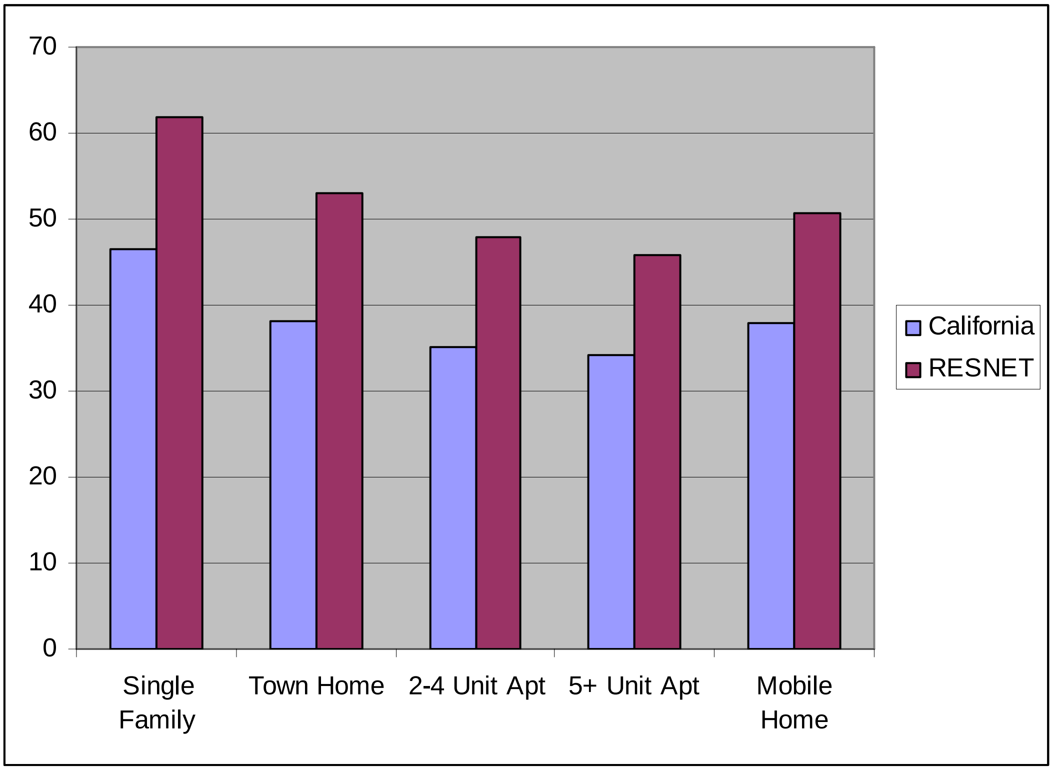
The RESNET assumption is based on the number of bedrooms, instead of conditioned floor area and is shown below.

Equation 6

$$GPD = 30 + 10 \times BR$$

The RESNET water heating assumption is on the order of 33% to 40% higher than California. See Figure 14.

Figure 14 – RESNET vs. California Hot Water Consumption

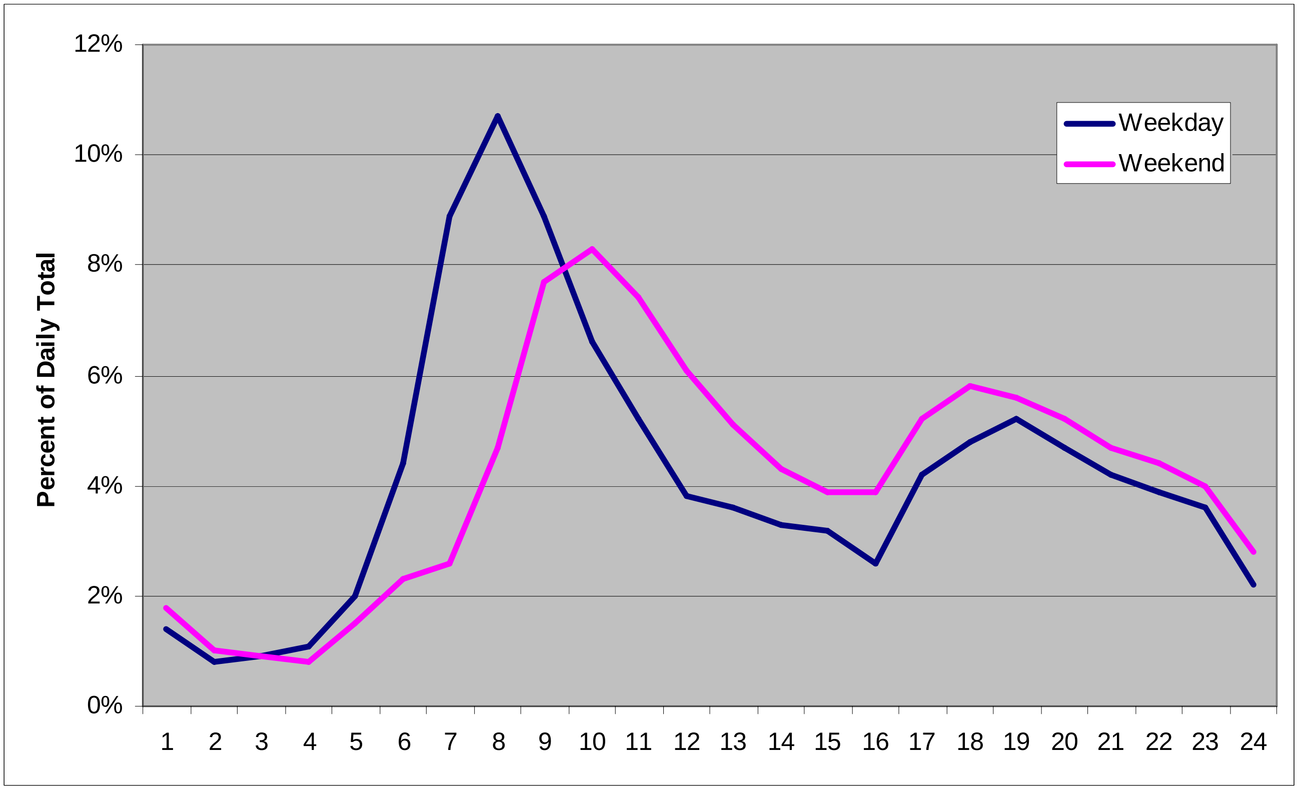


Vertical axis is gallons per day.

Schedules

RESNET does not specify an hourly schedule for hot water consumption. California specifies separate schedules for weekdays and weekends as shown in Figure 15.

Figure 15 – California Hourly Hot Water Consumption Schedules



Location (Within Conditioned Space)

Neither California nor RESNET specify the location of the water heater. Modern codes require venting of gas appliances so in new homes the water heater is typically located in the garage or other unconditioned space. In older homes, the water heater may be located in conditioned space, and as a result, its operation could affect infiltration.

Distribution System

The California standards consider the distribution system for hot water. The concept of distribution system multipliers (DSM) is used. These are adjustments to account for energy losses through the distribution system. See ACM2005 RG3.2.1.

On-Site Power Production

California compliance calculations offer no credit for photovoltaics or other forms of on-site power production. RESNET does through the "Purchased Energy Fraction" of the rated home. RESNET does not offer any direction of the types of PV calculations to make (see RESNET 303.4.1.8). The California New Solar Homes Partnership (NSHP) program has procedures for calculating the power production of PV systems.

Mechanical Ventilation

Mechanical ventilation is not modeled in 2005 Title 24. However, proposed updates to the 2008 standards include mechanical ventilation as a mandatory measure that will be modeled in both the proposed design and standard design homes.

Infiltration

California ACM models for air infiltration use the Sherman-Grimsrud method. The assumed specific leakage area (SLA) values are shown in Table 7 for the 2005 and 2008 standards. The 2005 default SLA values are used for all vintages of existing homes. When the proposed design has a qualifying air retarding building wrap, the SLA in the proposed design can be reduced by 0.5. With the 2005 standards, lower values may be used when the building envelope is diagnostically tested, but when an SLA lower than 3.0 is used, the house must have a qualifying mechanical ventilation system and the energy of that system has to be accounted for in the proposed design, but not the standard design. Mechanical ventilation is a mandatory measure with the 2008 standards. Diagnostic testing of air leakage is rarely used in California, in part because of the limited credit available (builders can get most of the credit from just using a building wrap). A leakage area substantially higher than 4.9 may occur for some older homes, but the ACM vintage table sets the SLA at 4.9 for all homes. Changes to these requirements are being proposed for the 2008 update to the California energy efficiency standards and are related to the mandatory requirements for mechanical ventilation.

RESNET uses a similar procedure to model infiltration, although the default is slightly different (4.8 instead of 4.9)[9]. A value lower than the default may be used for the rated house when the effective leakage area is determined through a blower door test. The procedure for performing the test is specified under Blower Door Test in RESNET Appendix A. For the purpose of sizing mechanical equipment, RESNET uses an air-changes-per-hour (ACH) method, as specified in 303.5.1.5.1.3.

Table 7 – Default Infiltration Rates (SLA)

Case	2005 Standards	2008 Standards
Unsealed ducts	4.9	4.3
Sealed ducts	4.4	3.8
No ducts	3.8	3.2
Note: To use the 4.4 SLA value for existing ducts, they shall be tested to a leakage of 6%.		

Natural Ventilation

Natural ventilation is modeled in the California performance calculations as the first cooling strategy. When natural ventilation can't maintain comfort conditions, an air conditioner is assumed

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[9] Note SLA in the ACM is defined as the leakage area per 10,000 ft^2 of floor area while in RESNET, SLA is defined with the same units for both the leakage area and the floor area. Therefore, RESNET gives its default value as 0.00048 where California states its default as 4.9.

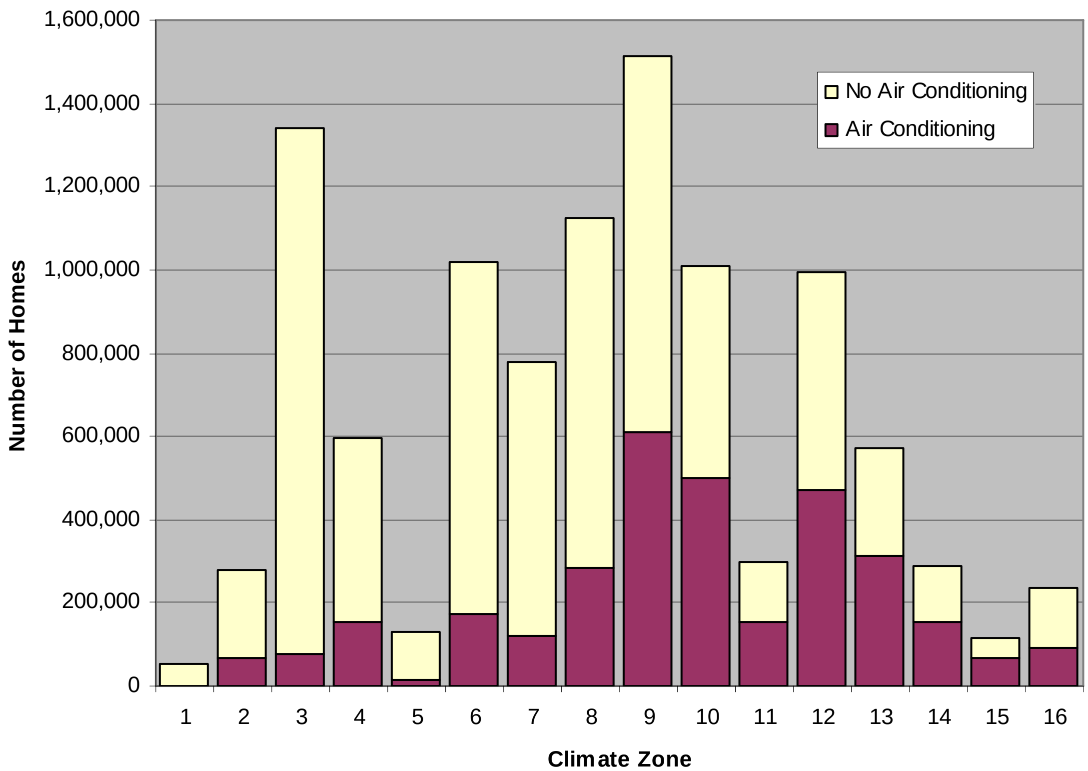
to operate. The free ventilation area in the proposed design is a function of the number and type of windows used. Sliding windows are assumed to have a free vent area of 10% of the rough frame opening, hinged windows 20% and fixed windows zero. The default free ventilation area is 10% of the window area. The default height difference between the inlet and the outlet is 2 ft for single story houses and 8 ft for multi-story houses. Natural ventilation is modeled using a combination of wind and stack effects. Natural ventilation is assumed to be unavailable between 11 pm and 5 am.

RESNET also assumes that windows operate when they can provide cooling.

Heated-Only Homes

Most existing homes in California are not air conditioned. Figure 16 shows the number of homes in each of the California climate zones and the bars indicate the number that are air conditioned vs. those that are not. Table 8 gives percentages. RESNET as well as California Standards compliance calculations assume that homes are always air conditioned for the purpose of calculating the rating or for determining compliance. Assuming air conditioning in homes that are not cooled could result in part of the discrepancy between utility bills and estimates produced by HERS tools.

Figure 16 – Air Conditioning Use in Existing California Homes



Source: RASS. Note the air conditioning cases include both central air conditioning and one or more room air conditioners.

Table 8 – Air-Conditioning Use in Existing California Homes

Climate Zone	Air-Conditioning	No Air-Conditioning
1	1%	99%
2	24%	76%
3	6%	94%
4	26%	74%
5	10%	90%
6	17%	83%
7	16%	84%
8	25%	75%
9	40%	60%
10	49%	51%
11	52%	48%
12	47%	53%
13	55%	45%
14	54%	46%
15	57%	43%
16	39%	61%

Parametric Study of Space Conditioning Modeling Assumptions

This section of the report describes a series of parametric variations of the modeling assumptions for space conditioning. Background information related to these modeling assumptions is presented in the previous section. The purpose of doing the parametric variations is to be able to evaluate possible modifications to the modeling assumptions that would make them more appropriate for older, existing buildings. These parametric variations only address space conditioning energy.

The parametric modeling simulations were performed using the building energy software program EnergyPro based on 2005 standards approved modeling assumptions.

Description of Variations

Prototype Buildings

Four prototype buildings were used in the analysis. These are described below.

Table 9 – Description of Prototype Buildings Used for Parametric Variations

	Apartment	SF-Large	SF-Small	Townhouse
Floor Area	780	2,700	1,500	1,400
Glass Area	71	357	172	183.3
Glass to Floor Area Ratio	9.1%	13.2%	11.5%	13.1%
Wall Area	507	2,861	1,429	1,663
Glass to Wall Area Ratio	14.0%	12.5%	12.0%	11.0%
HVAC	Gas/electric split system	Gas/electric split system	Gas/electric split system	Gas/electric split system
North Wall Area	208	720	309	396
glass	24	124	14	52.3
door	20	20	21	40
East Wall Area		522	309	612
glass		77	60	75
South Wall Area	208	720	309	333
glass	47	78	17	56
West Wall Area		522	309	99
glass		78	81	0
Slab		1,250	1,500	715
Floor Over Garage		200		
Attic Area	780	1,450	1,500	715
Bedrooms	1	5	3	2
General Description	See "Residential Housing Starts and Prototypes", Nittler, March 27, 2006	See "Residential Housing Starts and Prototypes", Nittler, March 27, 2006	Scaled down version of the 2,100 one story prototype. See "Residential Housing Starts and Prototypes", Nittler, March 27, 2006.	

House Age or Era (Energy Efficiency Measures)

Three sets of energy efficiency measures were modeled for each prototype representing homes built before 1978, homes built between 1979 and 1991, and homes built since 1992. These are shown in Table 10.

Table 10 – Assumptions on Era and Energy Efficiency Measures

Insulation U-Factor	Before 1978	1979-1991	1992 and Later
Roof	0.079	0.049	0.049
Wall	0.356	0.110	0.102
Raised Floor w/crawl	0.099	0.099	0.046
Raised Floor w/out crawl	0.238	0.238	0.064
Framing-Factor	0.73	0.730	0.730
Ducts	R-2.1	R-2.1	R-4.2
Fenestration	Single glazing in metal frame	Double glazing in metal frame	Double glazing in metal fram
U-Factor	1.28	0.79	0.79
SHGC	0.80	0.70	0.70
Central Furnace AFUE	0.75	0.78	0.78
Heat Pump HSPF	5.6	6.6	6.6
Cooling SEER	8.0	8.9	9.7

The energy efficiency parameters in Table 10 are a consolidation of the more detailed "vintage table" from the residential ACM manual. See Table 11.

Table 11 – Default Assumptions for Existing Buildings

Conservation Measure		Default Assumptions for Year Built (Vintage) Before 1978	1978 to 1983	1984 to 1991	1992 to 1998	1999 -2000	2001-2003	2004-2005	2006 and Later
INSULATION U-FACTOR									
Roof		0.079	0.049	0.049	0.049	0.049	0.049	0.049	0.049
Wall		0.356	0.110	0.110	0.102	0.102	0.102	0.102	0.102
Raised Floor –CrawlSp		0.099	0.099	0.099	0.046	0.046	0.046	0.046	0.046
Raised Floor-No CrawlSp		0.238	0.238	0.238	0.064	0.064	0.064	0.064	0.064
Slab Edge	F-factor =	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
Ducts		R-2.1	R-2.1	R-2.1	R-4.2	R-4.2	R-4.2	R-4.2	R-4.2
LEAKAGE									
Building (SLA)		4.9	4.9	4.9	4.9	4.9	4.9	4.9	4.9
Duct Leakage Factor (See Table 4-13)		0.86	0.86	0.86	0.86	0.86	0.89	0.89	0.89
FENESTRATION									
U-factor		Use Table 116-A - Title 24, Part 6, Section 116 for all Vintages							
SHGC		Use Table 116-B - Title 24, Part 6, Section 116 for all Vintages							
Shading Device		Use Table R3-7 for all Vintages							
SPACE HEATING EFFICIENCY									
Gas Furnace (Central)	AFUE	0.75	0.78	0.78	0.78	0.78	0.78	0.78	0.78
Gas Heater (Room)	AFUE	0.65	0.65	0.65	0.65	0.65	0.65	0.65	0.65
Heat Pump	HSPF	5.6	5.6	6.6	6.6	6.8	6.8	6.8	7.4
Electric Resistance	HSPF	3.413	3.413	3.413	3.413	3.413	3.413	3.413	3.413
SPACE COOLING EFFICIENCY									
All Types,	SEER	8.0	8.0	8.9	9.7	9.7	9.7	9.7	12.0
WATER HEATING									
Energy Factor		0.525	0.525	0.525	0.525	0.58	0.58	0.575	0.575
Rated Input, MBH		28.0	28.0	28.0	28.0	28.0	28.0	28.0	28.0

Table R3-11 from 2005 Residential ACM Approval Manual

Infiltration

The possible range of infiltration is not covered in the ACM vintage table so additional parametric variations were performed. These are described below:

- SLA 10 – This infiltration rate is essentially double the default ventilation rate for homes with ducted HVAC systems.
- SLA 4.9 – This is the default for ducted systems. The default is 3.8 for non-ducted HVAC systems.
- SLA 3.0 – if SLA is reduced below this level mechanical ventilation is required.
- SLA 1.5 – This is the lowest value that is allowed by the residential ACM manual.

Magnitude of Internal Gains

Four sets of internal gains are studied as defined below: The two patterns that are of principal interest are the ACM assumption and the RESNET assumption. The RESNET assumption is considerably higher than the ACM assumption and our studies indicate that the RESNET assumption is a little higher than the RASS findings.

- Very Low Internal Gains. Use half of the ACM assumption.
- ACM Assumptions. The ACM assumption for internal gains is 20,000 Btu/d per dwelling unit plus another 15 Btu/d-ft^2 of conditioned floor area.
- RESNET Assumptions (unadjusted for refrigerator, dishwasher and lighting). The RESNET assumption is 17,900 Btu/d per dwelling unit plus 23.8 Btu/d-ft^2 of conditioned area and 4,104 Btu/d-BR.
- Very High Internal Gains. Double the RESNET assumption.

Schedule of Internal Gains

The parametric variations described above all deal with the total magnitude of internal gains and not the hourly schedule of use. With TDV energy, the hourly schedule of use is significant. Two schedules of internal gains are evaluated in the parametric study:

- The ACM assumptions
- The hourly schedule derived from FSEC data of a set of Florida homes, which is the basis of the RESNET assumptions

Figure 17 shows the hourly pattern for internal gains that is specified in the residential ACM manual. Separate schedules are specified for the whole house and this schedule is used unless the HVAC system has the capability for zonal control. For zonal control, a separate schedule is provided for the living and sleeping areas. Figure 18 shows the seasonal variation that is specified by the residential ACM. This changes the magnitude of internal gains by month not the hourly schedule.

The FSEC schedule is only for internal loads from lighting and equipment and does not include internal loads from people. It is based on field monitoring of 171 homes in Florida during 1999 and 2000. See Figure 19. The FSEC data indicates an evening peak while the ACM data shows a pronounced morning and evening peak.

Figure 17 – ACM Hourly Schedules for Internal Gains – People, Lighting, and Equipment

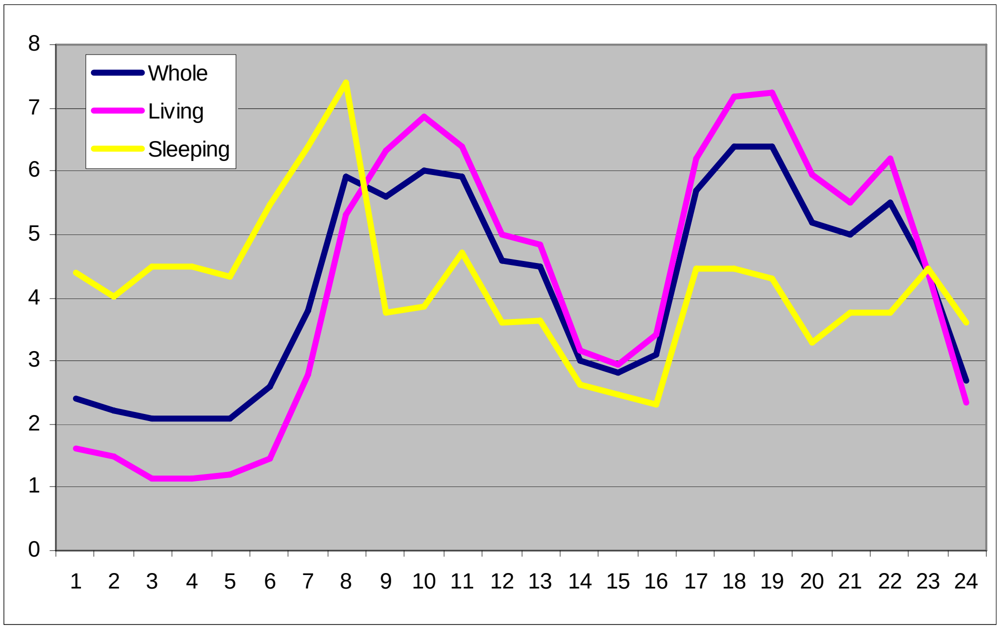


Figure 18 – Seasonal Multipliers for ACM Hourly Internal Gain Schedules – People, Lighting and Equipment

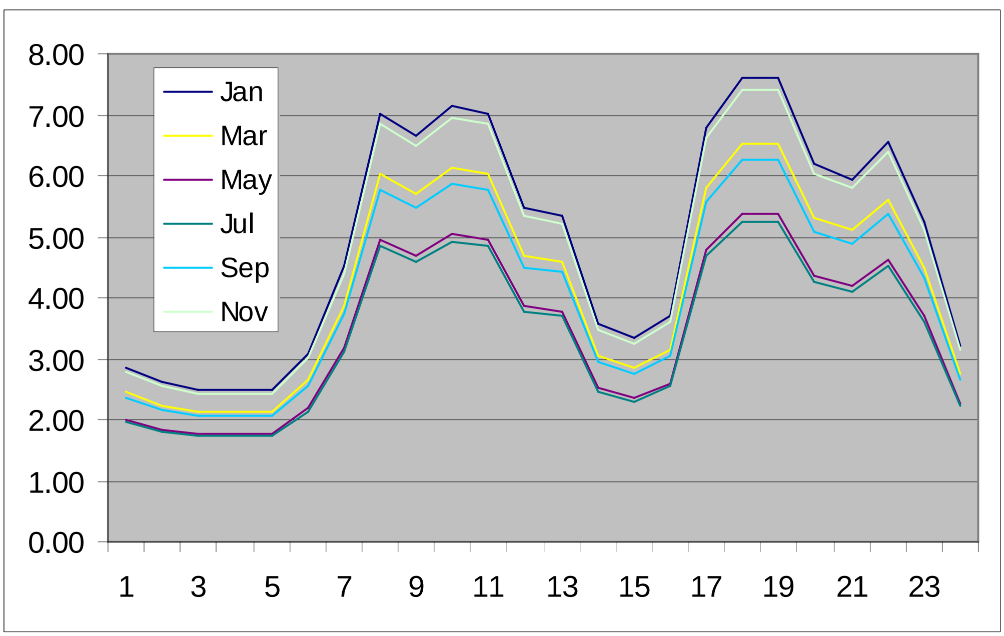
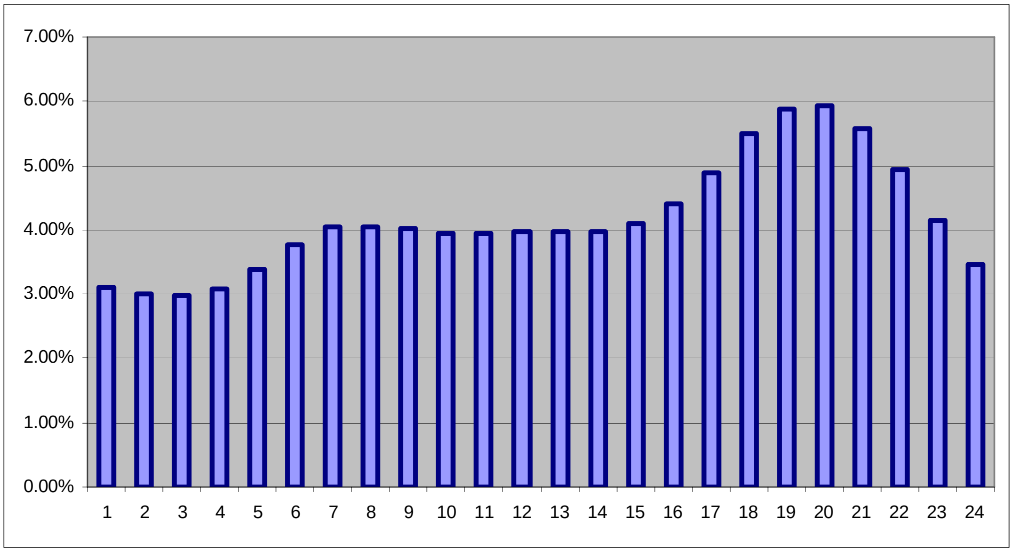


Figure 19 – Florida Schedule of Internal Gains - Lighting and Equipment Only



Source: FSEC (See http://www.fsec.ucf.edu/~pfairey/igain/)

Thermostats

Three sets of thermostat schedules are modeled as described below:

- The Current ACM assumptions
- The RESNET assumptions for the reference house (constant 68/78)
- A set of modeling assumptions representing behavior where the occupants only turn on the heating or air conditioning for specific periods of the day. This is approximated by setting the heating thermostat to 66 and the cooling thermostat to 80 between 5:00 AM and 8:00 AM and between 5:00 PM and 10:00 PM. At other times, the heating thermostat is set to 60 F and the cooling thermostat to 90 F.

Uninsulated Wall Cavities

Michael Blasnik and others have argued that the energy penalty of uninsulated walls tend to be overestimated by building energy modeling tools. While there is no detailed study of these phenomena, it can be rationalized in a number of ways. In email correspondence on this issue, Mr. Blasnik offered the following rationale:

1. Conductive regain of exfiltration and bypass heat loss through the building cavity can be fairly substantial especially in uninsulated cavities when the inside boundary is uninsulated and the leakage paths to the interior haven't been sealed.
2. Standard assumptions about construction that may be reasonable for most insulated (more recently built) homes, but don't reflect the construction practices more commonly found in uninsulated cavities (for example, unvented or minimally vented attics, thicker exterior board sheathing for attic and walls (pre plywood-era construction), and multiple layers of shingles on

roofs. These differences all can increase the effective R-value of the exterior boundary of the cavity, increasing the overall assembly R-value and the regain to the interior.

Another somewhat smaller consideration may be the more common installation of floors in attics in older homes (bags of clothes and sets of luggage stored in such attics may have some R-value) and closets, wall hangings, drapes, furniture, building chases, and stairways on exterior walls. All of these things add some R-value. In a home with existing insulation the impact may be trivial, but for an uninsulated building cavity, even a small boost in R-value could matter.

Another possibility is that older homes with lath and plaster walls have greater R-value and thermal mass than modern sheetrock. And there may be a more continuous air barrier due to lath and plaster walls, which results in less infiltration.

To study the impact of these possible differences for uninsulated walls, we modeled uninsulated walls, which are assumed for homes built before 1978, with a lower U-factor. The U-factor for an uninsulated wall from Joint Appendix IV is 0.356. In the alternative case, the uninsulated wall was modeled with a U-factor of 0.161, which represents a wall cavity with R-4 insulation.

Results

The results of the parametric variations are contained in a spreadsheet that allows information to be displayed in a variety of ways. The following figures include some of the results.

Figure 20 – Legend to Parametric Variation Graphs

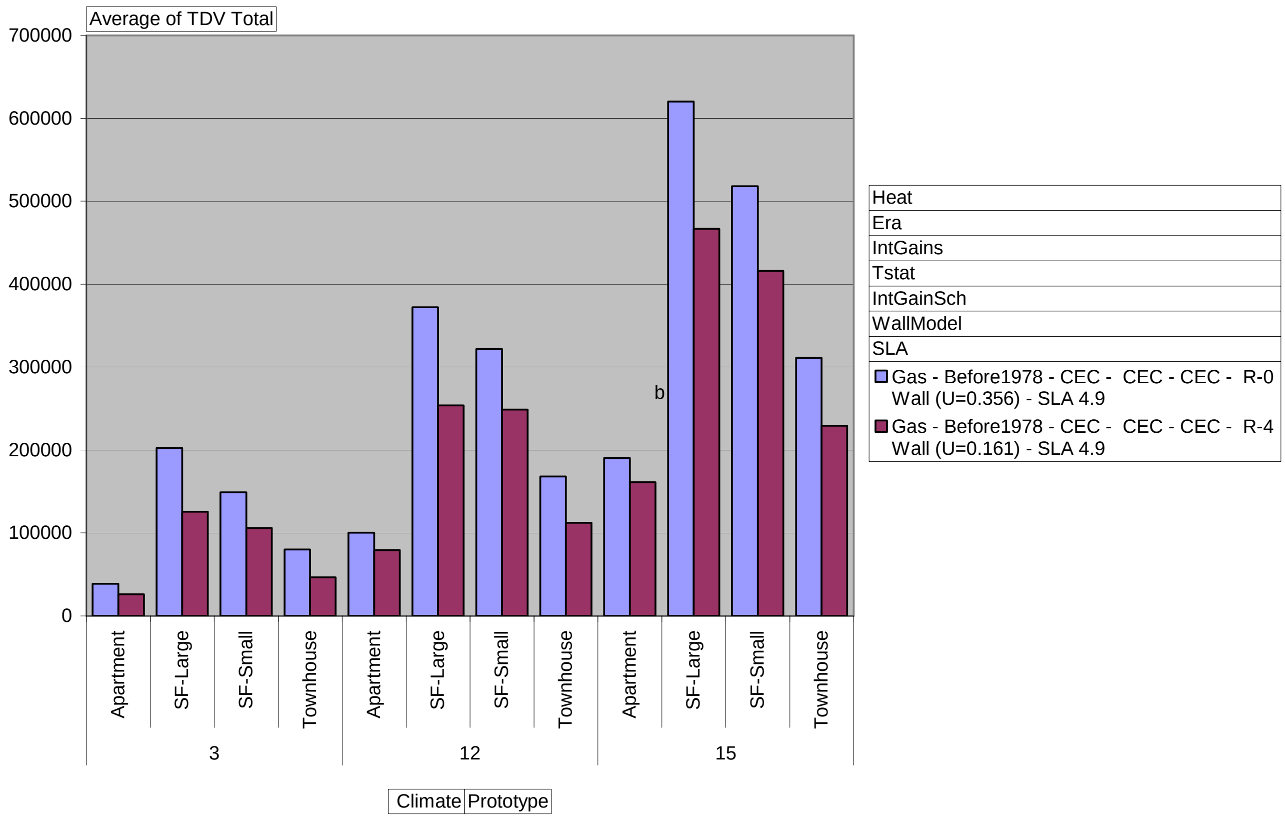
Heat
Era
IntGains
Tstat
IntGainSch
WallModel
SLA
■ Gas - Before1978 - CEC - CEC - CEC - R-0 Wall (U=0.356) - SLA 4.9 ■ Gas - Before1978 - CEC - CEC - CEC - R-4 Wall (U=0.161) - SLA 4.9

The parametric graphs that follow use a legend as shown on the left. The parameters that vary are defined earlier and are listed in the legend. The are:

Heat	Either: Gas or Electric
Era	Choices are: Before 1978, 1978-1992, and 1992 to present
IntGains	Either: Low, CEC, RESNET, High
Tstat	Either: CEC, RESNET, or Reduced
IntGainSch	Either: CEC or RESNET
WallModel	Either R-0 or R-4 (applies only to “Before 1978” uninsulated walls)
SLA	Either 1.5, 3.0, 4.9 or 10.0

The color bar legends at the bottom of the legend identify each of the parameters in the order they are listed above.

Figure 21 – Space Conditioning TDV Sensitivity of Wall Model – Before 1978

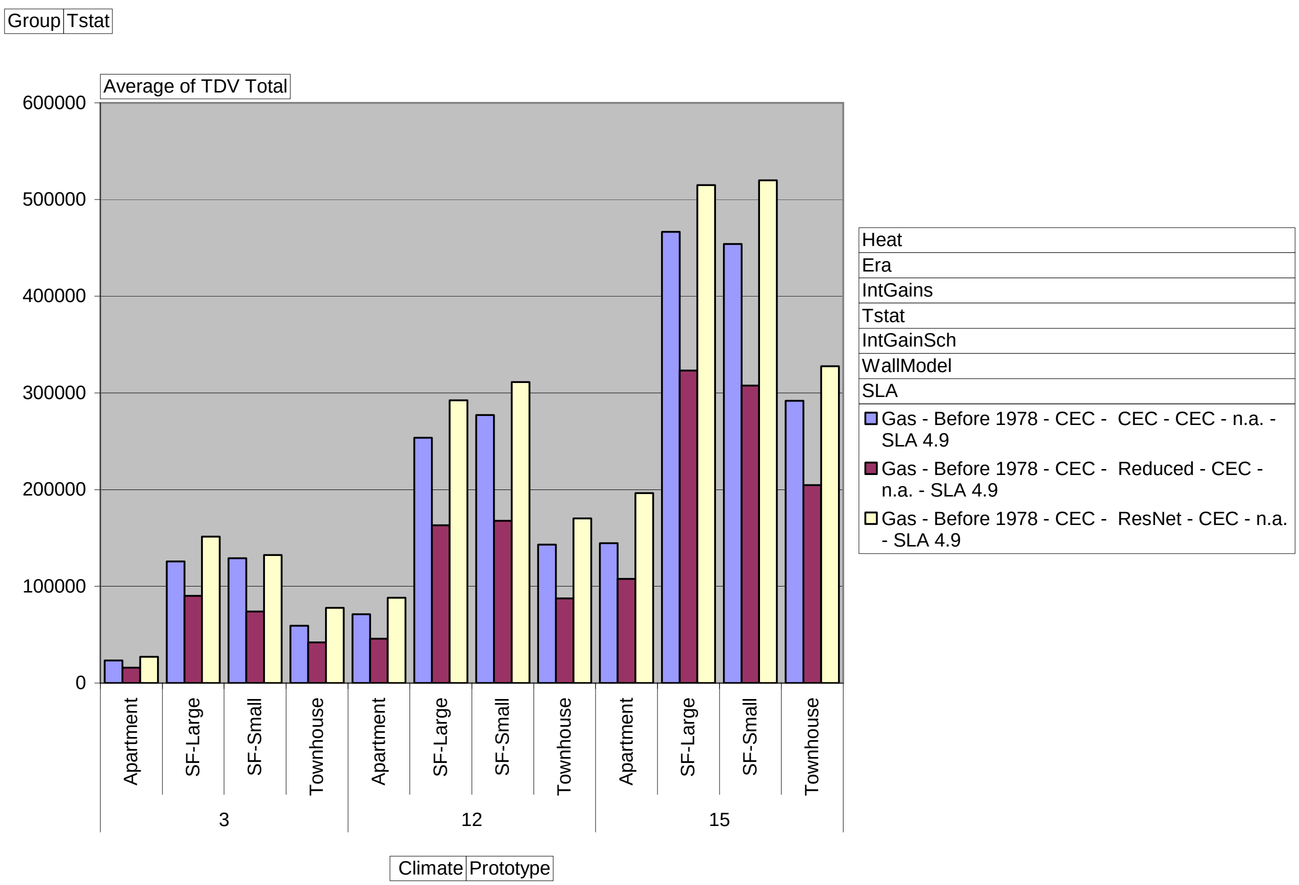


The light bars represent current modeling of uninsulated walls while the dark bars represent the assumption of R-4 in the cavity.

Observations:

1. As expected, the alternate wall models reduce energy use for the Before 1978 cases.

Figure 22 – Space Conditioning TDV Sensitivity of Thermostats – Before 1978

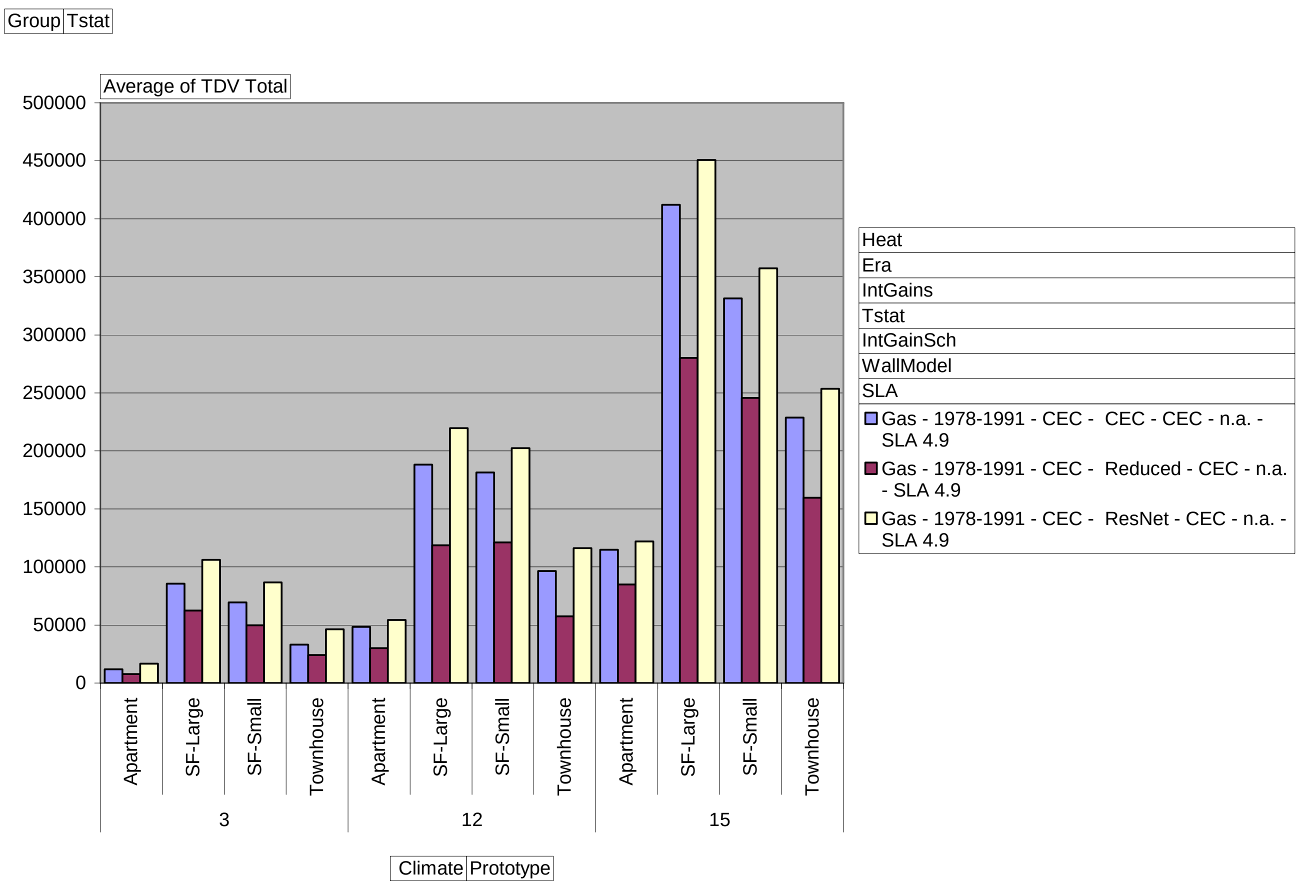


The left bars represent current ACM thermostat settings; the center bars represent the reduced settings and the bars on the right side represent the RESNET thermostat schedules.

Observations:

1. As expected the RESNET assumptions result in greater TDV energy use than the Energy Commission assumptions and the "Reduced" assumptions are considerably lower. The differences between the RESNET and Energy Commission assumptions are smaller.

Figure 23 – Space Conditioning TDV Sensitivity of Thermostats – 1978-1991

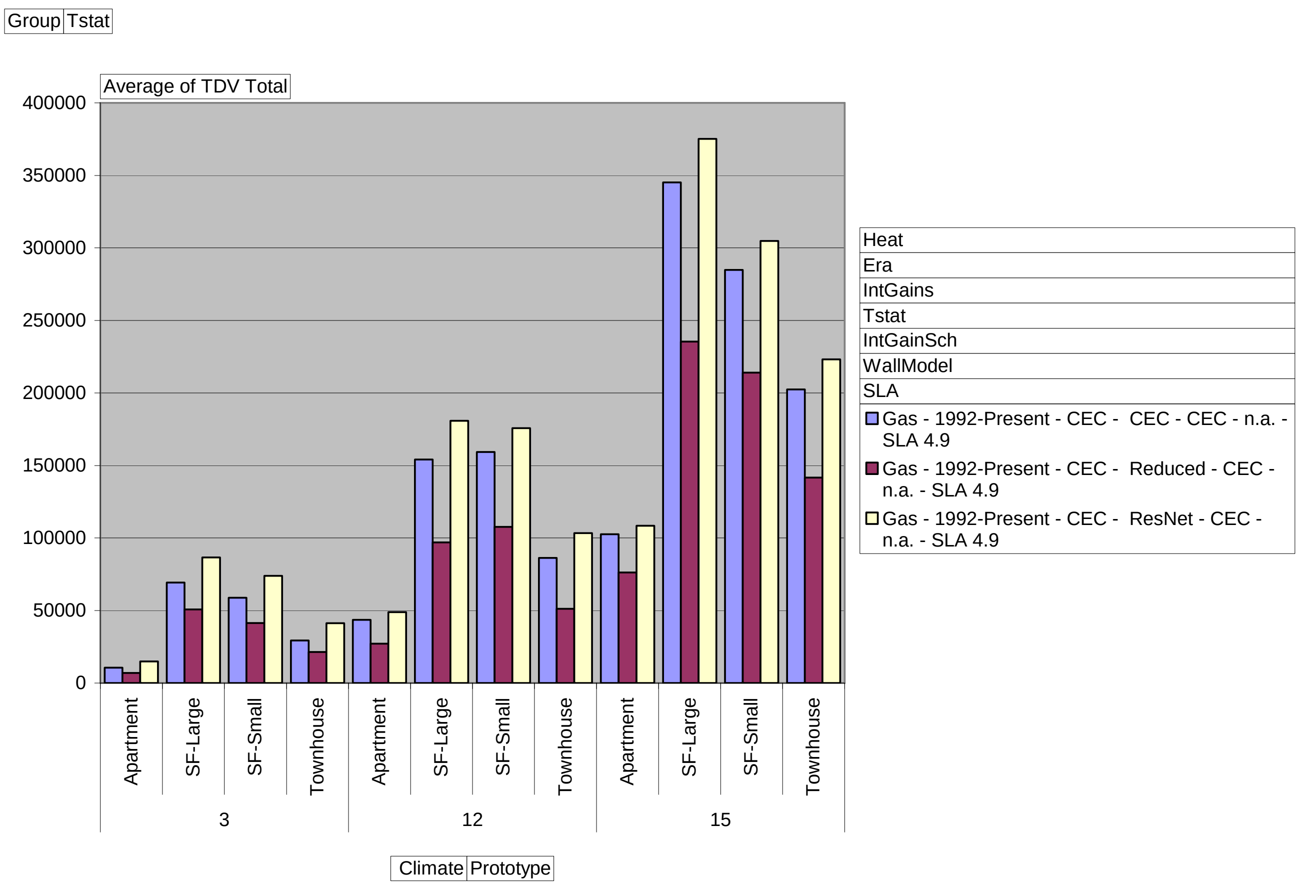


The left bars represent current ACM thermostat settings; the center bars represent the reduced settings and the bars on the right side represent the RESNET thermostat schedules.

Observations:

1. The differences between Energy Commission and RESNET are smaller.

Figure 24 – Space Conditioning TDV Sensitivity of Thermostats – 1992 to Present

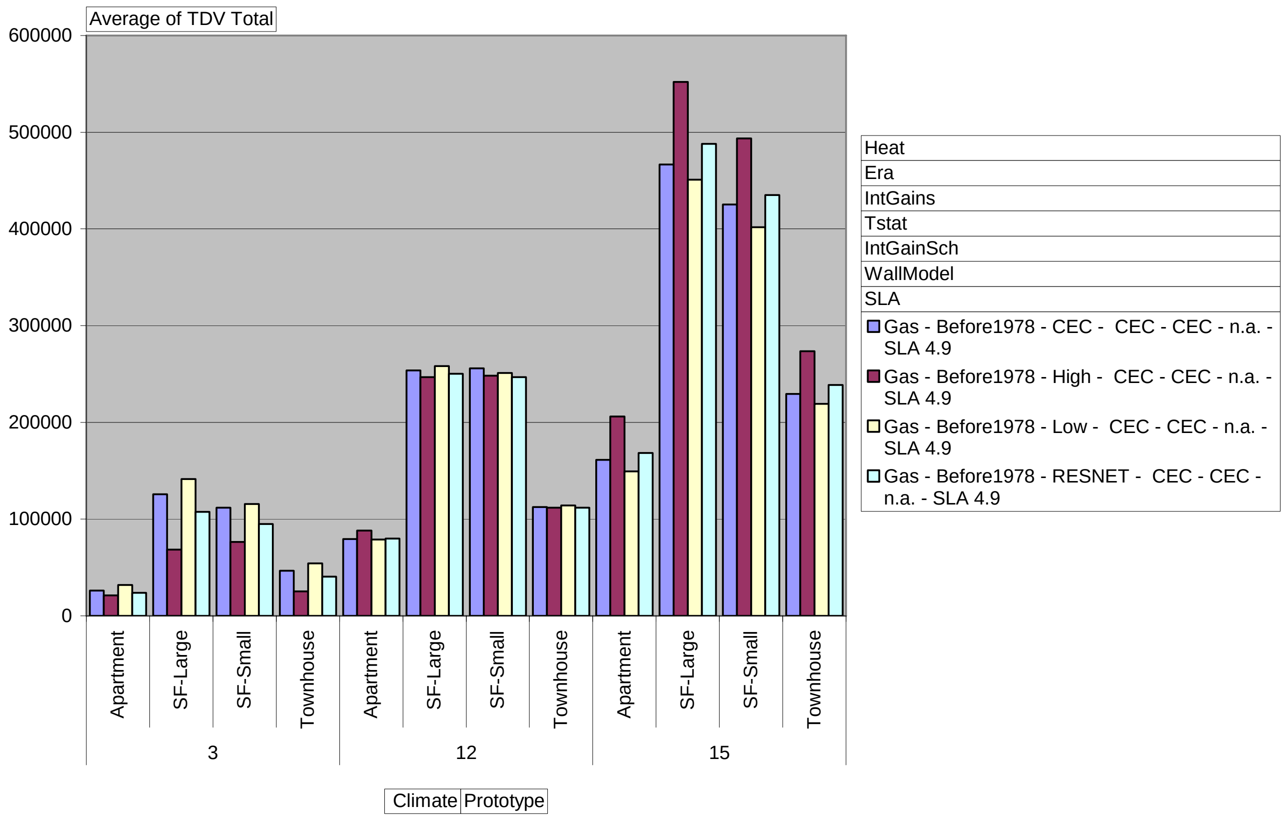


The left bars represent current ACM thermostat settings; the center bars represent the reduced settings and the bars on the right side represent the RESNET thermostat schedules.

Observations:

1. The differences between RESNET and Energy Commission seem to get smaller in better insulated houses.

Figure 25 – Space Conditioning TDV Sensitivity of Internal Gains – Before 1978

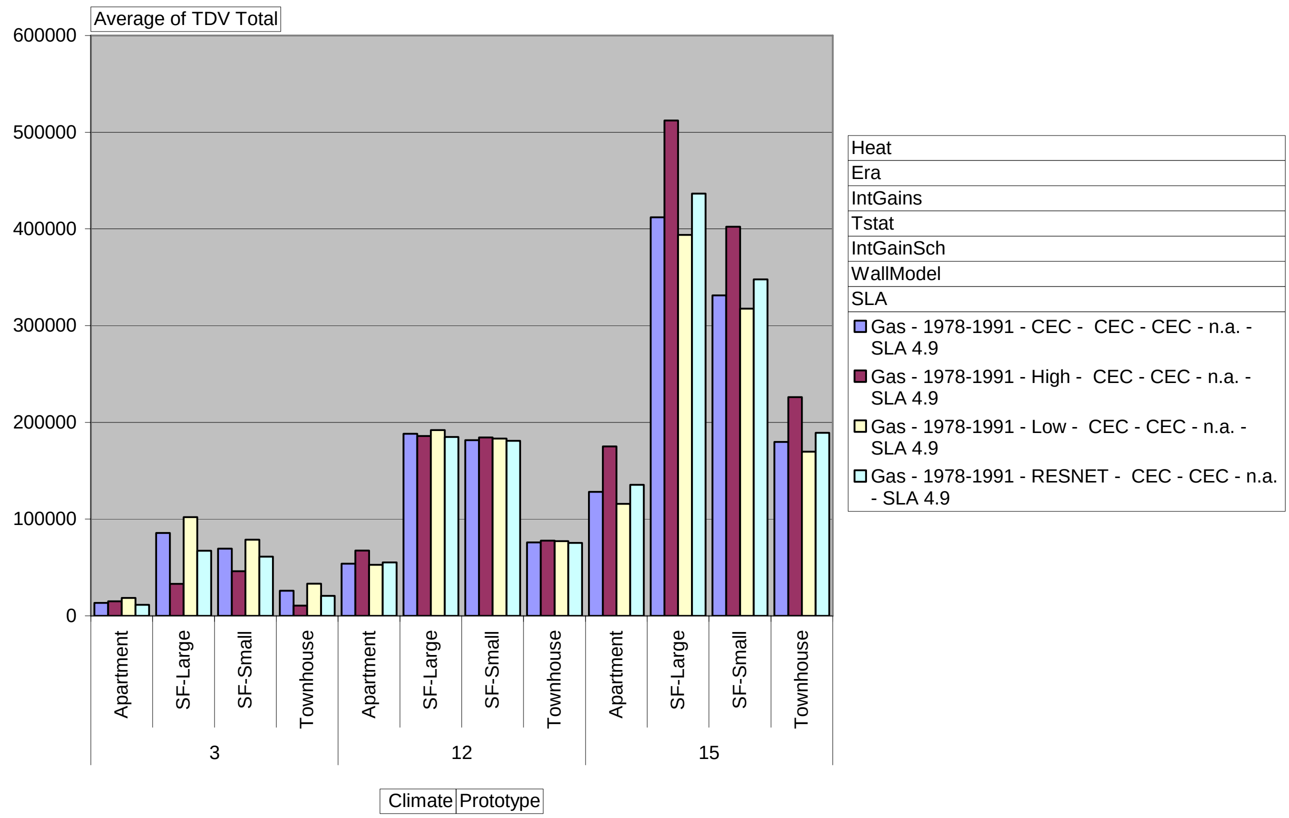


From left to right: ACM Assumption; double the RESNET assumption; half the ACM assumption; and the RESNET assumption.

Observations:

1. In mild coastal climates, high internal gains reduce TDV energy for space conditioning, while the opposite is true for very hot climates, such as climate zone 15. Internal gains do not make much difference in climate 12. This is clearly a heating vs. cooling impact.
2. The differences are less pronounced for apartments and in the case of climate 12 are so minor that less gains results in more energy.

Figure 26 – Space Conditioning TDV Sensitivity of Internal Gains – 1978-1991

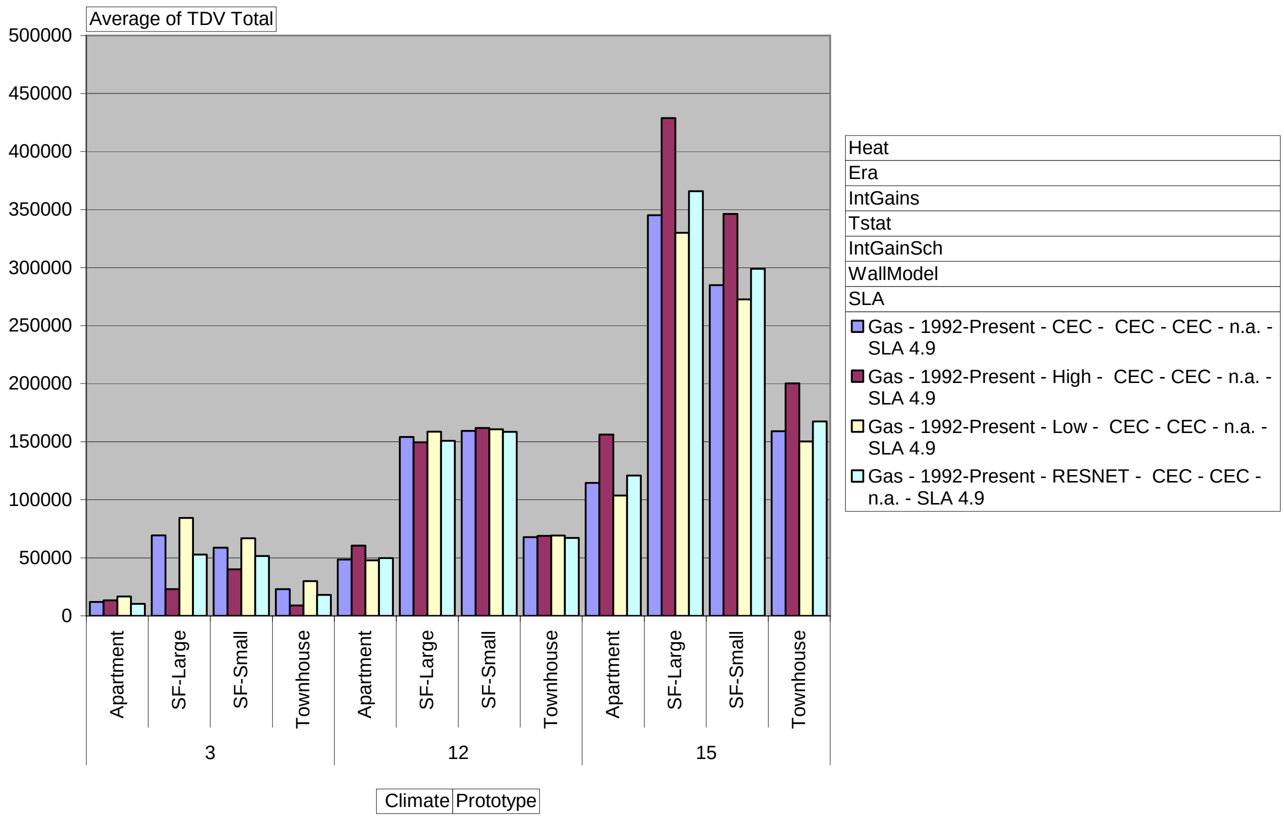


From left to right: ACM Assumption; double the RESNET assumption; half the ACM assumption; and the RESNET assumption.

Observations:

1. Same patterns as the "Before 1978" case.

Figure 27 – Space Conditioning TDV Sensitivity of Internal Gains – 1992 to Present

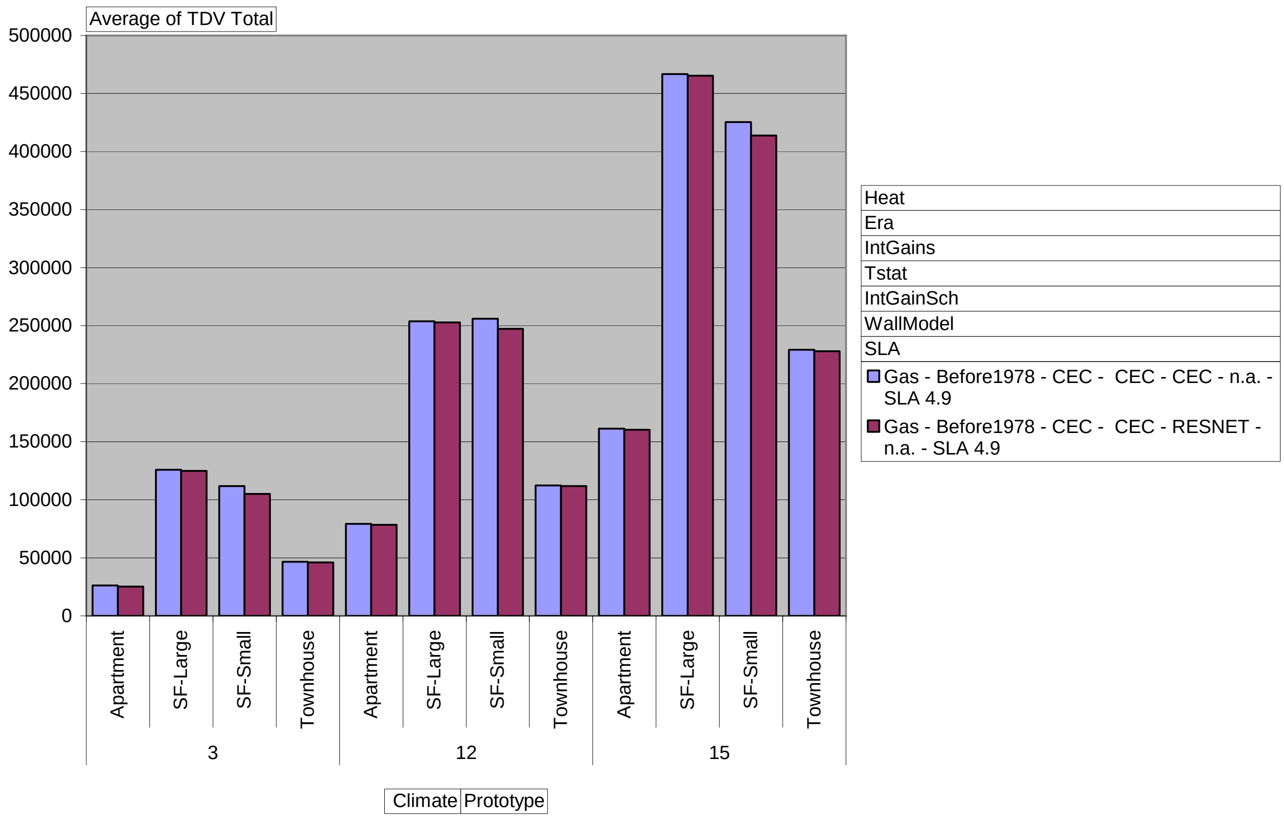


From left to right: ACM Assumption; double the RESNET assumption; half the ACM assumption; and the RESNET assumption.

Observations:

1. Same patterns as the "Before 1978" case. Impact of internal gains is not significantly affected by the era of the house or the energy efficiency features.

Figure 28 – Space Conditioning TDV Sensitivity of Internal Gains Schedule – Before 1978

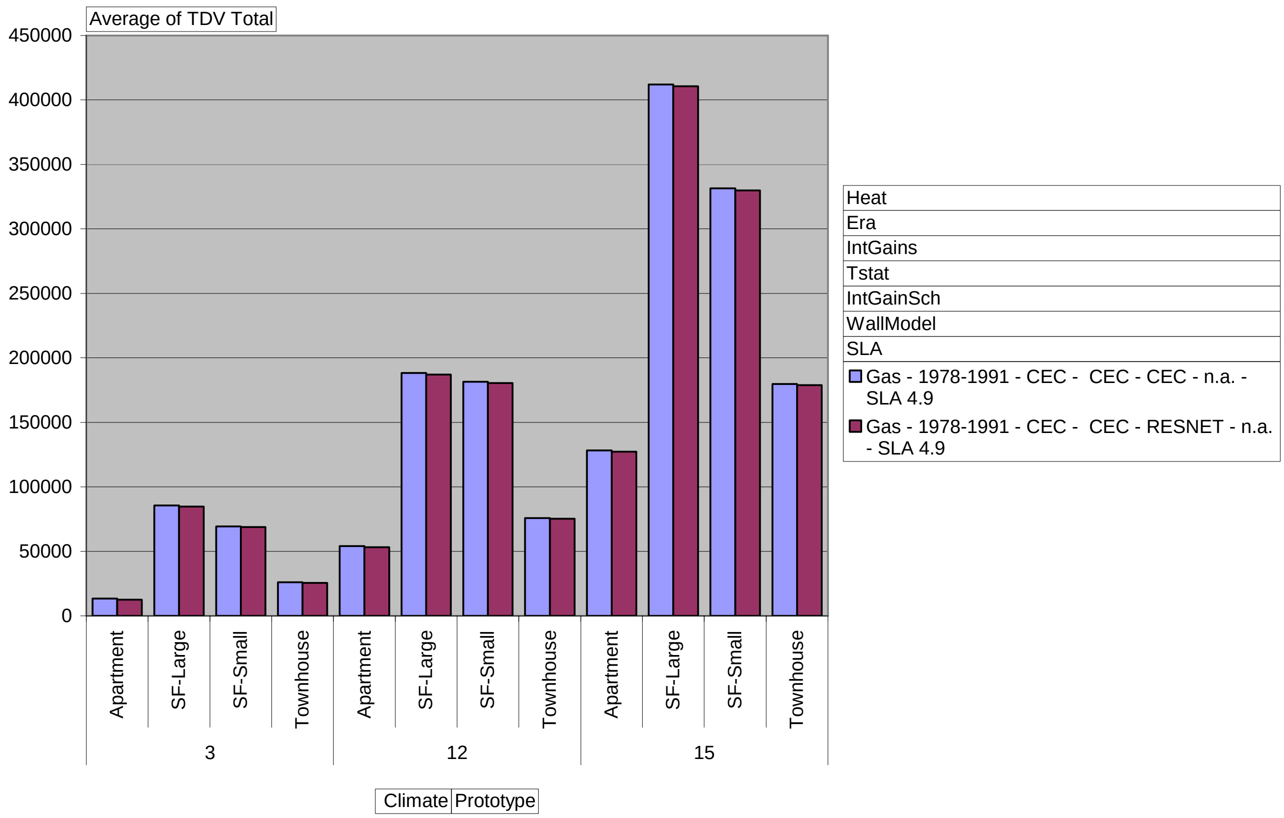


From left to right: ACM schedule; and RESNET/FSEC schedule

Observations:

1. The schedule does not make much difference. The FSEC/RESNET schedule results in a slight reduction, probably since load is shifted to later in the evening.

Figure 29 – Space Conditioning TDV Sensitivity of Internal Gains Schedule – 1978-1991

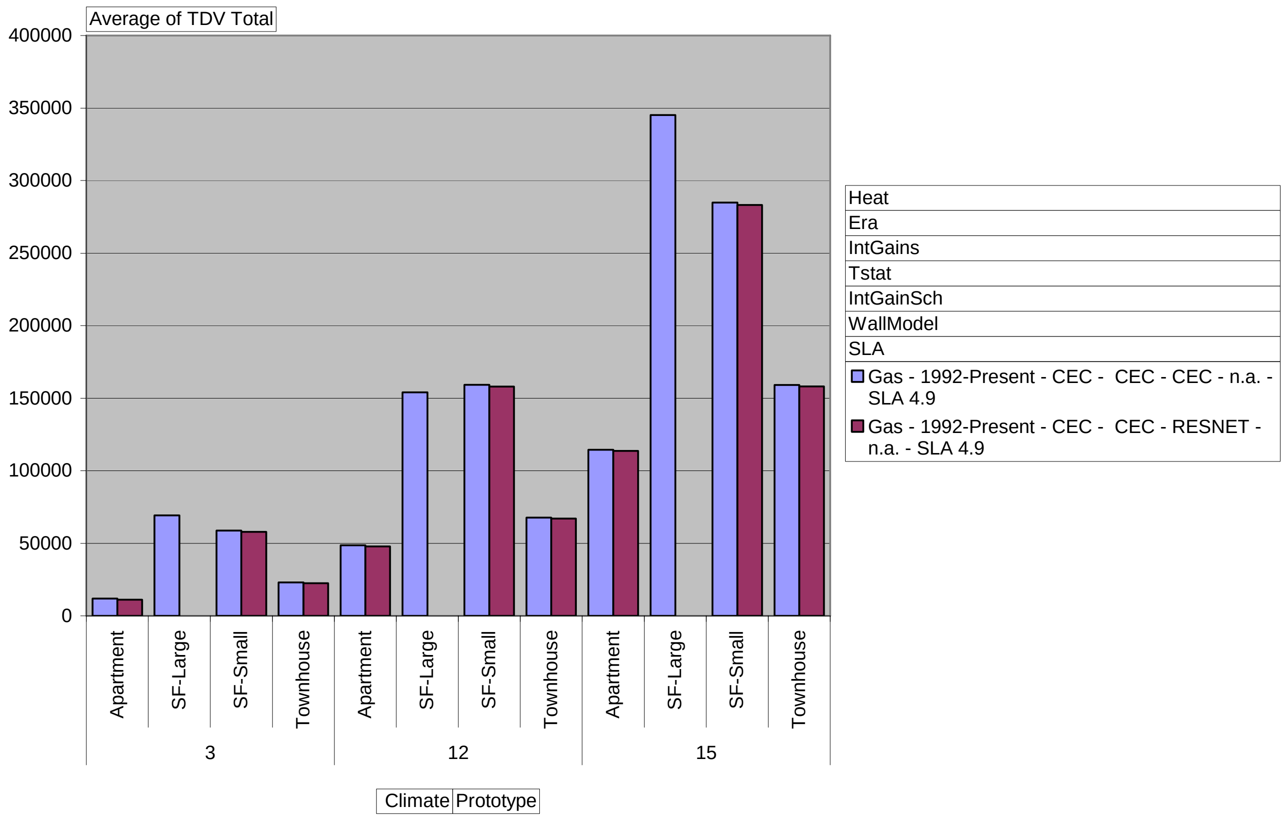


From left to right: ACM schedule; and RESNET/FSEC schedule

Observations:

1. Same patterns as the "Before 1978" case.

Figure 30 – Space Conditioning TDV Sensitivity of Internal Gains Schedule – 1992 to Present

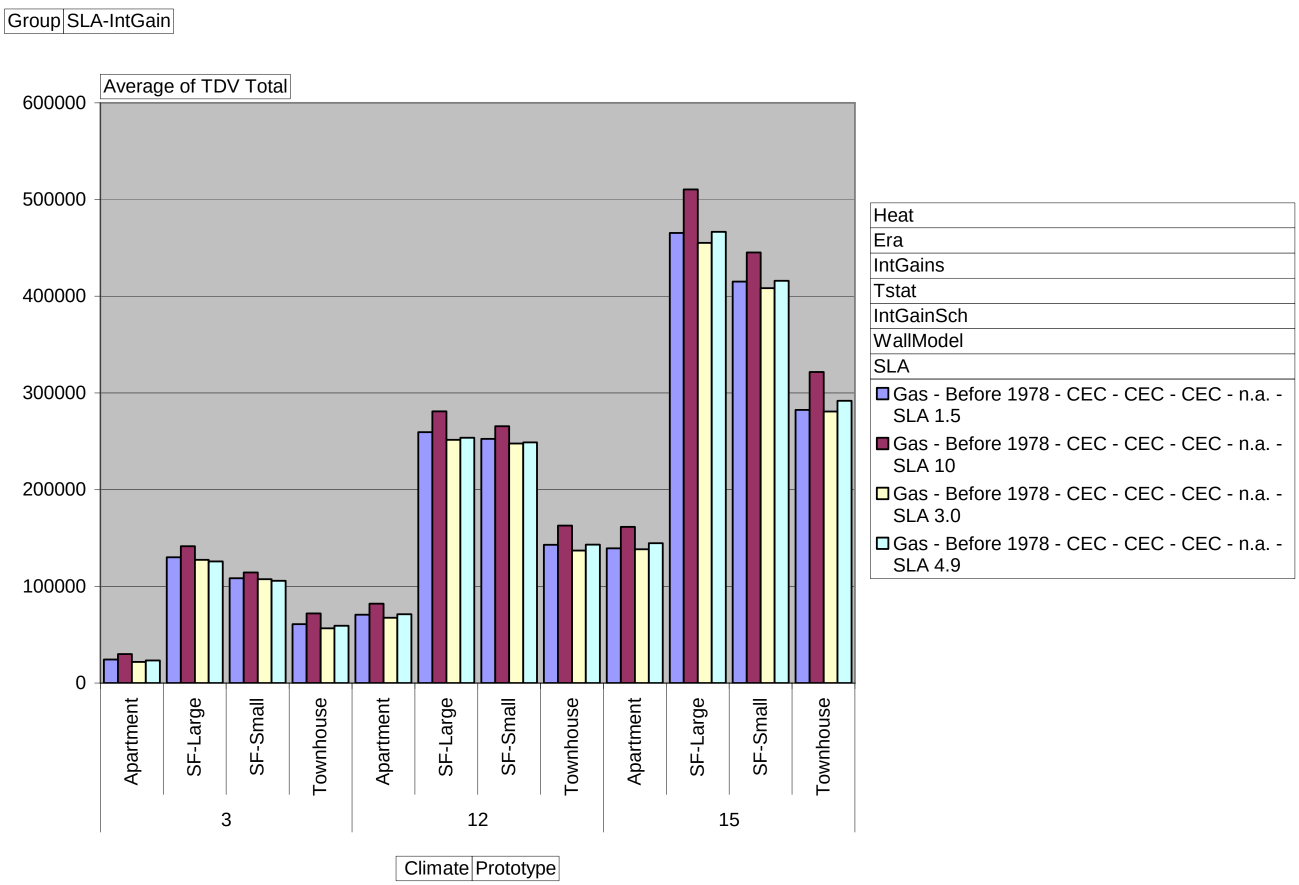


From left to right: ACM schedule; and RESNET/FSEC schedule

Observations:

1. Data is missing for SF-Large.
2. Same patterns as the "Before 1978" case.

Figure 31 – Space Conditioning TDV Sensitivity to SLA – Before 1978

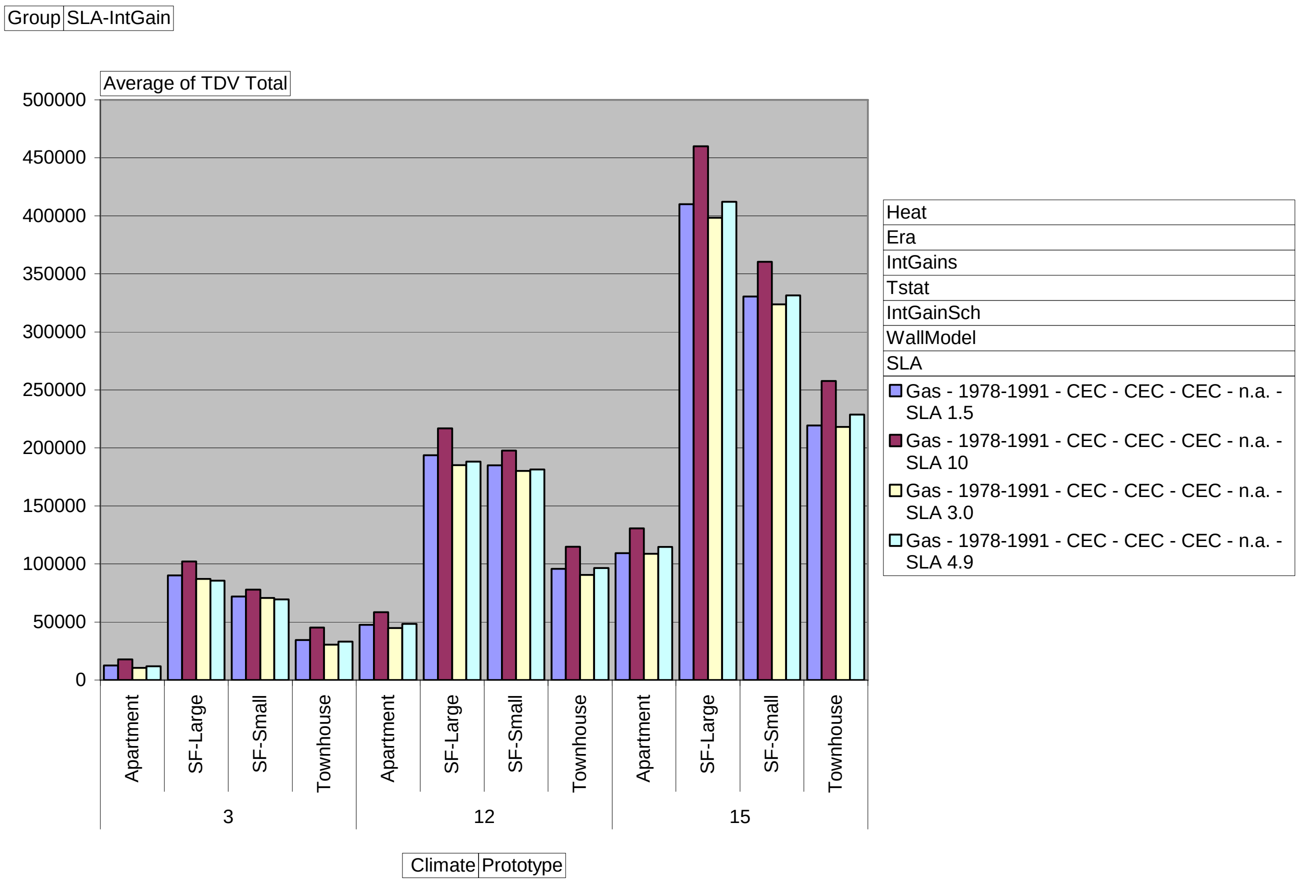


From left to right: SLA 1.5; SLA 10, SLA 3.0 and SLA 4.9 (the default)

Observations:

1. Small impact
2. The SLA 1.5 case is probably impacted by the assumed addition of an air-to-air heat exchanger.
3. The SLA 3.0 case results in the lowest energy use. This is as low as you are allowed to go without mechanical ventilation.
4. Same pattern for all prototypes and climates.

Figure 32 – Space Conditioning TDV Sensitivity to SLA – 1978-1991

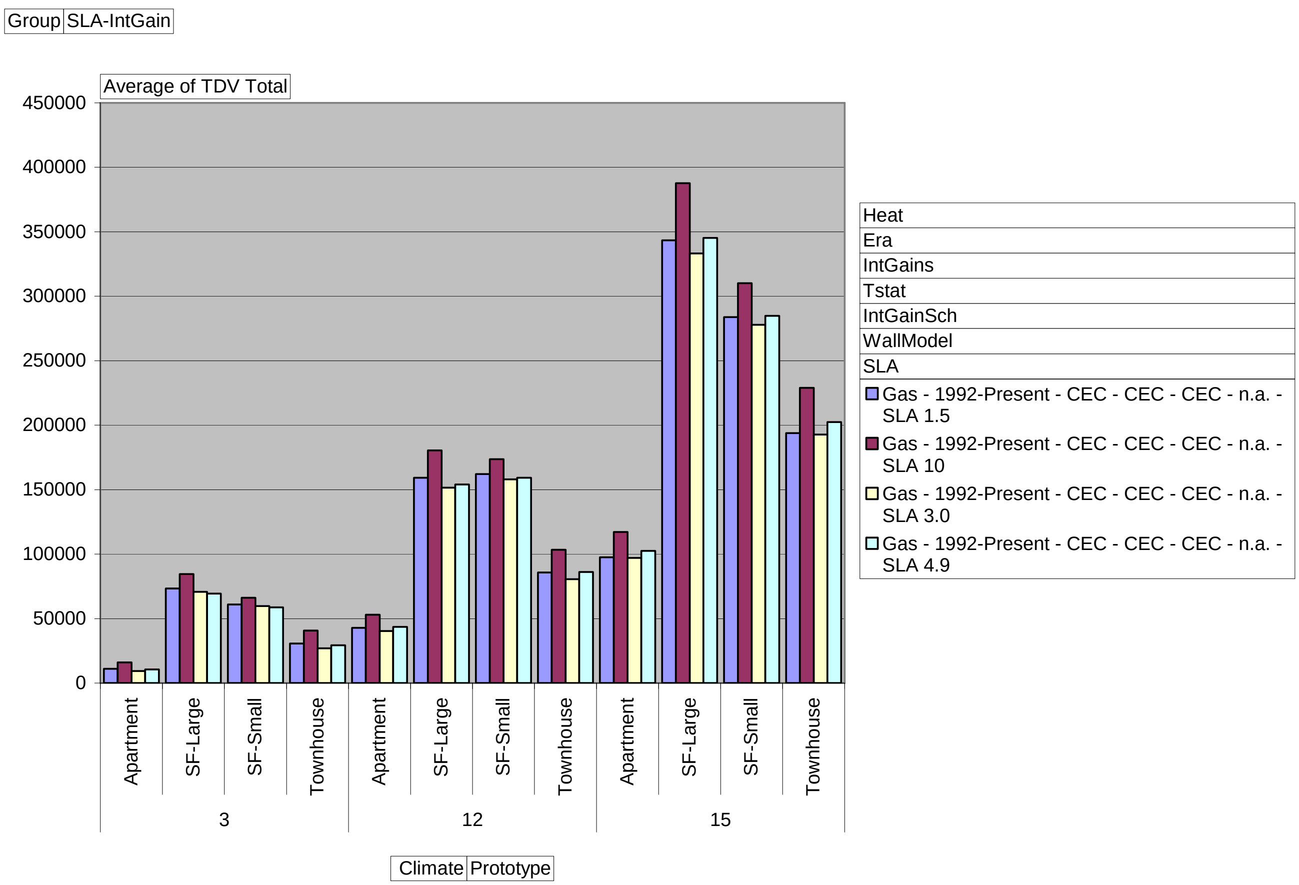


From left to right: SLA 1.5; SLA 10, SLA 3.0 and SLA 4.9 (the default)

Observations:

1. Same patterns as the "Before 1978" case.

Figure 33 – Space Conditioning TDV Sensitivity to SLA – 1992 to Present



From left to right: SLA 1.5; SLA 10, SLA 3.0 and SLA 4.9 (the default)

Observations:

1. Same patterns as the "Before 1978" case.

Recommended Lighting and Appliances Model

As indicated in Figure 3, lighting and appliances are very significant energy uses in homes. The electricity use, on average, is significantly greater than for air conditioning, heating, and water heating. Not only is the gas and electricity use from appliances and lighting an important end use, lights and appliances also affect internal gains. Higher internal gains increase cooling loads and reduce heating loads. Lower internal gains do the opposite.

An estimate of some components of lighting and appliance use can be based on observations made by the HERS rater. This section of the report recommends an appliance model be incorporated in HERS tools for estimating the energy use of lights and appliances and offering credit for energy efficiency. This report recommends the following:

1. Offer credits only for efficient lighting, refrigerators and dishwashers consistent with RESNET practices.

2. Account for the presence of a second refrigerator and increase the energy use of the rated home (and raise the HERS index) when one is present.
3. Account for the type of fuel used for range/ovens and dryers so that this can be accounted for in the calculation of TDV energy and internal gains. Base this on observations by the rater of an installed appliance or available gas/electric connections.
4. Adopt hourly schedules for refrigerators, people, lighting and equipment. See Table 12.
5. Produce separate estimates of electricity and gas use to accurately schedule loads and estimate TDV energy.[10]

Table 12 – Recommended Hourly Schedules for Lighting and Appliances Model (Percent of Daily Total)

Time	Refrigerators	People	Equipment	Interior Lighting	Exterior Lighting
1	4.2%	5.9%	3.1%	2.3%	0%
2	4.2%	5.9%	3.1%	1.9%	0%
3	4.2%	5.9%	3.2%	1.5%	0%
4	4.2%	5.9%	3.3%	1.7%	0%
5	4.2%	5.9%	3.6%	2.1%	0%
6	4.2%	5.9%	3.9%	3.1%	0%
7	4.2%	5.9%	4.0%	4.2%	0%
8	4.2%	4.6%	4.0%	4.1%	0%
9	4.2%	1.9%	4.2%	3.4%	0%
10	4.2%	1.9%	4.2%	2.9%	0%
11	4.2%	1.9%	4.2%	2.7%	0%
12	4.2%	1.9%	4.3%	2.5%	0%
13	4.2%	1.9%	4.4%	2.1%	0%
14	4.2%	1.9%	4.4%	2.1%	0%
15	4.2%	1.9%	4.6%	2.1%	0%
16	4.2%	1.9%	4.9%	2.6%	0%
17	4.2%	3.7%	5.4%	3.1%	0%
18	4.2%	4.3%	5.9%	4.4%	0%
19	4.2%	4.9%	5.5%	8.4%	0%
20	4.2%	4.9%	4.7%	11.7%	0%
21	4.2%	4.9%	4.3%	11.3%	25%
22	4.2%	5.2%	3.8%	9.6%	25%
23	4.2%	5.6%	3.6%	6.3%	25%
24	4.2%	5.9%	3.3%	3.8%	25%

[10] Table 13 has schedule weighted average kWh to TDV conversion factors for each of the climate zones and the recommended schedules. The values in Table 13 are multiplied times the electricity consumption to yield the TDV energy. A conversion of unity (1.0) is used for gas.

Table 13 – Schedule Weighted Average Annual TDV Multipliers for Electricity Conversion (kTDV/kWh)

Note: The highlighted columns are the schedules recommended for use in the model.

Climate Zone	Constant On Schedule	FSEC Schedule [1]	CEC 1999 Lighting Schedule [2]	1980 CEC Lighting Schedule [3]	CEC Equipment Schedule [3]	CEC ACM Internal Gains Schedule [4]	Lights on from 7-12 in the Evening	Lights on from 6-10 in the Evening
1	13.93	14.31	14.17	14.26	15.13	14.49	12.90	14.71
2	13.94	14.30	14.08	14.18	15.14	14.40	12.88	14.46
3	13.97	14.31	14.20	14.29	15.07	14.45	13.11	14.75
4	13.96	14.29	14.11	14.21	15.10	14.42	13.00	14.56
5	13.95	14.29	14.23	14.29	15.05	14.55	13.00	14.86
6	14.00	14.34	14.25	14.31	15.09	14.59	13.09	14.79
7	17.64	17.99	17.75	17.78	18.96	18.24	16.02	18.28
8	13.98	14.30	14.15	14.24	15.10	14.51	13.08	14.61
9	13.95	14.28	14.12	14.21	15.10	14.44	13.02	14.59
10	13.92	14.26	14.07	14.16	15.08	14.39	12.96	14.49
11	13.93	14.32	14.08	14.21	15.20	14.43	12.74	14.48
12	13.94	14.32	14.09	14.21	15.17	14.42	12.84	14.47
13	13.97	14.34	14.22	14.34	15.11	14.48	13.08	14.76
14	13.92	14.30	14.14	14.26	15.11	14.45	12.96	14.66
15	13.92	14.27	14.08	14.19	15.11	14.41	12.94	14.51
16	13.93	14.29	14.10	14.20	15.16	14.41	12.84	14.65

Notes

[1] See http://www.fsec.ucf.edu/~pfairey/igain/.

[2] Lighting Efficiency Technology Report, Volume I, California Baseline, CEC, September 1999, HMG.

[3] Assumptions Used with Energy Performance Computer Programs, Project Report No. 7, June 1980, CEC

[4] Schedule used for the distribution of internal gains in compliance calculations, 2005 Residential ACM Manual, P400-03-003ETF, Adopted November 5, 2003.

Table 14 shows the coefficients and assumptions related to the recommended lighting and appliances model. Credit is offered (energy use is reduced in the rated house) for energy efficient refrigerators, dishwashers and lighting. Energy use is increased in the rated home, but not the reference home when the rated home has a second refrigerator. The components for which there is a credit/penalty are highlighted in yellow. Other components are held constant for both the rated house and the reference house.

The expressions in Table 14 are developed through a regression analysis of the RASS data for existing homes in California. The third column shows the percentage of energy use that results in internal heat gain. 100% means that all of the energy results in heat gain, while 0% means that none of the energy results in heat gain. Columns four and five give the values for both the rated home and the reference home. Column six has the recommended hourly schedule. Most of these expressions include a constant and a variable component. Other electricity use, for instance is 1,650 kWh/year plus an additional 0.410 kWh/year for each square foot of conditioned floor area.

With the recommended model, internal gains would be calculated based on the assumptions shown in Table 14.

Table 14 – Coefficients and Assumptions for the Lighting and Appliances Model

Note: Credit in the rating is offered for the items shaded below.

Category	Energy Use	Percent Internal Gains	Rated House	Reference House	Schedule (see Table 12)
Electricity Use (kWh/year)	Refrigerator	100%	From EnergyGuide Label	775	Refrigerator
	Dishwasher	60%	EF from Energy Guide Label and RESNET Model	EF .46 and RESNET Model	Equipment
	Dryer (Electric)	30%	263 + 0.254 CFA if present	Same as Rated House	Equipment
	Range/Oven (Electric)	90%	92 + 0.118 CFA if present	Same as Rated House	Equipment
	Clothes Washer	100%	-64 + 0.108 CFA if present	Same as Rated House	Equipment
	Second Refrigerator	0%	-50 + 0.717 CFA, if present	Zero	Refrigerator
	Interior Lighting	100%	See below	See below	Interior Lighting
	Other	100%	1,650 + 0.410 CFA	Same as Rated House	Equipment
	Exterior Lighting	0%	See below	See below	Exterior Lighting
Gas Use (therms/year)	Range/Oven (Gas)	90%	31 + 0.008 CFA if present	Same as Rated House	Equipment
	Dryer (Gas)	30%	13 + 0.010 CFA if present	Same as Rated House	Equipment

Interior Lighting

The interior lighting energy for the rated house and the reference house should be determined using Equation 7.

Equation 7

$$Electricity_{InteriorLights} = (214 + 0.601 \times CFA) \times (Fract_{Portable} + (1 - Fract_{Portable}) \times PAM_{Interior})$$

where

$Electricity_{InteriorLights}$ Annual electricity use for interior lighting (kWh/year).

CFA Conditioned floor area (ft^2).

$PAM_{Interior}$ Power adjustment multiplier to account for high efficacy luminaires, location of the luminaires and the type of control for permanent luminaires. The $PAM_{Interior}$ for the reference house shall be fixed at 0.625. The $PAM_{Interior}$ for the rated house is determined from Equation 8.

Equation 8

$$PAM_{Interior} = \frac{\sum PAM_{Fixture,i} \times PAM_{Control,i} \times DailyHours_i \times Count_i}{\sum DailyHours_i \times Count_i}$$

where

$Fract_{Portable}$	Fraction of interior lighting power represented by portable lighting fixtures. This value shall be 0.22 or the value from Equation 9, whichever is greater.
$PAM_{Fixture,i}$	Power adjustment multiplier based on the type of the i^{th} fixture: 0.33 is used for hardwired high efficacy fixtures as defined in §150(k) of the California energy efficiency Standards; 0.67 is used for permanently mounted luminaires that are fitted with screw-in compact fluorescent lamps; and 1.00 is used for permanently mounted incandescent luminaires. See Table 16 for permanently installed luminaire types.
$PAM_{Control,i}$	Power adjustment multiplier based on the type of control serving the i^{th} fixture: 1.00 is used for a conventional on/off switch; 0.90 is used for a dimming control; and 0.80 is used for an occupant sensor.
$DailyHours_i$	The average daily hours of lighting operation based on the type of room in which the i^{th} fixture is located (see Table 15).
$Count_i$	The number of fixtures of this type. The count is determined following the rules in Table 17.

Equation 9

$$Fract_{Portable} = 0.22 \times \frac{28}{F} \times \frac{CFA}{2200}$$

$Fract_{Portable}$	Fraction of fixtures that are Portable (unitless)
F	Number of Hardwired fixtures for rated house
CFA	Conditioned Floor Area (ft^2)

Table 15 – Daily Lighting Hours – Interior

Location	$DailyHours_i$
Small Closet	0.5
Bedroom/WIC	1.4
Hall/Entry/Stairs/Other	2.0
Living	2.6
Utility/Laundry	2.6
Kitchen/Dining/Nook	3.4
Source: HMG 1999 Lighting Efficiency Technology Report, Volume 1, Figure 1-6	

Table 16 – Permanently Installed Luminaire Types

Classification	Definition
Permanently installed High efficacy	Meets the requirements of §152(k). Includes luminaires which can accept only linear fluorescent, compact fluorescent, or LED lamps.
Low efficacy	Any luminaire that accepts any type of incandescent lamp, and which has incandescent lamps installed
Screw-in high efficacy	Any luminaire that accepts screw based incandescent lamps, but which has screw based compact fluorescent or screw based LED installed. Any track lighting track that accepts medium screw based incandescent lamps, but which has medium screw-base track head with screw-in CFL, CFL track heads with factory installed ballast, or LED track heads

Table 17 – Rules for Determining Lighting Fixture Count

Luminaire Type	Examples/Description	Method of Counting
Track Lighting	Line-voltage or low-voltage track	Larger of: • One luminaire for each 3' of track length rounded up to 3 foot multiple, or • Actual number of track heads installed.
Linear Fluorescent (see Note 1)	Linear fluorescent luminaire, factory installed ballast	One luminaire per individual factory made luminaire, regardless of number of lamps per luminaire
LED (see Note 2)	Single diodes or clusters of diodes	One luminaire per cluster
	Linear row of diodes	One luminaire for each 3' length, rounded up to 3 foot multiple.
All Other	Incandescent luminaires including low voltage or line voltage	Count = 1 for luminaries with one lamp or one socket. Count = 1 luminaire for every two sockets, rounded up to the nearest whole number, for luminaires with multiple lamps or sockets

Note 1: A factory made luminaire is a complete lighting unit consisting of lamps and the parts designed to distribute the light, to position and protect the lamps, and to connect the lamp to the power supply.

Note 2: LED system, no screw bases, includes optics and power supply

Outdoor Lighting

The electricity use of outdoor lighting permanently attached to the building shall be determined using Equation 10.

Equation 10

$$Electricity_{OutdoorLights} = (-81 + 0.152 \times CFA) \times PAM_{Exterior}$$

where

$Electricity_{OutdoorLights}$ Annual electricity use for interior lighting (kWh/year).

CFA	Conditioned floor area (ft^2).
$PAM_{Exterior}$	Power adjustment multiplier to account for permanently mounted high efficacy luminaires and the type of control for the luminaire. The PAM for the reference house shall be determined based on minimum compliance with the mandatory lighting requirements. The PAM for the rated house is determined from Equation 11.

Equation 11

$$PAM_{Exterior} = \frac{\sum PAM_{Fixture,i} \times PAM_{Control,i} \times DailyHours_i \times Count_i}{\sum DailyHours_i \times Count_i}$$

where

$PAM_{Fixture,i}$	Power adjustment multiplier based on the type of the i^{th} fixture: 0.33 is used for hardwired high efficacy fixtures as defined in §150(k) of the California energy efficiency Standards; 0.67 is used for permanently mounted luminaires that are fitted with screw-in compact fluorescent lamps; and 1.00 is used for permanently mounted incandescent luminaires.
$PAM_{Control,i}$	Power adjustment multiplier based on the type of control serving the i^{th} fixture (see Table 18).
$DailyHours_i$	The average daily hours of lighting operation based on the location of the luminaire (see Table 19).
$Count_i$	The number of fixtures of this type of the count for the fixture type. The count is determined following the rules in Table 17.

Table 18 – Exterior Lighting Control Power Adjustment Multipliers

Control Type	$PAM_{Control}$
On/Off	1.00
Photocontrol with motion sensor (outdoor lighting only)	0.50
Occupant sensor (interior garage only)	0.80

Table 19 – Daily Lighting Hours – Exterior

Location	DailyHours
Indoor Garage	2.3
Outdoor – Front entry	6.0
Outdoor - Other (side/back)	2.0
Source: Impact Analysis of the 2005 Title 24 Energy Efficiency Standards, Eley Associates, Table 7.	

Recommended Modeling Assumptions for HERS

1. The modeling assumptions used for Title 24 compliance calculations are recommended, except as described below:
2. Lighting and Appliances Energy: Use the model recommended earlier in this section with the recommended schedules.
3. Internal Gains: Base internal gains on the recommended lighting and appliances model discussed above.
4. Uninsulated Wall Cavities: Modify Joint Appendix IV to include lower U-factors for uninsulated cavity walls
5. Air Conditioning in Heated-Only Homes: Assume air conditioning as recommended in the residential ACM manual for determining the rating, but do not assume air conditioning for the purpose of determining the cost effectiveness of recommended energy efficiency improvements.
6. Photovoltaic Systems: Model PV systems using the calculation procedures of the New Solar Homes Partnership (NSHP).

Task 2.2 – Rating Scale

The objective of this task is to thoroughly evaluate options for developing a statewide HERS rating scale that would be appropriate for both new and existing residences and which would account for the wide range of energy efficiency measures that exist in the California building stock.

Existing Rating Scales

RESNET HERS Index

Historically, HERS ratings used a scale from zero to 100 with a low score representing a poor house and a high score representing a zero energy house. This was used by CHEERS and the original RESNET ratings. In 2006 RESNET adopted a HERS index that turned the rating system around with a low score being good and a high score being bad. A score of 100 represents a house with energy use equal to the reference house; a score of zero is a house that uses zero energy; and a score greater than 100 is a house that performs worse than the reference house. The current RESNET HERS Index is as follows:

Equation 12

$$\text{HERS Index} = \frac{Btu_{Rated}}{Btu_{Reference}} \times 100$$

For the purposes of their HERS Index, RESNET includes all indoor energy uses in the estimates of energy for both the rated and reference house. In addition to the credit for space heating, space cooling and water heating that has always been addressed in HERS ratings, RESNET included credit for energy efficient refrigerators, dishwashers and lighting. Estimates of other plug load and appliance energy uses are included in the RESNET HERS rating but are held constant for both the rated house and the reference house. RESNET also offers a credit for on-site electric generation by making a reduction to the site energy of the rated house.

The reference house has the same floor area and surface areas as the rated house, but the thermal performance of envelope components is upgraded or downgraded to match the national consensus building standards that were in effect at the time RESNET was developing the HERS Index (RESNET used the 2003 International Energy Conservation Code (IECC) for its reference building).

Rating Scale Issues

Lighting and Appliance Energy

As discussed earlier, in California Building Energy Efficiency Standards compliance calculations include space heating, cooling and water heating energy. Lighting and other appliance energy use is regulated through mandatory requirements, and not included in the performance standards. Lighting and appliance energy are key energy uses in existing homes and installed appliances and permanently installed lighting are likely to stay with the home when occupants change. So those components are aspects of the relative energy efficiency of the home. A lighting and appliances model was recommended in the previous section. The model makes assumptions for most appliance and lighting loads and permits rating credits for some types of equipment. Because lighting can as often be portable as well as hard-wired, the lighting loads are based on the area of the home rather than observed fixtures. Efficiency credits for lighting will be based on an observation of the presence of high efficacy fixtures or compact fluorescent bulbs installed in hard-wired fixtures. Credit will also be given for advanced controls.

On-Site Renewable Generation

On-site electric generation is not considered in California Standards compliance calculations, however, it is considered in the RESNET HERS index. It is the consideration of solar production that makes a Rating of 0 – or a zero energy home – a realistic possibility within the RESNET system. The California Energy Commission in its 2007 Integrated Energy Policy Report recommends a goal of achieving zero-energy newly constructed homes by 2020 and has encouraged the combination of energy efficiency and photovoltaics in the New Solar Homes Partnership (NSHP) incentive program. To accomplish the goal of reaching zero-energy it is critically important to invest first in all cost-effective energy efficiency to reduce the home load to the smallest feasible so that the residual load can be feasibly met by photovoltaics.

To focus on the efficiency of the building itself, it is recommended that a HERS rating be based strictly on the energy efficiency of the building. In addition, it is recommended that a HERS rating that incorporates both the energy efficiency of the building and the on-site renewable generation be provided for full information. Existing on-site renewable generation should be included in the modeling of projected utility bills. The analysis of recommended energy efficiency improvements should include not only energy efficiency measures, but also the combination of implementing them together with on-site renewable generation.

Cap on Dwelling Unit Size

Large homes or dwelling units use more energy than smaller homes. An energy efficient large home can get the same score as an energy efficient small home.

The Commission should consider setting a cap on the size of the reference home, but modeling the rated home at its actual size. As long as the size of the rated home is less than the cap, there would be no impact on the rating, but when the home is greater than the cap, the rated home would have a higher score. The Commission should consider using a cap of 2,500 square feet for the reference home. That is slightly below the size established by LEED for a four bedroom home, 2,600 square feet, above which a home must earn more points to meet the LEED targets (LEED uses a lower cutoff for homes with fewer bedrooms). 2,500 square feet is one standard deviation (780 sf) above the average size single family home in the state (1,780 sf) according to the RASS dataset. Marin County uses a 3,500 square feet cap for their local ordinance for newly constructed homes. A more stringent 2,500 square feet budget is appropriate for the HERS program since the limit is not a firm cap on the energy budget that can be used within the home but is merely a way to incorporate the relative impact of house size into the rating.

Relationship to other Green Building Programs

Build-It-Green, LEED for Homes, and California Green Builder are all green building programs that focus on the residential market, although these programs currently focus on new construction rather than existing buildings. Energy efficiency is an extremely important part of green building programs, which also include consideration of water use, transportation, solid waste, construction waste diversion, indoor environmental quality and other factors. The green building movement is huge and growing. The Commission should coordinate with green building programs to incorporate the California HERS program into those programs once adopted by the Commission.

Greenhouse Gas Emissions

Energy consumption is one of the primary causes of greenhouse gas emissions. In developing the Impact Analysis for the 2008 edition of Title 24, the Commission developed emission factors for carbon dioxide (CO_2), nitrous oxides (NO_x), sulfur oxides (SO_x), and dust particles (PM_{10}). Hourly emission factors are developed for northern and southern California and keyed to the official Energy Commission climate zone weather files. Annual averages of these data are shown in Table 20 below.

Table 20 – Average Greenhouse Gas Emissions Associated with Energy Consumption.

	CO_2	NO_x	SO_x	PM_{10}
Electricity emissions	579	158	948	74.3
Units	tons/Gwh	lb/GWh	lb/GWh	lb/GWh
Gas emissions	5581	9200	6720	1000
Units	tons/Mtherm	lb/Mtherm	lb/Mtherm	lb/Mtherm

Because of the importance of making rapid and aggressive reductions in greenhouse gas emissions (GHG), the Commission should include an estimate of the GHG emissions of each house on the HERS report along with the HERS rating. Reporting on emissions other than CO_2 is probably unnecessary and will only serve to distract from the central focus of the report.

Stability Over Time

In establishing a reference for setting HERS ratings, the extent to which that reference should be stable over time or updated as it becomes outdated becomes an issue. For ratings to be useful in the marketplace, there is value in the rating remaining stable for some period after it is established for a particular home. When a rating approach is first established it is logical to base it on the Building

Energy Efficiency Standards in effect at that time. In California, Standards generally stay in effect until they are next updated, usually on a three year basis. In the process of updating Standards, improvements in how energy use is calculated are made also.

Under normal conditions it is natural for HERS rating approaches to be updated to incorporate new measures that come into the market (California uses a compliance options approval process to add such measures) and to upgrade calculation techniques as improvements are made. At points in time the reference Standards become dated and not particularly relevant as a basis of comparison and rating methods change enough to warrant a change out of the reference standard and calculations approach. RESNET experienced the imperative need for this in their 2006 change to a HERS Index based on the 2003 IECC (abandoning the old HERS rating scale based on the 1993 MEC).

During the coming 10 years when California will be moving as rapidly as possible to address global climate change, the urgency to make upgrades in the HERS rating reference may be even more important to consider. The Commission should be cognizant of the competing interests of stability and relevancy in making future decisions about the updating of the HERS ratings.

Recommendation

The Commission should move to a HERS Index rating approach, similar to that adopted by RESNET. The California HERS Index should be based on TDV energy and should use a reference home that complies with the 2008 Building Energy Efficiency Standards. The California HERS Index should be based on the following calculation:

Equation 13

$$\text{California HERS Index} = \frac{TDV_{Rated}}{TDV_{Reference}} \times 100$$

The TDV energy calculation for the reference house and the rated house should include all interior uses. The traditional uses of heating, cooling, and water heating are already produced by compliance software. The recommended lighting and appliances model discussed earlier should also be incorporated to estimate the energy of these components and offer a credit for energy efficient refrigerators, dishwashers and lighting.

The Commission should consider setting a cap on the size of the reference house of 2,500 square feet as explained above.

Outdoor lighting affixed to the house should be included in the rating, but other outdoor electric uses such as spas, pools, and well pumps should not. Those uses, which can be substantial, should be included by raters in the assessment of projected utility bills for the home and recommended cost-effective efficiency improvements.

Task 2.3 – HERS Provider Accreditation and Technical Guidelines

The objective of this task is to identify accreditation and procedural requirements from RESNET that may be appropriate for use in California. RESNET technical or modeling requirements will be considered in Task 2.1. The following are issues for consideration in California:

Provider Data Retention

Under RESNET, providers must maintain an electronic database of key data for every rating that they perform on a home that is seeking to qualify for a tax credit or other financial benefits, including the purpose of the rating, climate data, basic home parameters, and projected energy consumption. [2006 RESNET HERS Standards §102.1.4.12-§102.1.4.12.15.] This data retention requirement is a protection for the homeowner.

In addition, the provider must retain, annually, limited data for 10% of ratings or 500 homes (whichever is less). [§102.1.4.12.16.] The required data is: "1. homeowner authorization for the release of consumption information by utility companies," "2. climate data site used for energy estimation," and "3. any energy efficiency improvements made to the home and date of completion."

The Energy Commission has a similar requirement for field verification and diagnostic testing ratings. Section 1673(d) requires the provider to retain, for five years, the CF-1R, CF-6R, CF-4R, and any other reports required by Chapter 7 of the ACM manual for all homes diagnostically tested. Section 1673(e) says that the "providers shall maintain a database of the information specified in Section 1673(d) for a minimum 10% random sample of the homes actually field verified and diagnostically tested annually, or 500 such homes annually, whichever is less. Each provider shall provide this information annually in electronic form to the Commission . . ."

With the current cost of computer storage, the Commission should require the retention of all inputs and outputs for all rated homes. Such robust data retention will permit the Commission to analyze a host of issues relating to program performance in the future and will, as with RESNET, establish a database for public incentive qualifications. The Commission is already moving in the direction of requiring complete data retention by the raters and providers for the 2008 Building Energy Efficiency Standards.

Rater Continuing Education and Recertification

The Energy Commission currently requires review of the Provider's training materials, curriculum and tests whenever there are substantial changes to the Title 24 regulations. When those regulations are changed, rater training must be modified by the providers, reviewed by the Commission, and all raters are re-trained to maintain current certification. This training is specific to the regulations and the Commission's needs.

By contrast, RESNET presently requires 12 hours of continuing education every three years. Ten hours of the training must be approved by RESNET as specified in §102.1.3.3. RESNET is considering either increasing the continuing education requirement or requiring testing to accompany the training to improve the maintenance of rater skills. RESNET's continuing education requirements allow the rater to choose what topics they wish to get training on rather than requiring specific training when there are substantial changes to a provider's system.

The Energy Commission should continue to require re-training as the regulations or modeling tools are revised. The Commission should retain the authority to require supplemental continuing education with Commission designated curriculum should the need arise between the triennial recertification processes.

Rating Field Inspector

RESNET has an entry level certification known as a Rating Field Inspector that can perform the on-site inspection work for a rating but cannot perform and certify the required analysis to complete a home rating. The Commission should have a similar level of certification that takes minimal time to achieve and is targeted at the thousands of home inspectors already assessing homes at the time of sale. This will permit a relatively simple, lower cost, approach to conduct home energy ratings to improve market saturation.

Quality Assurance by the Provider

The Energy Commission requires the provider to specify the details of the quality assurance program, and reviews and approves the provider's application to ensure that the provider can effectively carry out their program to meet the Commission's regulatory requirements for quality assurance. In completing its review, the Commission requires all of the Provider's quality assurance personnel to be identified and to describe their qualifications. Consequently, the quality assurance personnel employed by the current Providers are well qualified as trainers and QA reviewers.

In comparison, RESNET requires a specific Quality Assurance Designee to be assigned for every RESNET provider. The designee can be an officer, employee, or contractor of the provider, but must pass either 1) the Rater Trainer exam, or 2) the RESNET Quality Assurance Designee test. To become a provider, the applicant must list on their application the QAD and his or her qualifications. [§102.1.1.1.]

The QAD may appoint multiple QAD delegates to complete the tasks required of the QAD. [§102.1.1.1.] A QAD delegate must be a rater who has completed at least 25 evaluations. [§102.1.2.1.] The quality assurance process for a QAD delegate's own ratings must comply with a maximum allowable variance in annual load of +/- 5%. [§102.1.2.1.1.] RESNET regulations state that the variance analysis applies to, "i.e. heating, cooling and water heater loads as impacted by insulation assessment, blower door tests, duct leakage to outside, sq. ft. of windows, weather station selection, etc." The QAD must pass the list of QAD delegates onto RESNET. [§102.1.2.3.]

The Energy Commission regulations should be more explicit about the review and approval of QA personnel for the Provider. To better describe their function, it is recommended that the equivalent entity to a QAD within the California providers be known as a Quality Assurance Manager. The QAD delegate should be known as a Quality Assurance Reviewer. The qualifications of both the

Quality Assurance Managers and Quality Assurance Reviewers should be submitted to the staff of the Commission for approval.

Task 2.4 – Implications of the Energy Policy Act of 2005

Status of the Energy Policy Act of 2005

The Energy Policy Act of 2005 establishes two types of tax credits that rely on HERS inspectors, one for new residential buildings and one for new and existing commercial buildings. Both credits are scheduled to expire on December 31, 2008.

To receive the residential tax credit, the building must be "certified . . . to have a level of annual heating and cooling energy consumption which is at least 50 percent below" a comparable dwelling unit constructed in minimum compliance with the 2004 Supplement to the 2003 IECC, possessing heating and cooling equipment with efficiencies required by the National Appliance Energy Conservation Act of 1987. [§45L(c)] The tax credit is given to the builder.

The residential certification must be performed by a Rater certified by RESNET "or an equivalent rating network", using software certified for that purpose by RESNET. [IRS Notices 2006-27, and 2006-28, and 2008-35.] Raters working for CalCERTS and CHEERS, which are both RESNET certified, are authorized to perform the residential tax credit inspection work in California. The new IRS language opening the certification to "equivalent rating networks" specifically refers to the state agency that administers energy efficiency standards. This means that if a provider is certified by the Energy Commission, they would be able to perform ratings for the purposes of establishing eligibility for the EPAct tax credits. RESNET has produced a list of eligible software for tax credit compliance purposes, which includes MICROPAS and EnergyPro (which are also certified by the Commission).

Task 2.5 – Role of Home Energy Inspectors and Raters in Improving Home Energy Efficiency

The objective of this task is to determine the appropriate levels of home inspection and rating services for the California existing home market and to identify associated roles and responsibilities.

Description of the Types of Existing Ratings, Audits and Inspections

RESNET recognizes just one procedure for rating homes, a detailed evaluation that involves measurement and diagnostic testing. Like California, HERS raters at the national level have primarily been involved in new construction and in particular activities related to the EnergySTAR program and other beyond-code programs. Only recently has RESNET begun the process to extend its procedures to existing homes. An Energy Audit Framework was adopted by the RESNET Board in March 2007 to begin to address the existing home market and to develop national consensus standards for energy audits in a comparable manner as their national consensus standards for Home Energy Ratings.[11] In the process RESNET intends to clarify the role of home energy raters and building performance contractors in providing energy audits.

In California, a HERS rating system that relies on site inspections by home energy inspectors has been piloted. Home inspectors are an unlicensed profession in California. The primary statute that applies to home inspectors is §7195 of the Business and Professions Code. This statute defines a home inspection as a noninvasive, physical examination, performed for a fee in connection with a real estate transfer. The inspection is intended to identify material defects in a building. A material defect is defined as "a condition that significantly affects the value, desirability, habitability, or safety of the dwelling."

Home inspectors are specifically prohibited from repairing or making improvements to properties for which they have performed an inspection.

Section 7195 was modified in 2001 by AB 1574. This modification says that home inspectors may provide energy information during the inspection, but does not require it. The statute states that the following items which may be included in the energy inspection.

- A noninvasive inspection of insulation R-values in attics, roofs, walls, floors, and ducts.
- The number of window glass panes and frame types.
- The heating and cooling equipment and water heating systems.
- The age and fuel type of major appliances.
- The exhaust and cooling fans.

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11 RESNET National Energy Audit Framework, Adopted by the RESNET Board of Directors on March 13, 2007

- The type of thermostat and other systems.
- The general integrity and potential leakage areas of walls, window areas, doors, and duct systems.
- The solar control efficiency of existing windows.

AB 1574 also modified the public resources code to add §25401.7 (the Warren-Alquist Act) on home inspectors. This provision says that a buyer or seller may request a home inspection, and references §7195 of the Business and Professions Code. When an inspection is performed, the home inspector is required to provide contact information for one or more non-profits, utilities or state agencies that can provide more information.

GeoPraxis operates a program called EnergyCheckup that uses home inspectors to collect information about the energy efficiency features of homes. The information the inspector collects correlates with the items describe under Section 7195, as described above. This information is then analyzed by GeoPraxis and a HERS rating report is produced which includes a set of recommended improvements.

Separation of HERS Raters from Home Improvement Services

As mentioned in the previous section, California statute prevents home inspectors from engaging in home improvements for homes they have inspected (for a home transaction) for a period of 12 months. In addition, the HERS regulations for Title 24 compliance field verification (see Title 20 §1673(i)) require that HERS providers be financially independent from HERS raters and that both providers and raters be financially independent from the builder or the contractor responsible for home improvements. An underlying policy with the California HERS program is that the organization or person doing the rating should not be financially associated with a company or organization that is in the business of making money on home improvements.

RESNET has a different method of consumer protection. RESNET providers and raters may have a financial interest in the builder or home improvement contractor, as long as this information is disclosed. Figure 34 is a form used by RESNET raters to disclose this information.

The Commission believes it is important to address conflict of interest by maintaining separation of financial interests between raters and home improvement contractors except in the special case of Building Performance Contractors.

Figure 34– RESNET Disclosure Form

RESNET HOME ENERGY RATING
Standard Disclosure

For home located at: 2342 Maybee Ave.

City: Denver **State:** CO

1. ☐ The Rater or the Rater's employer is receiving a fee for providing the rating on this home.

2. ☐ In addition to the rating, the Rater or Rater's employer has also provided the following consulting services for this home:

   ☐ A. Mechanical system design
   ☐ B. Moisture control or indoor air quality consulting
   ☐ C. Performance testing and/or commissioning other than required for the rating itself
   ☐ D. Training for sales or construction personnel
   ☐ E. Other (specify below)

3. ☐ The Rater or Rater's employer is:

   ☐ A. The seller of this home or their agent
   ☐ B. The mortgagor for some portion of the financed payments on this home
   ☐ C. An employee, contractor or consultant of the electric and/or natural gas utility serving this home

4. ☐ The Rater or Rater's employer is a supplier or installer of products, which may include:

	Installed in this home by:		**OR**	**Is in the business of:**	
HVAC systems	☐ Rater	☐ Employer		☐ Rater	☐ Employer
Thermal insulation systems	☐ Rater	☐ Employer		☐ Rater	☐ Employer
Air sealing of envelope or duct systems	☐ Rater	☐ Employer		☐ Rater	☐ Employer
Windows or window shading systems	☐ Rater	☐ Employer		☐ Rater	☐ Employer
Energy efficient appliances	☐ Rater	☐ Employer		☐ Rater	☐ Employer
Construction (builder, developer, construction contractor, etc.)	☐ Rater	☐ Employer		☐ Rater	☐ Employer
Other (specify below):	☐ Rater	☐ Employer		☐ Rater	☐ Employer

H.I. Scorer
Rater's Printed Name

303 333 2222
Certification #

Rater's Signature

May 11, 2007
Date

I attest that the above information is true and correct to the best of my knowledge. As a Rater or Rating Provider I abide by the rating quality control provisions of the Mortgage Industry National Home Energy Rating Standard as set forth by the Residential Energy Services Network (RESNET). The national rating quality control provisions of the rating standard are contained in Chapter One 4.C.8 of the standard and are posted at http://www.natresnet.org/accred/standards.pdf.

RESNET Form 03001-1

Over the past several years a new industry segment, the building performance contractor, has emerged to provide "whole-house" diagnostic testing and remedial services for existing homes. The building performance contracting service is grounded in identifying improvements to the energy efficiency of the older home, but also, and often more importantly, achieves coincident improvements in comfort, health and safety, indoor air quality and noise attenuation. Building performance contractors have organized to develop training and certification programs and pursue the advancement of these services in several states. The Building Performance Institute (BPI), headquartered in New York, has been an umbrella organization for this effort. The US Environment Protection Agency has sponsored pilot building performance contracting programs in several states through their Home Performance with Energy Star program.

In California, the California Building Performance Contractors Association (CBPCA) is actively pursuing expanded use of building performance contractors. CBPCA is affiliated with Home Performance with Energy Star and BPI, and has received third-party program funding through the CPUC's Public Goods Charge program and from the Sacramento Municipal Utility District. Its purpose is to "train and validate HVAC, insulation, and remodeling professionals in the use of scientific methods and equipment for holistically diagnosing and repairing a home's comfort and energy problems." CBPCA is one of the three HERS Providers that the Energy Commission has approved for overseeing HERS raters field verification and diagnostic testing for showing compliance with Title 24. CBPCA also utilizes a Commission-approved Third Party Quality Control Program for field verification.

In adopting the HERS procedures for Title 24 field verification in conjunction with the 2005 Building Energy Efficiency Standards, the Commission adopted rules for Third Party Quality Control Programs. A Third Party Quality Control Program provides training to installers, collects data concerning each installation, completes data checking to evaluate the validity and accuracy of the data, and provides direction to installers to retest and correct problems when data checking determines a problem with the installation. Third Party Quality Control Programs are expected to significantly improve the reliability of work completed by installers participating in the programs. The work of installing contractors remains subject to field verification by HERS raters under the oversight of HERS providers, but at a reduced sampling rate (sampling of 1 in 30 installations rather 1 in 7 installations).

The Commission should consider whether the Third Party Quality Control Program concept should be used to provide HERS rater verification of the work performed by building performance contractors in a similar way as Third Party Quality Control Programs are used for Title 24 field verification.

Recommendations

Roles, Functions, and Services That Should be Addressed by the California HERS Program

The California Energy Commission is directed by statute to adopt a California Home Energy Rating System Program that insures:

- Consistent, accurate and uniform ratings based on a single statewide rating scale, and
- Reasonable estimates of potential utility bill savings, and reliable recommendations on cost-effective measures to improve energy efficiency.

There are several specific steps that are entailed in delivering these elements of a California Home Energy Rating. These steps can be completed in whole or in part for several purposes, including showing compliance with the California Building Energy Efficiency Standards, completing an Energy Audit or completing all of the steps in their entirety to result in the designation of a rating to a home for comparative purposes. In fulfilling these purposes, whether Standards compliance, energy audit or full rating, there are several entities providing services in California who can be engaged to provide the steps of a California Home Energy Rating, either in their entirety by one individual or in combination by a team of individuals. Also, the completion of the steps of a California Home Energy Rating can be completed with varying levels of the use of diagnostic testing. Also, completion of a California Home Energy Rating should recognize the existence of two sources of related information that homeowners commonly have access to, Utility Bill Reports and online Homeowner Surveys, and take advantage of these sources of information to aid in providing the California Home Energy Rating to homeowners.

Utility Bill Report

The utility bill report is currently available from the IOU and/or municipal utility to the home owner upon demand. It is easy for them to obtain. The customer just visits the utility's website and enters the account number and additional identifying information. The website accesses the customer's utility bill history for the customer and produces a simple report showing actual monthly electricity and gas usage and costs for the last 12 months. Another option for customers is to call their respective utility and request this information via the telephone. The utilities can either send the summary information via regular mail or via fax. This information can help the customer see which months the customer might consider implementing some behavioral conservation efforts in order to reduce energy costs. The HERS rater/energy auditor should be very familiar with the process for obtaining this information from the utilities so that energy bill information can be considered for part of the cost effectiveness analysis. The Energy Commission should consider working with the utilities for possible standardization for the format of this information and facilitating the process for the HERS raters/energy auditors to obtain the information.

Homeowner Survey

Utilities often provide an online homeowner survey (sometimes referred to as an online energy audit) that is the homeowner's self-assessment of a home's energy use and general energy efficiency improvement options. The homeowner would go to the website and enter information about their home: zip code, square footage, number of stories, era of the house, etc. The era would key into default information on insulation levels, equipment efficiency and window performance. The homeowner may also indicate if they have comfort problems within the house, for example, whether it gets too cold or gets too hot. The survey may also include some questions as to how the owner operates the house, such as the level of hot water use and thermostat settings for the furnace. The website would then create a report for the customer.

The report from the self assessment includes some basic recommendations and tips on how to improve the energy efficiency of the home and may include a projection of future energy bills. The HERS rater/energy auditor should be very familiar with the availability of these online homeowner survey websites and the information that they provide.

California Home Energy Rating

A California Home Energy Rating is a method of evaluating the overall energy performance of a home, identifying cost effective improvements, assessing potential energy bill savings resulting from those improvements to make recommendations to homeowners, and establishing an energy rating that can be used to compare the relative energy of one home to others. The process can be separated into the following steps:

- Inspection of the existing conditions of the home's energy-related features
- Analysis of the energy impact of those features
- Identification of potential energy efficiency improvements for that home
- Evaluation of the cost effectiveness of each improvement
- Recommendations to the homeowner of the cost effective improvements
- Designation of a rating of the comparative energy efficiency of the home
- Production of a label that communicates the rating

These steps can be accomplished in whole or in part for different purposes. For example, all seven steps can be provided for the purpose of developing and assigning a California HERS rating to a newly constructed or existing home. The same steps absent the determination of cost effectiveness can be applied to the use of field verification and diagnostic testing to comply with the California Building Energy Efficiency Standards. The first five steps are completed for an energy audit, which may or may not include steps 6 and 7.

The steps of a California Home Energy Rating can be completed either in its entirety by one person or by a combination of people who specialize in one or more of the steps.

A California Home Energy Rating can also be completed with different levels of the use of diagnostic testing, ranging from 1) inspections based solely on observations that can be made visually, through 2) diagnostic testing of individual, specific building features or end-use equipment, or all the way to 3) comprehensive, whole-house assessments that make use of multiple diagnostic testing tools.

Energy Audit

An Energy Audit is a subset of a California HERS Rating that includes the same first five steps as a HERS Rating but typically may leave out the last two steps[12]. The California HERS Program statute directed the Commission to ensure that these steps result in reasonable estimates of potential utility bill savings and reliable recommendations of cost-effective measures to improve energy efficiency to protect consumers. The subset of steps that are commonly completed in an Energy Audit also should be completed in a consistent, accurate and uniform manner to accomplish the intent of the California HERS program.

Home Energy Inspection

Home inspectors are allowed by California law to provide a non-invasive physical examination of a home's existing energy efficiency features. While this inspection is not sufficient by itself to be considered a California HERS rating or energy audit, the home inspector being in the home creates an opportunity to collect information about the home's existing energy efficiency features that can serve as input into a HERS rating or energy audit analysis. This approach has been demonstrated in California by the GeoPraxis Energy Checkup program. Under this program, a trained home inspector collects energy efficiency data using a data entry form. The inspector then enters the data into laptop software and sends the information via the Internet to a centralized analysis function that uses building energy simulation software to validate and analyze the data and automatically generate an online Energy Checkup Report with an energy rating and a set of recommended improvements to the homeowner.

Energy Analyst

California's Building Energy Efficiency Standards rely almost exclusively on a performance approach that requires Energy Analysts to complete analysis of the energy impact of energy-related building features using Commission approved methods. As a result an infrastructure of Energy Analysts has developed in California to assist builders and homeowners in showing compliance. When compliance requires field verification and diagnostic testing, these Energy Analysts commonly team with a certified HERS rater who completes the field verification. Similar teams have formed in California to provide both the energy analysis and the field verification tasks needed to qualify

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[12] Note that it is a relatively simple matter to complete the final two steps of a California HERS rating once the first five steps, that commonly are commonly included in an Energy Audit are complete.

homes for the federal tax credit. The California HERS Program should cover the use of Energy Analysts to receive data from a home inspector or field verifier and perform the analysis steps, including evaluating and recommending energy efficiency improvements.

Building Performance Contractor

Building Performance Contractors evaluate the overall performance of a home through comprehensive whole-house assessments using multiple diagnostic tools. Often the building performance contractor works in a forensic manner to identify and redress concerns with the health and safety, comfort and/or energy consumption of a home. They do the steps of an energy audit in a highly detailed fashion using extensive diagnostic testing equipment, prepare a scope of work spelling out exactly how the improvements are to be installed, and either do the work or serve as a general contractor for the work. Similar to an Energy Auditor, they commonly do not complete the final two steps in the California HERS rating process.

Task 2.6 – Recommendations and Energy Measure Costing

The Public Resources Code (§25942) says that statewide home energy rating programs shall include "reasonable estimates of potential utility bill savings and reliable recommendations on cost effective measures to improve energy efficiency". The key words are "reasonable" and "reliable".

The purpose of this task is to identify and evaluate different approaches for developing energy efficiency recommendations. A prioritized list of recommended energy efficiency measures would provide the homeowner or home buyer with information on opportunities to improve the energy efficiency of their home.

Background

HERS Precedents for Recommendations

RESNET

RESNET does not require that rating tools produce recommendations.

RemRATE

The RemRATE software is a proprietary software developed by Architectural Energy Corporation that is used for HERS systems in most states except California and Florida. RemRATE produces a list of recommendations using a rolling basecase approach (see discussion later). The RemRATE developers do not provide a list of measures or costs. This is left to the HERS providers that license and use the software. RemRATE, does, however, provide a database structure so that HERS providers can enter data on energy efficiency measures in a consistent format that can be used by the software.

The RemRATE database requires that HERS providers or raters define each of the measures for upgrades. Each measure consists of a starting point, an ending point, a performance improvement, and an incremental cost. For instance, the starting point may be no wall insulation, the ending point might be R-11 wall insulation, the performance improvement might be a change in U-factor, and the cost might be $\$1.10/ft^2$. Likewise, the starting point for an air conditioner measure might be an SEER of 8, the ending point might be an SEER of 12 and the cost might be $350/ton.

RemRATE then evaluates all the possible improvements, finds the one with the highest benefit to cost ratio, and adds that measure to the moving basecase. The process is repeated, as described above, until all cost effective measures are added to the list of recommendations.

CHEERS

Early research on CHEERS[13] followed an approach similar to RemRATE.

Databases of Energy Measures and Costs

Database for Energy Efficiency Resources (D.E.E.R.)

The Database for Energy Efficiency Resources (D.E.E.R.) is supported by the Energy Commission and the CPUC. It is intended to provide not only cost information but also estimates of energy and peak demand savings values and effective useful life (EUL), all in one data base. The data base is intended for program planners, regulatory reviewers and planners, utility and regulatory forecasters, and consultants supporting utility and regulatory research and evaluation efforts. D.E.E.R. has been designated by the CPUC as its source for deemed impact costs for program planning.

The D.E.E.R. database was most recently updated in 2005. The database has more than 130,000 unique records representing over 360 unique measures. The data is presented as a web-based searchable data set. The entire D.E.E.R. may be downloaded as an Access database and portions of the data are available as Excel spreadsheets. When appropriate, data is broken out by the 16 California climate zones and by 36 different building types, five building vintages for single family, multifamily, and nonresidential, and four building vintages for mobile homes. A user's guide and the data can be found at http://eega.cpuc.ca.gov/deer/.

Commercially Available Cost Databases

A number of cost databases are available commercially on either a one time purchase or on a subscription basis. R.S. Means is one of the most widely used databases. See http://www.rsmeans.com/. Another widely used cost estimation guide is from Saylor Publications, http://www.saylor.com/index.html. These and other cost estimating guides are available as hard covered books, databases, and cost estimating software. The commercially available sources do not focus specifically on energy efficiency measures (like DEER), but rather cover the complete range of building construction costs. These cost databases include regional multipliers to account for regional variations in labor costs.

Cross Checking Energy Savings against Utility Bills

As noted earlier in the report, lifestyle and behavioral issues greatly affect energy consumption. There will be times when energy consumption predicted by the energy models will be greater or less than actual energy consumption, as indicated by the utility bills. To address this issue, it is recommended that California HERS tools have the capability of performing an analysis of utility bills

[13] California Home Energy Rating System, Research, Evaluation and Design, CHEERS, 1991, Eley Associates.

so that model estimates can be compared to utility bill data normalized for the typical weather year represented on the official Energy Commission climate zone weather file.

Inverse Modeling[14]

The utility bill analysis should be consistent with ASHRAE Research Paper 1050, "Inverse Modeling Toolkit: Numerical Algorithms".[15] The four-parameter change-point model is used for heating only and cooling only analysis while the five-parameter change-point model is used for both heating and cooling analysis. In both cases, the independent variable is outside temperature. These modes of operation are described in greater detail below:

- **Heating Only**: This mode is used to analyze gas consumption in rated homes that use gas for space heating. The heating only mode also is used to analyze electricity consumption in rated homes that are not air conditioned and use electricity for space heating.
- **Cooling Only:** This mode is used to analyze electricity consumption in rated homes that use electricity for air conditioning and gas or other non-electric energy for space heating.
- **Heating and Cooling**: This mode is used to analyze electricity consumption in rated homes that use electricity for both space cooling and space heating, for instance an electric heat pump.

Four-Parameter Model

The four-parameter model has two forms as shown in **Error! Reference source not found.**. The form of the equation is shown in Equation 14. In this equation, E is the estimate of daily energy (either electricity or gas), T is the daily average outside temperature, β_1 is the constant term, β_2 is the slope to the left of the balance point temperature, β_3 is the slope to the right of the balance point temperature, and β_4 is the balance point temperature. Each of the beta coefficients shall be calculated from utility bills and concurrent weather data using procedures described in the Inverse Model Toolkit.[16]

Equation 14

$$E = \beta_1 + \beta_2 (T - \beta_4) + \beta_3 (T - \beta_4)$$

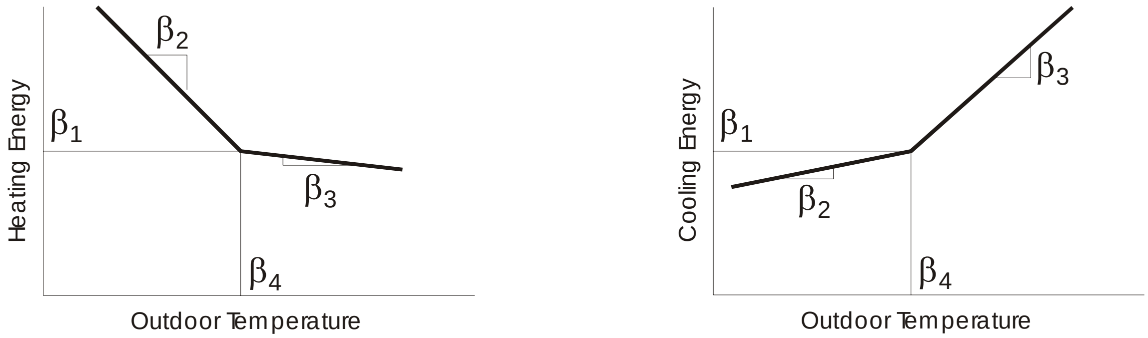
---

14 Energy code compliance and the HERS rating index would be calculated through direct modeling, whereby data on the physical characteristics of the building are entered and estimates of electricity and gas consumptions are produced. Inverse modeling is a technique whereby the answers are inputs to the model and a simple expression is generated that explains variations in energy use, usually as a function of outdoor temperature, but other independent variables may be considered if they can be quantified. Direct energy modeling looks forward, where inverse modeling looks back. The most common application of inverse modeling has been to verify savings in utility programs or performance contracts.

15 Kissock, K., Haberl, J., Claridge, D. 2003. "Inverse Model Toolkit (1050RP): Numerical Algorithms for Best-Fit Variable-Base Degree-Day and Change-Point Models", ASHRAE Transactions-Research, KC-03-2-1 (RP-1050).

16 *Ibid*.

Figure 35 – Four-Parameter Regression Model



Source: Inverse Model Toolkit (1050RP)

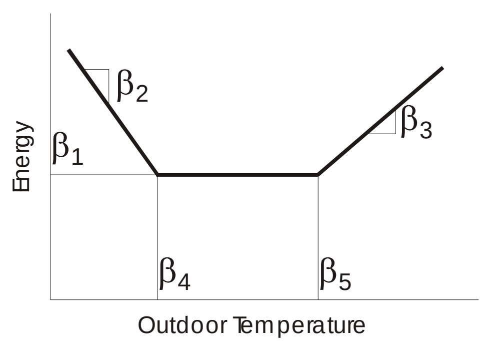
Five-Parameter Model

The five-parameter model is shown in Figure 36 and Equation 15. E is the estimate of daily energy (electricity), T is the daily average outside temperature, β_1 is the constant term, β_2 is the slope to the left of the balance point temperature, β_3 is the slope to the right of the balance point temperature, β_4 is the balance point temperature for heating, and β_5 is the balance point temperature for cooling. Each of the beta coefficients shall be calculated from utility bills and concurrent weather data using procedures described in the Inverse Model Toolkit.[17]

Equation 15

$$E = \beta_1 + \beta_2 (T - \beta_4) + \beta_3 (T - \beta_5)$$

Figure 36 – Five-Parameter Regression Model



Source: Inverse Model Toolkit (1050RP)

Data Input

The following format is recommended for the climate data and the utility bill data to standardize input and reduce the need for data input.

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[17] *Ibid.*

Table 21 – Standard Text Format for Climate Data

Sample Data	Notes
1 1 1995 43.0 1 2 1995 40.6 1 3 1995 47.5 1 4 1995 49.2 1 5 1995 48.6 1 6 1995 48.0 1 7 1995 51.9 1 8 1995 52.9 1 9 1995 58.4 1 10 1995 56.3 1 11 1995 53.5 1 12 1995 53.9 1 13 1995 56.1 1 14 1995 57.5 1 15 1995 50.1 1 16 1995 46.7 1 17 1995 41.2 1 18 1995 46.1 1 19 1995 45.3 1 20 1995 43.9 1 21 1995 48.1 1 22 1995 50.9 1 23 1995 52.4 1 24 1995 52.0 1 25 1995 51.5 1 26 1995 49.3 1 27 1995 49.7	Columns: 1. Month 2. Day 3. Year 4. Average Daily Temperature Columns (data fields) shall be separated by tabs, spaces, or commas. File may contain any amount of data as long as it encompasses the period of time for which utility bill data is provided (see Table 22 below) Data for several California cities is available at http://www.engr.udayton.edu/weather/.

Table 22 – Standard Text Format for Utility Bill Data

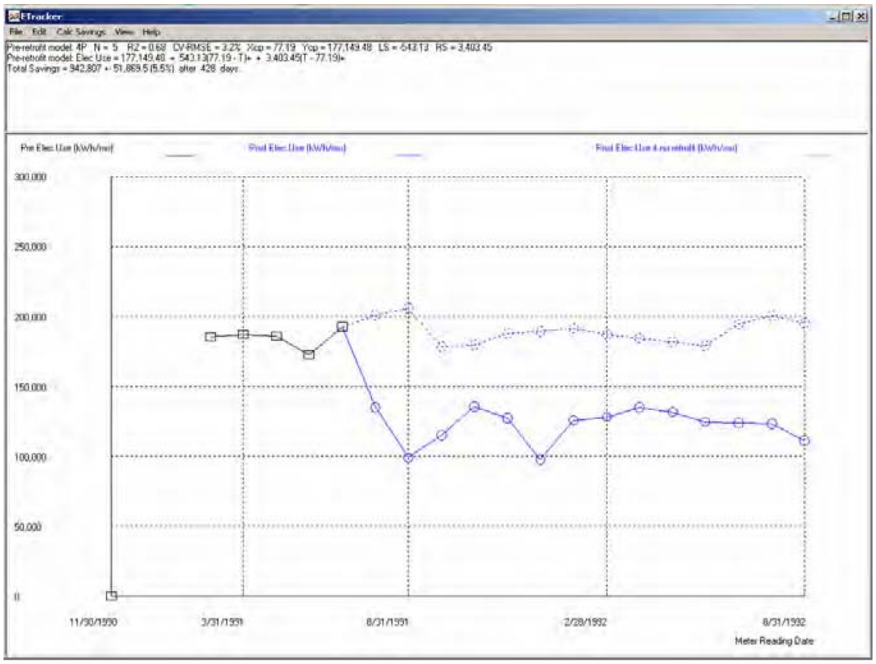
Sample Data	Notes
10 31 1990 -99 722 527 1 1 11 30 1990 -99 1409 1126 1 1 12 31 1990 -99 1093 1443 1 1 1 31 1991 -99 809 1301 1 1 2 28 1991 185200 1180 1392 1 1 3 31 1991 187000 1461 1351 1 1 4 30 1991 185700 1690 872 1 1 5 31 1991 172300 2021 914 1 1 6 30 1991 192500 2420 770 1 1 7 31 1991 134700 1747 701 2 2 8 31 1991 99000 1470 577 2 2 9 30 1991 115100 1013 343 2 2 10 31 1991 135400 753 299 2 2 11 30 1991 127400 572 351 2 2 12 31 1991 97700 634 334 2 2 1 31 1992 125700 436 414 2 2 2 28 1992 128000 615 383 2 2 3 31 1992 134500 717 412 2 2 4 30 1992 131500 775 423 2 2 5 31 1992 124500 905 445 2 2 6 30 1992 123500 1271 435 2 2 7 31 1992 123100 1439 437 2 2 8 31 1992 110900 1224 449 2 2	Columns 1. meter reading month 2. meter reading day 3. meter reading year 4. electricity consumption (kWh/month) 5. peak electrical demand (kW) 6. thermal energy consumption (units/month) 7. pre/post indicator for electricity use 8. pre/post indicator for thermal energy use Each column should be separated by at least one space, a tab or a comma. If energy use data are missing or unavailable, enter no-data flags "-99" in their place; The "pre/post" indicators in columns 7 and 8 define the pre and post retrofit periods. Enter "1" to represent data from before the retrofit, and "2" to represent data from after the retrofit.

Post-Retrofit Evaluation

It is recommended that HERS software have the capability to evaluate post-retrofit energy consumption through inverse modeling (described above) and to compare it to what the home would have used had there been no retrofit. Figure 37 is an example produced by the ETracker software which implements the recommended procedure.[18]

[18] The procedure for described above along with the standardized data is implemented in the ETracker software which may be downloaded from http://www.engr.udayton.edu/weather/. This tool may be used for comparison and to verify a correct implementation of the procedure.

Figure 37 – Example Post-Retrofit Utility Bill Analysis



Recommended Approach

The Energy Commission is directed by Statute to achieve reasonable estimates of potential utility bill savings and reliable recommendations on cost effective measures to improve energy efficiency. In order to meet this directive, the Commission through its regulations should establish a reasonable level of quality and consistency regarding the costing of measures, procedures for evaluating cost effectiveness, and consideration of how the measures will be financed. These regulations should endeavor to both standardize the process as appropriate and also allow flexibility for consideration of unique conditions applicable to the individual homeowner and project.

A fully standardized approach would have the advantage of highly consistent recommendations among HERS providers, raters, and energy auditors. This would require establishing a means to maintain a quality and up-to-date statewide database of measures and costs. However, local conditions are a strong influence on costs, and it would be difficult to keep track of these differences at a statewide level.

HERS providers are in a better position to monitor local variations in cost and could identify the need to adjust the statewide database. Providers could also set up a process whereby data is provided to them by home owners or buyers who contract for home improvement services in response to a HERS report.

Considering the above, it is recommended that the HERS system have the capability to generate recommendations using both a Standard Approach and a Custom Approach. The Standard approach would be mandatory for every rating and the Custom Approach would be optional.

Alternative assumptions used with the Custom Approach would be reported to the HERS provider by the rater and approved by the provider.

The Standard Approach will result in the same set of recommendations, no matter who does the rating or which HERS system is used. The "cost effective" set of recommendations resulting from the Custom Approach will depend on the specific cost and financing assumptions associated with the individual home owner and project.

1. Cost-Effective Methodology and Criteria

Making recommendations for improving the energy efficiency of the house requires choosing between various options for improvement based on some criteria or within some set of constraints. The process is much like an optimization process and can be quite elaborate if all combinations and permutations are considered in the process. There are a number of possible strategies for making decisions and some are described below. [19]

- **All That's Cost Effective**. With this strategy, the recommendations would include all measures that are determined to be cost effective.
- **Fixed Budget**. With this strategy, the homeowner or homebuyer would specify a construction budget for energy efficiency improvements and the HERS program would determine the package of measures that fit the budget and produce the greatest energy savings.
- **Minimum Level of Performance**. With this strategy, recommendations would be produced that would bring the house up to some specified level of energy performance at the least cost. This approach would be appropriate to achieve compliance with an energy efficiency program that required a maximum HERS index, for instance. If the minimum level of performance to quality for a program were a HERS index of 80, for instance, then with this strategy, the recommendations would include a collection of measures which would bring the house to the desired level of performance at the least cost.
- **Customer Identified Measures**. With this strategy, the home owner may propose one or more measures they prefer in combination with other measures that are determined to be cost effective as a whole.

It is recommended that the "All That's Cost Effective" be used as the Standard Approach and required in all ratings. The fixed budget, minimum level of performance, and customer identified measures approaches have merit, and HERS providers are encouraged to offer these approaches as an option with the Custom Approach.

There are multiple approaches to determine cost effectiveness. The approach used for the California building energy efficiency standards is life-cycle cost effectiveness determined based on the Energy Commission's adopted forecasts of energy costs (electricity and gas) over the useful life of the measures and adopted discount rate. Based on this information, the energy savings are determined

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[19] Some of the material in this section was adapted from early research on CHEERS. See Eley Associates. California Home Energy Rating System, Research, Evaluation and Design, CHEERS, 1991, Eley Associates.

over the life of the measure and discounted to net present value. If the cost premium for the measure is less than the net present value of the energy savings, then the measure is considered to be cost effective. This is the approach that is recommended for the Standard Approach.

For the Custom Approach, alternative approaches would be permitted, to enable greater consistency with energy efficient mortgages or other available financing. For instance, a cashflow approach could be used where the first year energy savings would be shown to be equal to or greater than the additional mortgage payments with consideration of tax benefits and other factors relevant to the home owner.

2. Estimating Energy Cost Savings

To develop cost effective recommendations, it is necessary to estimate the energy cost savings associated with individual measures. The energy models to be used to calculate the rating are well suited for this purpose. However, we recommend that the modeling assumption used for ratings that all homes have air conditioning, be waived for the purposes of developing the recommendations. If a rated home does not have air conditioning, then energy savings resulting from cooling measures should not be considered, for example, no cooling measures would be included in the list of measures for homes that are not air conditioned. Otherwise, for the Standard Approach it is recommended that the standard HERS modeling rules be required and no variations be permitted. With the Custom Approach raters would be permitted to vary thermostat settings, schedules of operation and other factors to match the occupancy patterns of the home owner if known.

In estimating cost savings the Standard Approach would use the life-cycle cost methodology used to justify the Standards, which incorporates Energy Commission adopted forecasts of electricity and gas costs. For the Custom Approach, it is recommended that the utility rate that is in effect for the rated house be used in the analysis. If the house is unoccupied and no utility rate is in effect, then the most common rate for homes in the area should be used. Most residential utility rates are tiered, that is the price per unit of consumption increases as consumption increases. For this reason, it is important to include all energy uses in the analysis, even though recommendations may not be generated for them. Examples are pools, spas, and of course lighting and appliances. The recommended lighting and appliances model will address possible energy savings from refrigerator, dishwasher or lighting improvements and also provide an estimate for other uses.

3. Types of Measures to Be Considered

It is recommended that HERS recommendations address all components of energy use that affect the HERS index. For the Standard approach recommendations are not required for ancillary energy uses not included in the rating, such as pools, spas, etc. or other uses such as miscellaneous electricity use that are fixed between the rated home and the reference home. The following categories of measures shall be considered in developing the recommendations:

Building Envelope

- Attic insulation
- Wall insulation
- Window replacement
- Weather stripping and sealing
- Awnings, trellises, or other shading devices
- Shade trees

Lighting
- Energy efficient luminaires
- Screw in CFLs
- Automatic controls

HVAC
- Equipment replacement
- Equipment tune-up
- Charge
- Air flow
- Duct sealing
- Duct insulation

Water heating
- Equipment replacement
- Demand control
- Solar

Appliances
- Refrigerator
- Dishwasher

Photovoltaic systems

For the Custom approach recommendations are encouraged for ancillary energy uses not included in the rating, such as pools, spas, or other miscellaneous electricity uses. An example would be screw-in compact fluorescents lamps in portable lighting.

4. Analytic Considerations and Methodology

Developing an ordered list of recommendations from a database of possibilities requires a specific approach. The most widely accepted methodology is a procedure sometimes referred to as a rolling basecase. With the rolling basecase method, you start with the home in its present condition. This is the initial basecase. From this base, all possible measures are identified and the energy savings, implementation costs, and possibly maintenance costs are estimated. The next step is to calculate the benefit cost ratio (energy savings divided by measure cost) of each of the possible measures. The measure with the highest benefit to cost ratio is then added to the home and the home with the new measure becomes the new basecase.

The whole process is repeated again for the new basecase, that is, all measures are identified and their benefit cost ratio is determined relative to the new basecase. The measure with the highest benefit to cost ratio is added to the basecase and a new basecase is created. This process is repeated again and again as long as measures are available that have a benefit to cost ratio greater than one. The rank order of measures is the sequence in which they were added to the basecase.

With the above approach, many measures are mutually exclusive and the list of possibilities become smaller with each new basecase, for example, once a new air conditioner is installed, all the other air conditioner upgrades drop off the list.

The rolling basecase approach is recommended for the Standard Approach and is also potentially useful for the Custom Approach.

5. Requirements for HERS Providers to Maintain Cost Data

It is recommended that HERS providers have primary responsibility for developing and maintaining up-to-date databases on energy efficiency measures and costs. HERS providers should draw from the D.E.E.R. database and other published databases as necessary. A summary of the D.E.E.R. database is provided as Appendix D of this research report.

HERS providers are expected to coordinate updates on a regular basis in collaboration with the Energy Commission, no less frequently than annually, to maintain a common database of measures and costs for use with the Standard Approach for developing recommendations.

Probably the most reliable cost data will be firm bids from contractors to homeowners to carry out the recommended work. We recommend that HERS providers establish cost databases that can be updated from construction bids. This exchange of information would be done with the knowledge and permission of the homeowner.

Qualifying the Recommendations

The recommendations made using the Custom Approach should disclose all non-standard assumptions and information used to make the recommendations. The statements shown below are examples.

- The following recommendations are based on the assumption that the cost of the improvements are financed through an energy efficiency mortgage at a rate of __% and that the homeowner is in a __% tax bracket.
- Future maintenance costs are discounted to present value at the rate of __%.
- Energy cost savings are based on the __ utility rate provided by __. Average electricity cost at the margin of the savings is __/kWh and average gas cost as the margin of the savings is __/therm.

Also, when a utility bill analysis shows a considerable variation from the predictions of the energy model, qualifying statements should be added to the recommendations page of the HERS report stating that the utility bills show higher or lower energy consumption from the model. The qualifying statements should explain the common reasons for variations between the model and bills, for example, lifestyle or unaccounted for energy uses such as pools or spas.

Task 2.7 – Rating Report Content and Labeling Requirements

The purpose of the rating report is to communicate the results of the rating, projected utility bills, the recommendations, and perhaps historic consumption data. In communicating this information, it is extremely important that the report makes a clear distinction between energy efficiency and energy conservation. Energy efficiency is the relative capability of a home to deliver the desired services the occupant wants (for example, comfort, functionality) with low energy consumption based on the performance characteristics of the home's features and equipment, without consideration for changes in the behavior of the occupant. Energy conservation is the reduction in actual energy use of the home, including the behavior of the occupant, with the goal of avoiding wasteful or unnecessary energy uses.

The HERS index is an indicator of energy efficiency. Through our choice of modeling assumptions (discussed earlier in this report) we will attempt to establish standard modeling assumptions that represent reasonable home energy use patterns so that the energy estimates that are used for the HERS index are representative of typical consumption. Actual consumption, by contrast, will vary from home to home depending on how the home is used, the intensity of lights and appliances that are used in the home, the number of occupants, and other lifestyle factors.

RESNET specifies the information that is to be included on the rating certificate, but does not specify the exact format for this information. Software developers and HERS providers are provided with some latitude in how the information is laid out on the page. Figure 38 is an example report produced by RemRATE, which meets the RESNET requirements. The report and the associated HERS index focuses on energy efficiency. This simple, one-page report is uncluttered, easy to understand, and summarizes the principal energy efficiency features of the home.

Information required by RESNET is as follows:

- The numerical rating derived from the RESNET scale.
- A star rating corresponding to the numerical rating (1 to 5+ stars).
- Estimated annual energy use for: space heating, space cooling, domestic hot water, and all other energy uses, as well as a total.
- Estimated annual energy cost for the same four elements, as well as a total.
- Location of the home.
- Person conducting the rating.
- Date of the rating.
- The rating software and version number.
- A statement in 8 pt. font or bigger stating, "The home Energy Rating Standard Disclosure for this home is available from the rating provider." It will include the Provider's address and phone number.

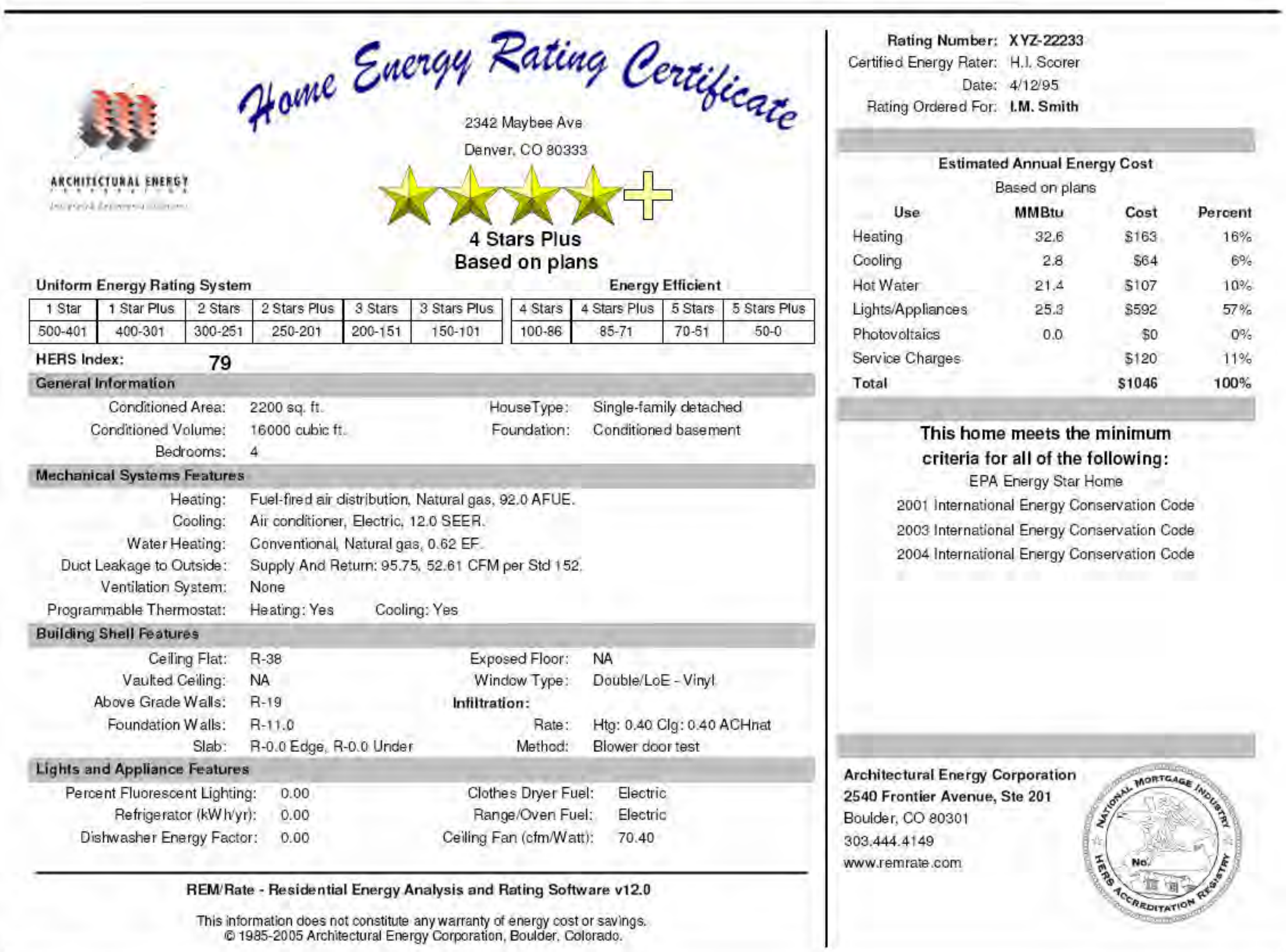
If it includes recommended improvements, those shall include:

- Estimated annual cost savings.
- The "Energy Value" of the improved home (net present value of savings, in this case calculated over 23 years).

The Commission should follow a similar report framework, and should outline the required content of the rating report. The first page of the report should illustrate in a simple, persuasive, recognizable manner the overall energy rating for the building. Providers and Raters should also be permitted to add supplemental information to the reports, such as available rebates, or to recommend building improvements that are not the most cost effective but still desirable, such as photovoltaics.

Figure 39 is a recommendations report produced by RemRATE. This sample report lists six measures with an estimated cost premium of $1,097.

Figure 38 – Example HERS Index Report (RemRATE)



Home Energy Rating Certificate

ARCHITECTURAL ENERGY

2342 Maybee Ave
Denver, CO 80333

4 Stars Plus
Based on plans

Uniform Energy Rating System — Energy Efficient

1 Star	1 Star Plus	2 Stars	2 Stars Plus	3 Stars	3 Stars Plus	4 Stars	4 Stars Plus	5 Stars	5 Stars Plus
500-401	400-301	300-251	250-201	200-151	150-101	100-86	85-71	70-51	50-0

HERS Index: 79

General Information

Conditioned Area: 2200 sq. ft.
HouseType: Single-family detached
Conditioned Volume: 16000 cubic ft.
Foundation: Conditioned basement
Bedrooms: 4

Mechanical Systems Features

Heating: Fuel-fired air distribution, Natural gas, 92.0 AFUE.
Cooling: Air conditioner, Electric, 12.0 SEER.
Water Heating: Conventional, Natural gas, 0.62 EF.
Duct Leakage to Outside: Supply And Return: 95.75, 52.61 CFM per Std 152.
Ventilation System: None
Programmable Thermostat: Heating: Yes Cooling: Yes

Building Shell Features

Ceiling Flat: R-38
Exposed Floor: NA
Vaulted Ceiling: NA
Window Type: Double/LoE - Vinyl
Above Grade Walls: R-19
Infiltration:
Foundation Walls: R-11.0
Rate: Htg: 0.40 Clg: 0.40 ACHnat
Slab: R-0.0 Edge, R-0.0 Under
Method: Blower door test

Lights and Appliance Features

Percent Fluorescent Lighting: 0.00
Clothes Dryer Fuel: Electric
Refrigerator (kWh/yr): 0.00
Range/Oven Fuel: Electric
Dishwasher Energy Factor: 0.00
Ceiling Fan (cfm/Watt): 70.40

REM/Rate - Residential Energy Analysis and Rating Software v12.0

This information does not constitute any warranty of energy cost or savings.
© 1985-2005 Architectural Energy Corporation, Boulder, Colorado.

Rating Number: XYZ-22233
Certified Energy Rater: H.I. Scorer
Date: 4/12/95
Rating Ordered For: I.M. Smith

Estimated Annual Energy Cost
Based on plans

Use	MMBtu	Cost	Percent
Heating	32.6	$163	16%
Cooling	2.8	$64	6%
Hot Water	21.4	$107	10%
Lights/Appliances	25.3	$592	57%
Photovoltaics	0.0	$0	0%
Service Charges		$120	11%
Total		$1046	100%

This home meets the minimum criteria for all of the following:
EPA Energy Star Home
2001 International Energy Conservation Code
2003 International Energy Conservation Code
2004 International Energy Conservation Code

Architectural Energy Corporation
2540 Frontier Avenue, Ste 201
Boulder, CO 80301
303.444.4149
www.remrate.com

Figure 39 –Example Recommendations Report (RemRATE)

Improvement Analysis Home Energy Rating Certificate

Recommendations for Energy Improvement Upgrade

The measures below, if implemented, will upgrade the energy rating to the value shown below.

#	Measure Description	Measure Cost	Annual Energy Savings	Annual Loan(1) Increase	Net Annual Savings
1	Equip 3: DHW: Measure:Rented -> Inst	$500	$299	$500	$-201
2	AG Walls- Measure:Increase by R-4	$62	$24	$62	$-37
3	Infiltration: Measure:Achieve 0.4ACH	$320	$143	$320	$-177
4	Thermostat: Measure:New T-stat	$50	$16	$50	$-34
5	Ceiling 1: Attic Measure:Increase by R-8	$100	$16	$100	$-84
6	Perf Adj 1: HEAT: Measure:LVFurnaceRepair	$65	$83	$65	$18
	Total	$1097	$581	$1097	$-516

[1] Interest Rate = 0.000%; Term = 1 years

Health, Safety, Comfort, and House Durability Recommendations

These measures do not impact the energy rating, but are highly recommended for your home.

A:	
B:	
C:	
D:	
E:	

Upgraded Energy Rating: 4 Stars

HERS Index: 95

The Home Energy Rating Standard Disclosure for this home is available from the rating provider.

REM/Rate - Residential Energy Analysis and Rating Software v12.33

This information does not constitute any warranty of energy cost or savings.

Rating Number: XYZ-22233
Certified Energy Rater: H.I. Scorer
Rating Date: 4/12/95
Rating Ordered For: **I.M. Smith**
2342 Maybee Ave.
Denver, CO 80333

After upgrade, this home meets or exceeds the minimum criteria for all of the following:

Annual Energy Cost Comparison ($/yr)

Use	Before	After	Savings
Heating	$1087	$796	$291
Cooling	$147	$156	$-9
Hot Water	$223	$164	$59
Lights/Appliances	$611	$611	$0
Photovoltaics	$-0	$-0	$0
Service Charge	$120	$120	$0
Total	**$2188**	**$1847**	**$341**

TITLE
Company
Address
City, State, Zip
Phone #
Fax #

APPENDIX A – CALIFORNIA BUSINESS AND PROFESSIONS CODE, SECTION 7195-7199

7195. For purposes of this chapter, the following definitions apply:

(a) (1) "Home inspection" is a noninvasive, physical examination, performed for a fee in connection with a transfer, as defined in subdivision (e), of real property, of the mechanical, electrical, or plumbing systems or the structural and essential components of a residential dwelling of one to four units designed to identify material defects in those systems, structures and components. "Home inspection" includes any consultation regarding the property that is represented to be a home inspection or any confusingly similar term.

(2) "Home inspection," if requested by the client, may include an inspection of energy efficiency . Energy efficiency items to be inspected may include the following:

(A) A noninvasive inspection of insulation R-values in attics, roofs, walls, floors, and ducts.

(B) The number of window glass panes and frame types.

(C) The heating and cooling equipment and water heating systems.

(D) The age and fuel type of major appliances.

(E) The exhaust and cooling fans.

(F) The type of thermostat and other systems.

(G) The general integrity and potential leakage areas of walls, window areas, doors, and duct systems.

(H) The solar control efficiency of existing windows.

(b) A "material defect" is a condition that significantly affects the value, desirability, habitability, or safety of the dwelling. Style or aesthetics shall not be considered in determining whether a system, structure, or component is defective.

(c) A "home inspection report" is a written report prepared for a fee and issued after a home inspection. The report clearly describes and identifies the inspected systems, structures, or components of the dwelling, any material defects identified, and any recommendations regarding the conditions observed or recommendations for evaluation by appropriate persons.

(d) A "home inspector" is any individual who performs a home inspection.

(e) "Transfer" is a transfer by sale, exchange, installment land sales contract, as defined in Section 2985 of the Civil Code, lease with an option to purchase, any other option to purchase, or ground lease coupled with improvements, of real property or residential stock cooperative, improved with or consisting of not less than one nor more than four dwelling units.

7196. It is the duty of a home inspector who is not licensed as a general contractor, structural pest control operator, or architect, or registered as a professional engineer to conduct a home inspection with the degree of care that a reasonably prudent home inspector would exercise.

7196.1. (a) Nothing in this chapter shall be construed to allow home inspectors who are not registered engineers to perform any analysis of the systems, components, or structural integrity of a dwelling that would constitute the practice of civil, electrical, or mechanical engineering, or to exempt a home inspector from Chapter 3 (commencing with Section 5500), Chapter 7 (commencing with Section 6700), Chapter 9 (commencing with Section 7000), or Chapter 14 (commencing with Section 8500) of Division 3.

(b) This chapter does not apply to a registered engineer, licensed land surveyor, or licensed architect acting pursuant to his or her professional registration or license, nor does it affect the obligations of a real estate licensee or transferor under Article 1.5 (commencing with Section 1102) of Chapter 2 of Title 4 of Part 3 of Division 2 of, or Article 2 (commencing with Section 2079) of Chapter 3 of Title 6 of Part 4 of Division 3 of, the Civil Code.

7197. (a) It is an unfair business practice for a home inspector, a company that employs the inspector, or a company that is controlled by a company that also has a financial interest in a company employing a home inspector, to do any of the following:

(1) To perform or offer to perform, for an additional fee, any repairs to a structure on which the inspector, or the inspector's company, has prepared a home inspection report in the past 12 months.

(2) Inspect for a fee any property in which the inspector, or the inspector's company, has any financial interest or any interest in the transfer of the property.

(3) To offer or deliver any compensation, inducement, or reward to the owner of the inspected property, the broker, or agent, for the referral of any business to the inspector or the inspection company.

(4) Accept an engagement to make an inspection or to prepare a report in which the employment itself or the fee payable for the inspection is contingent upon the conclusions in the report, preestablished findings, or the close of escrow.

(5) A home protection company that is affiliated with or that retains the home inspector does not violate this section if it performs repairs pursuant to claims made under the home protection contract.

(b) This section shall not affect the ability of a structural pest control operator to perform repairs pursuant to Section 8505 as a result of a structural pest control inspection.

7198. Contractual provisions that purport to waive the duty owed pursuant to Section 7196, or limit the liability of the home inspector to the cost of the home inspection report, are contrary to public policy and invalid.

7199. The time for commencement of a legal action for breach of duty arising from a home inspection report shall not exceed four years from the date of the inspection.

APPENDIX B – HERS REGULATIONS

1670. Scope.

These regulations establish the California Home Energy Rating System Program pursuant to Public Resources Code Section 25942, including procedures for the training and certification of raters, and a certification program for home energy rating system organizations (herein referred to as providers) and for home energy rating services (herein referred to as rating systems). These regulations apply only to field verification and diagnostic testing services pursuant to Chapter 7 of the ACM Manual for demonstrating compliance with Title 24 building energy performance standards. Regulations for other home energy rating services will be addressed in a subsequent rulemaking proceeding. Until the subsequent rulemaking is concluded, home energy rating system services other than field verification and diagnostic testing are not required to be certified.

1671. Definitions.

For the purposes of these regulations, the following definitions shall apply:

ACM Manual means the Low-Rise Residential Alternative Calculation Method Approval Manual (Energy Commission Publication No. P-400-98-003) adopted in Section 10-109(b)(2) of Title 24, Part 1 of the California Code of Regulations.

Certified, as to a provider and rating system, means having successfully completed the certification requirements as specified by Section 1674.

Commission means the State of California Energy Resources Conservation and Development Commission, commonly known as the California Energy Commission.

Financial Interest means an ownership interest, debt agreement, or employer/employee relationship. Financial interest does not include ownership of less than 5% of the outstanding equity securities of a publicly traded corporation.

Independent Entity means having no financial interest in, and not advocating or recommending the use of any product or service as a means of gaining increased business with, firms or persons specified in Section 1673(i).

NOTE: The definitions of "independent entity" and "financial interest," together with Section 1673(i), prohibit conflicts of interest between providers and raters, or between providers/raters and builders/subcontractors.

Provider means an organization that administers a home energy rating system in compliance with these regulations (referred to as a "home energy rating service organization" in Section 25942 of the Public Resources Code).

Rater means a person performing the site inspection and data collection required to produce a home energy rating or the field verification and diagnostic testing required for demonstrating compliance with the Title 24 energy performance standards, who is listed on a registry in compliance with Section 1673(c).

Rating means a representation on a 0 to 100 scale of the annual source energy efficiency of a home, as specified in Section 1672(c).

Rating System means the materials, analytical tools, diagnostic tools and procedures to produce home energy ratings and provide home energy rating and field verification and diagnostic testing services (referred to as "home energy rating services" in Section 25942 of the Public Resources Code).

Service Water Heating means service water heating as defined in Section 101(b) of Title 24, Part 6 of the California Code of Regulations.

Source Energy means source energy as defined in Section 101(b) and calculated as specified in Section 102 of Title 24, Part 6 of the California Code of Regulations.

NOTE: Authority: Public Resources Code Sections 25942 and 25213.

Reference: Public Resources Code Sections 25942 and 25213.

1672. Requirements for Rating Systems.

(a) Rating Site Inspections and Diagnostic Testing. Each rating shall be based on a site inspection of the home, and diagnostic testing as specified by the rating system. Each rating system shall have documented procedures for site inspection and diagnostic testing of rated homes.

(b) Energy Uses Rated. Each rating system shall rate the total combined energy efficiency of the following energy uses of each home rated:

(1) space heating;

(2) space cooling; and

(3) service hot water.

(c) Rating Scale. Each rating system shall rate the annual source energy efficiency of homes on a scale of 0 to 100. The rating shall be for the combined total of the three energy uses described in Section 1672(b).

(d) Field Verification and Diagnostic Testing. The provider and rater shall provide field verification and diagnostic testing of energy efficiency improvements as a condition for those improvements to qualify for Title 24 building energy performance standards compliance credit, as required by Chapter 7, Appendix F, and Sections 3.8.3 and 3.9 of the ACM Manual. Providers and raters shall not knowingly provide untrue, inaccurate or incomplete field verification or diagnostic testing information or report field verification or test results that were not conducted in compliance with these regulations. Providers and raters shall not knowingly accept payment or consideration in exchange for reporting a rating or field verification and diagnostic test result that was not in fact conducted and reported in compliance with these regulations.

1673. Requirements for Providers.

(a) Training and Certification Procedures for Raters. Each provider shall conduct the following rater training and certification procedures.

(1) Each provider's training program shall include classroom and field training for rater applicants in analysis, theory and practical application in at least the following areas:

(A) home energy consumption and efficiency data collection, organization and analysis;

(B) principles of heat transfer;

(C) building energy feature design and construction practice, including construction quality assurance and "house as a system" concepts;

(D) safety practices relevant to home energy auditing procedures and equipment; (E) home energy audit procedures;

(F) energy efficiency effects of building site characteristics;

(G) types and characteristics of space heating, space cooling, service hot water and hard wired lighting systems;

(H) mathematical calculations necessary to utilize the rating system;

(I) the function and proper use of diagnostic devices including but not necessarily limited to: duct leakage testing equipment, blower doors and air flow and pressure measurement devices;

(J) construction types, equipment types and their associated energy efficiency ramifications;

(K) field verification and diagnostic testing requirements of Chapter 7, Appendix F, and Sections 3.8.3 and 3.9 of the ACM Manual; and

(L) California Home Energy Rating System Program requirements specified in these regulations.

(2) The training shall include thorough instruction in the use of the provider's rating system.

(3) The training shall require rater applicants to satisfactorily perform field verification and diagnostic testing for at least two homes in the presence and under the direct supervision of the provider's trainer. The provider shall review and approve this field verification and diagnostic testing for accuracy and completeness.

(4) The provider shall require each rater applicant to take a written and practical test that demonstrates his or her competence in all subjects specified in Section 1673(a)(1). The provider shall retain all results of these tests for five years from the date of the test.

(5) Each provider may establish a Commission-approved challenge test that evaluates competence in each area addressed by the provider's training program. If a rater applicant successfully passes this challenge test, the provider may waive the classroom training

requirement and the written and practical test requirements for that applicant. An applicant who passes this challenge test must also successfully meet the requirements specified in Section 1673(a)(3).

(b) Rater Agreements. As a condition of rater registry under Section 1673(c), each provider shall ensure that a rater applicant who has met the requirements of Section 1673(a) has entered into an agreement with the provider to provide home energy rating and field verification and diagnostic services in compliance with these regulations. The agreement shall require raters to:

(1) provide home energy rating and field verification services in compliance with these regulations;

(2) provide true, accurate, and complete ratings, field verification and diagnostic testing; and

(3) comply with the conflict of interest requirements as specified in Section 1673(i).

(c) Rater Registry. As a condition of rater registry, each provider shall certify to the Commission that a rater applicant has met the requirements of Section 1673(a) and entered into an agreement meeting the requirements of Section 1673(b). The provider shall maintain a registry of all raters who meet these requirements, provide an electronic copy of the registry to the Commission, and make that registry available in printed or electronic form upon written request.

(d) Field Verification and Diagnostic Testing Data Collection. Each provider shall collect and maintain for a period of five years, the following information for each home for which field verification and diagnostic testing service is provided:

(1) Certificates of Field Verification and Diagnostic Testing;

(2) Certificates of Compliance;

(3) Installation Certificates; and

(4) other reports made pursuant to Chapter 7 of the ACM Manual.

Alternatively, the information contained in these documents may be collected and stored electronically as long as all of the content and certification signatures from the specified documents are retained.

(e) Field Verification and Diagnostic Testing Evaluation. Providers shall maintain a database of the information specified in Section 1673(d) for a minimum 10% random sample of the homes actually field verified and diagnostically tested annually, or 500 such homes annually, whichever is less. Each provider shall provide this information annually in electronic form to the Commission for evaluating the effectiveness of field verification and diagnostic testing. To the extent that the Commission makes this information public, it will do so only in aggregated form. All of this information shall be organized according to climate zones as defined in Section 101(b) of Title 24, Part 6 of the California Code of Regulations.

(f) Data Submittal. Upon the Commission's request, but not more frequently than annually, a provider shall submit to the Commission the total of the number of homes for which field verification and diagnostic testing services were provided since the last data submittal, and a report of the following information for each home for which field verification and diagnostic testing service was provided:

(1) the energy efficiency improvements field verified and diagnostic tested;

(2) whether or not the builder chose to include the home in a sample for field verification and diagnostic testing as specified in Section 7.4 of the ACM Manual;

(3) whether or not initial field verification and testing as specified in Section 7.4.1 of the ACM Manual was conducted on the home;

(4) whether or not the home in a sample was actually selected and field verified and diagnostically tested as specified in Section 7.4.2 of the ACM Manual;

(5) whether or not the home in a sample was actually selected for resampling and field verified and diagnostically tested after a sampling failure was found in the sample as specified in Section 7.4.3 of the ACM Manual;

(6) whether or not the home in a sample was field verified and diagnostically tested and corrective action was taken after a resampling failure was found in the sample as specified in Section 7.4.3 of the ACM Manual;

(7) whether or not the homeowner declined to have field verification, diagnostic testing and corrective action taken after occupancy as specified in Section 7.4.3 of the ACM Manual.

All of this information shall be organized according to climate zones as defined in Section 101(b) of Title 24, Part 6 of the California Code of Regulations. To the extent the Commission makes this information public, it will do so only in an aggregated form.

(g) Training Materials Retention. Each provider shall retain for at least five years after the last date they are used at least one copy of all materials used to train raters.

(h) Quality Assurance. Each provider shall have a quality assurance program that provides for at least the following:

(1) Initial review. The provider shall review and approve for accuracy and completeness the field verification and diagnostic testing documentation for at least the first five homes which a rater performs after completion of the requirements specified in Section 1673(a)(1), (2) and (3), not including those homes field verified and diagnostically tested under the provider's direct supervision as specified in Section 1673(a)(3).

(2) Field checks of raters. For each rater, the provider shall annually evaluate the greater of one home or one percent of the rater's annual total of homes for which field verification and diagnostic testing services were provided. The provider shall independently repeat the field verification and diagnostic testing to check whether field verification and diagnostic testing was accurately completed by the rater, and determine whether information was completely collected and reported as required by Chapter 7 of the ACM Manual.

(3) Complaint response system. Each provider shall have a system for receiving complaints. The provider shall respond to and resolve complaints related to ratings and field verification and diagnostic testing services and reports. Providers shall ensure that raters inform

purchasers and recipients of ratings and field verifications and diagnostic testing services about the complaint system. Each provider shall retain all records of complaints received and responses to complaints for five years after the date the complaint is presented to the provider.

(i) Conflict of Interest.

(1) Providers shall be independent entities from raters who provide field verification and diagnostic testing.

(2) Providers and raters shall be independent entities from the builder and from the subcontractor installer of energy efficiency improvements field verified or diagnostically tested.

1674. Certification of Providers and Rating Systems.

(a) Application. A person or entity wishing to be certified as a provider and wishing to have a rating system certified shall submit four copies of an application to the Commission. The application shall contain:

(1) a complete copy of all field verification and diagnostic testing procedures, manuals, handbooks, rating system descriptions, and training materials;

(2) a detailed explanation of how the rating system meets each requirement of Section 1672;

(3) a detailed explanation of how the provider meets each requirement of Section 1673;

(4) the name, address, and telephone number of the provider and a statement of where its principal place of business is and where and upon whom service of legal process can be made;

(5) upon Commission request, if the provider is a corporation, a copy of the articles of incorporation and the current by-laws;

(6) if the provider is a partnership, the names, addresses, telephone numbers, and partnership status (for example, general, managing) of all the partners, and a copy of the current partnership agreement;

(7) the names, addresses, telephone numbers, and business relationships of all the provider's owners, parents, subsidiaries, and affiliates;

(8) a statement that ratings are accurate, consistent and uniform, utility bill estimates are reasonable, and recommendations on cost-effective energy efficiency improvement measures are reliable;

(9) a statement that the provider understands and will not knowingly fail to comply with the requirements of these regulations; and

(10) a statement under penalty of perjury that all statements in the application are true, provided in the form specified by Section 2015.5 of the Code of Civil Procedure.

(b) Confidentiality of Information. Any provider who submits the required application information and wishes to have that information treated as confidential in order to limit its disclosure shall, at the time of submitting the information, apply for a confidential designation as specified in Section 2505 of Title 20 of the California Code of Regulations.

(c) Commission Consideration.

(1) The Commission's Executive Director may request additional information from the applicant necessary to evaluate the application.

(2) The Executive Director shall provide a copy of its evaluation to interested persons. The Executive Director may convene a workshop to receive comments from interested persons.

(4) Within 90 days of receiving the complete application, the Executive Director shall send to the Commission and to the applicant a written recommendation that the Commission certify the provider and its rating system or deny that certification.

(5) The Executive Director shall recommend certifying the provider and rating system if it finds the following:

(A) the rating system meets all of the requirements of Section 1672; and

(B) the provider meets all of the requirements of Section 1673.

(6) The Commission shall act on the recommendation at its next regularly scheduled Business Meeting that is at least fifteen days after the date that the recommendation was mailed to the applicant.

(7) The Commission shall certify the proposed provider and rating system if it confirms the Executive Director's findings in Section 1674(c)(5).

(8) Upon certification the Commission shall assign the provider a three-digit identification number.

(d) Re-certification. A certified provider shall notify the Commission whenever any change occurs in any of the information, documentation, or materials, the provider submitted to the Commission under Section 1674(a), and shall submit the changed information to the Commission. Where this changed information could affect the provider's compliance with these regulations, the Commission may require that the provider and the rating system be re-certified under the process described in Section 1674. The Executive Director may waive re-certification for non-substantive changes. The Commission may also require that providers and rating systems be re-certified if the requirements of these regulations are amended or modified.

1675. Review by the Commission.

(a) Annual Review. The Commission may annually review the performance of providers certified under Section 1674 to determine whether the providers comply with the requirements of these regulations. This review may include interviewing recipients of ratings and field verification and diagnostic testing services and reports on a voluntary basis.

(b) Complaint Proceedings. Any person or entity may file a complaint concerning any violation of these regulations as provided for in Section 1230 et. seq. of Title 20 of the California Code of Regulations. The Commission may, for good cause, conduct an investigation and, if necessary, hearing, under the procedures established in Section 1230 et. seq. of Title 20 of the California Code of Regulations.

Each provider shall provide all information requested by the Commission regarding any annual review or complaint proceeding.

(c) Commission Determination. If the Commission determines there is a violation of these regulations or that a provider is no longer providing rating, field verification and diagnostic testing services, the Commission may revoke the certification of the provider pursuant to Section 1230 et. seq. of Title 20 of the California Code of Regulations.

APPENDIX C – APPLIANCE ENERGY EFFICIENCY RATINGS

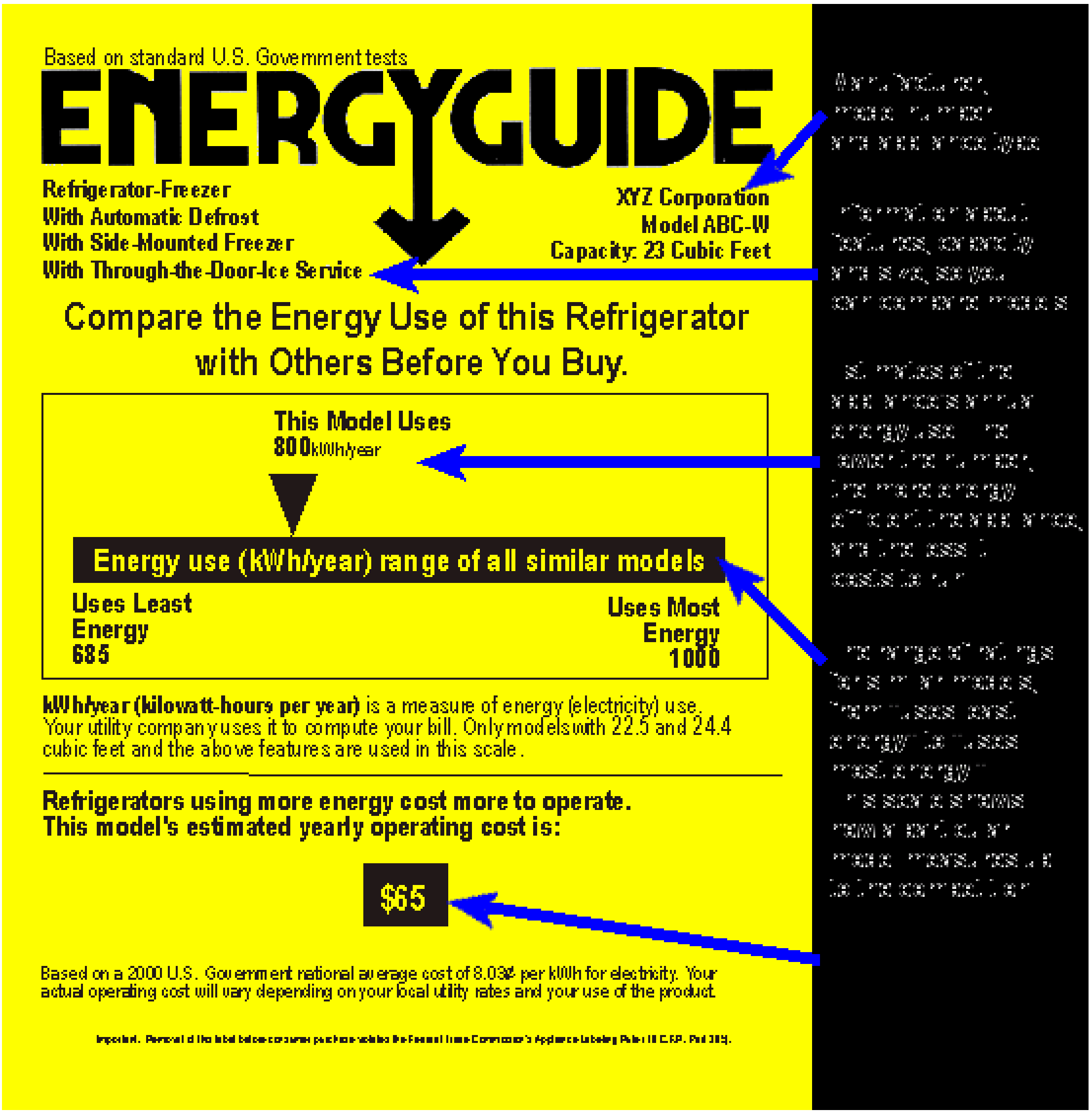


Figure 40 – Example EnergyGuide Label

The ENERGY STAR label is the government's seal of approval. It was created by the U.S. Department of Energy and the U.S. Environmental Protection Agency. These agencies set the criteria to help shoppers for large and small home appliances identify the most energy-efficient products on the market. ENERGY STAR-labeled appliances exceed existing federal efficiency standards, typically, by 13 to 20 percent, and as much as 110 percent for some appliances. Customers can be assured that the appliance being purchased is a high-performance product which will reduce the operating cost of that appliance or product every month during the course of its lifetime.

Appliances	Rating	Special Considerations
Refrigerators and Freezers	Look for the FTC (Federal Trade Commission) label on the appliance to tell you how much electricity, in kilowatt-hours (kWh) a particular model will use in one year. The smaller the number, the less energy it uses.	Look for an "energy saver" switch on models with the freezer on top. When buying a frost-free refrigerator, find one with an energy-efficient option. Refrigerators with freezers on top are more efficient than those with freezers on the side. Look for heavy door hinges, which create a good door seal. ENERGY STAR®-labeled units exceed federal standards by at least 20%.
Dishwashers	EF is the Energy Factor. This number represents the number of complete cycles that a dishwasher will operate while using one kilowatt-hour of electricity. ENERGY STAR® dishwashers have an EF of 0.52 or greater, 13% better than current federal standards.	Look for features that will reduce water use, such as booster heaters and smart controls. Ask how many gallons of water the dishwasher uses during different cycles. Dishwashers that use the least amount of water will cost the least to operate.
Programmable Thermostats		Look for a thermostat that allows you to easily use two separate programs; an "advanced recovery" feature that can be programmed to reach the desired temperature at a specific time; a hold feature that temporarily overrides the setting without deleting preset programs. Look for the ENERGY STAR® label.
Clothes Washers	EF stands for Energy Factor. The EF is the number of complete cycles that a clothes washer will operate while using one kilowatt-hour of electricity. ENERGY STAR® units must have an EF of 2.5 or more above the current federal standard of 1.18.	Look for the following design features that help clothes washers cut water usage: front-loading design, water level controls, "suds-saver" features, spin cycle adjustment, and large capacity. For double the efficiency, buy an ENERGY STAR® unit.
Hot Water Heaters	EF is the Energy Factor rating the overall efficiency of the heater. The FHR is the First Hour Rating of the system, which measures the maximum hot water the heater will deliver in the first hour of use from a cold start.	Buy a water heater with a thick insulating shell. If you want hot water fast, the FHR rating will be important to you. Sizing is important – call your local utility for advice.

APPENDIX D - DATABASE OF MEASURES AND COSTS

Cost data for the HERS energy efficiency cost measures are taken from the D.E.E.R. database. Adjustment multipliers based on climate zone are taken from the PG&E Codes and Standards Enhancement (CASE) project used to develop the 2008 Title 24 prescriptive envelope requirements.

Ceiling insulation measures include a baseline of either no insulation or R-19 insulation. Wall insulation measures include a baseline of no insulation for a 2x4 wall with R-13 cavity insulation (U=0.102).

Building Envelope Measures

Table D-23 – Insulation Measures

Measure Description	Base Description	Appl.	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
Ceiling R-19 Insulation	R-0 Ceiling Insulation	RET	$0.00	$0.38	$0.00	$0.24	$0.62	SqFt
Ceiling R-0 to R-30 Insulation-Batts	R-0 Ceiling Insulation	RET	$0.00	$0.56	$0.00	$0.19	$0.76	SqFt
Ceiling R-0 to R-38 Insulation-Batts	R-0 Ceiling Insulation	RET	$0.00	$0.70	$0.00	$0.16	$0.86	SqFt
Ceiling Vintage to R-30 Insulation-Batts	R-19 Ceiling Insulation	RET/NEW	$0.38	$0.56	$0.19	$0.19	$0.76	SqFt
Ceiling Vintage to R-38 Insulation-Batts	R-19 Ceiling Insulation	RET/NEW	$0.38	$0.70	$0.33	$0.16	$0.86	SqFt
Ceiling Vintage to R-49 Insulation-Batts	R-30 Ceiling Insulation	RET/NEW	$0.56	$0.70	$0.14	$0.16	$0.86	SqFt
Floor R-13 Insulation-Batts	R-0 Floor Insulation	RET	$0.00	$0.27	$0.00	$0.42	$0.69	SqFt
Floor R-0 to R-19 Insulation Batts	R-0 Floor Insulation	RET	$0.00	$0.38	$0.00	$0.51	$0.89	SqFt
Floor R-0 to R-30 Insulation Batts	R-0 Floor Insulation	RET	$0.00	$0.56	$0.00	$0.78	$1.34	SqFt
Floor R-19 to R-30 Insulation-Batts	R-19 Floor Insulation	RET/NEW	$0.38	$0.56	$0.19	$0.78	$1.34	SqFt
Wall 2x4 R-15 Insulation-Batts	2x4 Wall w/R-13 Insulation	RET/NEW	$0.27	$0.31	$0.03	$0.30	$0.61	SqFt
Wall 2x6 R-19 Insulation-Batts	2x4 Wall w/R-13 Insulation	RET/NEW	$0.27	$0.38	$0.10	$0.28	$0.65	SqFt
Wall 2x6 R-21 Insulation-Batts	2x4 Wall w/R-13 Insulation	RET/NEW	$0.27	$0.41	$0.14	$0.27	$0.68	SqFt
Wall 2x6 R-19 Insulation-Batts	2x4 Wall w/R-15 Insulation	RET/NEW	$0.31	$0.38	$0.07	$0.28	$0.65	SqFt
Wall 2x6 R-21 Insulation-Batts	2x4 Wall w/R-15 Insulation	RET/NEW	$0.31	$0.41	$0.10	$0.27	$0.68	SqFt
Wall 2x6 R-21 Insulation-Batts	2x6 Wall w/R-19 Insulation	RET/NEW	$0.38	$0.41	$0.03	$0.27	$0.68	SqFt
Wall 2x4 R-13 Batts + R-5 Rigid	2x4 Wall w/R-13 Insulation	RET/NEW	$0.27	$0.72	$0.45	$0.65	$1.37	SqFt
Wall 2x6 R-19	2x6 Wall w/R-19	RET/NEW	$0.38	$0.82	$0.45	$0.74	$1.56	SqFt

Measure Description	Base Description	Appl.	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
Batts + R-5 Rigid	Insulation							
Wall 2x6 R-21 Batts + R-5 Rigid	2x6 Wall w/R-21 Insulation	RET/NEW	$0.41	$0.86	$0.45	$0.98	$1.84	SqFt
Wall Blow-In R-13 Insulation	2x4 Wall w/out Insulation	RET	$0.00	$0.15	$0.00	$1.17	$1.32	SqFt
Ceiling R-value for oldest vintages increased to 'new' level	Ceiling R-value based on vintage and climate zone	RET	$0.00	$376.23	$0.00	$239.83	$616.06	1000 SqFt
Floor insulation raised to 2005 levels	T24 minimum floor insulation levels	RET	$0.00	$0.27	$0.00	$0.42	$0.69	SqFt

Table D-24 – Window Replacement Cost Data

Measure Description	Base Description	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
U-0.50 / SHGC-0.65 (clear) Window	Double Pane Clear Window	$16.41	$17.13	$0.72	$2.07	$19.20	SqFt
U-0.40 / SHGC-0.65 (clear) Window	Double Pane Clear Window	$16.41	$11.03	($5.38)	$2.07	$13.10	SqFt
U-0.35 / SHGC-0.55 (clear) Window	Double Pane Clear Window	$16.41	$11.85	($4.56)	$2.07	$13.92	SqFt
U-0.25 / SHGC-0.35 (clear) Window	Double Pane Clear Window	$16.41	$13.48	($2.93)	$2.07	$15.55	SqFt
U-0.50 / SHGC-0.40 (tint) Window	Double Pane Clear Window	$16.41	$26.79	$10.38	$2.07	$28.86	SqFt
U-0.40 / SHGC-0.40 (tint) Window	Double Pane Clear Window	$16.41	$20.70	$4.29	$2.07	$22.77	SqFt
U-0.35 / SHGC-0.32 (tint) Window	Double Pane Clear Window	$16.41	$20.74	$4.33	$2.07	$22.81	SqFt
U-0.25 / SHGC-0.22 (tint) Window	Double Pane Clear Window	$16.41	$18.51	$2.10	$2.07	$20.58	SqFt
U-0.50 / SHGC-0.40 (tint) Window	Double Pane Tinted Window	$16.41	$26.79	$10.38	$2.07	$28.86	SqFt
U-0.40 / SHGC-0.40 (tint) Window	Double Pane Tinted Window	$16.41	$20.70	$4.29	$2.07	$22.77	SqFt
U-0.35 / SHGC-0.32 (tint) Window	Double Pane Tinted Window	$16.41	$20.74	$4.33	$2.07	$22.81	SqFt
U-0.25 / SHGC-0.22 (tint) Window	Double Pane Tinted Window	$16.41	$18.51	$2.10	$2.07	$20.58	SqFt

Lighting Measures

Table D-25 – Screw-in CFLs

Measure Description	Base Description	Purchase Volume	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
7-13 Watt < 800 Lumens - screw-in	40W Incandescent	Low	$0.57	$4.98	$4.40	$3.77	$8.18	Lamp
13 Watt ≥800 Lumens - screw-in	60W Incandescent	Low	$0.61	$4.87	$4.26	$3.77	$8.04	Lamp
14 Watt - screw-in	60W Incandescent	Low	$0.61	$5.25	$4.64	$3.77	$8.41	Lamp
15 Watt - screw-in	60W Incandescent	Low	$0.61	$5.62	$5.01	$3.77	$8.79	Lamp
16 Watt - screw-in	60W Incandescent	Low	$0.61	$6.00	$5.39	$3.77	$9.16	Lamp
18 Watt < 1,100 Lumens - screw-in	60W Incandescent	Low	$0.61	$6.74	$6.14	$3.77	$9.91	Lamp
18 Watt ≥1,100 Lumens - screw-in	75W Incandescent	Low	$0.61	$6.37	$5.77	$3.77	$9.54	Lamp
19 Watt ≥1,100 Lumens - screw-in	75W Incandescent	Low	$0.61	$6.73	$6.12	$3.77	$9.89	Lamp
20 Watt - screw-in	75W Incandescent	Low	$0.61	$7.08	$6.47	$3.77	$10.25	Lamp
23 Watt - screw-in	100W Incandescent	Low	$0.61	$6.66	$6.05	$3.77	$9.82	Lamp
25 Watt <1,600 Lumens - screw-in	75W Incandescent	Low	$0.61	$8.85	$8.24	$3.77	$12.02	Lamp
25 Watt ≥1,600 Lumens - screw-in	100W Incandescent	Low	$0.61	$7.24	$6.63	$3.77	$10.40	Lamp
26 Watt <1,600 Lumens - screw-in	75W Incandescent	Low	$0.61	$9.21	$8.60	$3.77	$12.37	Lamp
26 Watt ≥1,600 Lumens - screw-in	100W Incandescent	Low	$0.61	$7.52	$6.92	$3.77	$10.69	Lamp
28 Watt - screw-in	100W Incandescent	Low	$0.61	$8.10	$7.50	$3.77	$11.27	Lamp

Measure Description	Base Description	Purchase Volume	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
32 Watt - screw-in	100W Incandescent	Low	$0.61	$9.26	$8.65	$3.77	$12.43	Lamp
36 Watt - screw-in	150W Incandescent	Low	$2.22	$9.19	$6.97	$3.77	$10.75	Lamp
50 Watt - screw-in	150W Incandescent	Low	$2.22	$12.77	$10.55	$3.77	$14.32	Lamp

Table D-26 – Lighting Control Measures

Measure Name	Measure Description	Base Description	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
Small area lighting sensor control	lighting level reduced based on bldg type, activity area	N/A	$0.00	$210.13	$0.00	$112.21	$322.34	kW Ctrl
Large area lighting sensor control	lighting level reduced based on bldg type, activity area	N/A	$0.00	$99.38	$0.00	$90.67	$190.06	kW Ctrl
Add daylighting controls to side-lit space w/ cont. ctrl	add daylighting controls, min. lumen level based on bldg type	N/A	$0.00	$1,139.65	$0.00	$87.26	$1,226.91	kW Ctrl
Add daylighting controls to side-lit space w/ 2-step ctrl	add daylighting controls, min. lumen level based on bldg type	N/A	$0.00	$617.17	$0.00	$87.26	$704.43	kW Ctrl
Add daylighting controls to top-lit space w/ cont. ctrl	add daylighting controls, min. lumen level based on bldg type	N/A	$0.00	$733.20	$0.00	$23.80	$757.00	kW Ctrl
Add daylighting controls to top-lit space w/ 1-step ctrl	add daylighting controls, min. lumen level based on bldg type	N/A	$0.00	$79.20	$0.00	$23.80	$103.00	kW Ctrl

Measure Name	Measure Description	Base Description	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
Add daylighting controls to top-lit space w/ 2-step ctrl	add daylighting controls, min. lumen level based on bldg type	N/A	$0.00	$79.20	$0.00	$23.80	$103.00	kW Ctrl
Timeclock for Lighting	minimum unoccupied lighting power density based on bldg type	N/A	$0.00	$76.96	$0.00	$41.73	$118.69	Timeclock
Occ-Sensor - Wall box	Assume control 3 2-lamp fixtures w/T8 34W EL Ballast	No Occupancy Sensor	$0.00	$42.28	$0.00	$35.00	$77.28	Sensor
Timeclock:	Controling 4 - 70W (95W w/ballast) HPS fixtures	No Timeclock	$0.00	$123.01	$0.00	$116.88	$239.89	Timeclock
Photocell:	Assume in conjunction with time-clock controling 4 - 70W (95W w/ballast) HPS fixtures	No Photocell	$0.00	$12.06	$0.00	$47.75	$59.81	Photocell

HVAC Measures

Table D-27 – Whole House Ventilation

Measure Description	Base Description	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
Whole House Fan (CFM <4000)	No Night Ventilation/Economizer	$0.00	$450.91	$0.00	$244.12	$695.03	Fan
Whole House Fan (CFM 4000-6000)	No Night Ventilation/Economizer	$0.00	$243.17	$0.00	$269.72	$512.89	Fan
Whole House Fan (CFM 6000-8000)	No Night Ventilation/Economizer	$0.00	$400.56	$0.00	$295.32	$695.88	Fan
Whole House Fan (CFM >8000)	No Night Ventilation/Economizer	$0.00	$409.65	$0.00	$320.92	$730.57	Fan

Table D-28 – Air Conditioning Unit Replacement

Measure Description	Base Description	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
13 SEER (11.09 EER) Split System Air Conditioner, 2 ton (24,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$371.85	$663.23	$291.39	$604.18	$1,267.41	tons
13 SEER (11.09 EER) Split System Air Conditioner, 2.5 ton (30,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$330.39	$595.02	$264.63	$483.34	$1,078.36	tons
13 SEER (11.09 EER) Split System Air Conditioner, 3 ton (36,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$279.72	$549.55	$269.83	$402.78	$952.33	tons
13 SEER (11.09 EER) Split System Air Conditioner, 3.5 ton (42,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$297.76	$517.07	$219.31	$345.24	$862.31	tons
13 SEER (11.09 EER) Split System Air Conditioner, 4 ton (48,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$287.19	$492.71	$205.52	$302.09	$794.80	tons
13 SEER (11.09 EER) Split System Air Conditioner, 5 ton (60,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$233.49	$458.60	$225.11	$241.67	$700.27	tons
14 SEER (11.99 EER) Split-System Air Conditioner, 2 ton (24,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$371.85	$802.16	$430.32	$604.18	$1,406.34	tons
14 SEER (11.99 EER) Split-System Air Conditioner, 2.5 ton (30,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$330.39	$706.17	$375.77	$483.34	$1,189.51	tons
14 SEER (11.99 EER) Split-System Air Conditioner, 3 ton (36,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$279.72	$642.17	$362.45	$402.78	$1,044.95	tons
14 SEER (11.99 EER) Split-System Air Conditioner, 3.5 ton (42,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$297.76	$596.46	$298.70	$345.24	$941.70	tons
14 SEER (11.99 EER) Split-System Air Conditioner, 4 ton (48,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$287.19	$562.17	$274.99	$302.09	$864.26	tons
14 SEER (11.99 EER) Split-System Air Conditioner, 5 ton (60,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$233.49	$514.18	$280.68	$241.67	$755.85	tons
15 SEER (12.72 EER) Split-System Air Conditioner, 2 ton (24,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$371.85	$941.09	$569.25	$604.18	$1,545.27	tons
15 SEER (12.72 EER) Split-System Air Conditioner, 2.5 ton (30,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$330.39	$817.31	$486.92	$483.34	$1,300.65	tons
15 SEER (12.72 EER) Split-System Air Conditioner, 3 ton (36,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$279.72	$734.79	$455.07	$402.78	$1,137.57	tons
15 SEER (12.72 EER) Split-System Air Conditioner, 3.5 ton (42,000 Btu)	10 SEER(8.7 EER) Split-System Air Conditioner	$297.76	$675.84	$378.08	$345.24	$1,021.09	tons

Measure Description	Base Description	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
condenser and matched cased coil							
15 SEER (12.72 EER) Split-System Air Conditioner, 4 ton (48,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$287.19	$631.64	$344.45	$302.09	$933.72	tons
15 SEER (12.72 EER) Split-System Air Conditioner, 5 ton (60,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$233.49	$569.75	$336.25	$241.67	$811.42	tons
16 SEER (11.61 EER) Split System Air Conditioner, 2 ton (24,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$371.85	$1,080.02	$708.17	$604.18	$1,684.19	tons
16 SEER (11.61 EER) Split System Air Conditioner, 2.5 ton (30,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$330.39	$928.45	$598.06	$483.34	$1,411.79	tons
16 SEER (11.61 EER) Split System Air Conditioner, 3 ton (36,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$279.72	$827.41	$547.68	$402.78	$1,230.19	tons
16 SEER (11.61 EER) Split System Air Conditioner, 3.5 ton (42,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$297.76	$755.23	$457.47	$345.24	$1,100.48	tons
16 SEER (11.61 EER) Split System Air Conditioner, 4 ton (48,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$287.19	$701.10	$413.91	$302.09	$1,003.19	tons
16 SEER (11.61 EER) Split System Air Conditioner, 5 ton (60,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$233.49	$625.32	$391.83	$241.67	$866.99	tons
17 SEER (12.28 EER) Split-System Air Conditioner, 2 ton (24,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$371.85	$1,218.95	$847.10	$604.18	$1,823.12	tons
17 SEER (12.28 EER) Split-System Air Conditioner, 2.5 ton (30,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$330.39	$1,039.59	$709.20	$483.34	$1,522.93	tons
17 SEER (12.28 EER) Split-System Air Conditioner, 3 ton (36,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$279.72	$920.03	$640.30	$402.78	$1,322.81	tons
17 SEER (12.28 EER) Split-System Air Conditioner, 3.5 ton (42,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$297.76	$834.62	$536.86	$345.24	$1,179.86	tons
17 SEER (12.28 EER) Split-System Air Conditioner, 4 ton (48,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$287.19	$770.57	$483.38	$302.09	$1,072.65	tons
17 SEER (12.28 EER) Split-System Air Conditioner, 5 ton (60,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$233.49	$680.89	$447.40	$241.67	$922.56	tons
18 SEER (13.37 EER) Split-System Air Conditioner, 2 ton (24,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$371.85	$1,357.87	$986.03	$604.18	$1,962.05	tons
18 SEER (13.37 EER) Split-System Air Conditioner, 2.5 ton (30,000 Btu)	10 SEER(8.7 EER) Split-System Air Conditioner	$330.39	$1,150.74	$820.34	$483.34	$1,634.08	tons

Measure Description	Base Description	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
condenser and matched cased coil							
18 SEER (13.37 EER) Split-System Air Conditioner, 3 ton (36,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$279.72	$1,012.64	$732.92	$402.78	$1,415.43	tons
18 SEER (13.37 EER) Split-System Air Conditioner, 3.5 ton (42,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$297.76	$914.01	$616.25	$345.24	$1,259.25	tons
18 SEER (13.37 EER) Split-System Air Conditioner, 4 ton (48,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$287.19	$840.03	$552.84	$302.09	$1,142.12	tons
18 SEER (13.37 EER) Split-System Air Conditioner, 5 ton (60,000 Btu) condenser and matched cased coil	10 SEER(8.7 EER) Split-System Air Conditioner	$233.49	$736.46	$502.97	$241.67	$978.13	tons
13 SEER (11.09 EER) Split System Air Conditioner, 3 ton (36,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$549.55	$549.55	$ -	$235.95	$785.50	tons
14 SEER (11.99 EER) Split-System Air Conditioner, 2 ton (24,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$663.23	$802.16	$138.93	$353.93	$1,156.09	tons
14 SEER (11.99 EER) Split-System Air Conditioner, 2.5 ton (30,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$595.02	$706.17	$111.14	$283.14	$989.31	tons
14 SEER (11.99 EER) Split-System Air Conditioner, 3 ton (36,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$549.55	$642.17	$92.62	$235.95	$878.12	tons
14 SEER (11.99 EER) Split-System Air Conditioner, 3.5 ton (42,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$517.07	$596.46	$79.39	$202.24	$798.70	tons
14 SEER (11.99 EER) Split-System Air Conditioner, 4 ton (48,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$492.71	$562.17	$69.46	$176.96	$739.14	tons
14 SEER (11.99 EER) Split-System Air Conditioner, 5 ton (60,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$458.60	$514.18	$55.57	$141.57	$655.75	tons
15 SEER (12.72 EER) Split-System Air Conditioner, 2 ton (24,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$663.23	$941.09	$277.86	$353.93	$1,295.02	tons
15 SEER (12.72 EER) Split-System Air Conditioner, 2.5 ton (30,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$595.02	$817.31	$222.28	$283.14	$1,100.45	tons
15 SEER (12.72 EER) Split-System Air Conditioner, 3 ton (36,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$549.55	$734.79	$185.24	$235.95	$970.74	tons
15 SEER (12.72 EER) Split-System Air Conditioner, 3.5 ton (42,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$517.07	$675.84	$158.77	$202.24	$878.09	tons
15 SEER (12.72 EER) Split-System Air Conditioner, 4 ton (48,000 Btu)	T24 minimum: 13 SEER(11.09 EER) Split	$492.71	$631.64	$138.93	$176.96	$808.60	tons

Measure Description	Base Description	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
condenser and matched cased coil	System Air Conditioner						
15 SEER (12.72 EER) Split-System Air Conditioner, 5 ton (60,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$458.60	$569.75	$111.14	$141.57	$711.32	tons
16 SEER (11.61 EER) Split System Air Conditioner, 2 ton (24,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$663.23	$1,080.02	$416.78	$353.93	$1,433.94	tons
16 SEER (11.61 EER) Split System Air Conditioner, 2.5 ton (30,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$595.02	$928.45	$333.43	$283.14	$1,211.59	tons
16 SEER (11.61 EER) Split System Air Conditioner, 3 ton (36,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$549.55	$827.41	$277.86	$235.95	$1,063.36	tons
16 SEER (11.61 EER) Split System Air Conditioner, 3.5 ton (42,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$517.07	$755.23	$238.16	$202.24	$957.48	tons
16 SEER (11.61 EER) Split System Air Conditioner, 4 ton (48,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$492.71	$701.10	$208.39	$176.96	$878.06	tons
16 SEER (11.61 EER) Split System Air Conditioner, 5 ton (60,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$458.60	$625.32	$166.71	$141.57	$766.89	tons
17 SEER (12.28 EER) Split-System Air Conditioner, 2 ton (24,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$663.23	$1,218.95	$555.71	$353.93	$1,572.87	tons
17 SEER (12.28 EER) Split-System Air Conditioner, 2.5 ton (30,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$595.02	$1,039.59	$444.57	$283.14	$1,322.73	tons
17 SEER (12.28 EER) Split-System Air Conditioner, 3 ton (36,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$549.55	$920.03	$370.47	$235.95	$1,155.98	tons
17 SEER (12.28 EER) Split-System Air Conditioner, 3.5 ton (42,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$517.07	$834.62	$317.55	$202.24	$1,036.86	tons
17 SEER (12.28 EER) Split-System Air Conditioner, 4 ton (48,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$492.71	$770.57	$277.86	$176.96	$947.53	tons
17 SEER (12.28 EER) Split-System Air Conditioner, 5 ton (60,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$458.60	$680.89	$222.28	$141.57	$822.46	tons
18 SEER (13.37 EER) Split-System Air Conditioner, 2 ton (24,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$663.23	$1,357.87	$694.64	$353.93	$1,711.80	tons
18 SEER (13.37 EER) Split-System Air Conditioner, 2.5 ton (30,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$595.02	$1,150.74	$555.71	$283.14	$1,433.88	tons
18 SEER (13.37 EER) Split-System Air Conditioner, 3 ton (36,000 Btu)	T24 minimum: 13 SEER(11.09 EER) Split	$549.55	$1,012.64	$463.09	$235.95	$1,248.59	tons

Measure Description	Base Description	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
condenser and matched cased coil	System Air Conditioner						
18 SEER (13.37 EER) Split-System Air Conditioner, 3.5 ton (42,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$517.07	$914.01	$396.94	$202.24	$1,116.25	tons
18 SEER (13.37 EER) Split-System Air Conditioner, 4 ton (48,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$492.71	$840.03	$347.32	$176.96	$1,016.99	tons
18 SEER (13.37 EER) Split-System Air Conditioner, 5 ton (60,000 Btu) condenser and matched cased coil	T24 minimum: 13 SEER(11.09 EER) Split System Air Conditioner	$458.60	$736.46	$277.86	$141.57	$878.03	tons
13 SEER (11.07 EER) / 8.1 HSPF (3.28 COP) A/C Heat pump, 2 ton (24,000 Btu) heat pump	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-System Heat Pump	$419.48	$775.78	$356.30	$604.18	$1,379.96	tons
13 SEER (11.07 EER) / 8.1 HSPF (3.28 COP) A/C Heat pump. 3 ton (36,000 Btu) heat pump	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-System Heat Pump	$363.18	$630.84	$267.66	$402.78	$1,033.63	tons
13 SEER (11.07 EER) / 8.1 HSPF (3.28 COP) A/C Heat pump, 4 ton (48,000 Btu) heat pump	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-System Heat Pump	$335.04	$558.38	$223.34	$302.09	$860.46	tons
13 SEER (11.07 EER) / 8.1 HSPF (3.28 COP) A/C Heat pump, 5 ton (60,000 Btu) heat pump	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-System Heat Pump	$318.15	$514.90	$196.75	$241.67	$756.57	tons
14 SEER (12.19 EER) / 8.6 HSPF (3.52 COP) A/C Heat Pump, 2 ton (24,000 Btu) heat pump	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-System Heat Pump	$419.48	$904.24	$484.76	$604.18	$1,508.41	tons
14 SEER (12.19 EER) / 8.6 HSPF (3.52 COP) A/C Heat Pump, 3 ton (36,000 Btu) heat pump	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-System Heat Pump	$363.18	$728.78	$365.60	$402.78	$1,131.56	tons
14 SEER (12.19 EER) / 8.6 HSPF (3.52 COP) A/C Heat Pump, 4 ton (48,000 Btu) heat pump	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-System Heat Pump	$335.04	$641.05	$306.01	$302.09	$943.14	tons
14 SEER (12.19 EER) / 8.6 HSPF (3.52 COP) A/C Heat Pump, 5 ton (60,000 Btu) heat pump	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-System Heat Pump	$318.15	$588.41	$270.26	$241.67	$830.08	tons
15 SEER (12.70 EER) / 8.8 HSPF (3.74 COP) A/C Heat Pump, 2 ton (24,000 Btu) heat pump	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-System Heat Pump	$419.48	$1,032.70	$613.22	$604.18	$1,636.87	tons
15 SEER (12.70 EER) / 8.8 HSPF (3.74 COP) A/C Heat Pump, 3 ton (36,000 Btu) heat pump	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-System Heat Pump	$363.18	$826.72	$463.53	$402.78	$1,229.50	tons
15 SEER (12.70 EER) / 8.8 HSPF (3.74 COP) A/C Heat Pump, 4 ton (48,000 Btu) heat pump	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-System Heat Pump	$335.04	$723.73	$388.69	$302.09	$1,025.81	tons
15 SEER (12.70 EER) / 8.8 HSPF (3.74 COP) A/C Heat Pump, 5 ton (60,000 Btu) heat pump	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-System Heat Pump	$318.15	$661.93	$343.78	$241.67	$903.60	tons
16 SEER (12.06 EER) / 8.4 HSPF (3.48 COP) A/C Heat Pump, 2 ton (24,000	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-	$419.48	$1,161.15	$741.68	$604.18	$1,765.33	tons

Measure Description	Base Description	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
Btu) heat pump	System Heat Pump						
16 SEER (12.06 EER) / 8.4 HSPF (3.48 COP) A/C Heat Pump, 3 ton (36,000 Btu) heat pump	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-System Heat Pump	$363.18	$924.65	$561.47	$402.78	$1,327.44	tons
16 SEER (12.06 EER) / 8.4 HSPF (3.48 COP) A/C Heat Pump, 4 ton (48,000 Btu) heat pump	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-System Heat Pump	$335.04	$806.40	$471.36	$302.09	$1,108.49	tons
16 SEER (12.06 EER) / 8.4 HSPF (3.48 COP) A/C Heat Pump, 5 ton (60,000 Btu) heat pump	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-System Heat Pump	$318.15	$735.45	$417.30	$241.67	$977.12	tons
17 SEER (12.52 EER) / 8.6 HSPF (3.26 COP) A/C Heat Pump, 2 ton (24,000 Btu) heat pump	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-System Heat Pump	$419.48	$1,289.61	$870.13	$604.18	$1,893.79	tons
17 SEER (12.52 EER) / 8.6 HSPF (3.26 COP) A/C Heat Pump, 3 ton (36,000 Btu) heat pump	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-System Heat Pump	$363.18	$1,022.59	$659.40	$402.78	$1,425.37	tons
17 SEER (12.52 EER) / 8.6 HSPF (3.26 COP) A/C Heat Pump, 4 ton (48,000 Btu) heat pump	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-System Heat Pump	$335.04	$889.08	$554.04	$302.09	$1,191.16	tons
17 SEER (12.52 EER) / 8.6 HSPF (3.26 COP) A/C Heat Pump, 5 ton (60,000 Btu) heat pump	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-System Heat Pump	$318.15	$808.97	$490.82	$241.67	$1,050.64	tons
18 SEER (12.88 EER) / 8.5 HSPF (3.32 COP) A/C Heat Pump, 2 ton (24,000 Btu) heat pump	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-System Heat Pump	$419.48	$1,418.07	$998.59	$604.18	$2,022.25	tons
18 SEER (12.88 EER) / 8.5 HSPF (3.32 COP) A/C Heat Pump, 3 ton (36,000 Btu) heat pump	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-System Heat Pump	$363.18	$1,120.52	$757.34	$402.78	$1,523.31	tons
18 SEER (12.88 EER) / 8.5 HSPF (3.32 COP) A/C Heat Pump, 4 ton (48,000 Btu) heat pump	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-System Heat Pump	$335.04	$971.75	$636.71	$302.09	$1,273.84	tons
18 SEER (12.88 EER) / 8.5 HSPF (3.32 COP) A/C Heat Pump, 5 ton (60,000 Btu) heat pump	10 SEER(8.7 EER)/6.8 HSPF(3.0 COP) Split-System Heat Pump	$318.15	$882.49	$564.34	$241.67	$1,124.16	tons
13 SEER (11.07 EER) / 8.1 HSPF (3.28 COP) A/C Heat pump. 3 ton (36,000 Btu) heat pump	T24 minimum: 13 SEER(11.07 EER)/8.1 HSPF(3.28 COP) A/C Heat pump	$630.84	$630.84	$ -	$235.95	$866.79	tons
14 SEER (12.19 EER) / 8.6 HSPF (3.52 COP) A/C Heat Pump, 2 ton (24,000 Btu) heat pump	T24 minimum: 13 SEER(11.07 EER)/8.1 HSPF(3.28 COP) A/C Heat pump	$775.78	$904.24	$128.46	$353.93	$1,258.16	tons
14 SEER (12.19 EER) / 8.6 HSPF (3.52 COP) A/C Heat Pump, 3 ton (36,000 Btu) heat pump	T24 minimum: 13 SEER(11.07 EER)/8.1 HSPF(3.28 COP) A/C Heat pump	$630.84	$728.78	$97.94	$235.95	$964.73	tons
14 SEER (12.19 EER) / 8.6 HSPF (3.52 COP) A/C Heat Pump, 4 ton (48,000 Btu) heat pump	T24 minimum: 13 SEER(11.07 EER)/8.1 HSPF(3.28 COP) A/C	$558.38	$641.05	$82.67	$176.96	$818.01	tons

Measure Description	Base Description	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
	Heat pump						
14 SEER (12.19 EER) / 8.6 HSPF (3.52 COP) A/C Heat Pump, 5 ton (60,000 Btu) heat pump	T24 minimum: 13 SEER(11.07 EER)/8.1 HSPF(3.28 COP) A/C Heat pump	$514.90	$588.41	$73.52	$141.57	$729.98	tons
15 SEER (12.70 EER) / 8.8 HSPF (3.74 COP) A/C Heat Pump, 2 ton (24,000 Btu) heat pump	T24 minimum: 13 SEER(11.07 EER)/8.1 HSPF(3.28 COP) A/C Heat pump	$775.78	$1,032.70	$256.92	$353.93	$1,386.62	tons
15 SEER (12.70 EER) / 8.8 HSPF (3.74 COP) A/C Heat Pump, 3 ton (36,000 Btu) heat pump	T24 minimum: 13 SEER(11.07 EER)/8.1 HSPF(3.28 COP) A/C Heat pump	$630.84	$826.72	$195.87	$235.95	$1,062.67	tons
15 SEER (12.70 EER) / 8.8 HSPF (3.74 COP) A/C Heat Pump, 4 ton (48,000 Btu) heat pump	T24 minimum: 13 SEER(11.07 EER)/8.1 HSPF(3.28 COP) A/C Heat pump	$558.38	$723.73	$165.35	$176.96	$900.69	tons
15 SEER (12.70 EER) / 8.8 HSPF (3.74 COP) A/C Heat Pump, 5 ton (60,000 Btu) heat pump	T24 minimum: 13 SEER(11.07 EER)/8.1 HSPF(3.28 COP) A/C Heat pump	$514.90	$661.93	$147.04	$141.57	$803.50	tons
16 SEER (12.06 EER) / 8.4 HSPF (3.48 COP) A/C Heat Pump, 2 ton (24,000 Btu) heat pump	T24 minimum: 13 SEER(11.07 EER)/8.1 HSPF(3.28 COP) A/C Heat pump	$775.78	$1,161.15	$385.37	$353.93	$1,515.08	tons
16 SEER (12.06 EER) / 8.4 HSPF (3.48 COP) A/C Heat Pump, 3 ton (36,000 Btu) heat pump	T24 minimum: 13 SEER(11.07 EER)/8.1 HSPF(3.28 COP) A/C Heat pump	$630.84	$924.65	$293.81	$235.95	$1,160.60	tons
16 SEER (12.06 EER) / 8.4 HSPF (3.48 COP) A/C Heat Pump, 4 ton (48,000 Btu) heat pump	T24 minimum: 13 SEER(11.07 EER)/8.1 HSPF(3.28 COP) A/C Heat pump	$558.38	$806.40	$248.02	$176.96	$983.36	tons
16 SEER (12.06 EER) / 8.4 HSPF (3.48 COP) A/C Heat Pump, 5 ton (60,000 Btu) heat pump	T24 minimum: 13 SEER(11.07 EER)/8.1 HSPF(3.28 COP) A/C Heat pump	$514.90	$735.45	$220.56	$141.57	$877.02	tons
17 SEER (12.52 EER) / 8.6 HSPF (3.26 COP) A/C Heat Pump, 2 ton (24,000 Btu) heat pump	T24 minimum: 13 SEER(11.07 EER)/8.1 HSPF(3.28 COP) A/C Heat pump	$775.78	$1,289.61	$513.83	$353.93	$1,643.54	tons
17 SEER (12.52 EER) / 8.6 HSPF (3.26 COP) A/C Heat Pump, 3 ton (36,000 Btu) heat pump	T24 minimum: 13 SEER(11.07 EER)/8.1 HSPF(3.28 COP) A/C Heat pump	$630.84	$1,022.59	$391.74	$235.95	$1,258.54	tons
17 SEER (12.52 EER) / 8.6 HSPF (3.26 COP) A/C Heat Pump, 4 ton (48,000 Btu) heat pump	T24 minimum: 13 SEER(11.07 EER)/8.1 HSPF(3.28 COP) A/C Heat pump	$558.38	$889.08	$330.70	$176.96	$1,066.04	tons

Measure Description	Base Description	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
17 SEER (12.52 EER) / 8.6 HSPF (3.26 COP) A/C Heat Pump, 5 ton (60,000 Btu) heat pump	T24 minimum: 13 SEER(11.07 EER)/8.1 HSPF(3.28 COP) A/C Heat pump	$514.90	$808.97	$294.07	$141.57	$950.54	tons
18 SEER (12.88 EER) / 8.5 HSPF (3.32 COP) A/C Heat Pump, 2 ton (24,000 Btu) heat pump	T24 minimum: 13 SEER(11.07 EER)/8.1 HSPF(3.28 COP) A/C Heat pump	$775.78	$1,418.07	$642.29	$353.93	$1,772.00	tons
18 SEER (12.88 EER) / 8.5 HSPF (3.32 COP) A/C Heat Pump, 3 ton (36,000 Btu) heat pump	T24 minimum: 13 SEER(11.07 EER)/8.1 HSPF(3.28 COP) A/C Heat pump	$630.84	$1,120.52	$489.68	$235.95	$1,356.47	tons
18 SEER (12.88 EER) / 8.5 HSPF (3.32 COP) A/C Heat Pump, 4 ton (48,000 Btu) heat pump	T24 minimum: 13 SEER(11.07 EER)/8.1 HSPF(3.28 COP) A/C Heat pump	$558.38	$971.75	$413.37	$176.96	$1,148.71	tons
18 SEER (12.88 EER) / 8.5 HSPF (3.32 COP) A/C Heat Pump, 5 ton (60,000 Btu) heat pump	T24 minimum: 13 SEER(11.07 EER)/8.1 HSPF(3.28 COP) A/C Heat pump	$514.90	$882.49	$367.59	$141.57	$1,024.06	tons

Table D-29 – Refrigerant Charge and Duct Sealing

Measure Name	Measure Description	Base Description	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
Typical Refrigerant Charge Adjustment (< ±20% rated charge)	Standard Cooling Performance (proper refrigerant charge)	Clg Eff Decreased by 15%	$0.00	$10.36	$0.00	$28.00	$38.36	tons
High Refrigerant Charge Adjustment (>= ±20% rated charge)	Standard Cooling Performance (proper refrigerant charge)	Clg Eff Decreased by 15% & Supply Duct Leakage 20%	$0.00	$17.87	$0.00	$28.47	$46.33	tons
Typical Refrigerant Charge Adjustment (< ±20% rated charge) + Duct Sealing	Standard Cooling Performance, reduced duct loss	Cooling Performance degraded, standard duct loss	$0.00	$27.03	$0.00	$119.24	$146.27	tons
High Refrigerant Charge Adjustment (>= ±20% rated charge) + Duct Sealing	Standard Cooling Performance, reduced duct loss	Cooling Performance degraded, standard duct loss	$0.00	$34.53	$0.00	$119.71	$154.24	tons
Duct Sealing (Total Leakage Reduced from 40% of AHU flow to 12%)	Duct Sealing (Total Leakage Reduced from 40% of AHU flow to 12%)	Supply/return/OA leakage 20/16/4% of AHU flow	$0.00	$16.67	$0.00	$91.24	$107.91	Tons
Duct Sealing (Total Leakage Reduced from 24% of AHU flow to 12%)	Duct Sealing (Total Leakage Reduced from 24% of AHU flow to 12%)	Supply/return/OA leakage 12/9.6/2.4% of AHU flow	$0.00	$16.67	$0.00	$91.24	$107.91	Tons

Table D-30 – Duct Insulation

Measure Description	Base Description	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
Old vintage increases duct insulation to R-4.2, 78-91 vintage to R-8	Duct insulation level a function of Vintage/System type	$0.00	$0.68	$0.00	$2.40	$3.08	SqFt

Table D-31 – Evaporative Cooler Costs

Measure Description	Base Description	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
Direct Evaporative Cooler	10 SEER(8.7 EER) Split-System Air Conditioner	$839.17	$813.44	($25.73)	$814.12	$1,627.56	Cooler
Direct-Indirect Evaporative Cooler	10 SEER(8.7 EER) Split-System Air Conditioner	$839.17	$1,553.00	$713.83	$814.12	$2,367.12	Cooler

Table D-32 – Heating System Replacement Costs

Measure Description	Base Description	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
Condensing 90 AFUE (1.11 HIR) Furnace, 60,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$9.57	$21.53	$11.96	$19.98	$41.51	kBtuh
Condensing 90 AFUE (1.11 HIR) Furnace, 70,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$8.65	$18.37	$9.72	$17.12	$35.49	kBtuh
Condensing 90 AFUE (1.11 HIR) Furnace, 80,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$7.96	$16.20	$8.24	$14.98	$31.18	kBtuh
Condensing 90 AFUE (1.11 HIR) Furnace, 90,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$7.42	$14.69	$7.27	$13.32	$28.01	kBtuh
Condensing 90 AFUE (1.11 HIR) Furnace,100,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$6.99	$13.65	$6.66	$11.99	$25.63	kBtuh
Condensing 90 AFUE (1.11 HIR) Furnace, 110,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$6.64	$12.94	$6.31	$10.90	$23.84	kBtuh
Condensing 90 AFUE (1.11 HIR) Furnace, 115,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$6.48	$12.69	$6.21	$10.42	$23.11	kBtuh
Condensing 90 AFUE (1.11 HIR) Furnace, 120,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$6.34	$12.49	$6.15	$9.99	$22.48	kBtuh
Condensing 90 AFUE (1.11 HIR) Furnace, 125,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$6.21	$12.34	$6.13	$9.51	$21.85	kBtuh
Condensing 90 AFUE (1.11 HIR) Furnace, 140,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$5.88	$12.13	$6.25	$8.56	$20.69	kBtuh
Condensing 92 AFUE (1.11 HIR) Furnace, 60,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$9.57	$22.50	$12.93	$19.98	$42.48	kBtuh
Condensing 92 AFUE (1.11 HIR) Furnace,	80 AFUE(1.23 HIR) Furnace	$8.65	$19.34	$10.69	$17.12	$36.46	kBtuh

Measure Description	Base Description	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
70,000 Btu single stage							
Condensing 92 AFUE (1.11 HIR) Furnace, 80,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$7.96	$17.17	$9.21	$14.98	$32.15	kBtuh
Condensing 92 AFUE (1.11 HIR) Furnace, 90,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$7.42	$15.66	$8.24	$13.32	$28.98	kBtuh
Condensing 92 AFUE (1.11 HIR) Furnace,100,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$6.99	$14.62	$7.63	$11.99	$26.61	kBtuh
Condensing 92 AFUE (1.11 HIR) Furnace, 110,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$6.64	$13.92	$7.28	$10.90	$24.81	kBtuh
Condensing 92 AFUE (1.11 HIR) Furnace, 115,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$6.48	$13.66	$7.18	$10.42	$24.08	kBtuh
Condensing 92 AFUE (1.11 HIR) Furnace, 120,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$6.34	$13.46	$7.12	$9.99	$23.45	kBtuh
Condensing 92 AFUE (1.11 HIR) Furnace, 125,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$6.21	$13.31	$7.10	$9.51	$22.83	kBtuh
Condensing 92 AFUE (1.11 HIR) Furnace, 140,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$5.88	$13.10	$7.22	$8.56	$21.66	kBtuh
Condensing 94 AFUE (1.11 HIR) Furnace, 60,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$9.57	$23.48	$13.90	$19.98	$43.45	kBtuh
Condensing 94 AFUE (1.11 HIR) Furnace, 70,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$8.65	$20.31	$11.66	$17.12	$37.44	kBtuh
Condensing 94 AFUE (1.11 HIR) Furnace, 80,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$7.96	$18.14	$10.18	$14.98	$33.13	kBtuh
Condensing 94 AFUE (1.11 HIR) Furnace, 90,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$7.42	$16.64	$9.22	$13.32	$29.95	kBtuh
Condensing 94 AFUE (1.11 HIR) Furnace,100,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$6.99	$15.59	$8.60	$11.99	$27.58	kBtuh
Condensing 94 AFUE (1.11 HIR) Furnace, 110,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$6.64	$14.89	$8.25	$10.90	$25.79	kBtuh
Condensing 94 AFUE (1.11 HIR) Furnace, 115,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$6.48	$14.64	$8.15	$10.42	$25.06	kBtuh
Condensing 94 AFUE	80 AFUE(1.23	$6.34	$14.44	$8.09	$9.99	$24.43	kBtuh

Measure Description	Base Description	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
(1.11 HIR) Furnace, 120,000 Btu single stage	HIR) Furnace						
Condensing 94 AFUE (1.11 HIR) Furnace, 125,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$6.21	$14.29	$8.07	$9.51	$23.80	kBtuh
Condensing 94 AFUE (1.11 HIR) Furnace, 140,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$5.88	$14.08	$8.19	$8.56	$22.64	kBtuh
Condensing 96 AFUE (1.11 HIR) Furnace, 60,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$9.57	$24.45	$14.88	$19.98	$44.43	kBtuh
Condensing 96 AFUE (1.11 HIR) Furnace, 70,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$8.65	$21.29	$12.63	$17.12	$38.41	kBtuh
Condensing 96 AFUE (1.11 HIR) Furnace, 80,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$7.96	$19.12	$11.16	$14.98	$34.10	kBtuh
Condensing 96 AFUE (1.11 HIR) Furnace, 90,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$7.42	$17.61	$10.19	$13.32	$30.93	kBtuh
Condensing 96 AFUE (1.11 HIR) Furnace,100,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$6.99	$16.57	$9.58	$11.99	$28.55	kBtuh
Condensing 96 AFUE (1.11 HIR) Furnace, 110,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$6.64	$15.86	$9.23	$10.90	$26.76	kBtuh
Condensing 96 AFUE (1.11 HIR) Furnace, 115,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$6.48	$15.61	$9.12	$10.42	$26.03	kBtuh
Condensing 96 AFUE (1.11 HIR) Furnace, 120,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$6.34	$15.41	$9.07	$9.99	$25.40	kBtuh
Condensing 96 AFUE (1.11 HIR) Furnace, 125,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$6.21	$15.26	$9.05	$9.51	$24.77	kBtuh
Condensing 96 AFUE (1.11 HIR) Furnace, 140,000 Btu single stage	80 AFUE(1.23 HIR) Furnace	$5.88	$15.05	$9.17	$8.56	$23.61	kBtuh

Water Heating Measures

Table D-33 – Water Heating Measure Costs

Measure Description	Base Description	Application	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit

Measure Description	Base Description	Application	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
Improved EF of 0.53 (based on tank size/vintage), Gas, 30-75 gal tank; EF>=0.63	Gas, 30-75 gal tank; EF<=0.594	ROB/NEW	$474.18	$631.41	$157.22	$0.00	$0.00	WtrHtr
Improved EF of 0.53 (based on tank size/vintage), Gas, 30-75 gal tank; EF>=0.62	Gas, 30-75 gal tank; EF<=0.594	ROB/NEW	$474.18	$495.72	$21.54	$0.00	$0.00	WtrHtr
Improved EF of 0.53 (based on tank size/vintage), Gas, 40 gal tank; EF>=0.63	Gas, 40 gal tank; EF<=0.594	ROB/NEW	$375.65	$550.95	$175.30	$0.00	$0.00	WtrHtr
Improved EF of 0.53 (based on tank size/vintage), Gas, 50 gal tank; EF>=0.63	Gas, 50 gal tank; EF<=0.594	ROB/NEW	$455.73	$765.51	$309.77	$0.00	$0.00	WtrHtr
Improved EF of 0.53 (based on tank size/vintage), Gas, 40 gal tank; EF>=0.62	Gas, 40 gal tank; EF<=0.594	ROB/NEW	$375.65	$482.72	$107.07	$0.00	$0.00	WtrHtr
Improved EF of 0.53 (based on tank size/vintage), Gas, 50 gal tank; EF>=0.62	Gas, 50 gal tank; EF<=0.594	ROB/NEW	$455.73	$534.44	$78.71	$0.00	$0.00	WtrHtr
Improved EF of 0.53 (based on tank size/vintage), Gas, 40-50 gal tank; EF>=0.62	Gas, 40-50 gal tank; EF<=0.594	ROB/NEW	$375.65	$479.89	$104.24	$0.00	$0.00	WtrHtr
zero tank loss, improved EF of 0.67, Gas Tankless, Elec Ignition; 250kBtu/h	Gas Tank; EF<=0.60	RET/ROB/NEW	$1,844.19	$1,517.24	($326.95)	$250.90	$1,768.14	WtrHtr
zero tank loss	electric water heater with EF based on tank size	RET/ROB/NEW	$292.33	$789.30	$496.97	$270.75	$1,060.05	WtrHtr
DHW circulation pump turns off during low operation hours	DHW circulation pump runs continuously	RET/NEW	$0.00	$59.00	$0.00	$165.28	$224.27	Timeclock
Same tank size/capacity with improved efficiency burner (90%)	Tank size and burner capacity a function of building type, 80% eff	ROB/NEW	$2,033.91	$3,695.60	$1,661.69	$0.00	$0.00	WtrHtr

Measure Description	Base Description	Application	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
Same tank size/capacity with improved efficiency burner (90%)	Tank size and burner capacity a function of building type, 80% eff	ROB/NEW	$2,258.17	$3,919.86	$1,661.69	$0.00	$0.00	WtrHtr
Point of Use Water Heat, Gas Tankless, Elec Ignition; 150kBtu/h	Gas Tank; EF<=0.60	RET/ROB/NEW	$492.96	$863.60	$370.64	$250.90	$1,114.50	WtrHtr
Circulation Pump Timeclock	DHW circulation pump runs continuously	RET/NEW	$0.00	$59.00	$0.00	$165.28	$224.27	Timeclock
High Eff. Water Heater,Gas, 30-75 gal tank; EF>=0.63	Gas, 30-75 gal tank; EF<=0.594	ROB/NEW	$474.18	$631.41	$157.22	$0.00	$0.00	WtrHtr
High Eff. Water Heater,Gas, 30-75 gal tank; EF>=0.62	Gas, 30-75 gal tank; EF<=0.594	ROB/NEW	$474.18	$495.72	$21.54	$0.00	$0.00	WtrHtr
High Eff. Water Heater, Gas, 40 gal tank; EF>=0.63	Gas, 40 gal tank; EF<=0.594	ROB/NEW	$375.65	$550.95	$175.30	$0.00	$0.00	WtrHtr
High Eff. Water Heater, Gas, 50 gal tank; EF>=0.63	Gas, 50 gal tank; EF<=0.594	ROB/NEW	$455.73	$765.51	$309.77	$0.00	$0.00	WtrHtr
High Eff. Water Heater, Gas, 40 gal tank; EF>=0.62	Gas, 40 gal tank; EF<=0.594	ROB/NEW	$375.65	$482.72	$107.07	$0.00	$0.00	WtrHtr
High Eff. Water Heater, Gas, 50 gal tank; EF>=0.62	Gas, 50 gal tank; EF<=0.594	ROB/NEW	$455.73	$534.44	$78.71	$0.00	$0.00	WtrHtr
High Eff. Water Heater, Gas, 40-50 gal tank; EF>=0.62	Gas, 40-50 gal tank; EF<=0.594	ROB/NEW	$375.65	$479.89	$104.24	$0.00	$0.00	WtrHtr
Faucet Aerators	No Faucet Aerators	RET	$0.00	$7.12	$0.00	$5.58	$12.69	Aerator
Faucet Aerators	No Faucet Aerators	RET	$0.00	$2.14	$0.00	$5.58	$7.72	Aerator
Heat pump water heater, EF=2.9	Electric water heater, EF=0.88	ROB/NEW	$251.11	$1,539.13	$1,288.02	$122.83	$1,661.96	WtrHtr
Pipe Wrap	No Pipe Wrap	RET/NEW	$0.00	$0.37	$0.00	$2.44	$2.81	LinFt
Pipe Wrap	No Pipe Wrap	RET/NEW	$0.00	$0.36	$0.00	$2.44	$2.80	LinFt
Low Flow	Standard	RET	$0.00	$22.95	$0.00	$15.00	$37.95	Showerhead

Measure Description	Base Description	Application	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
Showerhead (<=2.0 gpm)	showerhead (2.5 gpm)							
Low Flow Showerhead (<=2.0 gpm)	Standard showerhead (2.5 gpm)	RET	$0.00	$8.49	$0.00	$15.00	$23.49	Showerhead
Gas, 30-75 gal tank; EF>=0.63	Gas, 30-75 gal tank; EF<=0.594	ROB/NEW	$474.18	$631.41	$157.22	$0.00	$0.00	WtrHtr
Gas, 30-75 gal tank; EF>=0.62	Gas, 30-75 gal tank; EF<=0.594	ROB/NEW	$474.18	$495.72	$21.54	$0.00	$0.00	WtrHtr
Gas, 40 gal tank; EF>=0.63	Gas, 40 gal tank; EF<=0.594	ROB/NEW	$375.65	$550.95	$175.30	$0.00	$0.00	WtrHtr
Gas, 50 gal tank; EF>=0.63	Gas, 50 gal tank; EF<=0.594	ROB/NEW	$455.73	$765.51	$309.77	$0.00	$0.00	WtrHtr
Gas, 40 gal tank; EF>=0.62	Gas, 40 gal tank; EF<=0.594	ROB/NEW	$375.65	$482.72	$107.07	$0.00	$0.00	WtrHtr
Gas, 50 gal tank; EF>=0.62	Gas, 50 gal tank; EF<=0.594	ROB/NEW	$455.73	$534.44	$78.71	$0.00	$0.00	WtrHtr
Gas, 40-50 gal tank; EF>=0.62	Gas, 40-50 gal tank; EF<=0.594	ROB/NEW	$375.65	$479.89	$104.24	$0.00	$0.00	WtrHtr
Elec, 30 gal; EF=0.93	Elec, 30 gal; EF=0.88	ROB/NEW	$139.76	$212.06	$72.30	$0.00	$0.00	WtrHtr
Elec, 40 gal; EF=0.93	Elec, 40 gal; EF=0.88	ROB/NEW	$195.43	$267.73	$72.30	$0.00	$0.00	WtrHtr
Elec, 50 gal; EF=0.93	Elec, 50 gal; EF=0.88	ROB/NEW	$251.11	$323.41	$72.30	$0.00	$0.00	WtrHtr
Elec, 60 gal; EF=0.93	Elec, 60 gal; EF=0.88	ROB/NEW	$306.79	$379.09	$72.30	$0.00	$0.00	WtrHtr
Elec, 80 gal; EF=0.93	Elec, 80 gal; EF=0.88	ROB/NEW	$418.14	$490.45	$72.30	$0.00	$0.00	WtrHtr
Point of Use Water Heat,Gas Tankless, Elec Ignition; 150kBtu/h	Gas Tank; EF<=0.60	RET/ROB/NEW	$492.96	$863.60	$370.64	$250.90	$1,114.50	WtrHtr

Appliances

Table D-34 – Refrigerator and Dishwasher Measure Costs

Measure Description	Base Description	Application	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
Energy Star Dish Washer, EF=0.58	EF=0.46, 160 wash cycles, electric water heat	ROB/NEW	$292.65	$426.30	$133.64	$0.00	$0.00	Dwasher
Energy Star Dish Washer, EF=0.61	EF=0.46, 160 wash cycles, electric water heat	ROB/NEW	$292.65	$426.30	$133.64	$0.00	$0.00	Dwasher
Energy Star Dish Washer, EF=0.64	EF=0.46, 160 wash cycles, electric water heat	ROB/NEW	$292.65	$426.30	$133.64	$0.00	$0.00	Dwasher
Energy Star Dish Washer, EF=0.58	EF=0.46, 215 wash cycles, electric water heat	ROB/NEW	$292.65	$426.30	$133.64	$0.00	$0.00	Dwasher
Energy Star Dish Washer, EF=0.61	EF=0.46, 215 wash cycles, electric water heat	ROB/NEW	$292.65	$426.30	$133.64	$0.00	$0.00	Dwasher
Energy Star Dish Washer, EF=0.64	EF=0.46, 215 wash cycles, electric water heat	ROB/NEW	$292.65	$426.30	$133.64	$0.00	$0.00	Dwasher
Refrigerator: Bottom Mount Freezer without through-the-door ice	Bottom Mount Freezer without through-the-door ice: 16.1 - 20 cf total volume	ROB/NEW	$880.00	$894.66	$14.66	$0.00	$0.00	Refrigerator
Refrigerator: Bottom Mount Freezer without through-the-door ice	Bottom Mount Freezer without through-the-door ice: 20.1 - 25 cf total volume	ROB/NEW	$945.00	$1,086.81	$141.81	$0.00	$0.00	Refrigerator
Refrigerator: Top Mount Freezer without through-the-door ice	Top Mount Freezer without through-the-door ice: <16.1cf total volume	ROB/NEW	$507.14	$450.75	($56.39)	$0.00	$0.00	Refrigerator

Measure Description	Base Description	Application	Base Equipment Cost	Measure Equipment Cost	Incremental Equipment Cost	Labor Cost	Installed Cost	Cost Unit
Refrigerator: Top Mount Freezer without through-the-door ice	Top Mount Freezer without through-the-door ice: 16.1 - 20 cf total volume	ROB/NEW	$448.64	$590.00	$141.36	$0.00	$0.00	Refrigerator
Refrigerator: Top Mount Freezer without through-the-door ice	Top Mount Freezer without through-the-door ice: 20.1 - 25 cf total volume	ROB/NEW	$537.75	$698.67	$160.92	$0.00	$0.00	Refrigerator
Refrigerator: Side Mount Freezer without through-the-door ice	Side Mount Freezer without through-the-door ice: up to 25 cf total volume	ROB/NEW	$939.60	$1,890.41	$950.81	$0.00	$0.00	Refrigerator
Refrigerator: Side Mount Freezer without through-the-door ice	Side Mount Freezer without through-the-door ice: 25 cf and higher total volume	ROB/NEW	$1,052.10	$1,150.48	$98.37	$0.00	$0.00	Refrigerator
Refrigerator: Side Mount Freezer with through-the-door ice	Side Mount Freezer with through-the-door ice: up to 25 cf total volume	ROB/NEW	$983.30	$1,153.52	$170.22	$0.00	$0.00	Refrigerator
Refrigerator: Side Mount Freezer with through-the-door ice	Side Mount Freezer with through-the-door ice: 25 cf and higher total volume	ROB/NEW	$928.74	$1,064.50	$135.76	$0.00	$0.00	Refrigerator
Refrigerator Recycling	Old extra refrigerator	RET	$0.00	------------>	$0.00	$0.00	$97.75	Refrigerator
Freezer removed	Old extra freezer	RET	$0.00	------------>	$0.00	$0.00	$97.75	Freezer

Table D-35 – Climate Zone Adjustment Factors

Zone	Representative City	Local Markup
1	Arcata	1.04
2	Santa Rosa	1.124
3	Oakland	1.166
4	San Jose	1.169
5	San Louis Obispo	1.05
6	Los Angeles	1.068
7	San Diego	1.044
8	Santa Ana	1.032
9	Pasadena	1.04
10	Riverside	1.059
11	Redding	1.084
12	Sacramento	1.097
13	Fresno	1.078
14	Mojave	1.021
15	Palm Springs	1.029
16	Truckee	1.084