Setting the Criteria for the 1992 California Residential Energy Standards

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ABSTRACT

This paper presents the methodology used to set the level of energy efficiency required by the 1992 California low-rise residential building energy-efficiency standards. The economically optimum level of energy performance is determined separately for seven components of the building envelope: ceilings at attics, vaulted ceilings, exterior walls, raised wood floors, raised concrete floors, slab-on-grade floors, and fenestration. For the opaque elements, the optimization is based on the thermal performance of insulation. The optimization for fenestration includes consideration of both shading coefficient and U-value.

The life-cycle cost (LCC) of every reasonable construction assembly is evaluated for each component of the building envelope. Energy savings are calculated using heating and cooling load coefficients. The load coefficients represent the change in heating and/or cooling load for a unit change in conduction through the opaque components but also include changes in solar radiation gain for fenestration. The load coefficients are developed for each component of the building envelope in the 16 California climatic zones.

Extensive sensitivity studies are performed to establish how the optimum levels of performance change with different discount rates, fuel price assumptions, internal gains, climatic conditions, and thermostat schedules. Sensitivity studies also evaluated the interaction between components.

INTRODUCTION

The enabling legislation for the California energy standards requires that the California Energy Commission (CEC) adopt standards that are cost-effective. Cost-effectiveness analysis is difficult in a complex policy arena where participating interests have much at stake. The ground rules frequently change as debate rages on which construction assemblies to consider, the costs of those constructions, discount rates, energy costs, and environmental externalities. The cost-effectiveness analysis procedure must, therefore, be simple and flexible yet provide sound information to the policy makers.

In the past, the standard as a whole has been shown to be cost-effective, and this is considered adequate to satisfy the legislative mandate. This can result in some requirements that may not be cost-effective being carried by other requirements that are very cost-effective.

METHODOLOGY

The methodology presented here ensures that the level of energy efficiency for each building component is cost-effective. It also shows policy makers the immediate implication of changes in assumptions and permits new construction assemblies and prices to be readily considered. Essentially, the method involves identifying all possible ways of constructing each component of the building envelope, estimating the cost of each construction alternative, estimating the energy use associated with each, and calculating the life-cycle cost of each. For each building component or class of construction, the optimum construction assembly is the one with the lowest life-cycle cost. This decision process is implemented with PC-based simplified models and presented graphically for ease of use by decision makers.

CLASSES OF CONSTRUCTIONS

The cost-effectiveness analysis is performed separately for different classes of constructions, for instance, both the attic and vaulted ceiling constructions for roofs. Similarly, calculations are performed separately for raised wood, raised concrete, and slab-on-grade floors. Within each class of construction, all reasonable construction assemblies are identified and estimates of thermal performance and cost are made for each.

Attics are considered with both loose fill and batt insulation. Two types of trusses are considered: a standard truss and a raised heel or "Arkansas" truss. The raised heel truss allows full insulation thickness to the edges of the ceiling.

Vaulted ceilings include standard fiberglass batts and high-density, 8.5-inch R-30 batt developed specifically for this application to allow ventilation in a 2×10-inch cavity. Blown-in insulation is not used because pitches are assumed to be steeper than 3:12. Some constructions also include rigid insulation in addition to the batt insulation. Rigid insulation can be applied at the ceiling or over the plywood deck.

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Walls are considered with cavity insulation alone and in combination with exterior rigid insulating sheathing. Rigid sheathings vary in thickness from one-half inch to two inches and material properties include polyisocyanurate and extruded smooth-cell polystyrene. Frame walls are constructed using 2×4 or 2×6 wood studs at 16 inches on center. Framed walls with 2×6 studs at 24 inches on center are also considered with a premium added for thicker gypsum board.

Raised wood floors are all assumed to be above a crawl space. Several levels of batt insulation are considered. Multifamily buildings sometimes have concrete flooring over a parking garage. Since insulation opportunities are different for this type of construction, a separate optimization is performed.

The majority of floors for new homes in California have slab-on-grade construction. Sometimes the footing and slab are poured as a monolithic assembly, but they can also be poured separately. The monolithic construction technology, more common with large builders, is more difficult to insulate and is assumed for the purpose of estimating construction costs. R-5 and R-7 extruded polystyrene insulation is considered at a depth of 16 inches.

Window frames analyzed in this report include aluminum with and without a thermal break and vinyl. Wood window frames are not analyzed for cost-effectiveness since the thermal performance of vinyl is roughly equivalent to wood and vinyl is less expensive. Measures considered to reduce the U-value include frame type, double glazing, low-emissivity coatings, argon fill, and suspended low-emissivity coated plastic film.

Cost Data Base

Construction costs are collected by surveying distributors, manufacturers, fabricators, and subcontractors. Costs are weighted averages for most products. Prices that are considered to be unreliable or unusually high or low are given a weighting of zero, which means that they would not be considered in the calculation of the weighted average price. Some prices, when they represent multiple price quotes or other surveys, are given a weight greater than one. In the case of windows, cost premiums are associated with changes in technology, for instance, a cost premium of double over single glass or a cost premium for a low-emissivity coating. Only cost differentials within a manufacturer's product line are considered. All costs are based on the distributor's or manufacturer's prices to a builder or specialty contractor. A 30% markup is added to account for the builder's overhead and profit. The construction costs were reviewed at several public workshops where builders, manufacturers, contractors, architects, and others were given the opportunity to comment on the cost data and offer additional information.

Thermal Performance of Constructions

The thermal performance (U-value) of opaque construction assemblies is determined using methods in the *ASHRAE Handbook—Fundamentals* (ASHRAE 1989). Insulation thickness at the edges of standard trusses is assumed to be reduced due to tapering. The calculated U-value for raised wood floor construction includes an additional R-6 to account for the buffering effect of the crawl space. Window performance is calculated with the Window 3.1 program (W&DG 1988).

Eliminating Constructions

When two or more constructions have the same cost but different U-values, the ones with the higher U-value may be eliminated since they will never be the lowest life-cycle cost choice. Similarly, when two or more constructions have the same U-value, only the one with the lowest cost need be considered. These principles are used with other measures of performance, such as shading coefficient and F-factor, to eliminate many of the constructions from further consideration.

Heating and Cooling Load Coefficients

The heating and cooling load coefficients (S_c and S_h) are determined through multiple computer runs using the CEC public domain, finite-difference energy simulation model (Barnaby and Mitchell 1988). These heating and cooling load coefficients represent the change in heating and cooling load, respectively, for a unit change in component performance. For most components, the unit change is building U×A. For slab edge insulation, it is the product of the slab perimeter and F2 factor. For window shading, it is the product of window area and shading coefficient.

These coefficients are calculated by systematically varying the performance of the component of interest. For each component, at least three computer runs are made: a low, medium, and high case. Calculations were made for a representative, two-story, 1761-ft^2 house selected to be typical of new construction in California. Each component was considered separately with the other components at the medium level. The middle case is selected to represent the level of conservation required by the pre-1992 standards. The low extreme is generally an uninsulated wall or roof component, while the high extreme represents maximum conservation (see Table 1).

Fenestration is assumed to be uniformly distributed in the four main compass points. While it is possible to perform the optimization separately for each orientation, this was not done since it was not considered practical to have different thermal performance criteria for each orientation.

TABLE 1
Parametric Variations of Building Components

Building Components	Performance Measure	Low	Medium	High
Ceiling	U-Value	0.077	0.035	0.017
Frame Wall	U-Value	0.393	0.098	0.033
Wood Raised Floor	U-Value	0.101	0.037	0.020
Concrete Raised Floor	U-Value	0.71	0.15	0.06
Slab-on-Grade	F-2	0.90	0.51	0.30
Glazing	U-Value	1.31	0.92	0.20
	Shading Coefficient	1.00	0.77	0.23

Energy Savings

The relative electricity and natural gas use associated with a construction assembly are given by the following equations for gas heating and electric cooling:

$$\delta kWh = \frac{U \times S_c}{SEER \times DE_c} + U \times S_h \times Fan, \quad (1)$$

$$\delta Therms = \frac{U \times S_h}{AFUE \times DE_h \times 100}, \quad (2)$$

where

U = U-value or performance measure associated with a construction assembly. For slab edge insulation, the F-factor is substituted, and for window solar gains, the shading coefficient (SC) is substituted.

S_c = cooling load coefficient representing the unit change in cooling load for a unit change in component performance.

S_h = heating load coefficient representing the unit change in heating load for a unit change in component performance.

$SEER$ = seasonal energy efficiency rating of the air conditioner. This is fixed at 10.0 for this study, the minimum NAECA requirement for a split-system air conditioner.

$AFUE$ = seasonal efficiency of the gas heating system. This is fixed at 78% for this study, the minimum NAECA requirement.

FAN = electricity use of the furnace fan (Wh/Btu). A value of 0.005 is used for this study.

DE_c = duct efficiency for cooling. A value of 87% is used for this study.

DE_h = duct efficiency for heating. A value of 88% is used for this study.

Windows have two performance measures—U-value and shading coefficient; the performance of each window is characterized by a combination of these measures. For windows, the δkWh and $\delta Therms$ terms are calculated separately for each performance measure and then added together.

For electric heating systems, the $\delta Therms$ drops out of the LCC equation and the δkWh equation changes as follows, with all of the terms previously defined. The HSPF (heating season performance factor) can be assumed to be 3.413 for electric resistance heat:

$$\delta kWh = \frac{U \times S_c}{SEER \times DE_c} + \frac{U \times S_h}{HSPF \times DE_h}. \quad (3)$$

Life-Cycle Cost

The relative life-cycle cost (LCC) of all construction assemblies is calculated using a simple equation. The absolute LCC is not required since the goal is to find the construction assembly within each class with the lowest LCC. The LCC analysis is performed for a square foot or unit of each envelope component. For instance, the LCC for walls is calculated for a single square foot of wall. Similarly, the construction cost and relative energy use for electricity and natural gas consumption are calculated for a single square foot of wall. The relative LCC for each construction assembly is calculated using Equation 4:

$$\delta LCC = \delta C + \delta kWh \times PV_e + \delta Therms \times PV_g, \quad (4)$$

where

δLCC = relative LCC of a construction assembly, \$;

δC = relative cost associated with the construction assembly, \$/ft^2;

δkWh = relative electricity use associated with a construction assembly, kWh/yr·ft^2;

$\delta Therms$ = relative natural gas use associated with a construction assembly, therms/yr·ft^2;

PV_e = present value of a kWh of electricity used each year over the life of the building, \$/(kWh/yr); a value of \$1.946/kWh/yr is used;

PV_g = present value of a therm of natural gas used each year over the life of the building, \$/(kWh/yr); a value of \$14.08 per therm is used.

Graphic Presentation of Results

Study of the equations for LCC and energy use reveals that many of the terms are constant for the comparative analysis of a set of construction alternatives. The constant terms include PV_e, PV_g, FAN, $SEER$, $AFUE$, DE_c, and DE_h. Only the heating and cooling load coefficients vary with climate (the S_h and S_c terms).

If the climate-dependent terms are plotted on a graph with the heating load coefficient (S_h) on the axis and the

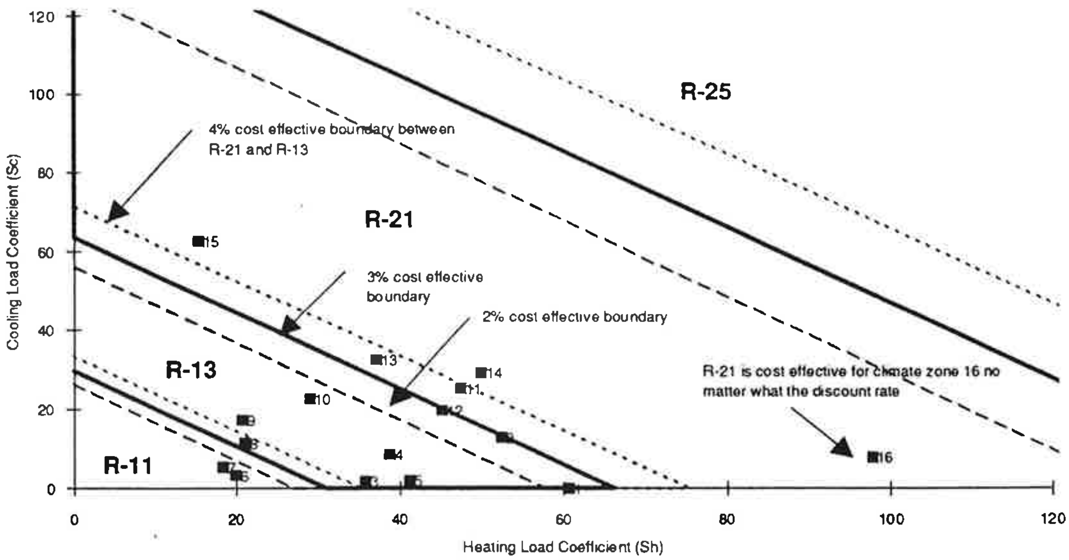

Figure 1 Illustration of graphic presentation method.

cooling load coefficient (S_c) on the axis, the cost-effective boundary between any two constructions can be plotted as a straight line.

For instance, Figure 1 shows the S_h and S_c terms for walls. The diagonal lines represent the cost-effective boundary between 2×4 studs at 16 in. o.c. with R-11, 2×4 studs at 16 in. o.c. with R-13 insulation, and 2×6 studs at 24 in. o.c. with R-21 insulation.

This graphic presentation is used to present and study the sensitivity of the results. When a point (a pair of S_h and S_c coordinates) is close to a line, then a change in the modeling assumptions or a change in the fixed assumptions may affect the outcome. If a point is squarely between two lines, then it is not likely that a change in modeling assumptions or fixed assumptions will affect the result.

The boundary condition between two construction types occurs when the life-cycle cost of the two construction types is equal. An equation for this condition can be stated by setting the life-cycle cost of the two construction types equal to each other as shown below:

$$\delta LCC_i = \delta LCC_j \ . \tag{5}$$

By substituting Equation 4 into Equation 5, the intercepts for the boundary can be determined as shown below:

$$\begin{aligned} &\delta C_i + PV_e \cdot \delta kWh_i + PV_g \cdot \delta Therms_i \\ &= \delta C_j + PV_e \cdot \delta kWh_j + PV_g \cdot \delta Therms_j \ (\delta C_j - \delta C_i) \\ &= PV_e\ (\delta kWh_i - \delta kWh_j) + PV_g (\delta Therms_i - \delta Therms_j) \\ &DC = PV_e\ DkWh + PV_g\ DTherms \end{aligned} \tag{6}$$

where

$$\begin{aligned} \Delta C &= \delta C_j - \delta C_i, \\ \Delta kWh &= \delta kWh_i - \delta kWh_j, \text{ and} \\ \Delta Therms &= \delta Therms_i - \delta Therms_j \ . \end{aligned} \tag{7}$$

The change in electricity consumption (ΔkWh) and the change in gas consumption ($\Delta Therms$) can be used with variations of Equations 2 and 3:

$$\Delta kWh = \frac{\Delta U \times S_c}{SEER \times DE_c} + \Delta U \times S_h \times Fan \ , \tag{8}$$

$$\Delta Therms = \frac{\Delta U \times S_h}{AFUE \times DE_h \times 100} \ . \tag{9}$$

When these equations are substituted into Equation 6, the intercepts for the boundary condition between two construction types can be calculated:

$$\delta_h\ Intercept = \frac{\Delta C}{\alpha_h \times \Delta U} \ , \tag{10}$$

$$\delta_h\ Intercept = \frac{\Delta C}{\alpha_c \times \Delta U} \ , \tag{11}$$

where

$$\alpha_c = \frac{PV_e}{SEER \times DE_c} \tag{12}$$

and

$$\alpha_h = PV_e \times Fan + \frac{PV_g}{AFUE \times DE_h \times 100} \ . \tag{13}$$

For a given set of economic assumptions and for a fixed heating and cooling system, α_h and α_c are constants so that the boundary between two constructions depends only on ΔC and ΔU.

Economic Assumptions

California policymakers are interested in seeing how a change in the discount rate affects the life-cycle cost results. In response, the boundary conditions are calculated for several sets of economic assumptions: (1) a 4% real discount rate, (2) a 3% real discount rate, and (3) a 2% real discount rate. In addition, calculations were made with a 2% real discount rate with environmental costs added to account for CO_2 and NO_x emissions, for the probability of oil spills, and other factors (Goldstein and Miller 1990); the results from this set of economic assumptions are not included in this paper, however.

Each of these sets of economic assumptions assumes a 30-year building life and electricity and gas costs predicted by the CEC. Each set is expressed as the present value of a unit of energy saved (See Table 2).

RESULTS

The life-cycle cost results are displayed graphically. The display consists of a plot of heating and cooling load coefficients for each of the climates. Each point on the figure represents one of the 16 climatic zones (see Figure 2). Climatic Zone 16, the mountainous area of the state, has a large heating load coefficient and a relatively small cooling load coefficient. Climatic Zone 15, by contrast, has a large cooling load coefficient and a relatively small heating load coefficient. Other climates, such as the central valley of California, have more balanced heating and cooling load coefficients. The further a point is from the origin, the more conservation can be justified for that climate.

The heating and cooling load coefficients represent the change in heating or cooling load for a unit change of building conduction. In this case, a large heating load coefficient means that a change in wall U-value will have a bigger impact.

The diagonal lines represent cost-effective boundaries between construction types. The position of this line changes with a change in discount rate and three positions are shown on the graph: 2%, 3%, and 4%. The solid line is the 3% boundary, which is the criterion used in California. The dashed line is the 2% boundary, and the dotted line is the 4% boundary.

For attics, R-30 is the cost-effective insulation level at the 3% discount rate for most climates. R-38 is cost-effective in climatic zones 14 and 16, and R-49 is cost-effective in climatic zone 15. R-19 is cost-effective in three moderate coastal climates: 3, 6, and 7. The choice of discount rate affects the results in several climates. If a 4% rate were used, R-30 (instead of R-38) would be cost-effective in climates 14 and 16, and R-19 (instead of R-30) would be cost-effective in climatic zone 5 (see Figure 3).

For vaulted ceilings and a 3% discount rate, R-30 insulation is cost-effective in climatic zones 2 and 10

TABLE 2
Present Value of Electricity and Natural Gal Savings

Discount Rate	Present Value of Electricity Savings $(kWh/yr)	Present Value of Gas Savings $/(therm/yr)
4%	1.733	12.371
3%	1.946	14.083
2%	2.203	16.165
2% with environmental costs	2.629	19.615

through 16. If the discount rate is changed to 4%, then R-19 becomes the cost- effective choice in climatic zone 10. R-19 is the cost-effective choice in climatic zones 1, 3, 4, 5, 7, 8, and 9. No insulation is cost-effective for climatic zone 6 (Long Beach) but by a narrow margin (see Figure 4).

For exterior walls and a 3% discount rate, R-21 insulation between 2×6 studs at 24 inches o.c. is cost-effective in climatic zones 11, 13, 14, 15, and 16. A 4% discount rate, however, changes the cost-effective choice to R-13 in 2×4 studs for climatic zones 11 and 13. R-13 in 2×4 studs at 16 inches o.c. is the cost- effective choice in climatic zones 1 through 5, 8, 9, 10, and 12. R-21 is very close to being cost-effective for climatic zones 2 and 12, however, and becomes cost-effective (along with climatic zone 1) if the discount rate were changed to 2%. Climatic zone 8 drops to R-11 with a 4% discount rate. R-11 is the cost-effective choice for climatic zones 6 and 7 (see Figure 5).

For raised wood floors and a 3% discount rate, R-30 insulation is cost-effective only in climatic zone 16 and only at the 2% discount rate. R-19 is the cost-effective choice in

Figure 2 *California climatic zones and representative cities.*

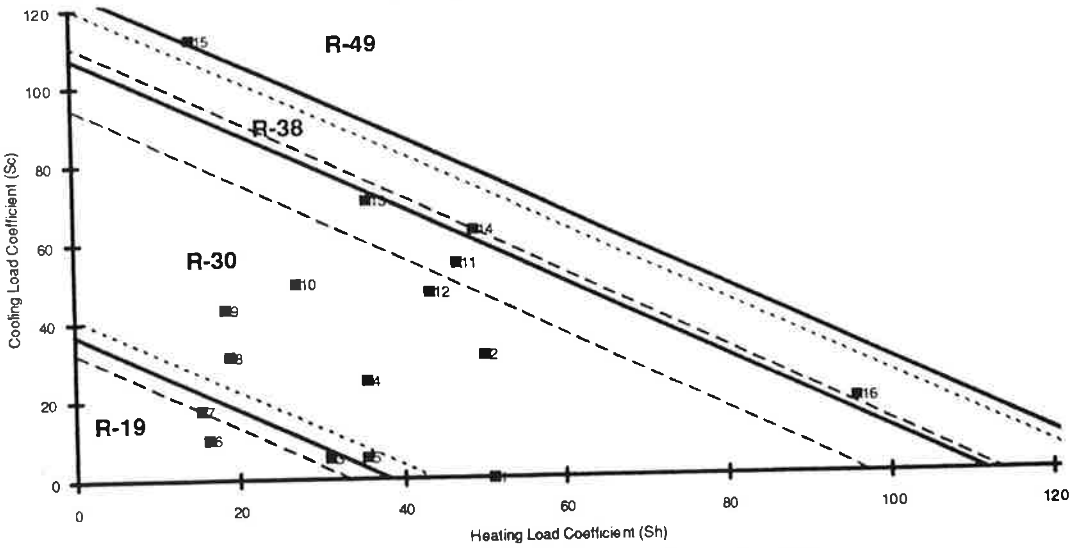

Figure 3 *Cost-effectiveness of attic insulation.*

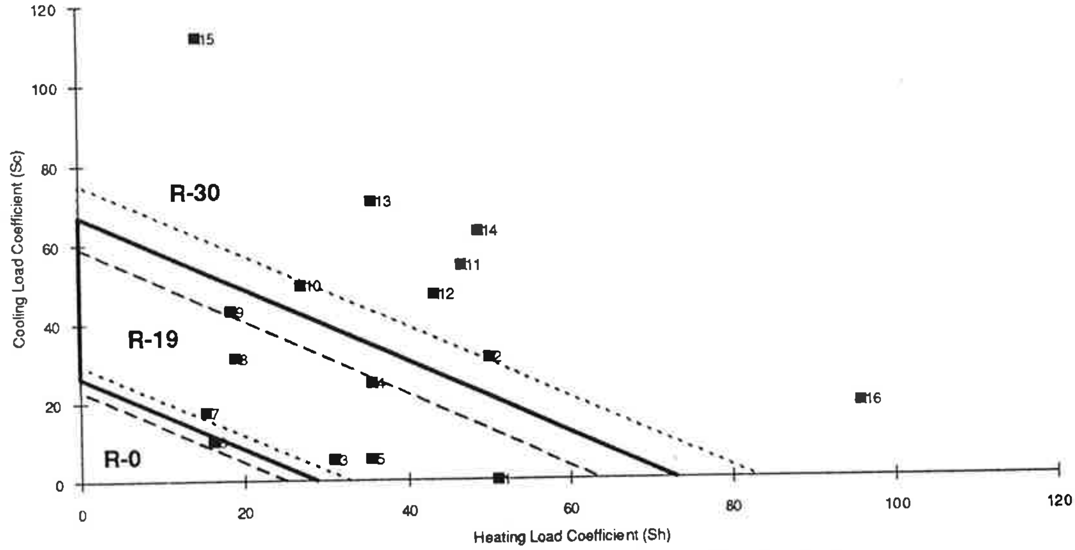

Figure 4 *Cost-effectiveness of vaulted ceiling insulation.*

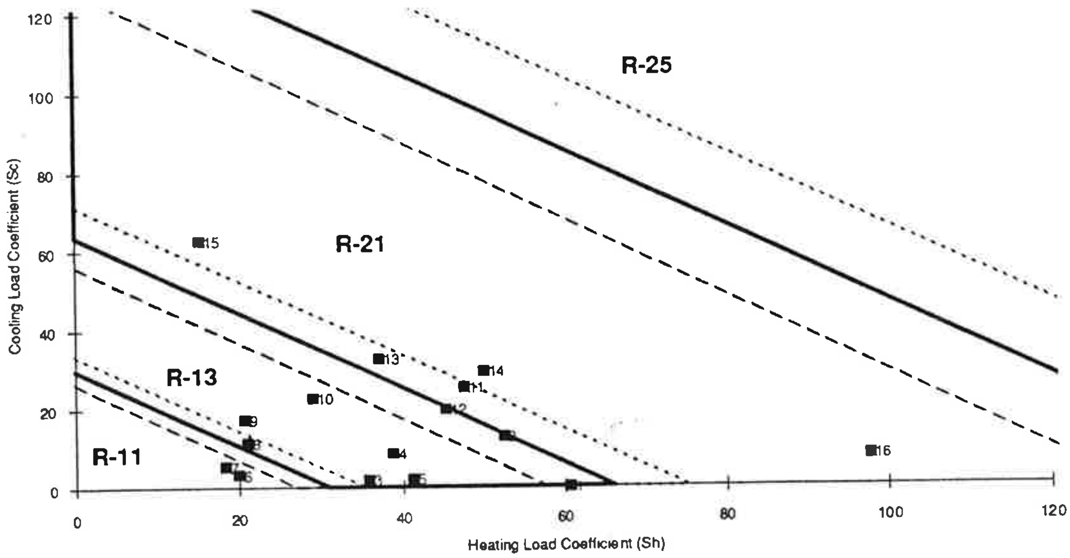

Figure 5 *Cost-effectiveness of wall insulation.*

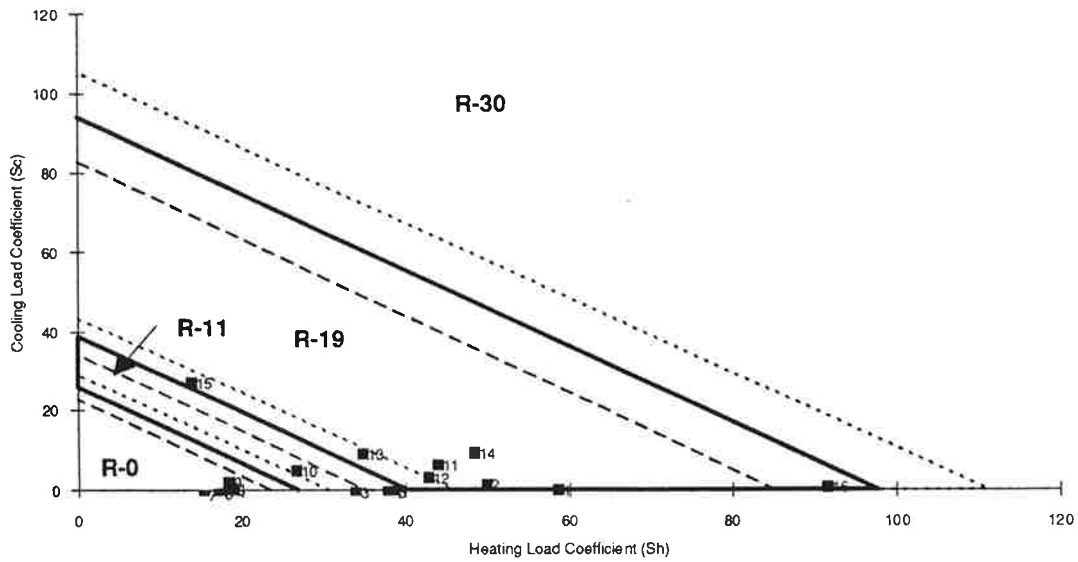

Figure 6 *Cost-effectiveness of wood floor insulation.*

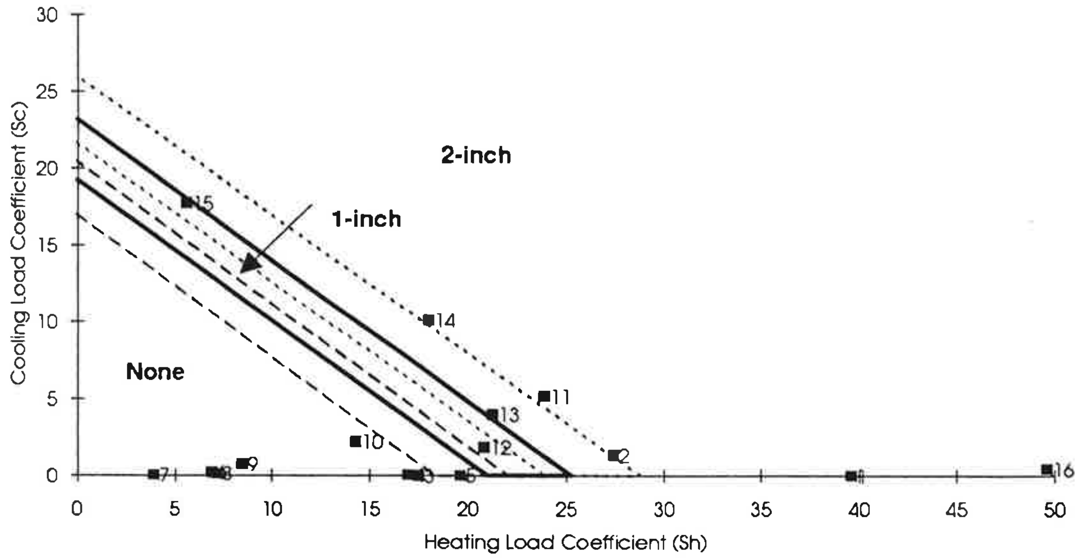

Figure 7 *Cost-effectiveness of concrete floor insulation.*

most of the other climatic zones. In many of the moderate coastal climates, no raised floor insulation is cost-effective. It is important to note that an R-6 buffering effect is assumed, and this reduces the effectiveness of insulation (see Figure 6).

For concrete floors, such as those over parking garages, it is cost-effective to spray on two inches (R-8) of cellulose insulation in climatic zones 1, 2, 11, 13, 14, and 16. One inch (R-4) is cost-effective for climatic zones 12 and 15. No insulation can be justified in climatic zones 3 through 10. The criteria lines for one and two inches of insulation are very close. This would suggest that the commission should consider eliminating the distinction between the two and just require some minimum amount of insulation in all but climatic zones 3 through 10 (see Figure 7).

At a 3% discount rate, slab-on-grade insulation is cost-effective only for climatic zone 16 and, in this case, it is cost-effective by a significant margin even with a 4% discount rate. A 2% discount rate justifies slab edge insulation in climatic zones 1 and 14 (see Figure 8).

For fenestration, the results cannot easily be presented in a simple graphic format because there are two sets of heating and cooling load coefficients—a set for changes in U-value and a set for changes in shading coefficient. A graph in a similar format would require four dimensions. The optimization procedure is essentially the same, however. The change in electricity and gas use is evaluated separately for the changes in fenestration U-value and shading coefficient, and the results are then added.

The fenestration results are presented in Tables 3 and 4. For the 3% discount rate, nothing more than single glass

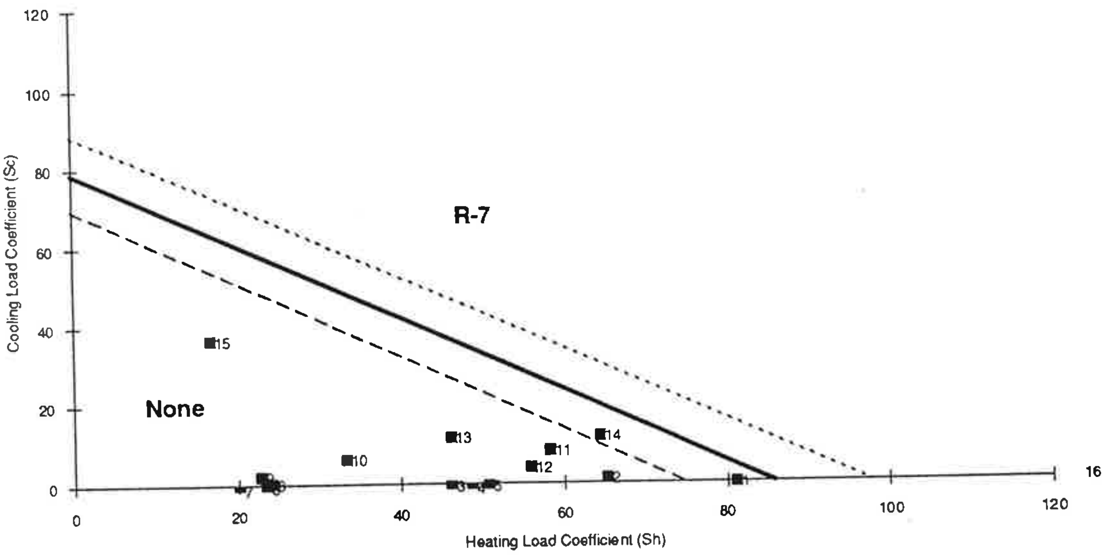

Figure 8 Cost-effectiveness of slab edge insulation.

is cost-effective in the moderate coastal and southern California climates (3, 6, 7, and 8). Double glass with a half-inch air gap and a standard aluminum frame is cost-effective in moderate inland climates (4, 5, 9, 10, and 12). Double glass in a thermal break frame is cost-effective in climates 1, 2, and 11. A thermal break frame with double glass and a low-emissivity, coated, suspended plastic film is cost-effective in climates 13 and 15. These are hot climates, and the low shading coefficient associated with this product is part of the reason for its cost-effectiveness. In the mountainous climate (16), double glass in a vinyl frame is the cost-effective choice because of its high solar transmission and low U-value.

SENSITIVITY ANALYSIS

Sensitivity to changes in the discount rate are shown in the figures presented above. The same format can also be used to evaluate changes in the cost of electricity or natural gas, the life of the building, and the efficiency of the heating or cooling system. All of these assumptions affect the α_h and α_c terms in Equations 10 and 11 and result in a shifting of the boundary lines (similar to a change in the discount rate). Variations in all these assumptions were evaluated as part of the study, in particular, electric resistance heating and duct efficiency. A summary of the results for electric resistance heat and a 3% discount rate is shown in Table 5. In California, an electric resistance heating system is more expensive to operate than the gas furnace assumed for the base case, and greater levels of conservation can be justified.

Changes in modeling assumptions result in a shifting of the points (the heating and cooling load coefficients change). Modeling assumptions evaluated include methods of calculating infiltration, climatic data, thermostat settings, and solar gains.

The analysis performed assumes that the interactions between conservation levels in envelope components are insignificant. To study the validity of this assumption, the base case for the parametric computer runs is changed to "loose" and "tight." "Tight" means that as variations in one component of the envelope are evaluated, the conservation level for the other components is set at the most stringent level (see Table 1). "Loose" means that the conservation level of the other components is set at the lowest level (see Table 1).

TABLE 3
Fenestration Results

Climatic Zone	2% Discount Rate	3% Discount Rate	4% Discount Rate
1	AtbDb1	AtbDb1	AtbDb1
2	AtbDb1	AtbDb1	AtbDb2
3	AlmDb2	AlmSg1	AlmSg1
4	AlmDb2	AlmDb2	AlmDb2
5	AlmDb2	AlmDb2	AlmAlg
6	AlmSg1	AlmSg1	AlmSg1
7	AlmSg1	AlmSg1	AlmSg1
8	AlmDb2	AlmSg1	AlmSg1
9	AlmDb2	AlmDb2	AlmDb2
10	AlmHm7	AlmDb2	AlmDb2
11	AlmHm7	AtbDb1	AlmDb2
12	AtbDb1	AlmDb2	AlmDb2
13	AtbHm7	AtbHm7	AlmDb2
14	AtbDb1	AtbDb1	AlmDb1
15	AtbHm7	AtbHm7	AtbHm7
16	VnlDb1	VnlDb1	AtbDb1

TABLE 4
Description of Cost-Effective Glazing Constructions

Fenestration Code	U-Value	Shading Coefficient	Description
AlmSg1	0.989	1.000	Aluminum frame, single glazing
AlmDb2	0.660	0.884	Aluminum frame, double glazing with ½-inch air gap
AtbDb1	0.554	0.885	Aluminum thermal break frame with double glazing
AtbHm7	0.396	0.540	Aluminum thermal break frame with double glazing and suspended low-emissivity coated plastic film
VnlDbl	0.420	0.886	Vinyl frame with double glazing

Figures 9 and 10 show the impact of changes in these assumptions for a subset of five climatic zones and for walls and attics. In these figures, the open squares represent the modeling assumptions that are consistent with the analysis presented in the previous graphs. The open squares are the base case for this analysis. The solid squares are the same except that more solar gain is assumed to reach the house (a 25% reduction instead of 50%). The solid triangles are higher thermostat settings for heating and lower settings for cooling. The solid circles represent the load coefficients with no insulation in the base-case building. The open circles represent the load coefficients with near maximum insulation in the base-case building.

The thermostat schedules are the most significant of the modeling assumption changes (compare the open squares and the solid triangles). With the alternative schedules, more insulation can be justified for both walls and attics. The same pattern holds with other building components as well. The alternative thermostat settings (solid triangles) eliminate daytime setback for both heating and cooling, causing insulation levels to be more significant. The California Energy Commission decided to use the alternative thermostat schedules as the basis of the standards on the recommendation of several participants in the process.

The solar gain assumption is far less significant—compare the open squares and the solid squares. These are mostly on top of each other, indicating that this assumption has little significance for attics or walls. This assumption was significant, however, for fenestration, giving more benefit to fenestration constructions with a low shading coefficient.

In most climates, the heating load coefficients are smaller when the base-case building has very high levels of insulation (see the open circles). This is because the heating balance point temperature is lower with high levels of insulation. At a lower balance point, the building is in a heating mode for fewer hours and the benefit of insulation and low U-value fenestration is lessened. The insulation level in the base case has an almost negligible effect on the cooling load coefficients.

CONCLUSIONS

The energy conservation standards development approach presented here offers a powerful combination of comprehensive life-cycle analysis of all construction assemblies, flexibility to incorporate alternative and evolving assumptions, and the ability to display results in a form usable for policy decisions. It was used very successfully in the development of the 1992 California Energy Standards for residential buildings.

TABLE 5
LCC Results for Electric Resistance Heating

Building Envelope Component	Climatic Zone 3	Climatic Zone 7	Climatic Zone 13	Climatic Zone 14	Climatic Zone 16
Attic Ceiling R-Value	R-30	R-30	R-60	R-60	R-60 with raised heel truss
Vaulted Ceiling R-Value	R-30	R-19	R-60	R-60	R-30
Raised Wood Floor R-Value	R-19	R-11	R-30	R-30	R-30
Slab Edge R-Value	R-7	R-0	R-7	R-7	R-7
Wall R-Value	R-21	R-13	R-21	R-11 cavity + R-14 sheathing	R-21 cavity + R-14 sheathing
Fenestration Type	AlmSg1	AlmSg1	AtbHm7	AtbHm7	VnlDb1

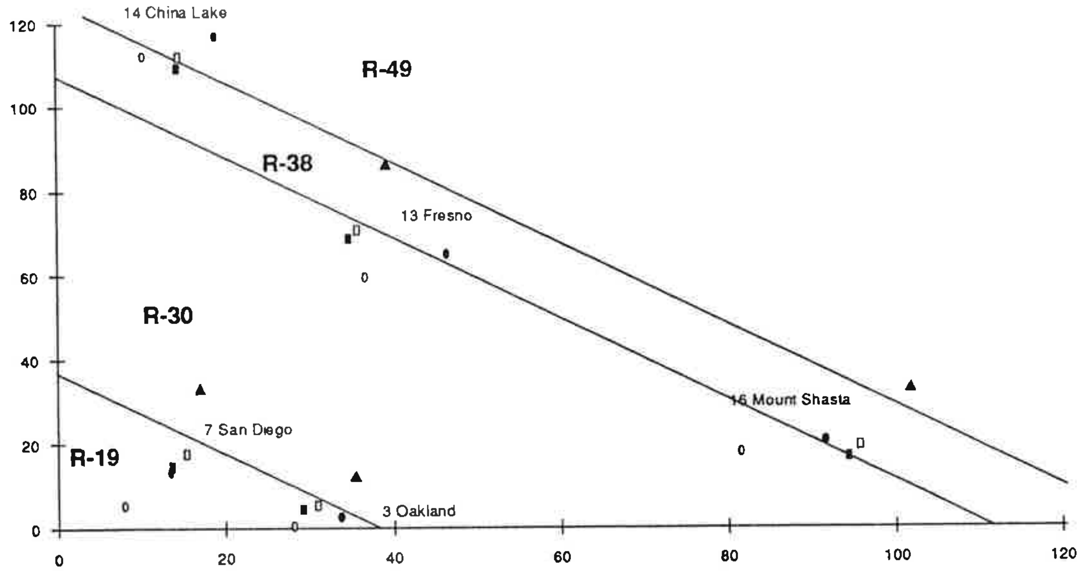

Figure 9 *Sensitivity to modeling assumptions—attics.*

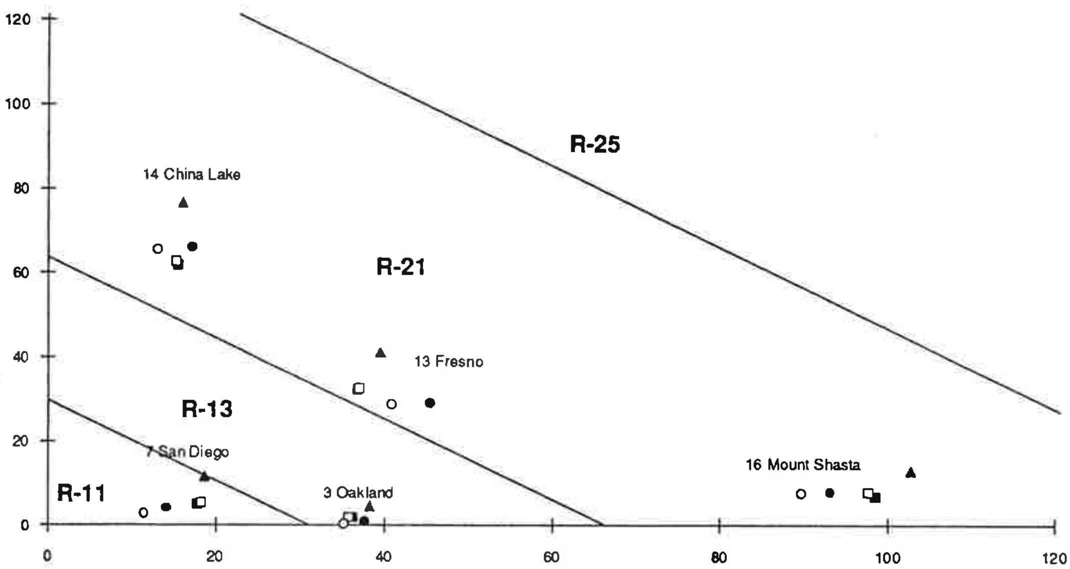

Figure 10 *Sensitivity to modeling assumptions—walls*

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