THE PERFORMANCE OF AN ENERGY EFFICIENT RESIDENCE VS A CONVENTIONAL COMPARISON HOME

By

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How much energy can be saved in a typical new home with off-the-shelf products and techniques? Are the savings worth the extra cost? Do predicted energy savings agree with actual energy savings?

To answer these and many more practical questions, the Technology and Energy Conservation Division of Policy Development and Research of the Housing and Urban Development Department sponsored the design and construction of an Energy Efficient Residence (EER) and a Conventional Comparison Home (CCH) by the NAHB Research Foundation, Inc.

At a similar conference cosponsored last year by the Department of Energy and ASTM Committee C-16, I reported on the details of construction of these two homes and their comfort and energy use performance for a portion of the heating season and a portion of the cooling season for which we then had data. Today I will report on detailed operating data for both homes while occupied for one complete calendar year, February 1, 1978 to January 31, 1979.

The objective of this research was to demonstrate and measure, through the design, construction and evaluation of two full scale homes, the potential for saving energy in a typical new home using available products and techniques on a value effective basis. The contract called for selecting a typical best selling model of a merchant builder, redesigning it for more extensive energy conservation, without changing its size or exterior appearance significantly, and then comparing the performance of the two homes.

My paper last year* described the two homes in detail. However, for complete comprehension that information is repeated. The CCH selected had three bedrooms, two baths, a full basement, 111.1 m^2 (1196 ft^2) and was located in Mt. Airy, Maryland, about 64 km (40 miles) north of Washington, D.C.

From an energy efficiency standpoint, the rectangular, one story CCH model was already rather well protected thermally, had its basement about one-half below grade on the average, and was designed, oriented and sited advantageously.

In building the EER, the overall dimensions were modified slightly by adding a vestibule and outdoor storage to one end of the house, although this did not add to habitable space. The appearance was changed slightly by moving the entry door from near the center to the end and a large front porch was reduced to a small covered entryway. The interior was changed a little by converting the kitchen and living room/dining room space into a living room, a separate family retreat room (somewhat like a country kitchen and a retreat from the

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*Presented at the Thermal Insulation Conference, cosponsored by the Department of Energy and ASTM Committee C-16, Tampa, Florida, October 23, 1978 energy crisis) and a kitchen area with a low divider wall between them. Double doors were placed between the family retreat and living rooms.

The fireplace in the EER was located in one end of the family retreat room. Further, in both homes, the kitchens and retreat and dining rooms were located on the south side. Thus, in the EER, the double doors could be closed, and on a winter day, the heat from the kitchen appliances and the fireplace as needed, along with the passive solar gain, could be used to keep that portion of the home comfortable even if no additional energy was being used for heating.

The CCH was well protected thermally. Its level of protection, based on our massive data bank of housing characteristics collected annually, was somewhat higher than the national average at that time (1976). Its principal features related to energy use follow:

DESIGN AND PLANNING FEATURES

- Compact Rectangular plan (7.9 x 14.0 m) (26 x 46 ft)
- South facing windows provide passive solar gain in winter
- East facing glass shaded by carport and west facing glass only 1.5% of floor area
- Single story
- Full basement, about 50% below grade with south wall fully exposed above grade

FOUNDATION/FLOOR

- Dry basement construction
- Gravel and sump with drainage to daylight under slab
- 0.15-mm (6-mil) polyethylene film under slab and behind concrete block walls where they are backfilled
- Exposed walls parged to seal block against air infiltration and rain
- R-11 (RSI 1.94) unfaced insulation attached with stick clips to basement walls above grade and 610 mm (2 ft) below grade
- Glass fiber sill sealer between foundation and sill plate
- R-11 (RSI 1.94) band joist insulation
- Basement aluminum storm windows

EXTERIOR WALLS

- Conventional 38 x 89-mm (2 x 4) wall framing 406 mm (16 in.) o.c. - approximately 20% of the opaque wall area is framing lumber
- R-11 (RSI 1.94) kraft vapor barrier faced insulation
- R-1.22 (RSI 0.21) insulation board sheathing
- Aluminum siding without backer
- Small amount of brick veneer (wainscoting) on front elevation

DOORS/WINDOWS

- Standard wood double hung windows, medium quality
- Standard aluminum storm windows, tight fitting
- Paneled wood front entrance door with two small glazed openings
- Field installed weatherstripping on the exterior doors
- Total window area 8.5% of floor area

ROOF/CEILING

- Conventional 38 x 89-mm (2 x 4) trusses
- Gable end vents provide 0.09 m^2 (1 ft^2) of ventilation for each 27.9 m^2 (300 ft^2)
- R-19 (RSI 3.35) blown fiberglass insulation
- Continuous 0.15-mm (6-mil) polyethylene vapor barrier below insulation
- 305 mm (12 in.) soffit overhang provides partial summer shading for south facing windows

HEATING/COOLING SYSTEM

- Electric resistance furnace - forced air system
- Uninsulated ducts located within the conditioned space
- Masonry fireplace penetrating exterior wall

WATER HEATING/APPLIANCES

- Standard electric resistance 197-litre (52-gal) capacity water heater
- Frost-free refrigerator
- Range hood vented to outside
- Standard model dishwasher, clothes washer and dryer
- Standard electric range and oven

While no special efforts were made to make the CCH tight against air infiltration, the builder's normal building practices including storm windows, sill sealer, caulking, weatherstripping, etc., resulted in a home with a relatively low level of air infiltration - 0.35 air changes per hour measured under a variety of winter conditions using the sulfur hexafluoride method.

Both lots sloped downward sharply to the south so that the basement wall in each home was essentially completely below grade at the front (north) elevation and completely above grade at the rear (south) elevation.

The features of the EER related to energy conservation follow:

DESIGN AND PLANNING FEATURES

- Compact rectangular plan [(7.9 x 14 m) (26 ft x 46 ft for habitable area)]
- Unconditioned vestibule/storage room buffers end wall
- Vestibule "air lock" entrance isolates conditioned space
- 2.29 m (7 ft-6 in.) ceiling height reduces exterior wall area
- Family retreat room can be closed off for comfort conditioning
- Special fireplace has glass doors, damper, outdoor combustion air duct and a provision for circulating room air around firebox
- Increased area of south facing windows on main floor provide passive solar gain in winter
- Roof overhang designed to completely shade south facing windows in summer
- Deciduous trees on south side of home provide summer shading for basement wall and basement glass
- North facing window area reduced, and east and west facing windows eliminated

FOUNDATION/FLOOR

- Dry basement construction with gravel and sump drainage to daylight under slab
- 0.15-mm (6-mil) polyethylene film beneath slab and behind concrete block walls to top of backfill
- Exposed walls parged and painted to seal concrete block against air infiltration and rain
- 38 x 64 - 610 mm (2 x 3 - 24 in.) o.c. basement wall studs set out 76 mm (3 in.) from wall to accommodate full thickness of (RSI 3.35) R-19 insulation with no insulation compression
- R-19 (RSI 3.35) pressure fit insulation batts on south, east and west basement walls
- R-11 (RSI 1.94) pressure fit insulation batts on north basement walls
- 51 mm (2 in.) thick plastic foam perimeter insulation 610 mm (2 ft wide), at exposed slab edges
- 25.4 mm (1 in.) glass fiber sill sealer between foundation and sill plate
- R-19 (RSI 3.35) band joist insulation

- All utility entrances sealed with heavy caulk
- Basement storm windows

EXTERIOR WALLS

- Optimum Value Engineered (OVE) wall framing including 2-stud corners reduces lumber area to about 10% of opaque wall area
- Bottom plate sealed to deck with construction adhesive
- R-19 (RSI 3.35) unfaced pressure fit insulation batts in walls, compressed to 140 mm (5.5 in.) equals R-17.9 (RSI 3.15)
- Continuous 0.15-mm (6-mil) polyethylene vapor barrier behind drywall
- R-5 (RSI 0.88) plastic foam sheathing also covers band joist
- Plywood box-header over openings -- insulated same as walls
- 2-stud corner posts with drywall backup clips and drywall clips at partition intersections
- Surface mounted electrical outlets with wiring beneath floor to avoid penetrating exterior walls

DOORS/WINDOWS

- Insulated steel entrance door with small double glazed openings and magnetic weatherstrip
- Mechanical door closer on outside entrance door
- Insulated steel, weatherstripped inner vestibule door
- Interior doors permit closing off family retreat area for comfort conditioning
- Well weatherstripped high quality windows with double insulating glass plus storm windows (triple glazing)
- Insulating drapes used at windows to reduce winter heat loss and summer heat gain
- Cracks around door and window frames filled with insulation and sealed with caulking
- Window area adjusted to 6.7% of floor area facing north and 12.2% of floor area facing south - average 9.4%

ROOF/CEILING

- Trusses cantilevered over wall top plate to allow full thickness of insulation at exterior wall
- 305 mm (12 in.) thick R-38 (RSI 6.69) pressure fit insulation batts installed from below
- Continuous 0.15-mm (6-mil) polyethylene vapor barrier below insulation
- Gable end vents provide 0.09 m^2 (1 ft^2) of ventilation for each 27.9 m^2 (300 ft^2) of ceiling
- 610 mm (24 in.) soffit overhang provides summer shading for south facing windows
- Attic access door located in vestibule outside of conditioned area
- Only one surface mounted ceiling lighting fixture (kitchen), others wall mounted to avoid penetrating ceiling

HEATING/COOLING SYSTEM

- Triple split heat pump, 240 volt 5 kw, two stage supplemental heat. Capacity at 8°C (47°F), 4981 W (17,000 Btuh); Coefficient of Performance (COP) 2.7; capacity at -8°C (17°F), 2344 W (8,000 Btuh), COP 1.5. 283ℓ/s 600 ft^3/m at 124 Pa (0.5 in.) static pressure. Compressor installed indoors.
- Simplified duct system with low inside registers and low central return - very short branch runs
- All ducts within conditioned space and trunk duct lined with 13 mm (1/2 in.) fiberglass duct liner (to maintain temperature of air delivered to habitable rooms)
- Controlled bypass on condenser coil for improved summer dehumidification
- Heat exchanger (desuper heater) on heat pump compressor to supplement domestic water heating energy

- Separate dehumidifier to control winter humidity without introducing outdoor air
- Manually controlled bathroom resistance heaters for increased comfort (if needed)
- Prefabricated circulator fireplace as noted above
- Large south facing windows in family retreat area contribute passive solar heating in winter

WATER HEATING/APPLIANCES

- Heavily insulated water heater with temperature set back to 49°C (120°F)
- Hot and cold water pipes insulated to reduce heat loss and control summer condensation
- Low water use devices on kitchen faucet, bathroom faucets and shower heads
- High efficiency refrigerator with improved insulation, energy saving feature
- Electric range with heavily insulated standard oven plus microwave oven
- Energy saving dishwasher uses less water and air circulation drying
- Front loading clothes washer uses less water, has load size scale and selector switch
- Bathroom vent fans with double damper, one at bathroom and one at exterior wall
- Fluorescent lighting, four times as efficient as standard incandescent bulbs, used whenever appropriate

Table 1 summarizes the calculated heating and cooling loads in watts (Btuh) at the design conditions of -13°C (+9°F) for heating and 34°C (94°F) for cooling.

Source	Heating				Cooling			
	CCH		EER		CCH		EER	
	W	Btuh	W	Btuh	W	Btuh	W	Btuh
Ceilings	1,351	(4,610)	624	(2,130)	1,222	(4,170)	481	(1,640)
Walls	1,614	(5,510)	800	(2,730)	762	(2,600)	363	(1,240)
Windows	1,808	(6,170)	964	(3,290)	1,884	(6,430)	1,641	(5,600)
Doors	483	(1,650)	76	(260)	234	(800)	161	(550)
Foundation	1,480	(5,050)	694	(2,370)	334	(1,140)	1,289	(4,400)
Infiltration	2,000	(6,825*)	1,008	(3,440*)	1,755	(5,990)	1,289	(4,400)
Internal Load	-		-		952	(3,250)	952	(3,250)
Total Heating Load	8,736	(29,815)	4,166	(14,220)				
Total Cooling Load					7,143	(24,380)	5,034	(17,180)

Table 1. Calculated heating and cooling loads at design conditions
Btuh x 0.293 = W

*Based on actual wintertime air infiltration measurements which averaged 0.35 for the CCH and 0.19 air changes per hour for the EER

Table 2, below, shows the projected annual energy consumption in gigajoules (MMBtu's).

Energy Use	CCH		EER	
	GJ	MMBtu	GJ	MMBtu
Heating	57.0	(54.0*)	13.6	(12.9*)
Cooling	12.4	(11.8)	8.8	(8.3)
Hot Water	13.0	(12.3)	10.3	(9.8)
Appliances	16.0	(15.2)	13.7	(13.0)
Miscellaneous	14.2	(13.5)	13.7	(13.0)
Total Energy Use	112.7	(106.8)	60.1	(57.0)

Projected energy savings in EER 52.5 GJ/year - (49,800,000 Btu/yr)
Estimated savings on electric bills @ 0.97¢/MJ (3.5¢/Kwh) - $511/yr

Table 2. Projected annual energy consumption
MMBTu x 1.055 = GJ

GENERAL OCCUPANCY OBSERVATIONS

- The EER was occupied November 1, 1977, and the CCH was occupied February 1, 1978, each by a family of four people including two young school age children.
- The fireplace was not used in either home. Occupants of both homes open windows when the outdoor temperature is cool in the summertime.
- Occupants of the EER seldom used the microwave oven. Occupants of the CCH do not cook very often, frequently eating out.
- The south facing windows on the EER provide significant solar gain on sunny winter days. On these days, with the blower on and set to run continuously, the compressor stopped operating, even on days with -7 to -1°C (20 to 30°F) outdoor temperatures, between 10 a.m. and noon and typically remained off until 6 p.m. to 8 p.m. in the evenings.
- Hot water use was similar for both families, approximately 7522 litres (1987 gal) per month for the CCH and 7279 litres (1923 gal) per month for the EER. Less hot water was used in the EER even though the lower thermostat setting on the hot water heater in the EER resulted in the temperature stabilizing at the kitchen tap, (after running for five minutes) at 46°C (114°F), and 67°C (152°F) in the CCH.
- The number of times the exterior doors were opened was measured in both homes. In the winter, in the EER, they averaged about 30 per day and 45 per day in the CCH. Instrumentation data are not available for the EER home during the summer months, but it is believed to be approximately 70 per day, the same as the 70 per day openings recorded for the CCH.

COMFORT PERFORMANCE

Extensive comfort and related measurements were made in both homes during both the heating and cooling season. Also, we discussed comfort conditions with the occupants.

*Based on actual wintertime air infiltration measurements which averaged 0.35 for the CCH and 0.19 air changes per hour for the EER.

In the ASTM/DOE paper presented last year and referred to above, I described in detail the results of the extensive comfort measurements. However, for overall comprehension a few of the key measurements are summarized again.

- In both homes the thermostats were set in the winter at approximately 21°C (70°F) and at 24°C (75°F) in the summer.
- The full basements in both homes were partially heated. The average wintertime air temperature in the EER basement was 19.3°C (66.7°F) and in the CCH, 16.3°C (61.4°F).
- Based on the air temperature measurements, it can be concluded that the comfort conditions in both homes were good to excellent. Also, the abbreviated and nonconventional air duct distribution system used in the EER provides excellent comfort conditions during both winter and summer. Higher interior surface temperatures of 2 to 3°C (4 to 6°F) for walls, 3 to 7°C (5 to 13°F) for window and door surfaces and 1 to 4°C (2 to 7°F) for ceilings, along with lower rates of air infiltration and passive solar gain, contributed to producing superior comfort conditions in the EER compared to the good conditions in the CCH.

  (Several factors, other than construction, probably contributed to the higher surface temperatures and it is not possible to separate their individual effects. Among these factors were: (1) the greater sun insolation on the EER house on the days of the measurements which affects the MRT, as well as the inner and outer wall surface temperatures, (2) the higher humidity in the EER house which increases the overall surface heat-transfer coefficient, and (3) the 1°C (1°F) higher ambient air temperature in the EER house at the time of MRT measurements.)

- A number of miscellaneous surface temperature readings were taken in both homes. The results were about as expected with the exception of a dramatic difference for the inside surface temperature of the masonry fireplace in the CCH which was located on (and through) an exterior wall. The inside surface temperature of the brick was 13.6°C (56.5°F), 7.5°C (13.5°F) below the adjacent room air temperature. This was nearly as low as the surface temperature (11.9°C) (53.5°F) of the single glazed picture window. Subsequent infrared thermographs readily identified the relatively warm exterior surface of the fireplace.
- Floor-to-ceiling air temperature distribution in both homes was good. There was a difference of about 1 to 2°C (2° to 3°F) from floor (76 mm) (3 in. above) to ceiling (152 mm) (6 in. below) in the EER with one exception. In the family retreat room the temperature difference between floor and ceiling was 3°C (6°F), (during a sunny winter day) indicating the effect of the passive solar gain. Even with the registers blocked in the bedrooms of the EER, the temperature differences, floor to ceiling, were still in the 1 to 2°C (2 to 3°F) range.
- Room-to-room temperature variation at the 1.8 m (6-ft) level above the floor was 1.1°C (1.9°F) in the EER, excluding the family retreat/kitchen area which had a 2.7°C (4.8°F) higher temperature (on a sunny winter day) than the house average. In the CCH, room-to-room temperature variation at the 1.8 m (6-ft) level above the floor was 2.6°C (4.6°F).
- Basement wall surface temperatures in the EER were about 1.9 to 3.6°C (3.5 to 6.5°F) higher than in the CCH and ranged from about 16.9°C (62.5°F) near the floor to about 19°C (66°F) near the ceiling in the EER and about 14°C (57°F) and 16°C (60°F) respectively in the CCH.

PERFORMANCE

Projected consumption of electricity for heating and for cooling the EER and CCH were calculated by standard procedures. We expected both homes to perform substantially better than the results of such calculations in the winter but did not expect that their actual performance would be as much better in the summer than the projected performance, see Table 3.

As indicated in Table 3, the standard procedure for calculating annual energy use substantially overestimates that use. In this case at least, it greatly exaggerates calculated energy savings. This may tend to encourage lower levels of thermal protection. On the other hand, it might also tend to increase expenditures for energy conservation techniques by justifying more savings than actually occur, depending on the view point of the builder, buyer or designer. At best this results in seriously oversizing equipment, which adds to cost and wastes energy. At worst, it misleads the consumer into believing that energy savings will be greater than actually occur. It appears that, for homes with a "high" vs "very high" level of thermal protection, the method results in predicting an even greater difference between actual and projected use. However, data on only two homes do not prove that point. Within certain limits of thermal protection though, such as those in these homes, it is reasonable to believe that the above is true.

	Heating Oct 1-May 19				Cooling May 20-Sept 30			
	EER		CCH		EER		CCH	
	MJ	Kwh	MJ	Kwh	MJ	Kwh	MJ	Kwh
Projected	1309	(4711*)	5213	(18766*)	592	(2133)	779	(2803)
Actual	951	(3422)	3239	(11659)	461	(1660)	669	(2410)
Difference	358	(1289)	1974	(7107)	131	(473)	109	(393)
% Difference	27.	27.4		37.9		19.5		14.0

Table 3. Electricity Consumption - Kwh x 0.2777 = MJ
Heating Only and Cooling Only
EER vs. CCH
February 1, 1978 - January 31, 1979

The summer weather data were not adequate, due to mechanical recording equipment failures, to determine the actual cooling hours at the site. But other data indicate that summer weather was typical.

The EER home showed dramatic reduction in energy use for heating compared to the CCH. Table 4 summarizes the energy use for the EER and the CCH by heating season and by cooling season. The table also shows energy use for the hot water heater, all the major appliances, instrumentation, lighting and miscellaneous, subtotals and totals for the homes.

For heating only, the EER home used 70.6% less energy, or a total of 951 MJ (3422 Kwh) for 231 days. While it is not particularly meaningful, it is interesting to note the very low average hourly use - slightly more than 0.6 of a kilowatt per hour. In the month of February (1100 D.D.), the use of heating energy averaged 1.01 Kw per hour.

The large percentage reduction is even more significant when it is realized that there was nearly a 47% decrease in energy used for water heating and,

*Adjusted for actual number of heating Degree Days, actual measured air infiltration and, for the EER, a heat pump SPF of 1.9. Cooling projected use adjusted for estimated actual equipment EER based on manufacturer's data.

	Heating Season					Cooling Season				
	CCH		EER		CCH-EER Diff %	CCH		EER		Diff %
	MJ	Kwh	MJ	Kwh		MJ	Kwh	MJ	Kwh	
Heating Energy	3239	11659	957	3422	70.6		-		-	-
Cooling Energy		-		-	-	669	2410	461	1660	31.1
Hot Water Heater	1419	5110	754	2714	46.9	617	2220	281	1011	54.5
Range	98	351	168	604	(41.9)**	42	151	87	313	(51.8)
Refrigerator	277	997	215	774	22.4	198	713	112	403	43.5
Dishwasher	10	36	25	90	(60.0)	6	21	16	59	(64.4)
Clothes Washer	21	77	11	38	50.6	11	40	6	22	45.0
Clothes Dryer	194	697	147	529	24.1	94	338	77	276	18.3
Dehumidifier		-	13	45	-		-		-	-
Light & Misc.	330	1187	270	971	18.2	139	502	151	544	(7.7)
Subtotal Appl.	929	3345	848	3051	8.8	491	1769	449	1617	8.6
Subtotal Appl. + H.W.H.	2349	8455	1601	5765	31.8	1107	3985	730	2628	34.1
Instrumentation	39	141	48	171	(17.5)	23	81	28	99	(18.2)
Subtotal Appl. + H.W.H. + Instru.	2388	8596	1649	5936	30.9	1129	4066	758	2727	32.9
Total House	5626	20255	2599	9358	53.8	1799	6476	1219	4387	32.3

Table 4. Summary Total Energy Use - MJ (Kwh) by Heating Season* and Cooling Season* EER vs. CCH

therefore, the energy gain to the environment from the water heater was lower in the EER than in the CCH. Also, there was nearly 9% less energy used for appliances. This difference in internal use for appliances and water heating is nearly 750 MJ (2700 Kwh) for the heating season or about 485 watts per hour.*** This is small, but in relation to the very low average energy use of only 0.17 MJ (0.62 Kwh), it is large. Actual savings would have been greater percentage-wise had it not been for the considerably larger internal use of energy in the CCH home during the heating season.

On cooling, the results are significant, although not quite as striking. Total cooling energy used was 31.1% less in the EER than in the CCH, a difference of 377 MJ (1357 Kwh) or a little more than 0.4 of a Kw per hour. In this case, the heat gain from this internal use works in the direction of making the savings for the EER home appear to be better than it would have been had the internal loads been the same. As noted above, the effect is small since 89% of the difference is due to energy for water heating, only a small part of which adds to internal load.

*Heating Season October 1 - May 19
Cooling Season May 20 - September 30

**( ) indicate % energy use greater in EER

***The effect is probably relatively small however, since 89% of the difference is due to energy for water heating, only a small part of which adds to internal load.

Total energy use during the heating season was 53.8% lower, and during the cooling season 32.3% lower, in the EER than in the CCH home. All energy use during the heating season amounted to 5626 MJ (20255 Kwh) or 75.8% of the annual use for the CCH and 2599 MJ (9358 Kwh) or 68.1% of annual use for the EER.

As can be seen in Table 5, the total difference for all energy use between the two homes was 3606 MJ (12981 Kwh), a 48.6% reduction. This is equal to an actual energy saving of $545 for the year at the weighted average rate of 1.17¢/MJ (4.2¢/Kwh).

	CCH		EER		Diff. %
	MJ	Kwh	MJ	Kwh	
Heating	3239	11659	951	3422	70.6
Cooling	669	2410	447	1610	31.1
Water Heater	2036	7330	1035	3725	49.2
Range	139	502	255	917	(45.3)*
Refrigerator	475	1710	327	1177	31.1
Dishwasher	16	57	41	149	(61.7)
Clothes Washer	33	117	18	65	44.4
Clothes Dryer	288	1035	224	805	22.2
Dehumidifier	--	--	13	45+	--
Lights and Misc.	469	1689	421	1515	10.3
Subtotal Appliances	1419	5110	1298	4673	8.6
Subtotal Appl. plus H.W.H.	3456	12440	2333	8398	32.5
Instruments	62	222	75	270	(17.8)
Total House	7425	26731	3819	13750	48.6

Table 5. Summary Total Energy Use
CCH vs. EER
February 1978 - January 1979

In the preparation of the final analysis and report on this project, we are estimating on a rational basis, the amount of heat gain from the water heater, passive solar energy and human loads. Actual counts of people occupancy taken from the log books showed essentially identical internal loads due to occupancy. The difference in passive solar gain between the two homes was small because there was substantially more south facing glass in the CCH on the lower level than in the EER. On the upper level the situation was reversed. On a preliminary basis, it appears that 278 MJ (1,000 Kwh) more than the 3606 (12981 Kwh) noted above would have been saved had the internal loads been equal.

In our preliminary analyses, it appears that the energy conservation techniques applied to the building envelope accounted for about 48% of the savings while the different HVAC system accounted for about 23% and the water heater savings accounted for about 25%.

The total cost of the added energy conserving techniques to the buyer at the time of sale of the EER was about $5400. This could be reduced to about $4400 ignoring the extra cost of the vestibule, change in carport, storage and porch arrangement, all of which in our opinion contributed very little to energy conservation in this house.

*( ) indicate % energy use greater in EER

Assuming the price of energy increases at the rate of 10% per year and the alternate investment rate is 9%, the time-to-recoup-investment for the cost of modifications to the envelope would be about 12 years, 3 years for the HVAC system, one year for the hot water heater (including the major portion of the total benefit which we attribute to the different operating temperatures) and about 5 years for the energy efficient refrigerator. If the extra cost of the vestibule and other minor modifications, which probably contributed little to a reduction in energy use, were eliminated, the time-to-recoup-investment on the modifications to the envelope would be about 7.8 years.