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SANTA CRUZ SUMMER STUDY PAPERS*

Prepared for the Summer Study on Energy Efficient Buildings
conducted at the
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by

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*Work performed under the auspices of the U.S. Department of Energy,
Office of Solar Applications.

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In the seven years since the oil embargo, conservation has been the single most important factor in reducing this nation's dependence on imports and helping to alleviate the energy crisis. If we look back at the extrapolated predictions of energy demand that were made in 1973, and compare those with actual consumption in 1980, we find huge differences; differences due almost entirely to conservation. At 1973 efficiency levels, the 1978 economy would have used 85.1 quads of energy rather than the 77.5 actually consumed. The missing 7.6 quads is due to improved efficiency and has added more than 2.5 times the energy service to the economy as the combined increases in imported oil, nuclear power, and coal extraction (Vince Taylor, "The Easy Path Energy Plan", Union of Concerned Scientists).

Unfortunately, conservation is sometimes portrayed as sacrifice; doing without. This is not what we are talking about. The effective type of conservation is through improved methods and efficiency. Getting more for less.

For example, the chemical industries in this country have made enormous increases in the efficiency of their processes. People are choosing to buy more fuel-efficient autos, replacing cars that get 14 mpg with ones that get 42, trading in refrigerators that use 137 kWh/month for ones that use 50, installing solar hot water heaters that reduces use from 15 kWh per day to 3. When one does these things lifestyle is not impaired.

Solar energy can work to advantage with energy conservation in reducing the heating energy requirements of buildings. In fact, there is normally an economic optimum mix between energy conservation and solar energy in any given situation. They work together effectively.

One notion to be dispelled right at the beginning is the common idea that solar energy is so materials intensive and requires so much energy in construction as to be impractical. A close look at the numbers puts this misconception to rest. Of course there are some solar applications where this is true, but they are generally not economic anyway. If one looks at solar water heating or passive solar applications in the net energy sense, the payback times are quite short. For example, if one analyzes a Trombe wall, which is one of the most energy intensive of the passive approaches, and accounts for all of the energy which went into its construction, including cement manufacture, transportation, installation, and everything, and calculates the annual energy savings which it will produce, the payback time is found to be about one-half year. South-facing double glazing, or insulation for that matter, pay back their energy investment in even shorter periods.

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In our pursuit of energy-efficient buildings we are in danger of losing sight of the larger objective -- quality of construction. Energy efficiency is just one part of quality. We now know how to construct buildings, which, combining energy conservation and passive solar, use only 10% of the heating energy of their contemporary neighbors. This has been demonstrated in cost-effective installations in a wide variety of climates. Energy efficient buildings not only use less fuel; properly built, they are more comfortable.

I have had the good fortune to own a quality house and this has conditioned my thinking. It is visually, aesthetically, and physically a nice place to live. It naturally stays at about 70-75 F in the summer and 65-70 F in winter. Minor intervention with backup heat in the winter and occasional window adjustments in the spring and fall keep it within the comfort range even during extremes of weather. I feel that my quality of life has been enhanced by the experience of living there and have tried to help others to learn how it can be done.

Before the reader condemns me too quickly for a smug or elitist attitude, I should point out that the house was designed and built not by me but by solar developers Susan and Wayne Nichols in 1976 at a cost of \$35 per sq ft -- very comparable to other houses in the area. The construction reflects their general attitude of building quality into their houses. Their success in the marketplace (their second passive solar subdivision is sold out before completion) is testimony that buyers, too, look for quality. The houses are generally quite comfortable, using less than \$100 per year of heating energy in a 6000 degree-day climate.

The principal problem I have encountered is that most people simply do not believe that these goals of quality can be achieved simply and at reasonable expense. What we are actually discussing is an added cost of construction of 5% to 10%. The extra investment in resource energy is usually offset by less than one year's fuel savings.

Once the concept of quality begins to be brought back into the building, a variety of different attitudes and practices emerge. A few unrelated examples: 1) one begins to look at household appliances, not for minimum first cost and maximum short-term amenity, but questions of longevity, operating energy, and ease of repair become of equal or greater importance. 2) The ability of a house to coast easily through power outages without freezing or a commercial building to keep operating through a brownout become appreciated. 3) The enhancement of visual and olfactory quality achieved through raising plants in the house, either for food or pleasure, takes on a new meaning.

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In an effort to simplify matters or with a desire to promote a particular technology, we often become locked into a single-minded approach. Often the result is to belittle contributions that might be made by another technology. In most cases this works against the interest of a best overall solution.

A frequent case where this occurs is in consideration of solar energy vis-a-vis conservation. Solar is basically a supply technology while conservation seeks to curb demand. Often the best approach, both in terms of economics and utilization of resources, is a balance design -- conservation and solar; working together.

A case in point is in the design of a building. Although it is often stated that proper building design consists of first doing energy conservation and then doing solar, some designers fail to seek out an optimum mix between the two. The result may be an exaggerated solar building that is inadequately insulated -- a "solar heated barn". It will not only be overly expensive but probably not as comfortable as a balanced design. Another possible result may be a superinsulated building with practically no solar contribution -- a "styrofoam igloo". This building might appeal to some but seem drab to others who would prefer a closer rapport with the outside environment. As we shall see, it might also be less cost effective than a balanced approach and less secure against utility outages.

Another example would be a photovoltaic system installed into a building with standard appliances. Again, an unnecessary initial expense will be required to overcome an excessive demand. A better approach would be a careful installation of the most efficient appliances and load management techniques available and a smaller power supply.

Note that both the above examples have stressed efficiency rather than sacrifice.

In a balanced design, one seeks to develop an optimum mix between different strategies that work well together. In the language of the economist, an optimum mix occurs when the marginal cost* of a conservation strategy is just equal to the marginal cost of a solar strategy which yields the same benefit. If there are more than two strategies being optimized, then the marginal cost of each are made equal (to yield the same benefit).

Balanced design often incorporates factors not particularly amenable to economic or numerical optimization procedures. Thermal comfort is one such factor (although methods of quantifying comfort have been developed). The

*Marginal cost refers to the added cost of the improvement, for example, the cost of adding one sq ft of solar collection area or one extra inch of insulation.

architect faces many non-quantifiable aspects in the design of every building, where the program and personality of the client must receive major consideration. A variety of different design approaches may lead to very similar initial costs and energy savings but quite different buildings, aesthetically and functionally. A good architect will suggest those designs which are both energy responsible and most responsive to client needs and preferences.

In a recent study ("Annual Heating and Cooling; A Comparison of Passive Design Options", in preparation) Donald Watson and Keith Harrington investigated the energy performance of 25 different building energy design strategies in 20 different U.S. cities. Some results of the study are shown in Table I. The analysis covers a severe winter week and two numbers are given for each option in each city. One is a rank ordering (from 1 to 24) of the lowest energy designs. The second number gives the energy savings compared to a base case (in percent).

The "superinsulated" house is seen to do well in every climate, ranking first or second in Watson's analysis. However, note that a variety of approaches do quite well, giving very comparable savings. Also note that there are significant differences from city to city in both the potential savings and the rank ordering. One concludes that:

- a) Mixed strategies can perform as well or better than a pure conservation strategy.
- b) The results are quite climate dependent.

The importance of these results lies in the broad range of design strategies that can lead to similar energy savings. This is a happy result because it means that a much broader range of people can be reached than could be reached by any one pure strategy. The broader the number of options, the more likely is one to be found that will appeal to any particular element of the buying public. Another reason the results are important is that the solar access will vary appreciably from site to site, even in a particular subdivision. Even in new subdivisions laid out with a concern for solar access, there will be a few lots with the winter sun path blocked. These would be suitable for superinsulated houses but not for passive solar.

Balcomb ("Conservation and Solar: Working Together", attached) has developed a simple methodology for determining the optimum mix between solar and conservation. Some of these results are useful in understanding the nature of the way these two strategies work together. Figure 1 shows the energy savings obtained for different initial expenditures in solar (direct gain plus Trombe wall, both with R9 night insulation) and conservation.

Both costs and savings are relative to a reference house which is moderately well insulated (R11 walls, R19 roof, single glazing, no perimeter insulation, one air exchange per hour). The costs used are somewhat higher than used by the Sawhill study. The building heat load coefficient (HLC) is assumed to vary inversely with added cost of conservation, as follows:

HLC For 1500 sq ft Building		
<u>Btu/°F-day</u>	<u>Btu/DD ft²</u>	<u>Added cost, dollars</u>
12887	8.6	\$ 0
9173	6.1	\$1000
7121	4.7	\$2000
4920	3.3	\$4000
3758	2.5	\$6000

Wall, ceiling, and perimeter insulation, window glazing, and infiltration strategies are all adjusted to develop an optimum mix between one another at each level of overall conservation.

The savings due to solar are determined for a mix of direct gain and Trombe wall passive solar strategies. The solar glazing is covered at night with R9 insulation. The methodology developed in the DOE PASSIVE SOLAR DESIGN HANDBOOK, Volume II (J. D. Balcomb, et. al; DOE/CS-0127/2) is used to estimate solar performance using weather data for Dodge City, Kansas. The average add-on cost of the solar glazing is taken to be \$7.44 per sq ft of south collection area.

The dotted line on Figure 1 corresponds to an initial expense of \$4000 for solar and conservation combined, relative to the reference case. The "styrofoam igloo" approach is the point along the horizontal axis corresponding to an initial expense of \$4000 for conservation and none for solar. The savings is 62%, all due to the decreased heating load coefficient. The "solar heated barn" approach corresponds to the point along the vertical axis with an initial expense of \$4000 for 538 sq ft of additional solar aperture with the house insulation unchanged. The solar savings fraction is 63% but the load is unchanged so the energy savings is also 63%. As seen from the figure, a greater energy savings of 77% can be obtained with the same initial expense of \$4000 by investing \$1850 in conservation to obtain a 43% reduction in heat load coefficient and \$2150 for 289 sq ft of additional solar collection area. This results in a solar savings fraction of 60%.

The path shown as "optimum mix" on Figure 1, indicates the best allocation of any given initial level of expense for the assumed costs and the Dodge City climate.

Up to this point, consideration has been given to initial expense only. "Life-cycle" economics is a way to bring in the cost savings due to future reduced energy use. If the sum of these future savings is expressed in terms of an equivalent present value, then it can be compared directly with the initial investment. The sum of the savings and the initial investment is the "life-cycle cost". This can be compared with the life-cycle cost of the reference building. The difference is the "life-cycle savings".

Figure 2 shows contours of constant life-cycle savings for the same case as Figure 1 for a fuel cost of 7¢ per kWhr.* The maximum life-cycle savings is \$14325 (which corresponds to a minimum life-cycle cost). This large savings is possible because of the very high cost of the electricity required to heat the building -- initially \$1238 per year! By expending \$5929 for energy-conserving strategies (\$2775 for conservation and \$3154 for passive

solar) this is reduced to \$115 per year. Although the economic analysis is done using full discounting, inflation, fuel escalation, and other accepted techniques, it is interesting to note that the simple payback time is a quite-reasonable 5.3 years.

An important conclusion can be found in a study of Fig. 2. The shape of the constant life-cycle savings contours shows a fairly flat-topped mountain with steep sides. This means that the savings are quite insensitive to variations in design in the broad neighborhood of the optimum. This means that there is a fairly wide latitude for design variability. One can trade off a little more conservation for a little less passive solar or vice-versa. As mentioned earlier, this flexibility is important in catering to the desires of a heterogeneous clientele or accommodating different building sites with a variety of solar access.

Another result of this analysis is the finding that the life-cycle optimum point on Fig. 2 always lies on the optimum-mix line of Fig. 1. The point moves along the line as the cost of fuel is modified or any of the economic forecast parameters are changed. Thus one can't go too far wrong in designing reasonably close to the optimum-mix line.

The curves on Figs. 1 and 2 were drawn using costs of new buildings. A similar study was carried out for retrofitting. Costs were somewhat higher because the building was masonry and required insulation outside the existing walls. Energy savings were also larger because the house was virtually uninsulated. The character of the results are strikingly similar to Figs. 1 and 2 with a very similar optimum-mix line.

It is difficult to generalize about retrofit economics because each building and site are different, requiring a different analysis. However, the optimum-mix economics can be applied if the solar performance and economic parameters can be estimated. In most cases a balanced conservation-solar strategy will be economically and aesthetically preferable to a single strategy.

In most cases, sizing up to a retrofit is a straightforward process. General reduction of infiltration will normally be the easiest and most cost-effective strategy through a simple sealing of air leaks and other bypasses. Heat loss reductions of 10-30% can be expected at modest cost. Further reductions in energy consumption, although generally quite cost-effective, are complicated, more expensive, and less easy to generalize.

The south side of the building should be assessed for solar potential and a defensive or conservation approach taken on the roof and other building facades -- insulation to reduce winter losses and shading to reduce summer solar gains. The nature of the south-side solar retrofit will depend on a number of factors, including: solar access, existing south-side wall construction, space availability to setback line, and owner preference. An existing masonry wall is a natural for Trombe wall or solar sunspace retrofit. Frame walls are more conducive to added windows or convective loops although an attached sunspace with integral thermal storage is also possible.

A major factor in considering the economics of a retrofit is that the whole building is to be modified -- perhaps a major renovation. The impact on

the value of the property must be assessed. One can come to quite different conclusions, depending on whether the economics are viewed just in terms of minimum life-cycle energy costs or overall impact on the property value.

For example, consider the case of an add-on south sunspace. The most energy economic solution is probably a low-cost frame-and-plastic room costing perhaps \$5 per sq ft. The plastic may need to be replaced every few years due to ultraviolet, wind-flap, and general degradation, but the material is inexpensive. Of course, the aesthetic effect on the house is questionable, especially after a few years. The contrivance may even need to be dismantled prior to any attempt to sell the house due to a disreputable appearance. The other alternative would be a quality retrofit using quality materials like durable metal or wood and glass, or a very durable rigid plastic double glazing. The cost will naturally be much higher -- typically \$20 to \$30 per sq ft for a contractor-built project. The energy efficiency may be very similar to the low-cost frame-and-plastic solution but the overall effect on the house is altogether different. The quality retrofit will normally enhance the entire house, frequently becoming a focal point. A reappraisal of the property may well show an increase in value greater than the cost of the retrofit -- many such cases have been reported. Thus the retrofit may be justified on this basis alone and the energy savings becomes a bonus. Again a balanced approach will involve improving the other portions of the building envelope by upgrading insulation, improved windows, and general air tightening. One should note, however, that a major selling point for such improvements will most likely be the improved comfort of the house and the reduced energy consumption will again be the bonus.

Another important element of building integrity is a built-in ability to withstand utility outages without disastrous consequences (such as freezing pipes). This characteristic can also be built-in at reasonable cost with the combined use of very good conservation and passive solar gains. With no backup or appliance heat, the building temperatures will drift slowly, but minimum values above 50 F can generally be achieved in any of the lower 48 United States. The combination of heat-storing mass in the building, together with good insulation leads to a time response to changes in outside temperature of several days, enough to bridge over short-term periods of extreme cold. Protracted cloudy periods are generally not extremely cold and diffuse solar gains are still sufficient to increase inside temperatures 20 to 30 F above average outside temperatures. This difference in natural building response to weather can easily mean the difference between frozen pipes in a residence during a power outage or loss of productivity for a business during brownouts.

*The financial assumptions are as follows: backup heating is electric baseboard at current rates of 7¢/kWhr, escalation rate of electric energy cost is 8%, loan interest rate is 10%, loan period is 30 years, period of financial analysis is 10 years (time of resale), resale value of conservation and solar investment escalates at 4.5%, down payment fraction is 15%, marginal income tax rate is 25%, property tax rate is 2%, and operation and maintenance is 1% of the total incremental cost. Then the fixed charge rate is .0831 and the fuel cost levelizing factor is 1.500.

COST OF PASSIVE SOLAR

Fig. 1. Performance map showing the energy savings expected for different initial expenditures.

Fig. 2. Life cycle savings (in present dollars) compared to the conventional house. (The coordinates are the same so that Fig. 3 can be overlaid on Fig. 2. Backup heating is electric.)

	MINN	CHIC	SEAT	PHO	HART	DENY	SALT	KANS	FOST	NYRK	WASH	DALL	ATLA	NEW	SAN	HOUS	MIDL	PHNX	LOS	MIAM
	MINN	CHIC	SEAT	PHO	HART	DENY	SALT	KANS	FOST	NYRK	WASH	DALL	ATLA	NEW	SAN	HOUS	MIDL	PHNX	LOS	MIAM
TYPE 1																				
WS01	22	22	21	22	24	22	22	21	22	22	22	21	22	22	22	22	22	21	21	21
WS41	23	23	22	23	23	23	23	22	23	23	23	22	23	23	23	23	23	22	22	22
WS81	19	20	19	20	21	21	20	20	21	20	20	20	21	21	21	21	21	20	20	20
WS151	24	24	23	24	22	24	24	24	24	24	24	24	24	24	24	24	24	23	23	23
	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	3	4
TYPE 2																				
WS221	8	10	12	12	13	13	13	13	13	14	14	10	12	14	14	13	12	13	13	13
	-5	-1	-5	-5	-5	-5	-5	-5	-5	-5	-5	-6	-6	-6	-6	-7	-6	-6	-7	-6
WS231	15	16	17	17	17	17	17	18	17	17	17	16	18	18	18	18	18	17	15	15
	-3	-3	-3	-3	-3	-3	-3	-4	-3	-3	-3	-4	-4	-4	-4	-4	-4	-5	-5	-5
WS111	14	14	13	14	15	14	15	15	15	15	15	13	15	15	15	15	15	16	17	18
	-1	-3	-3	-3	-3	-3	-4	-4	-3	-3	-4	-5	-4	-5	-5	-5	-5	-5	-5	-5
TYPE 3																				
WS241	11	12	13	14	14	12	12	13	12	13	13	9	11	10	8	9	11	11	10	10
	-6	-5	-5	-5	-5	-5	-5	-5	-5	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6
WS161	9	9	10	12	13	8	11	12	11	12	11	8	13	13	12	14	13	13	12	12
	-5	-5	-6	-6	-5	-6	-6	-5	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6
WS181	21	17	15	15	14	19	19	19	19	18	18	12	14	11	10	16	16	16	16	16
	0	-1	-3	-3	-1	-1	-2	-2	-2	-2	-3	-3	-3	-4	-4	-4	-4	-4	-4	-4
WS301	20	21	20	21	21	20	21	21	20	21	21	18	20	20	17	20	20	14	17	17
	-1	1	0	0	0	-1	0	0	-1	1	1	-3	0	0	-4	0	0	-6	-1	-5
TYPE 4																				
WS601	-28	-31	-36	-33	-33	-33	-36	-34	-34	-35	-38	-37	-42	-52	-55	-49	-41	-55	-67	-88
	-4	-5	-6	-7	-7	-7	-6	-6	-6	-6	-7	-7	-7	-7	-7	-7	-7	-7	-7	-7
WS401	-8	-8	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9	-9
	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6	-6
WS281	12	11	8	11	13	10	9	10	11	11	10	8	15	10	9	11	13	11	12	12
	-4	-5	-6	-6	-5	-6	-7	-6	-6	-7	-6	-7	-7	-7	-7	-7	-7	-7	-7	-7
WS481	16	15	14	14	15	16	16	16	16	16	16	17	17	16	16	17	17	16	16	16
	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3	-3
WS281	18	18	18	18	18	18	18	17	18	19	19	19	19	17	20	19	19	19	19	19
	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
TYPE 5																				
WS641	-24	-27	-23	-31	-33	-36	-35	-31	-33	-38	-37	-31	-40	-51	-53	-46	-41	-50	-63	-88
	-16	-20	-15	-26	-26	-21	-25	-23	-23	-29	-25	-20	-30	-30	-31	-30	-33	-25	-28	-33
WS421	17	17	24	15	15	15	13	14	14	16	12	23	16	19	19	16	16	16	16	16
	-2	-2	3	-1	-7	-3	-5	-4	-4	-10	-8	0	-4	-3	-4	-4	-4	-4	-4	-4
WS411	13	13	16	8	8	11	8	10	8	10	8	15	8	7	10	10	10	10	10	10
	-5	-5	-3	-6	-3	-6	-6	-5	-7	-9	-10	-5	-9	-11	-10	-8	-12	-5	-5	-5
TYPE 6																				
WS291	5	5	8	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
	-6	-6	-6	-11	-13	-13	-16	-10	-17	-19	-16	-20	-41	-42	-29	-35	-48	-74	-94	-94
WS281	7	7	8	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
	-5	-5	-5	-10	-10	-10	-11	-9	-11	-12	-9	-9	-12	-22	-25	-17	-23	-35	-57	-57
WS201	10	8	8	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
	-3	-6	-7	-7	-7	-7	-7	-7	-8	-8	-9	-6	-9	-13	-14	-11	-9	-12	-17	-28

TABLE 1 Evaluation of Design Options by Type and by City Severe Winter Week
Upper numbers (from 0 to 24) indicate the rank order of the option in each city.
Lower numbers, if negative, indicate the % energy saved during the winter design week. (positive numbers indicate % added energy required).
Donald Watson and Keith Harrington Research on Climate Design for Home Builders
Conference Proceedings International Conference on Energy Use Management II
Pergamon Press 1979; also in Proceedings 4th National Passive Solar Conference
AS/ISES International Solar Energy Society, Newark, DE 1979

TECHNICAL POTENTIAL OF COMBINED PASSIVE
SOLAR AND CONSERVATION STRATEGIES

1980 Santa Cruz Summer Study

J. Douglas Balcomb
Los Alamos Scientific Laboratory

The optimum-mix economic methodology described in Ref. 1 has been used to determine the energy savings potential as a function of initial add-on investment for buildings located in several climates. For this study, the cost of energy conservation was developed as a smooth curve using data derived from the LBL Series V DOE-2 computer listings. The same 1176 sq ft building is used and also the same base case. The heating load coefficient, L , is in units of Btu/°F-day. The add-on cost is given by the following approximate formula:

$$C_c = 12630000/L - 1702$$

where C_c is the add-on cost of conservation. This corresponds to 1002 sq ft of opaque walls at a cost of \$.0335 per R per sq ft, 123 sq ft of non-south windows at a cost of \$2.63 per R per sq ft, 1176 sq ft of ceiling at a cost of \$0.0101 per R per sq ft, and a cost of reducing infiltration from 0.6 ACH to 0.3 ACH of \$500.

These numbers were developed from the LBL discrete costs. The above formula is the minimum-cost mix of these four conservation strategies assuming that all four are infinitely variable. This assumption is a reasonable one, as discussed in Ref. 1, but may slightly under-state the conservation cost. The base case corresponds to $C_c = 0$ and $L = 7418$ Btu/°F-day corresponding to $R_{\text{walls}} = 11$, $R_{\text{ceiling}} = 19$, double glazing, and 0.6 ACH.

The solar savings fraction, F , due to passive solar is the net savings, compared to an adiabatic wall of the same area. The assumed passive solar system is a mix of direct gain and Trombe wall both insulated at night with R_9 movable insulation. The solar add-on cost is taken to be \$7.44 per sq ft of solar glazing. The performance is estimated using the solar/load ratio correlation technique in Ref. 2. The degree-days are then corrected for internal energy generation by calculating a new balance-point temperature, $T_{\text{base}} = 70 - Q/L$, where Q is 53000 Btu/day, and then calculating the heating degree-days, DD , from tables given in Ref. 2 using this base.

The annual heating energy is calculated from the formula:

$$L \times (1-F) \times DD \times (1-F_0)$$

where F_0 is an "incidental" solar savings fraction due to extraneous solar gains through windows other than those explicitly figured in the south solar wall add-on cost formula. F_0 is estimated using the direct gain tables in Ref. 2 and varies from zero in Minneapolis to 0.24 in Phoenix.

For each city, the annual heating energy is given for different values of initial combined investment in conservation and passive solar. The insert on

each figure shows the optimum mix path, indicating the appropriate allocation of initial investment between passive solar and conservation. The numbers listed along this path show the energy cost which would make each point economic on a life-cycle basis. Fuel cost is assumed to escalate at the discount rate.

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1. J. D. Balcomb, "Conservation and Solar: Working Together", Fifth National Passive Conference, Amherst, Massachusetts, October 19-26, 1980. (LA-UR-80-2330)
2. J. D. Balcomb, et. al., "Passive Solar Design Handbook", published by the Department of Energy, January, 1980. DOE/CS-0127/1 & 2

INTERPRETING THE GRAPH

The circled points correspond to solar savings fractions of 0.1, 0.2, 0.3, etc., beginning at the left and proceeding to the right. For each point, the optimum mix of conservation and passive solar is calculated and then the resulting annual heating energy is calculated and plotted as a function of the combined cost of conservation and solar. The inset plot shows the allocation of initial investment between the two strategies. The circled points correspond to solar savings fractions of 0.1, 0.2, 0.3, etc., beginning at the lower left and proceeding toward the upper right. The dollar values printed next to each point give the current delivered fuel cost, in dollars per million Btu, corresponding to a life-cycle optimum.

Thus, on the above graph for Denver, the optimum mix pair corresponding to a solar savings fraction of 0.6 is an initial investment of \$2262 (\$949 for conservation and \$1313 for solar) and gives an annual heating energy of 7.6 million Btu. This would be life-cycle economic if the current delivered cost of auxiliary heat is greater than \$5.27 per million Btu.

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By far the predominant work on BEPS implementation has focused on enforcement through building codes. This has many problems, some of which have been discussed at the Summer Study. (Suffice it to say that the Achilles heel of the building code approach is reliance on the building inspector for enforcement.) It is not the purpose here to discuss the myriad problems, but to present alternative ideas for implementation discussed within the New Residential group.

The idea was to develop an implementation procedure which relies primarily on private-sector mechanisms. A series of possible mechanisms were discussed. One set of five mechanisms ("5 Steps to BEPS") were discussed at some length which seem to offer a viable alternative to the previous proposals. They bring existing buildings into the energy budget program, thus greatly increasing the potential impact. Another important point is that the proposed system is thought to be applied easily to commercial buildings.

The five mechanisms are as follows:

- 1) Escalated Block Billing
- 2) Energy Ratings for Buildings
- 3) Energy Rating Warranties
- 4) Energy Performance Monitoring
- 5) Loan Programs

The key mechanism relies on Energy Rating Warranties. This provides insurance-type pooling of money to provide for claims. It is somewhat analogous to Title Insurance except it is energy insurance. It is not energy performance insurance (since actual performance varies with occupant use characteristics) but more like BEPS Compliance Insurance. In essence, one can buy a warranty that a particular building is in compliance with BEPS. If the building is shown not to comply, then recourse is available to bring the building into compliance.

This series of implementation mechanisms are described below. These make a coherent whole which address each of the institutional factors which must be considered if a system is to work. There are other options which could be explored for each mechanism. The States could be given a choice of implementing a program which addresses each area in different ways.

Mechanism 1: ESCALATED BLOCK BILLING

This is very similar to a system in use in California already. It is an escalating rate structure. The energy bill for a building is figured by comparing the actual usage against a BEPS budget value for the same time period (based either on actual weather or average weather).

The following graph shows one possible result.

A low conservation rate is subsidized by higher block rates for those using more than the budget.

In this concept there are two broad categories of buildings: new and old. New buildings are those built after the BEPS go into effect. Old buildings are those built previously.

- 1) For new buildings, the BEPS budget levels are set based on the levels in effect when the building was completed.
- 2) For old buildings, the BEPS budget levels are determined based on average consumption for the particular building category in the particular climate zone where the building is located. The levels decline in time according to the following suggested schedule.

Thus the budget for each building (Btu/sq ft/degree-day) would be determined for each old building, based on the 1982 average use in that building category in that climate zone (assuming the program starts in 1982).

For example, if residences are found to use 18 Btu/ft²-DD on average in Washington, D.C. Then the budget for a 1500 sq ft house in Washington is $18 \times 1500 = 27,000$ Btu/DD in 1982-83. The budget decreases to $27,000 \times 0.92 = 24,840$ Btu/DD in 1983-84, etc., reaching a plateau of 13,500 Btu/DD after 1992. This budget is used to figure the utility rate break points as delineated on the previous chart.

This is just one example of a price incentive mechanism.

Mechanism 2: ENERGY RATINGS FOR BUILDINGS

Energy ratings would be given each new building. These would be a matter of public record and be posted conspicuously on the building prior to sale. They are somewhat analagous to EPA ratings for autos.

The ratings are pegged to a standard use profile; that is, they are based on a particular type and level of occupancy, a particular thermostat setting, etc.

One possible route would be to have the energy rating filed at the time of issuance of the building permit. The applicant simply would do the following:

- 1) Fills the Energy Rating number (in Btu/year)
- 2) Check the origin of the number from among the following choices.
 - ☐ individual
 - ☐ consultant
 - ☐ utility company
 - ☐ licenced energy rater

The building code official would be responsible only to see that the number given is less than or equal to the current BEPS value and not to certify the credibility of the number.

Such a rating system would raise energy consciousness. ("What's a btu, Henry?"; "What's that mean in dollars, Mr. Jones?"; "How many Btu's did we use last year, Mom?").

This is just one example of a rating mechanism.

Mechanism 3: ENERGY RATING WARRANTIES

Buildings sold under certain programs would require a warranty that guarantees compliance with the advertised Energy Rating filed in Mechanism 2. This might be FHA, VA, various state programs, etc. For other buildings, warranties would be voluntary.

Examples of warranties would be a statement such as: "This building complies with 1982 BFP's levels.", or "This building is certified to have an energy rating less than or equal to 10 million Btu/year (the energy rating) and to comply with 1982 BFP's levels." This statement would be backed up by the company issuing the warranty.

The warranty company would most likely not be the builder. Warranty companies might need to have some sort of state regulatory oversight to guarantee standards and financial responsibility; perhaps even carry federal or other re-insurance themselves. The warranties must be credible.

The warranty is the key to the entire implementation strategy. It is the guarantee. The builder would buy a warranty from the warranty company. For a fee (perhaps \$200 to \$300) the warranty company assumes responsibility that the building will comply with the energy rating which it has been given. If the building is shown not to comply, the warranty company must pay the expense of having the building upgraded to meet the energy rating.

In order to make the process of adjudication of claims both credible and timely, a Board of Energy Rating Adjudication, or some equivalent mechanism could be developed. This Board would hear complaints and make legally-binding findings.

Such a Board would have a small team of auditors who would inspect the building, performing tests as necessary, such as blower-door infiltration tests, guarded-hot-box insulation tests, furnace efficiency tests, solar access surveys, and doing calculations of overall energy performance. Actual utility bills would generally not be acceptable as prima-facie evidence of non-compliance but only as circumstantial evidence, and only when accompanied by certifiable evidence of building operation.

- 1) If the Board determines that the building is in compliance, then the cost of the proceedings, plus the cost of the test, would be borne by the claimant.
- 2) If the Board determines non-compliance, then the building must be upgraded, tested again to determine compliance, and all costs would be borne by the warranty company.

With this structure, centers of expertise would develop within the warranty companies. They would generally require some margin for error, perhaps 20% or so. They would have a small staff who are knowledgeable in building energy performance, especially the analysis side. This staff would look at plans and specifications and satisfy themselves that the risk is acceptable. They would then make site inspections to assure that the building is built in accordance with plan before final issuance of warranty.

The importance of this is that it would breed professionalism into the process of analyzing and inspecting buildings in the private sector, all voluntarily; it would simply be in the best interest of the warranty companies to develop this expertise.

Note again that the warranty is not on energy performance of the building, but on whether the building complies with an agreed-to construction practice which is predicted to yield the advertised energy performance in the given climate, provided that it is operated in accordance with a particular schedule of thermostat settings, door openings, night vents, etc. Innovative buildings would be difficult (or expensive) to warrant but this will not prevent innovative buildings from being built since all buildings do not require warranties. These buildings are traditionally owner-built and would fall outside those programs which mandate warranties. The cost of warranties would be kept reasonable since it will be a competitive free-enterprise system.

Mechanism 4: ENERGY PERFORMANCE MONITORING

In order to provide a mechanism whereby energy ratings develop an aura of reality, energy performance monitoring is necessary. This would most naturally be done through utilities who have an accurate in-place system of monitoring delivered utility energy. Several recommended measures are as follows:

- 1) The utility companies would keep records, building-by-building of actual building energy use and convert these to equivalent source energy using resource utilization factors applicable to each utility.
- 2) Aggregated information would be made public routinely (through PUC's) such as:
 - a) Actual Btu levels achieved, by housing type, year of construction, etc.
 - b) Comparisons with BHP's
 - c) Comparisons with Energy Ratings
- 3) Builders could request "utility certified" records, by subdivision. These would be useful advertising material for the builder.
- 4) Specific information would be available to each owner or tenant automatically -- this ties in with the escalated block billing.
- 5) Specific building information would be required to be made available to prospective buyers and appraisers at the time the building is put up for sale. (The information would not necessarily be made public unless the building is put up for open public sale).

- k) A requirement could be imposed by regulation that a building must comply with the in-force budget (see Mechanism #1) at the time of re-sale, either through:
 - a) demonstrated performance, or,
 - b) a warranty

Mechanism 5: LOAN PROGRAMS

Loan programs can be used to great effect to provide an incentive for energy efficiency and are also necessary to reduce the impact of rising energy prices for disadvantaged individuals. Loans are generally better than tax credits as a mechanism because, a) they are paid back, thus establishing a revolving fund, b) it does not bring the IRS or other tax-collecting entities into the picture (they never want to cooperate), and c) those who do not pay taxes can still benefit. Two different categories of loan programs could be considered:

- 1) As an incentive, loans could be facilitated for builders who provide Energy Rating Warranties. This should be the loan for the whole project (not just the solar or conservation add-on cost) and should carry through the entire project time frame.
- 2) If it is decided to ameliorate problems among those put to a severe disadvantage, loans could be made available at low or zero interest. These could be modeled along the lines of many existing or proposed programs at state, federal, or local levels.