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ENVIRONMENTAL PARTNERSHIP

CREAM RIDGE, NEW JERSEY

SOLAR ENERGY SYSTEM PERFORMANCE EVALUATION

OCTOBER 1981 THROUGH MARCH 1982

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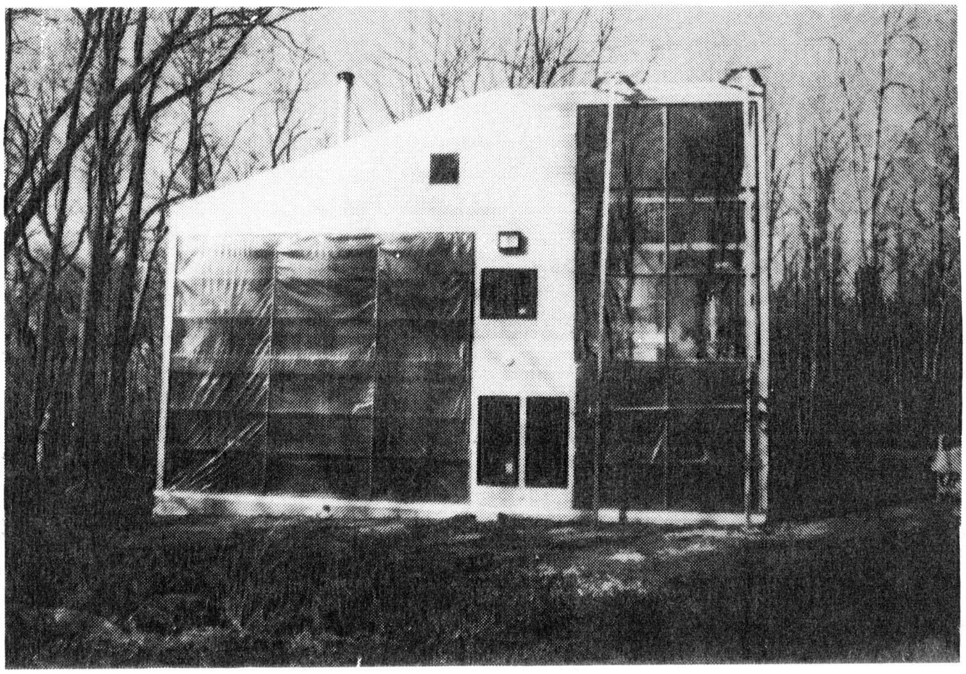
FOREWORD

This report is one of a series which describes the performance of solar energy systems in the National Solar Data Network (NSDN) for the entire heating or cooling season. Domestic hot water is also included, if there is a solar contribution. Some NSDN installations are used solely for heating domestic hot water and annual performance reports are issued for such sites. In addition, Monthly Performance Reports, prior to 1981, are available for the solar systems in the network.

The National Solar Data Network consists of instrumented solar energy systems in buildings selected from among the 5,000 installations built (since early 1977) as part of the National Solar Heating and Cooling Demonstration Program. The overall purpose of this program is to assist in the development of solar technologies for buildings by providing data and information on the effectiveness of specific systems, the effectiveness of particular solar technologies, and the areas of potential improvement. Vitro Laboratories Division responsibility in the NSDN, under contract with the Department of Energy, is to collect data daily from the sites, analyze the data, and disseminate information to interested users.

Buildings in the National Solar Data Network are comprised of residential, commercial and institutional structures which are geographically dispersed throughout the continental United States. The variety of solar systems installed employ "active" mechanical equipment systems or "passive" design features, or both, to supply solar energy to typical building thermal loads such as space heating, space cooling, and domestic hot water. Solar systems on some sites are used to supply commercial process heat.

The buildings in the NSDN program are instrumented to monitor thermal energy flows to the space conditioning, hot water, or process loads, from both the solar system and the auxiliary or backup system. Data collection from each site, and transmission to a central computer for processing and analysis is highly automated.



ENVIRONMENTAL PARTNERSHIP

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The Environmental Partnership site (also known as the Bonillia Home) is a two-story, single family home on a wooded lot in Cream Ridge, New Jersey. The wood platform-framed home uses three major passive solar energy systems – a 168-square-foot sunspace, a 344-square-foot Trombe wall and a "breadbox" type passive solar hot water heater. The system was designed to provide 75% of the total load at the site.

Environmental Partnership is equipped with:

Component	Description	Size
Collector	(1) Trombe wall	344 square feet
	(2) Sunspace	168 square feet
	(3) Passive domestic hot water preheat tank	43-square-foot skylight
Storage	50,000-pound concrete wall - 12 inches thick 32 phase-change rods by PSI - 3-foot length	
Auxiliary	(1) Dual-fuel wood/propane furnace by Yukon Industries, St. Paul, Minnesota	
	(2) Wood stove by RAIS Products, Aps., Denmark	
	(3) 50-gallon Waldorf Vitraglass auxiliary water heater - propane fuel	
	(4) "Whole-House" cooling fan by Chelsea Fans & Blowers	

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ENVIRONMENTAL PARTNERSHIP
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Equipment Solar Fraction[1]	30%
Conventional Fuel Savings[2]	25.46 million BTU or 278 gallons of propane

Seasonal Energy Requirements
October 1981 through March 1982
(Million BTU)

	Load	Solar Contribution	% Solar
Heating	41.27	14.00	34
Hot Water	8.91	1.28	14
Total	50.18	15.28	30

Environmental Data

	Measured Average	Long-Term Average
Outdoor temperature	40°F	41°F
Heating degree-days (Total)	4,521	4,458
Daily incident solar energy	599 BTU/ft^2*	928 BTU/ft^2

1. $\text{Solar Fraction} = \frac{\text{Solar Energy Supplied to Load}}{\text{Total Load}} \times 100$

2. $\text{Conventional Fuel Savings} = \text{Savings in BTU} \times 10.93 \times 10^{-6}$ gallons propane/BTU

* As measured in the vertical south-facing plane of collector

1.1. SUMMARY AND CONCLUSIONS

The Environmental Partnership site (also called the Bonillia Home) is a 2,050-square-foot single family residence on a five-acre wooded lot in Cream Ridge, New Jersey (south-southeast of Trenton, New Jersey). The building incorporates three major passive solar elements into the design - a two-story direct-gain sunspace, a Trombe wall, and a passive solar preheat tank located in a sleeping loft. Storage of solar energy is augmented by a series of phase-change rods in the railing of a second floor loft, as well as in the mass of the Trombe wall.

The home is constructed of wood, with one-inch by six-inch exterior siding over plywood, 5½ inches of cellulose fiber blown-in insulation in all walls and 12 inches in ceiling areas, a concrete block foundation and filled concrete block Trombe wall. The sunspace and Trombe wall are double-glazed. Interior movable curtains were not installed during construction; however, the site owner is considering the installation of some type of movable insulation system in the future.

The backup heating system at Environmental Partnership consists of a dual-fuel (propane/wood) forced-air furnace, which can be operated using either propane or wood. If the occupant chooses to use wood, a small amount of propane is used initially to ignite the wood in the firebox.

A small, free-standing wood stove is mounted adjacent to the Trombe wall in the living room, to augment the passive design features.

The overall performance of the Environmental Partnership site is presented in Table 1. Figure 1 shows the seasonal performance in graphic form. The figure shows the total equipment heat load, and internal energy gains, passive solar used, plus auxiliary energy consumed. The energy flow through the system during the six-month heating season is presented in Figure 2, the seasonal Energy Flow Diagram.

The passive features of the home supplied 30% of the total measured system load of 50.18 million BTU, of which 41.27 million BTU were equipment heat load and 8.91 million BTU attributed to the hot water subsystem load. The 30% solar fraction was below the 75% design solar fraction, but still represents significant energy savings. The overall equipment heat load per square foot of occupied space was 4.50 BTU/degree-day/ft^2, compared to a typical home which might require as much as 15 BTU/degree-day/ft^2 under similar conditions. This difference indicates that the home is well insulated and tightly constructed. The infiltration rate (defined as the number of total house volume air changes per hour) was assumed to be 0.5 air changes per hour, which is a low value compared to other typical homes. The thick insulation (5½ inches cellulose in the walls, 12 inches in ceilings) plus the insulated wood sash casement, awning, and picture windows (not double-hung) are further reasons for the low heat loss rate from the structure. The value of 0.5 air changes per hour was chosen as the assumed infiltration rate based on qualitative analysis of the construction techniques utilized, the measured infiltration rates at similarly constructed homes, and values available in the literature. Typically, nonpassive structures exhibit infiltration rates between 1.0 and 2.0 air changes per hour. Extremely "tight" passive homes exhibit values from 0.3 to 1.0; therefore 0.5 air changes per hour is a reasonable rate of exchange.

Table 1. SOLAR SYSTEM THERMAL PERFORMANCE

ENVIRONMENTAL PARTNERSHIP
OCTOBER 1981 THROUGH MARCH 1982

(All values in million BTU, unless otherwise indicated)

MONTH	SOLAR ENERGY TRANSMITTED(1)	SYSTEM LOAD	SOLAR ENERGY USED	AUXILIARY THERMAL ENERGY	OPERATING ENERGY	ENERGY SAVINGS FOSSIL	SOLAR FRACTION (%)
OCT	4.59	5.77	3.26	2.51	0.00	5.43	56
NOV	3.74	6.32	1.86	4.46	0.05	3.10	29
DEC	3.09	9.73	1.00	8.73	0.15	1.67	10
JAN	4.97	10.21	0.89	9.32	0.14	1.48	9
FEB	4.92	9.01	2.93	6.08	0.07	4.88	33
MAR	4.82	9.14	5.34	3.80	0.04	8.90	58
TOTAL	26.16	50.18	15.28	34.90	0.45	25.46	-
AVERAGE	4.36	8.36	2.55	5.82	0.08	4.24	30

(1)Heating glazing transmittance not including domestic hot water skylight.

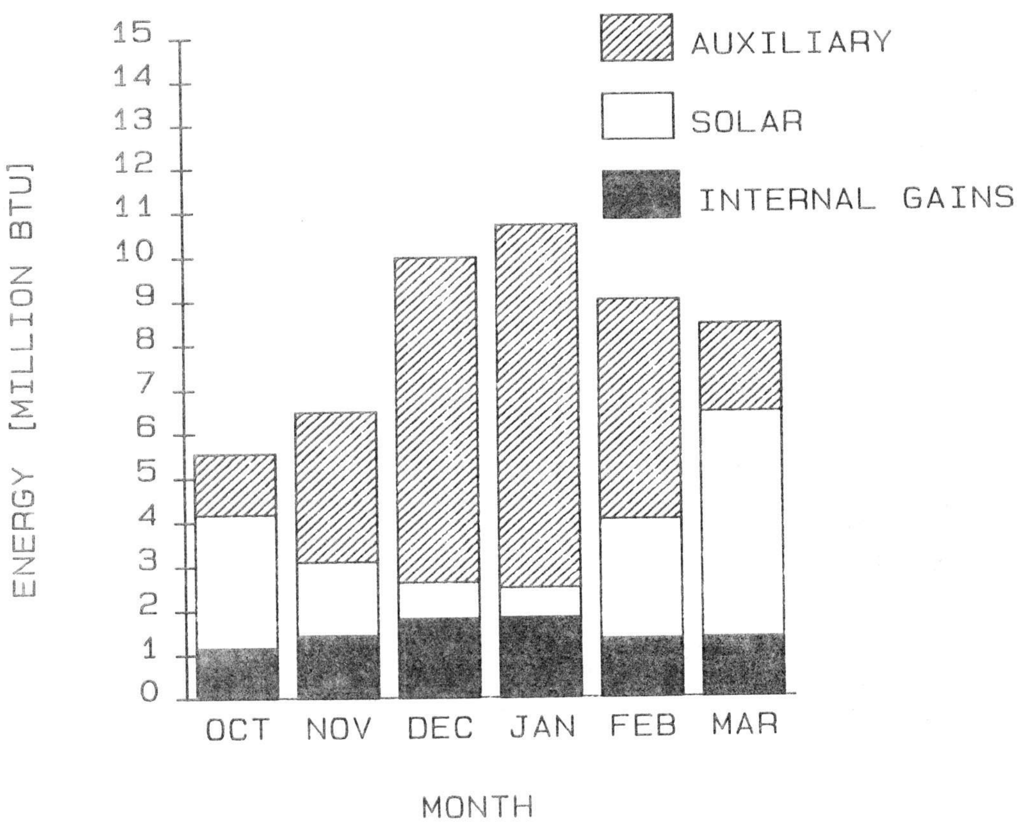

Figure 1. System Thermal Performance
Environmental Partnership
October 1981 through March 1982

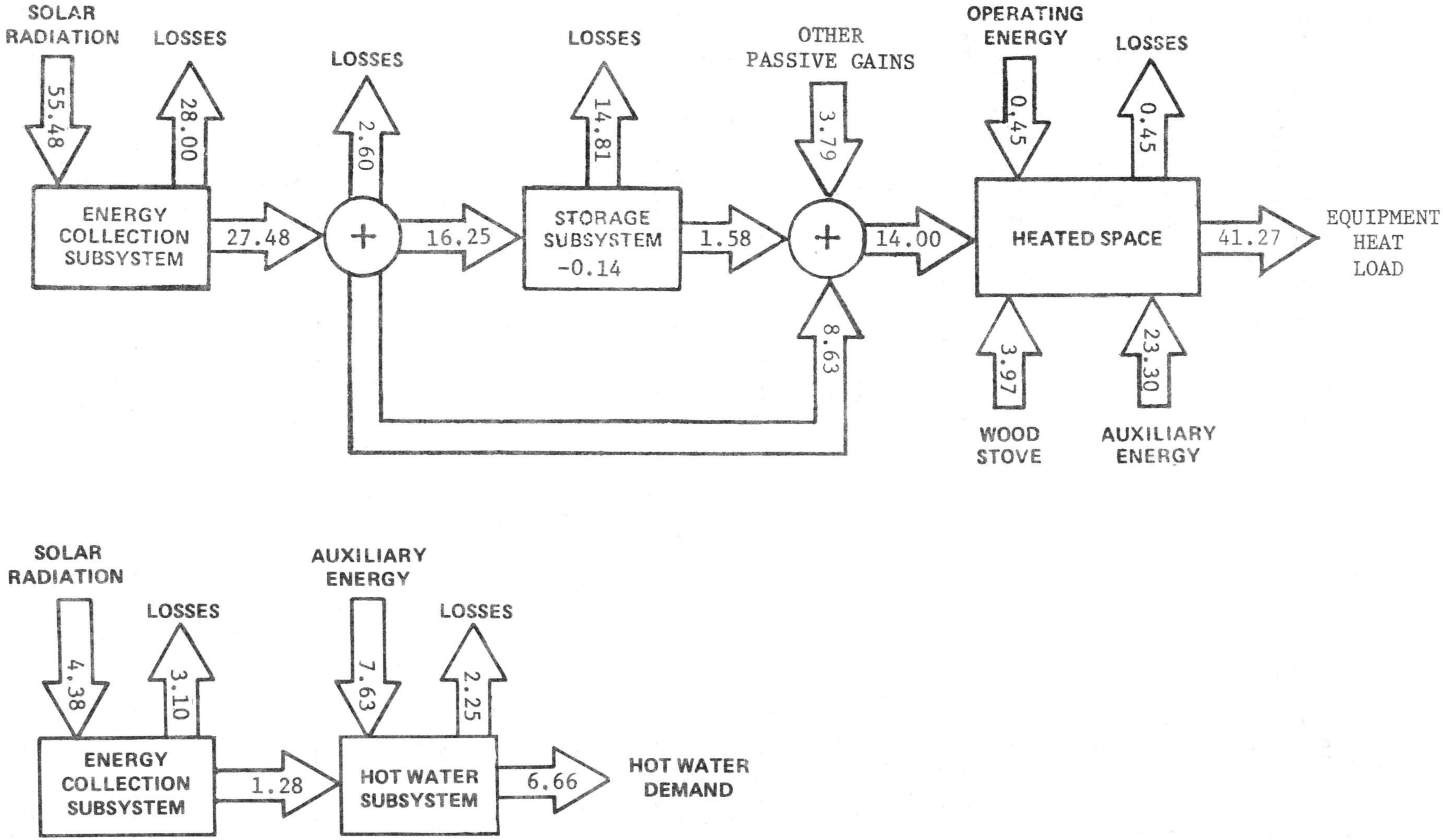

Figure 2. Energy Flow Diagram for Environmental Partnership
October 1981 through March 1982
(Figures in million BTU)

Table 2 presents the overall collector subsystem performance, and Tables 2A and 2B break down the performance of the Trombe wall and the sunspace individually. The overall incident radiation on the combined collector area of 512 square feet was 55.48 million BTU, of which an estimated 10.21 million BTU (18%) were actually collected. This figure for energy collection differs from the 14.00 million BTU shown on Table 5 on Page 1-10 and the Energy Flow Diagram due to several reasons:

- Measured data was used for the sunspace calculation, as compared to estimated passive contributions. An interior pyranometer was used to measure actual transmission from December to March. Estimated solar contributions are based on the difference between the heat loss from the building and the sum of all the energy sources.

- The energy collected from the Trombe wall was calculated using measured temperatures and a series of heat transfer calculations based on empirical heat transfer correlations. Overall convective and radiative heat transfer rates from the wall were calculated using these correlations.

- Collected energy from other windows on the east wall, west wall, and roof is not added to the 10.21 million BTU of measured energy collection. The addition of contributions from these sources would increase the passive contribution.

- The energy balance method of calculating passive solar energy consumption is subject to uncertainty - particularly in the case of the air infiltration rate estimate. This method causes the passive contribution to vary as the heat load varies. This solar contribution is, therefore, an estimate, and is very sensitive to adjustment of infiltration rate, etc.

Table 2. OVERALL COLLECTOR SUBSYSTEM PERFORMANCE

ENVIRONMENTAL PARTNERSHIP
OCTOBER 1981 THROUGH MARCH 1982

(All values in million BTU, unless otherwise indicated)

MONTH	TOTAL INCIDENT SOLAR RADIATION	SOLAR ENERGY COLLECTED	OVERALL EFFICIENCY (%)
OCT	9.76	1.96 E	20 E
NOV	7.95	1.50 E	19 E
DEC	6.28	1.12	18
JAN	10.49	1.86	18
FEB	9.62	1.85	19
MAR	11.38	1.92	17
TOTAL	55.48	10.21 E	-
AVERAGE	9.25	1.70 E	18 E

E Denotes estimated value.

Table 2a. TROMBE WALL COLLECTOR SUBSYSTEM PERFORMANCE

ENVIRONMENTAL PARTNERSHIP
OCTOBER 1981 THROUGH MARCH 1982

(All values in million BTU, unless otherwise indicated)

MONTH	TROMBE WALL INCIDENT SOLAR RADIATION	TRANSMITTED SOLAR RADIATION	ABSORBED SOLAR RADIATION	COLLECTED SOLAR RADIATION	TRANSMISSION (%)	TROMBE WALL COLLECTION EFFICIENCY (%)	TROMBE WALL LOSSES
OCT	6.47	3.04 E	2.82 E	0.41	47 E	6	2.55
NOV	5.34	2.51 E	2.33 E	0.27	47 E	5	2.05
DEC	4.22	2.08	1.93	0.11	49	3	1.89
JAN	7.05	3.32	3.08	0.21	47	3	2.84
FEB	6.46	3.31	3.08	0.24	51	4	2.72
MAR	7.65	3.24	3.01	0.34	42	4	2.76
TOTAL	37.19	17.50 E	16.25 E	1.58	-	-	14.81
AVERAGE	6.19	2.92 E	2.71 E	0.26	47 E	4	2.47

E Denotes estimated value.

Table 2b. SUNSPACE COLLECTOR SUBSYSTEM PERFORMANCE

ENVIRONMENTAL PARTNERSHIP
OCTOBER 1981 THROUGH MARCH 1982

(All values in million BTU, unless otherwise indicated)

MONTH	SUNSPACE INCIDENT SOLAR RADIATION	SUNSPACE TRANSMITTED SOLAR RADIATION	SUNSPACE ESTIMATED ABSORBED	LOSSES FROM SUNSPACE	TRANSMISSION (%)
OCT	3.29	1.55 E	1.55 E	1.17	47 E
NOV	2.61	1.23 E	1.23 E	1.25	47 E
DEC	2.06	1.01	1.01	1.52	49
JAN	3.44	1.65	1.65	1.80	47
FEB	3.16	1.61	1.61	1.49	51
MAR	3.73	1.58	1.58	1.42	42
TOTAL	18.29	8.63 E	8.63 E	8.65	-
AVERAGE	3.05	1.44 E	1.44 E	1.44	47 E

E Denotes estimated value. Interior pyranometer installed December 1981.

There are convection openings in the Trombe wall distributed through the upper and lower floors, which also allow solar energy to penetrate into the home. Actually, the agreement is quite reasonable between the 14.00 million BTU and 10.21 million BTU. The net difference, called "Other Passive Gains" on the Energy Flow Diagram, was 3.79 million BTU.

The overall collection efficiency was an estimated 18% of the total incident radiation. The Trombe wall (Table 2) had 37.19 million BTU of incident radiation on the glazing area of 344 square feet. An interior pyranometer measured a total of 17.50 million BTU transmitted through the glass, representing an overall transmission factor of 0.47. The "E" (estimated value) in the transmission column is due to the fact that the interior pyranometer readings were not available until December. The average value (47%) was substituted for those months.

Absorbed solar radiation is estimated to be 93% of the transmitted radiation, based on standard tabled values for the absorptivity of a flat black paint (93%). This radiation was 16.25 million BTU, but much of this was lost.

The estimated heat flux from the interior of the Trombe wall was 1.58 million BTU over the six-month season, which translates to an estimated overall collection efficiency of four percent. This indicates a fundamental problem at the site - the high exterior losses from the Trombe wall. The site owner operated the wall in a purely conductive mode; that is, the interior wall vents were not opened during the day. Energy was transferred through the wall in a conduction mode only, which may have limited the wall output to some extent. There was another problem with the wall which caused high exterior losses. There is a linear vent along the top of the exterior glazing which was not weatherstripped during the first three months of the heating season. The effect of this was to allow infiltration of cool outside air into the wall cavity with resultant losses. Although the weatherstrip was installed in December, there seemed to be little or no improvement in wall performance. The exterior losses were calculated to be 14.81 million BTU.

The sunspace provided most of the actual solar energy collection at the site. An estimated 8.63 million BTU were collected by the glazing and sunspace, which has a series of phase-change storage rods in a balustrade configuration behind it. These rods appeared to participate in releasing stored solar energy during evening hours; however, their net effect was small due to the fact that the loft is not a major traffic area. These rods were not included in the analysis of the home as their net effect was minimal.

All of the energy entering the sunspace is assumed to be absorbed, since cavities deeper than 10 feet are assumed to be black-body equivalents.

The conduction heat loss from the sunspace was as large as the solar energy collected, at 8.65 million BTU lost. This loss was due to the large (168 net square-foot) glass area. The typical "U" value for the glass was 0.45 BTU/ft^2-hr°F, while the typical insulated wall section had a "U" value of 0.05 BTU/ft^2-hr°F. The addition of a movable insulating curtain could reduce the heat loss from the glass area by up to one-third. This addition would be the single most effective method of increasing the solar heating contribution.

Table 3 presents the performance of the storage wall at Environmental Partnership. The storage wall released a total of 1.58 million BTU to the home, and lost 14.81 million BTU through the glazing. The net energy change in storage was -0.14 million BTU.

Table 3. STORAGE PERFORMANCE

ENVIRONMENTAL PARTNERSHIP
OCTOBER 1981 THROUGH MARCH 1982

(All values in million BTU, unless otherwise indicated)

MONTH	ENERGY TO STORAGE	ENERGY FROM STORAGE	CHANGE IN STORED ENERGY	STORAGE LOSSES	AVERAGE STORAGE TEMPERATURE (°F)	AVERAGE BUILDING TEMPERATURE (°F)
OCT	2.82 E	0.41	-0.14	2.55	77	68
NOV	2.33 E	0.27	0.01	2.05	70	62
DEC	1.93	0.11	-0.07	1.89	63	63
JAN	3.08	0.21	0.03	2.84	64	63
FEB	3.08	0.24	0.12	2.72	67	66
MAR	3.01	0.34	-0.09	2.76	70	67
TOTAL	16.25 E	1.58	-0.14	14.81	-	-
AVERAGE	2.71 E	0.26	-0.02	2.47	69	65

E Denotes estimated value.

The wall had a seasonal variation in temperature as well as a daily temperature swing. The mass wall participates less in the dead of winter (December and January) when the building temperature nearly equals the wall temperature. The performance of this wall indicates that a direct-gain option might have been a better choice in design, if sufficient storage mass were available near the sunspace to capture and reradiate stored solar energy to the living space. The wall did provide a net positive effect, since it was essentially adiabatic (i.e., no net heat transfer) during most of the six-month heating season.

The hot water subsystem performance is shown in Table 4. The total hot water load (defined as total solar contribution plus auxiliary thermal energy consumed) was 8.91 million BTU, of which 14%, or 1.28 million BTU, was supplied by solar energy collected from the preheat tank. A total of 4.38 million BTU was incident on the Domestic Hot Water (DHW) skylight. The total auxiliary thermal energy consumed was 7.63 million BTU, which was 60% of the total propane consumption of 12.72 million BTU.

The total hot water demand was 6.66 million BTU, which represents a total of 10,829 gallons raised from an average 52°F to 126°F delivery temperature.

The hot water preheat tank was less than half covered with a selective film coating during October through December. The remainder of the tank was covered in late December, but there was no increase in average solar contribution. The hot water demand was very similar from December to January. The

Table 4. DOMESTIC HOT WATER SUBSYSTEM

ENVIRONMENTAL PARTNERSHIP
OCTOBER 1981 THROUGH MARCH 1982

(All values in million BTU, unless otherwise indicated)

MONTH	HOT WATER LOAD	SOLAR FRACTION OF LOAD (%)	HOT WATER DEMAND	INCIDENT SOLAR RADIATION ON SKYLIGHT	SOLAR ENERGY USED	AUX THERMAL USED	AUX FOSSIL FUEL	SUP WATER TEMP (°F)	SUP WATER TEMP (°F)	HOT WATER CONSUMPTION (GALLONS)
OCT	1.38	17	1.01	0.94	0.24	1.14	1.91	58	123	1,891
NOV	1.27	15	1.11	0.58	0.19	1.08	1.80	54	126	1,844
DEC	1.56	12	1.22	0.44	0.18	1.38	2.29	51	127	1,920
JAN	1.33	16	1.22	0.57	0.21	1.12	1.87	49	128	1,876
FEB	1.33	17	1.08	0.72	0.23	1.10	1.84	50	126	1,704
MAR	2.04	11	1.02	1.13	0.23	1.81	3.01	51	127	1,594
TOTAL	8.91	-	6.66	4.38	1.28	7.63	12.72	-	-	10,829
AVERAGE	1.48	14	1.11	0.73	0.21	1.27	2.12	52	126	1,805

incident solar in the horizontal plane increased from 338 BTU/ft^2-day in December to 441 BTU/ft^2-day in January, representing a 30% increase in available radiation on the tank. The solar contribution increased from 0.18 million BTU in December to 0.21 in January, a 17% increase. Thus, it is not clear whether the film had any significant impact on performance.

Overall, the hot water subsystem performed quite well, due to its location in the warmest part of the home and the total lack of moving parts.

Tables 5 and 5a present the energy consumption for the Space Heating Subsystem over the six-month heating season.

The heating system provided (Equipment Heat Load, Table 5) 41.27 million BTU. The auxiliary furnace supplied 23.30 million BTU, of which 6.82 million BTU were supplied by the combustion of propane, and the remainder from the combustion of wood. Discussion with the site owner revealed that the total wood consumption was estimated to be one cord of mixed hardwood, with a heating value of about 25 to 30 million BTU. The total furnace output was, therefore, reasonable at 60% furnace efficiency. The 6.82 million BTU of propane were equivalent to 74.5 gallons of propane.

The wood stove in the living room was not utilized to the full extent possible. Discussion with the site owner indicated that the stove, when utilized, was fired with a small charge of wood (two to three small logs) per evening and allowed to burn slowly. The stove output was assumed to be 10,000 BTU/per hour. This was cross-checked against room temperature rise during operation to estimate the stove output. Operation time of the stove was

Table 5. SPACE HEATING SUBSYSTEM

ENVIRONMENTAL PARTNERSHIP
OCTOBER 1981 THROUGH MARCH 1982

(All values in million BTU, unless otherwise indicated)

MONTH	EQUIPMENT HEAT LOAD	PASSIVE SOLAR ENERGY USED	AUXILIARY ENERGY			OPERATING ENERGY	EQUIPMENT SOLAR FRACTION (%)
			TOTAL FURNACE OUTPUT	AUXILIARY FOSSIL FUEL	WOOD STOVE		
OCT	4.39	3.02	0.00	0.00	1.37	0.00	69
NOV	5.05	1.67	2.34	0.42	1.04	0.05	33
DEC	8.17	0.82	7.35	2.31	0.00	0.15	10
JAN	8.88	0.68	7.35	1.59	0.85	0.14	8
FEB	7.68	2.70	4.27	1.67	0.71	0.07	35
MAR	7.10	5.11	1.99	0.83	0.00	0.04	72
TOTAL	41.27	14.00	23.30	6.82	3.97	0.45	-
AVERAGE	6.88	2.33	3.88	1.14	0.66	0.08	34

Table 5a. SPACE HEATING SUBSYSTEM (Continued)

ENVIRONMENTAL PARTNERSHIP
OCTOBER 1981 THROUGH MARCH 1982

(All values in million BTU, unless otherwise indicated)

MONTH	EMPIRICAL HEATING DEGREE-DAYS	BUILDING HEAT LOAD	CONDUCTION LOSSES (UA $\Delta\tau$)	INFIL LOSSES	INTERNAL GAINS	AUX ENERGY CONSUMED	PASSIVE SOLAR ENERGY CONSUMED	BUILDING SOLAR FRACTION (%)
OCT	322	5.54	3.50	2.04	1.15	1.37	3.02	55
NOV	612	6.48	3.75	2.73	1.43	3.38	1.67	26
DEC	925	9.98	4.67	5.31	1.81	7.35	0.82	8
JAN	1,153	10.71	5.53	5.18	1.83	8.20	0.68	6
FEB	814	9.02	4.62	4.40	1.34	4.98	2.70	30
MAR	695	8.46	4.38	4.08	1.36	1.99	5.11	60
TOTAL	4,521	50.19	26.45	23.74	8.92	27.27	14.00	-
AVERAGE	754	8.37	4.41	3.96	1.49	4.54	2.33	28

determined by a temperature sensor located near the rear of the unit. When this sensor showed significant temperature increases, the stove was considered to be fired and the contribution estimated from the time of stove operation multiplied by its heat output rate. This gives a reasonable estimate of the contribution from the stove, which totaled 3.97 million BTU over the six-month season. December and March showed little or no stove use and are zeroed on the table.

A portable electric heater was operated during the heating season to warm one of the bedrooms for occupant comfort. The energy from this resistance heater is included in internal energy gains at the site.

The building heat load, Table 5a, (estimated total heat loss rate due to conduction losses through structural materials plus losses due to air infiltration) was 50.19 million BTU, of which 23.74 million BTU, or 47%, were due to air infiltration. Conduction losses through the walls, ceiling, and floors totaled 26.45 million BTU, or 53% of the total heat loss. The building solar fraction (solar heating contribution divided by total building heat load) was 28%. Internal energy gains were 8.92 million BTU, which include electric power consumed in the home plus other internal energy sources.

The passive solar energy used was 14.00 million BTU, which was calculated using the "energy balance" method. The difference between the building heat load and all the energy consumed in the building (auxiliary energy consumed plus internal gains) is considered to be passive solar energy used. The 14.00 million BTU of passive solar energy used include direct gains from the sunspace, the effect of the Trombe wall, plus other inputs of solar energy from east and west windows and gains from two rooftop skylights.

Three steps may be taken to improve heating system performance:

1. Install insulating movable curtains on all windows, particularly the sunspace glazing. This insulation would reduce night heat loss and increase solar fraction, plus improve comfort.

2. Utilize the convective Trombe wall vents during the day to improve wall performance. Convection gains could be improved using simple backdraft dampers designed to allow flow during sunny conditions and no flow during evening hours.

3. Remove some of the trees on the south-facing side of the lot. This removal would allow more sunlight to reach the lower portion of the Trombe wall and heat the downstairs bedrooms to a greater degree. This action could affect cooling in the summer, however.

Table 6, Passive System Environment, presents the building and ambient temperatures which were measured during the heating season. The building temperature averaged 65°F, which was slightly cool for normal comfort range. The lowest monthly average building temperature occurred in November at 62°F. Average minimum hourly building temperatures were 57°F, and fell as low as 54°F during December and January. The average storage temperatures during December and January were very close to the building temperatures during those months. This indicates that the mass wall did not significantly contribute

Table 6. PASSIVE SYSTEM ENVIRONMENT

ENVIRONMENTAL PARTNERSHIP
OCTOBER 1981 THROUGH MARCH 1982

MONTH	BLDG TEMP (°F)	MAX BLDG TEMP (°F)	MIN BLDG TEMP (°F)	INDOOR RELATIVE HUMIDITY (%)	AVERAGE STORAGE TEMP (°F)	AMBIENT TEMPERATURE (°F)	DAYTIME AMBIENT TEMP (°F)	INCIDENT SOLAR RADIATION (MILLION BTU)*
OCT	68	73	62	34	77	53	62	9.76
NOV	62	75	55	31	70	44	50	7.95
DEC	63	71	54	34	63	35	39	6.28
JAN	63	74	54	28	64	30	35	10.49
FEB	66	76	59	26	67	35	39	9.62
MAR	67	105	59	28	70	41	47	11.38
TOTAL	-	-	-	-	-	-	-	55.48
AVERAGE	65	79	57	30	69	40	45	9.25

* In the south-facing vertical wall of the home, not including the DHW skylight.

stored solar energy during these two months; however, there were some solar contributions from the sunspace.

The maximum building temperature in March was 105°F, which indicates a potential cooling problem which could affect summer comfort in the home. Shading the sunspace is the most obvious method of reducing overheating. This reduction could be accomplished with movable reflective insulation or some type of window blinds.

The site owner reported that the lower floor was cooler than the upper floors; this observation was confirmed by measured temperature data. Three distinct zones were examined during the season, the first (ground) floor, second floor, and the loft area. The first floor (Zone 1) contains the sleeping areas (two bedrooms) and a large recreation and laundry room, bath, and utility room, all located on a slab concrete floor. The lower floors have little direct-gain from the sun; they are solar heated by the lower sections of the Trombe wall. Zone 2 represents the second floor, including the living room and kitchen. Zone 3 contains the loft, storage area, and DHW/sleeping loft above the kitchen.

The following tabulation presents average temperatures in the three zones of the home:

Temperature Regimes

MONTH	ZONE 1 (°F)	ZONE 2 (°F)	ZONE 3 (°F)
OCT	70	74	77
NOV	65	68	71
DEC	61	63	67
JAN	61	63	67
FEB	63	65	68
MAR	65	67	71
AVERAGE	64	67	71

The measured data indicates the thermal stratification, by floors, which the site owner reported. The lower floor (Zone 1) averaged 64°F over the season, while the second floor (Zone 2) averaged 3°F warmer during the season. The upper zone, which was rarely used as a living space, was 7°F higher in average temperature than the lower floor. The natural rise of warmed air, coupled with the large glazing area upstairs for direct-gain, resulted in a much warmer temperature regime in the upper two zones. Much of the forced air heating system was closed off to the upper zones; they required little heat during most of the season. The lower zone was uncomfortably cool during much of the season. The small destagnation fan was rarely used, and the occupant reported that its output and overall effect was minimal. The destagnation duct was designed to collect warmed air from the upper floors and to distribute the warmed air to the lower floor. Its performance was poor due to undersizing.

The net energy savings shown in Table 7 relate the value of the energy savings from heating and hot water contributions to consumption of propane in the auxiliary hot air furnace and water heater. The furnace and heater were assumed to be 60% efficient for savings calculations. Total heating savings were 23.33 million BTU which represents the additional fuel which would have been required under identical loads if the building were not equipped with the solar components. The 23.33 million BTU of heating savings, when added to the 2.13 million BTU of hot water energy savings, becomes 25.46 million BTU. These savings are equivalent to a fuel savings of 278 gallons of liquid propane gas having an average heating value of 91,500 BTU/gallon. It should be noted that the building loss rate would probably be lower if the solar components were not integrated into the structure, so calculated savings would probably be lower. The sunspace and Trombe wall cause significant portions of the overall heat loss since they are highly conductive areas.

Table 7. ENERGY SAVINGS

ENVIRONMENTAL PARTNERSHIP
OCTOBER 1981 THROUGH MARCH 1982

(All values in million BTU)

MONTH	SOLAR ENERGY USED	SPACE HEATING FOSSIL FUEL	HOT WATER FOSSIL FUEL	NET ENERGY SAVINGS FOSSIL FUEL
OCT	3.26	5.03	0.40	5.43
NOV	1.86	2.78	0.32	3.10
DEC	1.00	1.37	0.30	1.67
JAN	0.89	1.13	0.35	1.48
FEB	2.93	4.50	0.38	4.88
MAR	5.34	8.52	0.38	8.90
TOTAL	15.28	23.33	2.13	25.46
AVERAGE	2.55	3.89	0.36	4.24

The weather during the 1981-1982 heating season (Table 8) in Cream Ridge, New Jersey was quite close to expected environmental conditions, with the exception of measured incident solar radiation on the south-facing vertical wall at the home. The measured average ambient temperature was 40°F, as compared to a 41°F expected average. The overall heating degree-days measured 4,521, as compared to an expected number of 4,458. The measured vertical insolation was 599 BTU/ft^2-day, as compared to 928 BTU/ft^2-day of solar radiation expected. The home is situated in a small clearing in the woods, and sunlight is filtered during the winter as it passes through the trees surrounding the home. Performance might be improved if some of the trees were removed; however, this might increase the summer cooling load. No light-blocking overhangs are included in the design, so summer cooling will be a concern at the site. A "whole-house" fan is used to draw cool air into the home and exhaust warm air from the upper floors. Overheating may occur in the sunspace.

Table 8. WEATHER CONDITIONS

ENVIRONMENTAL PARTNERSHIP
OCTOBER 1981 THROUGH MARCH 1982

MONTH	VERTICAL DAILY INCIDENT SOLAR ENERGY PER UNIT AREA (BTU/FT^2-DAY)		HORIZONTAL DAILY INCIDENT SOLAR ENERGY PER UNIT AREA (BTU/FT^2-DAY)		AMBIENT TEMPERATURE (°F)		HEATING DEGREE-DAYS	
	MEASURED	LONG-TERM AVERAGE	MEASURED	LONG-TERM AVERAGE	MEASURED	LONG-TERM AVERAGE	MEASURED	LONG-TERM AVERAGE
OCT	632	1,068	702	951	53	58	322	243
NOV	517	911	462	612	44	46	612	564
DEC	396	762	338	461	35	35	925	946
JAN	661	887	441	557	30	31	1,153	1,042
FEB	671	976	630	796	35	33	814	907
MAR	717	963	870	1,110	41	41	695	756
TOTAL	-	-	-	-	-	-	4,521	4,458
AVERAGE	599	928	573	747	40	41	754	743

1.2 SYSTEM OPERATION

1.2.1 TYPICAL SYSTEM OPERATION

Figures 3a, 3b, and 3c are plots of insolation and temperature data for a typical 24-hour period at Environmental Partnership on February 10, 1982.

Figure 3a represents a plot of three pyranometer readings: from the vertical exterior pyranometer, the horizontal pyranometer, and the interior pyranometer.

The top curve represents the output of the vertical pyranometer. Compare this to the horizontal plot, and note the attenuation at about 1100 hours, and

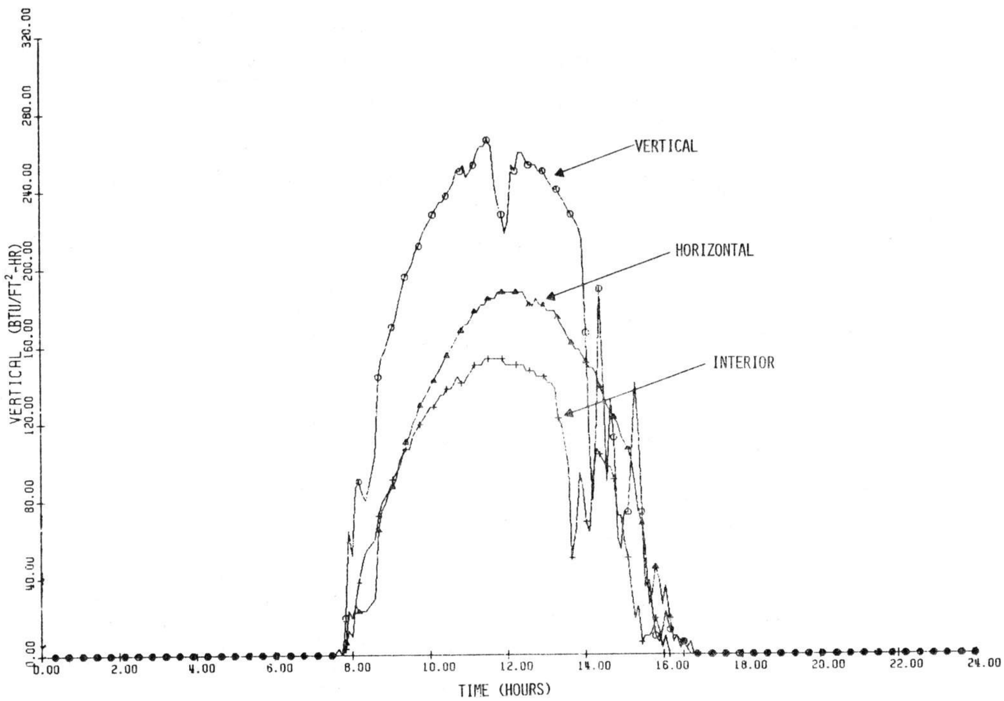

Figure 3a. Typical Insolation Data
Environmental Partnership
February 10, 1982

attenuation in the late afternoon due to trees. During this time, the horizontal radiation was fairly constant.

The interior pyranometer follows the exterior; however, the spike at 1100 hours was not carried through to the interior sensor.

Plot 3b shows the temperature regime at the internal and external temperature sensors on the Trombe wall. The external sensors (T204, T202) rise in temperature from around 60°F to over 100°F in about six hours. The internal sensors, being warmer than the exterior sensors during the evening, indicate heat loss from the wall during the evening. The thermal pulse transmitted from the exterior to the interior peaks about five hours later. This lag time is about right for a one-foot-thick Trombe wall.

The exterior sensors respond quickly to the input of solar radiation, while the interior responds to the pulse of energy flowing through the mass wall. The exterior sensors fall more quickly than the internal sensors, which verify the direction of the calculated losses from the exterior of the wall.

Figure 3c is a plot of three building temperatures and the outside ambient temperature on February 10. Note the following:

- The ambient temperature (T001) is relatively steady, but the minor variations result in a general downward trend over the 24-hour period.

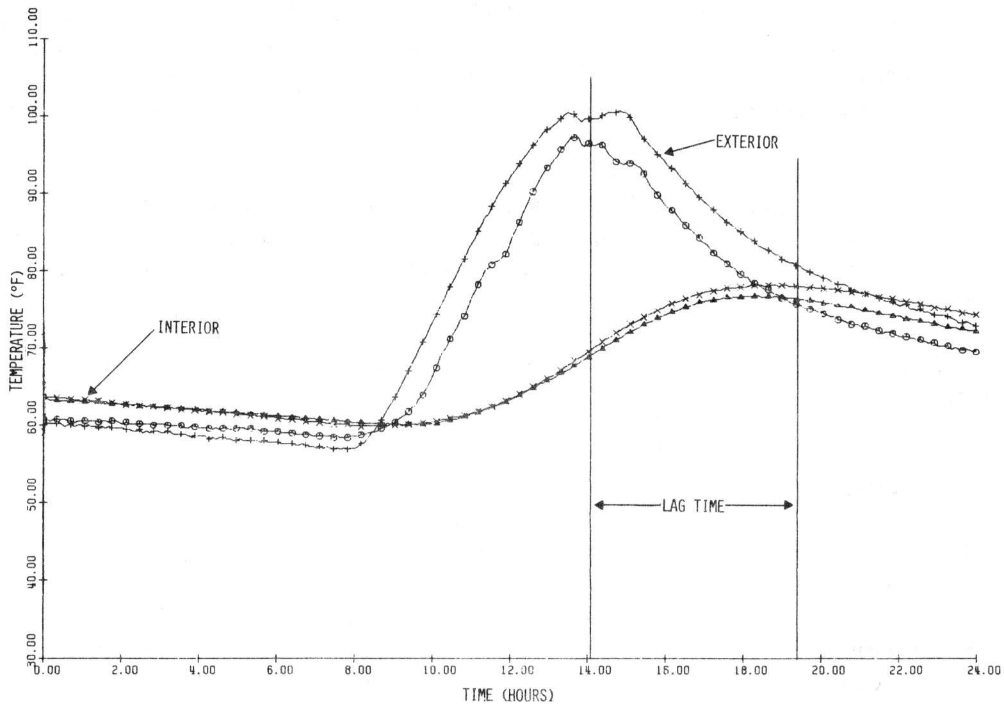

Figure 3b. Typical Trombe Wall Temperatures
Environmental Partnership
February 10, 1982

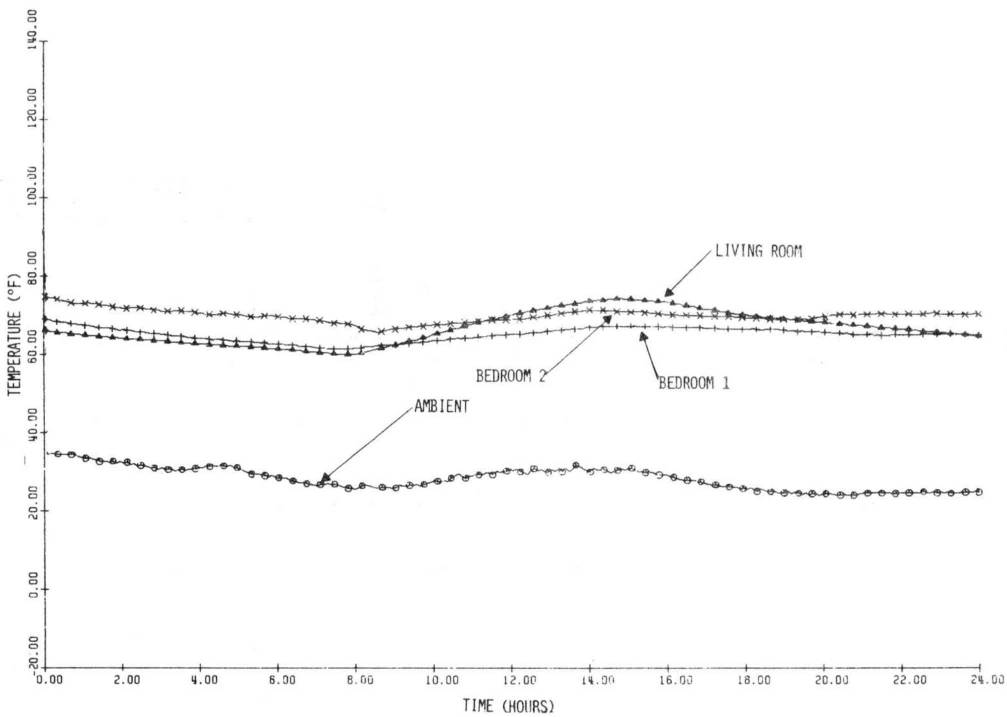

Figure 3c. Typical Temperatures, Indoor/Outdoor
Environmental Partnership
February 10, 1982

- The living room temperature (T407) follows the ambient temperature trace, and exhibits a more rapid rise after 0800 hours than the bedroom temperature sensors, T404 and T405. This rise is due to the closer coupling of this space with the exterior, due to the large window areas in the upper floors.

- The second bedroom (T405) is maintained at a higher temperature than the first bedroom (T404) due to the operation of a portable electric heater. The first bedroom temperature remains fairly steady with time.

- Both bedrooms remain at a steady temperature due to the effect of the mass wall.

1.2.2 SYSTEM OPERATING SEQUENCE

Operation of the dual-fuel wood/propane furnace on February 10, 1982 is shown on the bar chart in Figure 4.

The top bar represents the fan operation (EP400) during the typical 24-hour period. The fan activates at about 1400 hours, and cycles through two half-hour cycles. Gas is consumed at the beginning of each fan operating period to light the wood in the firebox. The furnace activates for a longer time period at 1745 hours; however, only five minutes of propane use occur. The remainder of the heating is due to the combustion of the wood charge.

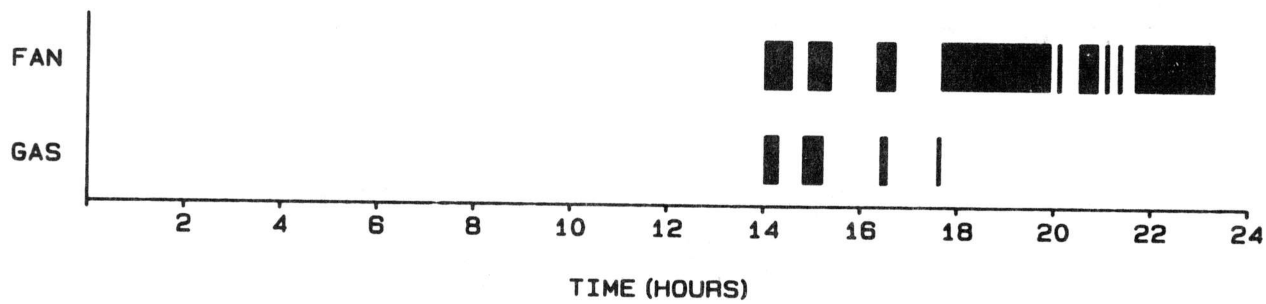

Figure 4. Typical System Operating Sequence
Environmental Partnership
February 10, 1982

SECTION 2

REFERENCES

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2. J. T. Smok, V. S. Sohoni, J. M. Nash, "Processing of Instrumented Data for the National Solar Heating and Cooling Demonstration Program," Conference on Performance Monitoring Techniques for Evaluation of Solar Heating and Cooling Systems, Washington, D.C., April 1978.

3. E. Streed, et al, Thermal Data Requirements and Performance Evaluation Procedures for the National Heating and Cooling Demonstration Program, NBSIR-76-1137, National Bureau of Standards, Washington, D.C., 1976.

4. ASHRAE Standard 93-77, Methods of Testing to Determine the Thermal Performance of Solar Collectors, The American Society of Heating, Refrigeration and Air Conditioning Engineers, Inc., New York, NY, 1977.

*5A. User's Guide to Monthly Performance Report, November 1981, SOLAR/0004-80/18, Vitro Laboratories, Silver Spring, Maryland.

*5B. Instrumentation Installation Guidelines, March 1981, Parts 1, 2, and 3, SOLAR/0001-81/15, Vitro Laboratories, Silver Spring, Maryland.

6. Solar Energy System Performance Evaluation, Environmental Partnership, July 1980 through March 1981, SOLAR/2077-81/14, Vitro Laboratories, Silver Spring, Maryland.

7. Monthly Performance Report, Environmental Partnership, October 1981, Vitro Laboratories, Silver Spring, Maryland.

8. Monthly Performance Report, Environmental Partnership, November 1981, Vitro Laboratories, Silver Spring, Maryland.

9. Monthly Performance Report, Environmental Partnership, December 1981, Vitro Laboratories, Silver Spring, Maryland.

10. Monthly Performance Report, Environmental Partnership, January 1982, Vitro Laboratories, Silver Spring, Maryland.

11. Monthly Performance Report, Environmental Partnership, February 1982, Vitro Laboratories, Silver Spring, Maryland.

12. Monthly Performance Report, Environmental Partnership, March 1982, Vitro Laboratories, Silver Spring, Maryland.

* Copies of these reports may be obtained from Technical Information Center, P.O. Box 62, Oak Ridge, Tennessee 37830.

APPENDIX A-1

SYSTEM DESCRIPTION

The Environmental Partnership site is a two-story single family home located in Cream Ridge, New Jersey, which utilizes a passive solar energy system for space heating and Domestic Hot Water (DHW) preheating.

The 2,050-square-foot home utilizes a 344-square-foot Trombe wall constructed of filled 12-inch concrete blocks, facing south, and glazed with insulated tempered glass. The wall has both interior and exterior vents, which allow energy rejection in the summer and venting of the wall to the interior in the winter, if needed. In addition, a sunspace of 168 square feet of south-facing insulated glass provides direct-gain to the kitchen and loft area. The loft area has 32 PSI Thermol-81 phase-change storage rods for auxiliary storage in the loft area.

Auxiliary thermal energy is provided by a wood-burning stove located in the living room on the second floor. A dual-fuel wood/propane forced-air furnace provides additional auxiliary thermal energy to the home.

A small destagnation fan operates to redistribute collected solar energy from the upstairs to the lower floors.

There is a "breadbox" type solar hot water preheater located in the south roof. A 42-square-foot double-glazed skylight with a concave reflector directly radiates a steel tank coated with a selective surface. The auxiliary hot water heater is propane-fired. The "breadbox" type heater uses no moving parts.

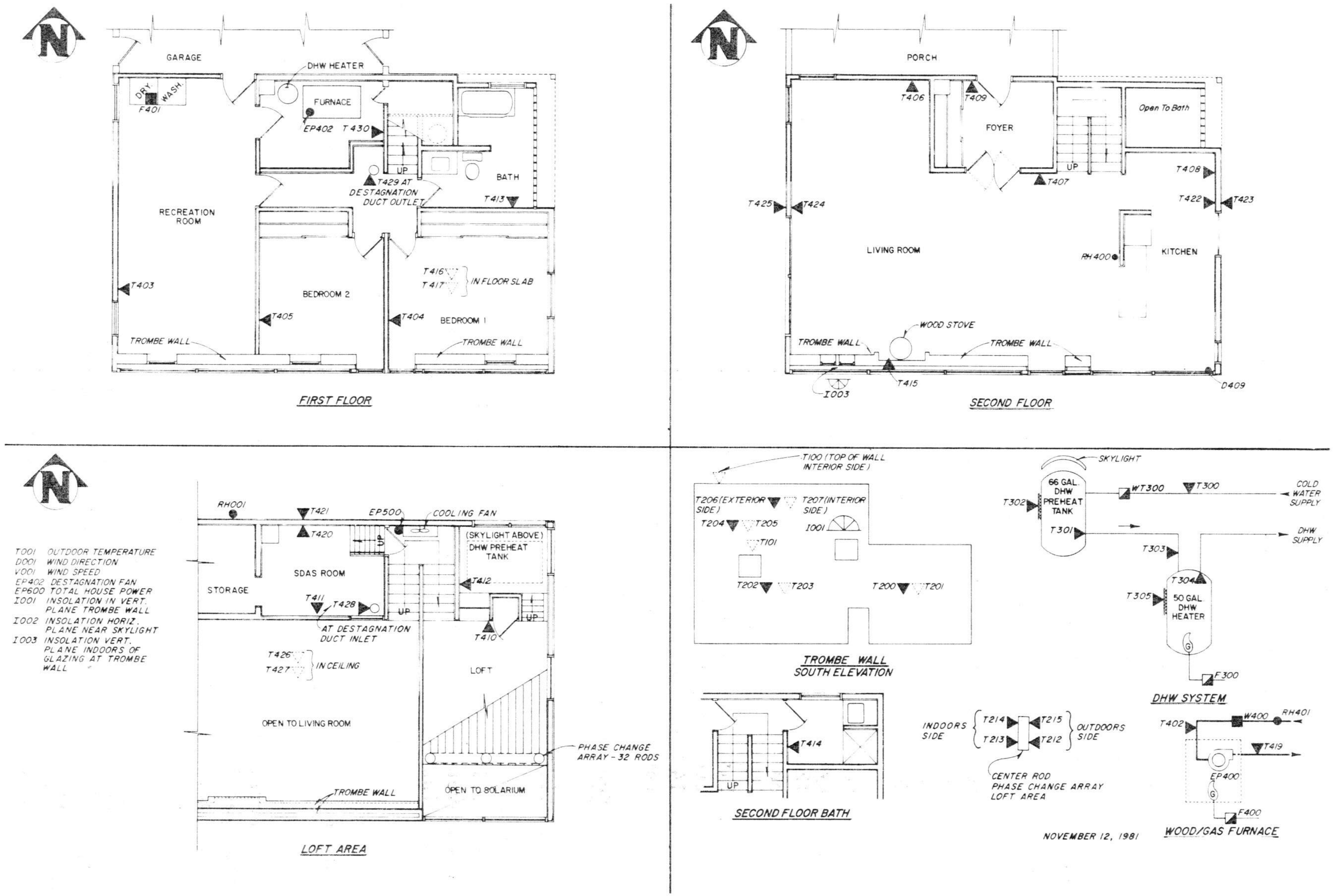

Figure A-1. Environmental Partnership Solar Energy System Schematic

APPENDIX A-2

EQUIPMENT AND SPECIFICATIONS

1. Building

Designer - Kelbaugh and Lee, PA
Princeton, New Jersey

Builder - R. M. Sweeten and Sons

Materials - Wood frame construction, block foundation
1-inch x 6-inch cedar exterior siding
cellulose fiber blown-in insulation
wood sash windows
double-glazed sunspace w/mullions
2-inch x 8-inch floor deck, 2-inch x 6-inch studs,
2-inch x 12-inch joists
yellow pine interior
gypsum board interior
12-inch x 12-inch concrete block Trombe wall, 50,000 lbs. mass
built-up roll roofing

Location - Five-acre wood lot, house on level section
Cream Ridge, New Jersey
14 miles SSE of Trenton, New Jersey
ravine to the west, trees on south side

2. Mechanical Equipment

Auxiliary Furnace

Yukon Husky - LWO 100
Yukon Industries
1880 Como Avenue
St. Paul, Minnesota

Input - 125,000 BTU
Output - 100,000 BTU
Nozzle - Size 90
1/3 hp blower
800 - 1400 cfm flow
24-inch x 16-inch wood chamber

Wood Stove

RAIS 3
RAIS Products, Aps.
Kirkevaenget 15
3450 Allerod, Denmark

Firebrick-lined wrought-iron stove,
top discharge

Windows

Caradco Corp.
Box 920
Rantoul, Illinois

Insulated windows
- casement
- awning
- picture

Selective Film

Berry Solar Film -
selective copper film
Woodbridge at Main
Edison, New Jersey

0.0028 copper film
¼ - ½ hard temper
emissivity at 60°F - 0.01
absorptivity at 60°F - 0.96

Preheat Tank

Stainless steel - custom-built locally

Trombe Wall

approximately 540 square feet
(12-inch x 12-inch x 8-inch)
concrete blocks
filled with mortar
93 pounds/block @ 0.2 BTU/pound°F
344 square feet
top and bottom interior vents
top exterior vent

Thermol Rods

PSI Energy Systems, Inc.
1533 Fen Park Drive
St. Louis, Missouri 63026

32 PSI "Thermol-81" Phase-Change
Storage Rods located in loft
handrail

Sunspace

Size	177.375	square feet
Mullions	4.125	square feet horizontal
	5.450	square feet vertical
Net	167.800	square feet

3. Floor Areas

Room	Approximate Floor Area (Ft^2)	Approximate Volume (Ft^3)
Recreation Room	312	2,496
Bedroom 2	118	1,003
Bedroom 1	148	1,256
Hallway	57	400
Bath	87	759
Living Room	594	5,401
Foyer	82	610
Kitchen	155	1,214
Stairs	29	300
Loft	141	1,198
Sleeping/DHW	46	172
2nd Bath	41	328
SDAS Room	83	493
Storage	100	(sealed)
Stairs	57	(included)
Totals	2,050	15,630

4. U-Values for Wall and Roof Section (from 1977 ASHRAE Fundamentals, Handbook)

(1) Walls - 5-1/2 inches cellulose fiber insulation - 12% framing factor

Component Layer		R Value At Joist	R Value At Wall
0	inside air	0.68	0.68
1	1/2-inch drywall	0.45	0.45
2	5-1/2 inches cellulose	-	17.25
3	stud - 2 inches x 6 inches	6.02	-
4	exterior sheath	0.93	0.93
5	cedar	0.79	0.79
6	outside air	0.17	0.17
Total		9.04	20.27

$U_w = (1/20.27 \times 0.88) + (1/9.04 \times 0.12)$

$U_w = 0.0567$

(2) Roof - 12 inches cellulose fiber insulation - 12% framing factor

Component Layer		R Value At Joist	R Value At Wall
0	inside air	0.17	0.17
1	built-up roof	0.33	0.33
2	3/4-inch ply deck	0.78	0.78
3	12 inches cellulose	-	37.50
4	joist - 2 inches x 12 inches	13.14	-
5	interior pine	0.77	0.77
6	inside air (horizontal)	0.61	0.61
Total		15.80	40.16

$U_c = (1/15.80 \times 0.12) + (1/40.16 \times 0.88)$

$U_c = 0.0288$

APPENDIX B

PERFORMANCE EVALUATION TECHNIQUES

The performance of the Environmental Partnership solar energy system is evaluated by calculating a set of primary performance factors which are based on those in the intergovernmental agency report Thermal Data Requirements and Performance Evaluation Procedures for the National Solar Heating and Cooling Demonstration Program (NBSIR-76/1137).

An overview of the NSDN data collection and dissemination process is shown in Figure B-1.

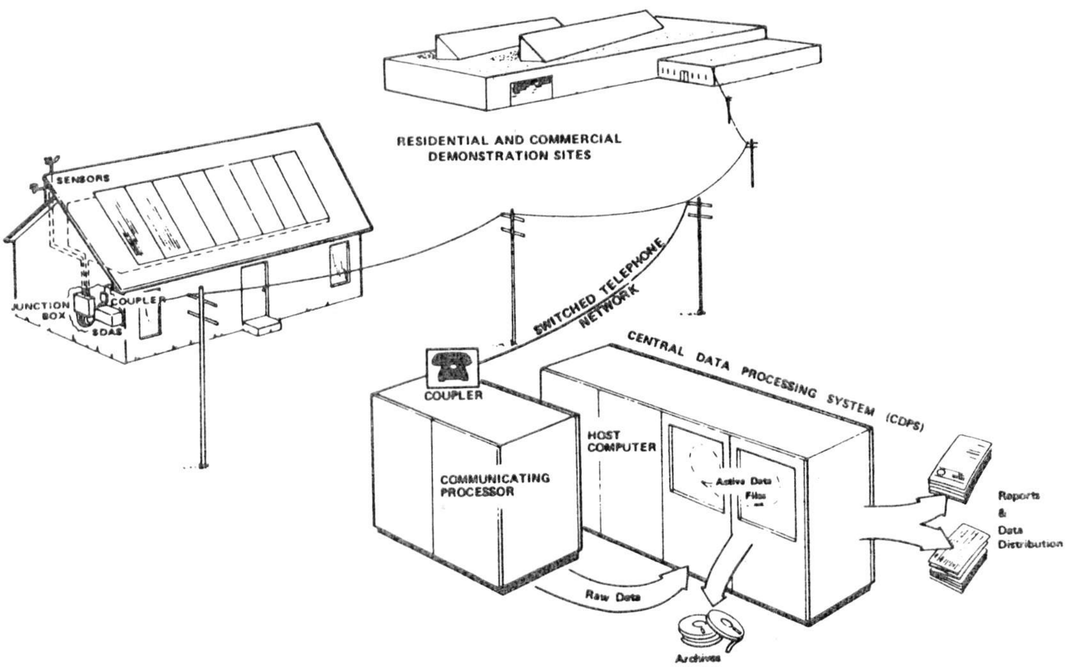

Figure B-1. The National Solar Data Network

DATA COLLECTION AND PROCESSING

Each site contains standard industrial instrumentation modified for the particular site. Sensors measure temperatures, flows, insolation, electric power, fossil fuel usage, and other parameters. These sensors are all wired into a junction box (J-box), which is in turn connected to a microprocessor data logger called the Site Data Acquisition Subsystem (SDAS). The SDAS can read up to 96 different channels, one channel for each sensor. The SDAS takes the analog voltage input to each channel and converts it to a 10-bit word. At intervals of every 320 seconds, the SDAS samples each channel and records the values on a cassette tape. Some of the channels can be sampled 10 times in each 320 second interval, and the average value is recorded in the tape.

Each SDAS is connected through a modem to voice-grade telephone lines which are used to transmit the data to a central computer facility. This facility is the Central Data Processing System (CDPS), located at Vitro Laboratories in Silver Spring, Maryland. The CDPS hardware consists of an IBM System 7, an IBM 370/145, and an IBM 3033. The System 7 periodically calls up each SDAS in the system and has the SDAS transmit the data on the cassette tape back to the System 7. Typically, the System 7 collects data from each SDAS six times a week, although the tape can hold three to five days of data, depending on the number of channels.

The data received by the System 7 are in the form of digital counts in the range of 0-1023. These counts are then processed by software in the CDPS, where they are converted from counts to engineering units (EU) by applying appropriate calibration constants. The engineering unit data called "detailed measurements" in the software are then tabulated on a daily basis for the site analyst. The CDPS is also capable of transforming this data into plots, graphs, and processed reports.

Solar system performance reports present system parameters as monthly values. If some of the data during the month is not collected due to solar system instrumentation system, or data acquisition problems, or if some of the collected data is invalid, then the collected valid data is extrapolated to provide the monthly performance estimates. Researchers and other users who require unextrapolated, "raw" data may obtain data by contacting Vitro Laboratories.

DATA ANALYSIS

The analyst develops a unique set of "site equations" (given in Appendix D) for each site in the NSDN, following the guidelines presented herein.

The equations calculate the flow of energy through the system, including solar energy, auxiliary energy, and losses. These equations are programmed in PL/1 and become part of the Central Data Processing System. The PL/1 program for each site is termed the site software. The site software processes the detailed data, using as input a "measurement record" containing the data for each scan interval. The site software produces as output a set of performance factors; on an hourly, daily, and monthly basis.

These performance factors (Appendix C) quantify the thermal performance of the system by computing energy flows throughout the various subsystems. The system performance may then be evaluated based on the efficiency of the system in transferring these energies.

Performance factors which are considered to be of primary importance are those which are essential for system evaluation. Without these primary performance factors (which are denoted by an asterisk in Appendix C), comparative evaluation of the wide variety of solar energy systems would be impossible. An example of a primary performance factor is SECA - Solar Energy Collected by the Array. This is quite obviously a key parameter in system analysis.

Secondary performance factors are data deemed important and useful in comparison and evaluation of solar systems, particularly with respect to component interactions and simulation. In most cases these secondary performance factors are computed as functions of primary performance factors.

There are irregularly occurring cases of missing data as is normal for any real time data collection from mechanical equipment. When data for individual scans or whole hours are missing, values of performance factors are assigned which are interpolated from measured data. If no valid measured data are available for interpolation, a zero value is assigned. If data are missing for a whole day, each hour is interpolated separately. Data are interpolated in order to provide solar system performance factors on a whole hour, whole day and whole month basis for use by architects and designers.

REPORTING

The performance of the Environmental Partnership solar energy system from October 1981 through March 1982 was analyzed and Monthly Performance Reports were prepared. See the following page for a list of these reports.

In addition, data are included in this report which are not in Monthly Performance Reports.

OTHER DATA REPORTS ON THIS SITE

Monthly Performance Reports:

July 1981
August 1981
September 1981
October 1981
November 1981
December 1981
January 1982
February 1982
March 1982

APPENDIX C

PERFORMANCE FACTORS AND SOLAR TERMS

The performance factors identified in the site equations (Appendix D) by the use of acronyms or symbols are defined in this Appendix in Section 1. Section 1 includes the acronym, the actual name of the performance factor, and a short definition.

Section 2 contains a glossary of solar terminology, in alphabetical order. These terms are included for quick reference by the reader.

Section 3 describes general acronyms used in this report.

SECTION 1. PERFORMANCE FACTOR DEFINITIONS AND ACRONYMS

ACRONYM	NAME	DEFINITION
AXE	Auxiliary Electric Fuel Energy to Load Subsystem	Amount of electrical energy required as a fuel source for all load subsystems.
AXF	Auxiliary Fossil Fuel Energy to Load Subsystem	Amount of fossil energy required as a fuel source for all load subsystems.
* AXT	Auxiliary Thermal Energy to Load Subsystems	Thermal energy delivered to all load subsystems to support a portion of the subsystem loads, from all auxiliary sources.
CAE	SCS Auxiliary Electrical Fuel Energy	Amount of electrical energy provided to the SCS to be converted and applied to the SCS load.
CAF	SCS Auxiliary Fossil Fuel Energy	Amount of fossil energy provided to the SCS to be converted and applied to the SCS load.
CAT	SCS Auxiliary Thermal Energy	Amount of energy provided to the SCS by a BTU heat transfer fluid from an auxiliary source.
* CL	Space Cooling Subsystem Load	Energy required to satisfy the temperature control demands of the space cooling subsystem.
CLAREA	Collector Array Area	The gross area of one collector panel multiplied by the number of panels in the array.
CLEF	Collector Array Efficiency	Ratio of the collected solar energy to the incident solar energy.
COPE	SCS Operating Energy	Amount of energy required to support the SCS operation which is not intended to be applied directly to the SCS load.
CSAUX	Auxiliary Energy to ECSS	Amount of auxiliary energy supplied to the ECSS.
* CSCEF	ECSS Solar Conversion Efficiency	Ratio of the solar energy supplied from the ECSS to the load subsystems to the incident solar energy on the collector array.

* Primary Performance Factors

ACRONYM	NAME	DEFINITION
CSE	Solar Energy to SCS	Amount of solar energy delivered to the SCS.
CSEO	Energy Delivered from ECSS to Load Subsystems	Amount of energy supplied from the ECSS to the load subsystems (including any auxiliary energy supplied to the ECSS).
* CSFR	SCS Solar Fraction	Portion of the SCS load which is supported by solar energy.
CSOPE	ECSS Operating Energy	Amount of energy used to support the ECSS operation (which is not intended to be supplied to the ECSS thermal state).
CSRJE	ECSS Rejected Energy	Amount of energy intentionally rejected or dumped from the ECSS subsystem.
* CSVE	SCS Electrical Energy Savings	Difference in the electrical energy required to support an assumed similar conventional SCS and the actual electrical energy required to support the demonstration SCS, for identical SCS loads.
* CSVF	SCS Fossil Energy Savings	Difference in the fossil energy required to support an assumed similar conventional SCS and the actual fossil energy required to support the demonstration SCS, for identical loads.
HAE	SHS Auxiliary Electrical Fuel Energy	Amount of electrical energy provided to the SHS to be converted and applied to the SHS load.
HAF	SHS Auxiliary Fossil Fuel Energy	Amount of fossil energy provided to the SHS to be converted and applied to the SHS load.
HAT	SHS Auxiliary Thermal Energy	Amount of energy provided to the SHS by a heat transfer fluid from an auxiliary source.
* HL	Space Heating Subsystem Load	Energy required to satisfy the temperature control demands of the space heating subsystem.

* Primary Performance Factors

ACRONYM	NAME	DEFINITION
HOPE	SHS Operating Energy	Amount of energy required to support the SHS operation (which is not intended to be applied directly to the SHS load).
HOURCT	Record Time	Count of hours elapsed from the start of 1977.
* HSFR	SHS Solar Fraction	Portion of the SHS load which is supported by solar energy.
HSE	Solar Energy to SHS	Amount of solar energy delivered to the SHS.
* HSVE	SHS Electrical Energy Savings	Difference in the electrical energy required to support an assumed similar conventional SHS and the actual electrical energy required to support the demonstration SHS, for identical SHS loads.
* HSVF	SHS Fossil Energy Savings	Difference in the fossil energy required to support an assumed similar conventional SHS and the actual fossil energy required to support the demonstration SHS, for identical SHS loads.
HWAE	HWS Auxiliary Electrical Fuel Energy	Amount of electrical energy provided to the HWS to be converted and applied to the HWS load.
HWAF	HWS Auxiliary Fossil Fuel Energy	Amount of fossil energy provided to the HWS to be converted and applied to the HWS load.
HWAT	HWS Auxiliary Thermal Energy	Amount of energy provided to the HWS by a heat transfer fluid from an auxiliary source.
HWCSM	Service Hot Water Consumption	Amount of heated water delivered to the load from the hot water subsystem.
* HWL	Hot Water Subsystem Load	Amount of energy supplied to the HWS.
* HWDM	Hot Water Demand	Energy required to satisfy the temperature control demands of the building service hot water system.

* Primary Performance Factors

ACRONYM	NAME	DEFINITION
HWOPE	HWS Operating Energy	Amount of energy required to support the HWS operation which is not intended to be applied directly to the HWS load.
HWSE	Solar Energy to HWS	Amount of solar energy delivered to the HWS.
* HWSFR	HWS Solar Fraction	Portion of the HWS load which is supported by solar energy.
* HWSVE	HWS Electrical Energy Savings	Difference in the electrical energy required to support an assumed similar conventional HWS and the actual electrical energy required to support the demonstration HWS, for identical HWS loads.
* HWSVF	HWS Fossil Energy Savings	Difference in the fossil energy required to support an assumed similar conventional HWS and the actual fossil energy required to support the demonstration HWS, for identical loads.
RELH	Relative Humidity	Average outdoor relative humidity at the site.
* SE	Incident Solar Energy	Amount of solar energy incident upon one square foot of the collector plane.
SEA	Incident Solar Energy on Array	Amount of solar energy incident upon the collector array.
* SEC	Collector Solar Energy	Amount of thermal energy added to the heat transfer fluid for each square foot of the collector area.
* SECA	Collected Solar Energy by Array	Amount of thermal energy added to the heat transfer fluid by the collector array.
SEDF	Diffuse Insolation	Amount of diffuse solar energy incident upon one square foot of a collector plane.
SEOP	Operational Incident Solar Energy	Amount of incident solar energy upon the collector array whenever the collector loop is active.

* Primary Performance Factors

ACRONYM	NAME	DEFINITION
* SEL	Solar Energy to Load Subsystems	Amount of solar energy supplied by the ECSS to all load subsystems.
* SFR	Solar Fraction of System Load	Portion of the system load which was supported by solar energy.
STECH	Change in ECSS Stored Energy	Change in ECSS stored energy during reference time period.
STEFF	ECSS Storage Efficiency	Ratio of the sum of energy supplied by ECSS storage and the change in ECSS stored energy to the energy delivered to the ECSS storage.
STEI	Energy Delivered to ECSS Storage	Amount of energy delivered to ECSS storage by the collector array and from auxiliary sources.
STEO	Energy Supplied by ECSS Storage	Amount of energy supplied by ECSS storage to the load subsystems.
STOCAP	Storage Tank Capacity	Volume of storage tank in gallons.
* SYSL	System Load	Energy required to satisfy all desired temperature control demands at the output of all subsystems.
* SYSOPE	System Operating Energy	Amount of energy required to support the system operation, including all subsystems, which is not intended to be applied directly to the system load.
* SYSPF	System Performance Factor	Ratio of the system load to the total equivalent fossil energy expended or required to support the system load.
* TA	Ambient Temperature	Average temperature of the ambient air.
* TB	Building Temperature	Average temperature of the controlled space of the building.
TCECOP	TCE Coefficient of Performance	Coefficient of performance of the thermodynamic conversion equipment.
TCEI	TCE Thermal Input Energy	Equivalent thermal energy which is supplied as a fuel source to thermodynamic conversion equipment.

* Primary Performance Factors

ACRONYM	NAME	DEFINITION
TCEL	Thermodynamic Conversion Equipment Load	Controlled energy output of thermodynamic conversion equipment.
TCEOPE	TCE Operating Energy	Amount of energy required to support the operation of thermodynamic conversion equipment which is not intended to appear directly in the load.
TCERJE	TCE Reject Energy	Amount of energy intentionally rejected or dumped from thermodynamic conversion equipment as a by-product or consequence of its principal operation.
TDA	Daytime Average Ambient Temperature	Average temperature of the ambient air during the daytime (during normal collector operation period).
* TECSM	Total Energy Consumed by System	Amount of energy demand of the system from external sources; sum of all fuels, operating energies, and collected solar energy.
THW	Service Hot Water Temperature	Average temperature of the service hot water supplied by the system.
TST	ECSS Storage Temperature	Average temperature of the ECSS storage medium.
* TSVE	Total Electrical Energy Savings	Difference in the estimated electrical energy required to support an assumed similar conventional system and the actual electrical energy required to support the system, for identical loads; sum of electrical energy savings for all subsystems.
* TSVF	Total Fossil Energy Savings	Difference in the estimated fossil energy required to support an assumed similar conventional system and the actual fossil energy required to support the system, for identical loads; sum of fossil energy savings of all subsystems.
TSW	Supply Water Temperature	Average temperature of the supply water to the hot water subsystem.

* Primary Performance Factors

ACRONYM	NAME	DEFINITION
WDIR	Wind Direction	Average wind direction at the site.
WIND	Wind Velocity	Average wind velocity at the site.

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* Primary Performance Factors

SECTION 2. SOLAR TERMINOLOGY

Absorptivity	The ratio of absorbed radiation by a surface to the total incident radiated energy on that surface.
Active Solar System	A system in which a transfer fluid (liquid or air) is circulated through a solar collector where the collected energy is converted, or transferred, to energy in the medium.
Air Conditioning	Popularly defined as space cooling, more precisely, the process of treating indoor air by controlling the temperature, humidity and distribution to maintain specified comfort conditions.
Ambient Temperature	The surrounding air temperature.
Auxiliary Energy	In solar energy technology, the energy supplied to the heat or cooling load from other than the solar source, usually from a conventional heating or cooling system. Excluded are operating energy, and energy which may be supplemented in nature but does not have the auxiliary system as an origin, i.e., energy supplied to the space heating load from the external ambient environment by a heat pump. The electric energy input to a heat pump is defined as operating energy.
Auxiliary Energy Subsystem	In solar energy technology the Auxiliary Energy System is the conventional heating and/or cooling equipment used as supplemental or backup to the solar system.
Array	An assembly of a number of collector elements, or panels, into the solar collector for a solar energy system.
Backflow	Reverse flow.
Backflow Preventer	A valve or damper installed to prevent reverse flow.
Beam Radiation	Radiated energy received directly, not from scattering or reflecting sources.
Collected Solar Energy	The thermal energy added to the heat transfer fluid by the solar collector.

Collector Array Efficiency	Same as Collector Conversion Efficiency. Ratio of the collected solar energy to the incident solar energy. (See also Operational Collector Efficiency.)
Collector Subsystem	The assembly of components that absorbs incident solar energy and transfers the absorbed thermal energy to a heat transfer fluid.
Concentrating Solar Collector	A solar collector that concentrates the energy from a larger area onto an absorbing element of smaller area.
Conversion Efficiency	Ratio of thermal energy output to solar energy incident on the collector array.
Conditioned Space	The space in a building in which the air is heated or cooled to maintain a desired temperature range.
Control System or Subsystem	The assembly of electric, pneumatic, or hydraulic, sensing, and actuating devices used to control the operating equipment in a system.
Controlled Delivered Energy	The heating load derived from the summation of measured solar and auxiliary components.
Cooling Degree-Days	The sum over a specified period of time of the number of degrees the average daily temperature is above 65°F.
Cooling Tower	A heat exchanger that transfers waste heat to outside ambient air.
Diffuse Radiation	Solar Radiation which is scattered by air molecules, dust, or water droplets and incapable of being focused.
Drain Down	An arrangement of sensors, valves and actuators to automatically drain the solar collectors and collector piping to prevent freezing in the event of cold weather.
Duct Heating Coil	A liquid-to-air heat exchanger in the duct distribution system.
Effective Heat Transfer Coefficient	The heat transfer coefficient, per unit plate area of a collector, which is a measure of the total heat losses per unit area from all sides, top, back, and edges.
Energy Gain	The thermal energy gained by the collector transfer fluid. The thermal energy output of the collector.

Energy Savings	The estimated difference between the fossil and/or electrical energy requirements of an assumed conventional system (carrying the full measured load) and the actual electrical and/or fossil energy requirements of the installed solar-assisted system.
Expansion Tank	A tank with a confined volume of air (or gas) whose inlet port is open to the system heat transfer fluid. The pressure and volume of the confined air varies as the system heat transfer fluid expands and contracts to prevent excessive pressure from developing and causing damage.
F-Curve	The collector instantaneous efficiency curve. Used in the "F-curve" procedure for collector analysis (see Instantaneous Efficiency).
Fixed Collector	A solar collector that is fixed in position and cannot be rotated to follow the sun daily or seasonably.
Flat-Plate Collector	A solar energy collecting device consisting of a relatively thin panel of absorbing material. A container with insulated bottom and sides and covered with one or more covers transparent to visible solar energy and relatively opaque to infrared energy. Visible energy from the sun enters through the transparent cover and raises the temperature of the absorbing panel. The infrared energy re-radiated from the panel is trapped within the collector because it cannot pass through the cover. Glass is an effective cover material (see Selective Surface).
Focusing Collector	A concentrating type collector using parabolic mirrors or optical lenses to focus the energy from a large area onto a small absorbing area.
Fossil Fuel	Petroleum, coal, and natural gas derived fuels.
Glazing	In solar/energy technology, the transparent covers used to reduce energy losses from a collector panel.

Heat Exchanger — A device used to transfer energy from one heat transfer fluid to another while maintaining physical segregation of the fluids. Normally used in systems to provide an interface between two different heat transfer fluids.

Heat Transfer Fluid — The fluid circulated through a heat source (solar collector) or heat exchanger that transports the thermal energy by virtue of its temperature.

Heating Degree-Days — The sum over a specified period of time of the number of degrees the average daily temperature is below 65°F.

Instantaneous Efficiency — The efficiency of a solar collector at one operating point, $\frac{Ti-Ta}{I}$, under steady state conditions (see Operating Point).

Instantaneous Efficiency Curve — A plot of solar collector efficiency against operating point, $\frac{Ti-Ta}{I}$ (see Operating Point).

Incidence Angle — The angle between the line to a radiating source (the sun) and a line normal to the plane of the surface being irradiated.

Incident Solar Energy — The amount of solar energy irradiating a surface taking into account the angle of incidence. The effective area receiving energy is the product of the area of the surface times the cosine of the angle of incidence.

Insolation — Incoming solar radiation.

Load — That to which energy is supplied, such as space heating load or cooling load. The system load is the total solar and auxiliary energy required to satisfy the required heating or cooling.

Manifold — The piping that distributes the transport fluid to and from the individual panels of a collector array.

Microclimate — Highly localized weather features which may differ from long-term regional values due to the interaction of the local surface with the atmosphere.

Nocturnal Radiation	The loss of thermal energy by the solar collector to the night sky.
Operating Energy	The amount of energy (usually electrical energy) required to operate the solar and auxiliary equipments and to transport the thermal energy to the point of use, and which is not intended to directly affect the thermal state of the system.
Operating Point	A solar energy system has a dynamic operating range due to changes in level of insolation (I), fluid input temperature (T), and outside ambient temperature (Ta). The operating point is defined as: $\frac{Ti-Ta}{I} \left(\frac{°F \times hr. \times sq. ft.}{BTU}\right)$
Operational Collector Efficiency	Ratio of collected solar energy to incident solar energy <u>only during the time the collector fluid is being circulated with the intention of delivering solar-source energy to the system</u>.
Outgassing	The emission of gas by materials and components, usually during exposure to elevated temperature, or reduced pressure.
Passive Solar System	A system which uses architectural components of the building to collect, distribute, and store solar energy.
Pebble Bed (Rock Bed)	A space filled with uniform-sized pebbles to store solar-source energy by raising the temperature of the pebbles.
Reflected Radiation	Insolation reflected from a surface, such as the ground or a reflecting element onto the solar collector.
Rejected Energy	Energy intentionally rejected, dissipated, or dumped from the solar system.
Retrofit	The addition of a solar energy system to an existing structure.
Selective Surface	A surface that has the ability to readily absorb solar radiation, but re-radiates little of it as thermal radiation.

Sensor	A device used to monitor a physical parameter in a system, such as temperature or flow rate, for the purpose of measurement or control.
Solar Conditioned Space	The area in a building that depends on solar energy to provide a fraction of the heating and cooling needs.
Solar Contribution of Load	The portion of total load actually met by solar energy.
Solar Fraction	The fraction of the total load supplied by solar energy. The ratio of solar energy supplied to loads divided by total load. Often expressed as a percentage.
Solar Savings Ratio	The ratio of the solar energy supplied to the load minus the solar system operating energy, divided by the system load.
Solar-Unique Operating Energy	Operating energy which is expended on the solar system.
Storage Efficiency, N_s	Measure of effectiveness of transfer of energy through the storage subsystem taking into account system losses.
Storage Subsystem	The assembly of components used to store solar-source energy for use during periods of low insolation.
Stratification	A phenomenon that causes a distinct thermal gradient in a heat transfer fluid, in contrast to a thermally homogeneous fluid. Results in the layering of the heat transfer fluid, with each layer at a different temperature. In solar energy systems, stratification can occur in liquid storage tanks or rock beds, and may even occur in pipes and ducts. The temperature gradient or layering may occur in a horizontal, vertical or radial direction.
System Performance Factor	Ratio of system load to the total equivalent fossil energy expended or required to support the system load.
Ton of Refrigeration	The heat equivalent to the melting of one ton (2,000 pounds) of ice at 32°F in 24 hours. A ton of refrigeration will absorb 12,000 BTU/hr, or 288,000 BTU/day.
Tracking Collector	A solar collector that moves to point in the direction of the sun.
Zone	A portion of a conditioned space that is controlled to meet heating or cooling requirements separately from the other space or other zones.

SECTION 3. GENERAL ACRONYMS

ASHRAE	American Society of Heating, Refrigeration, and Air Conditioning Engineering.
BTU	British Thermal Unit, a measure of heat energy. The quantity of heat required to raise the temperature of one pound of pure water one Fahrenheit degree. One BTU is equivalent to 2.932 x 10^{-4} kwh of electrical energy.
COP	Coefficient of Performance. The ratio of total load to solar-source energy.
DHW	Domestic Hot Water.
ECSS	Energy Collection and Storage System.
HWS	Domestic or Service Hot Water Subsystem.
KWH	Kilowatt Hours, a measure of electrical energy. The product of kilowatts of electrical power applied to a load times the hours it is applied. One kwh is equivalent to 3,413 BTU of heat energy.
NSDN	National Solar Data Network.
SCS	Space Cooling Subsystem.
SHS	Space Heating Subsystem.
SOLMET	Solar Radiation/Meteorology Data.

APPENDIX D

PERFORMANCE EQUATIONS

ENVIRONMENTAL PARTNERSHIP

INTRODUCTION

Solar energy system performance is evaluated by performing energy balance computations on the system and its major subsystems. These calculations are based on physical measurement data taken from each sensor every 320 seconds.* This data is then mathematically combined to determine the hourly, daily, and monthly performance of the system. This appendix describes the general computational methods and the specific energy balance equations used for this site.

Data samples from the system measurements are integrated to provide discrete approximations of the continuous functions which characterize the system's dynamic behavior. This integration is performed by summation of the product of the measured rate of the appropriate performance parameters and the sampling interval over the total time period of interest.

There are several general forms of integration equations which are applied to each site. These general forms are exemplified as follows: the total solar energy available to the collector array is given by

$$\text{SOLAR ENERGY AVAILABLE} = (1/60)\ \Sigma\ [\text{I001} \times \text{CLAREA}] \times \Delta\tau$$

where I001 is the solar radiation measurement provided by the pyranometer in BTU per square foot per hour, CLAREA is the area of the collector array in square feet, $\Delta\tau$ is the sampling interval in minutes, and the factor (1/60) is included to convert the solar radiation "rate" to the proper units of time.

Similarly, the energy flow within a system is given typically by

$$\text{COLLECTED SOLAR ENERGY} = \Sigma\ [\text{M100} \times \Delta H] \times \Delta\tau$$

where M100 is the mass flow rate of the heat transfer fluid in lb_m/min and ΔH is the enthalpy change, in BTU/lb_m, of the fluid as it passes through the heat exchanging component.

For a liquid system ΔH is generally given by

$$\Delta H = \bar{C}_p\ \Delta T$$

where $\bar{C}_p$ is the average specific heat, in BTU/lb_m-°F, of the heat transfer fluid and ΔT, in °F, is the temperature differential across the heat exchanging component.

* See Appendix B.

For an air system ΔH is generally given by

$$\Delta H = H_a(T_{out}) - H_a(T_{in})$$

where $H_a(T)$ is the enthalpy, in BTU/lb_m, of the transport air evaluated at the inlet and outlet temperatures of the heat exchanging component.

$H_a(T)$ can have various forms, depending on whether or not the humidity ratio of the transport air remains constant as it passes through the heat exchanging component.

For electrical power, a general example is

$$\text{ECSS OPERATING ENERGY} = (3413/60)\ \Sigma\ [\text{EP100}] \times \Delta\tau$$

where EP100 is the power required by electrical equipment in kilowatts and the two factors (1/60) and 3413 convert the data to BTU/min.

<u>Letter Designations</u>

C or CP	=	Specific Heat
D	=	Direction or Position
DS	=	Discrete Switch Position
EE	=	Electric Energy
EP	=	Electric Power
ET	=	Elapsed Time of Operation
F	=	Fuel Flow Rate
H	=	Enthalpy
HR	=	Humidity Ratio
HWD	=	Functional procedure to calculate the enthalpy change of water at the average of the inlet and outlet temperatures
I	=	Incident Solar Flux (Insolation)
M	=	Mass Flow Rate
N	=	Performance Parameter
P	=	Pressure
PD	=	Differential Pressure
Q	=	Thermal Energy
RHO	=	Density
T	=	Temperature
TD	=	Differential Temperature
V	=	Velocity
W	=	Heat Transport Medium Volume Flow Rate
WT	=	Total Volume Flow
TI	=	Time
_P	=	Appended to a function designator to signify the value of the function during the previous iteration

Subsystem Designations Number Sequence	Subsystem/Data Group
001 to 099	Climatological
100 to 199	Collector and Heat Transport
200 to 299	Thermal Storage
300 to 399	Hot Water
400 to 499	Space Heating
500 to 599	Space Cooling
600 to 699	Building/Load

EQUATIONS USED TO GENERATE MONTHLY PERFORMANCE VALUES

SCAN LEVEL

AVERAGE AMBIENT TEMPERATURE (^{o}F)

TA = T001/60

AVERAGE BUILDING TEMPERATURE (^{o}F)

TB1 = (T403 + T404 + T405 + T406 + T407 + T408 + T409 + T410 + T411 + T412 + T413 + T414)/12

TB = TB1/60

AVERAGE RELATIVE HUMIDITY (%)

RELH = RH001 x (1/60)

RELHION = RH400 x (1/60)

DAYTIME AVERAGE TEMPERATURE (^{o}F)

TDA = T001 x (1/360) ± 3 hours from solar noon

TIME OF DAY - BUILDING TEMPERATURES (^{o}F)

TMID = TB 12 hours from solar noon

T6AM = TB 6 hours from solar noon

TNOON = TB at solar noon

T6PM = TB 6 hours after solar noon

ZONE 1 TEMPERATURE (^oF)

$TZONE1 = (T403 + T404 + T405 + T413)/4 \times (1/60)$

ZONE 2 TEMPERATURE (^oF)

$TZONE2 = (T414 + T406 + T407 + T408 + T409)/5 \times (1/60)$

ZONE 3 TEMPERATURE (^oF)

$TZONE3 = (T410 + T411 + T412)/3 \times (1/60)$

TST-WALL - TROMBE WALL TEMPERATURES (^oF)

TST-WALL = (T200 + T201 + T202 + T203 + T204 + T205 + T206 + T207)/8 x (1/60)

TST-ROD - PSI ROD TEMPERATURES (^oF)

TST-ROD = (T214 + T213 + T212 + T215)/4 x (1/60)

TST-SLAB - CONCRETE FLOOR TEMPERATURES (^oF)

TST-SLAB = (T416 + T417)/2 x (1/60)

TST - STORAGE TEMPERATURE (^oF)

TST = TST-WALL

VERTICAL INCIDENT SOLAR RADIATION (BTU/ft^2-hr)

SE = I001/60

HORIZONTAL INCIDENT SOLAR RADIATION (BTU/ft^2-hr)

SE1 = I002/60

INTERIOR SOLAR RADIATION (BTU/ft^2-hr)

SE2 = I003/60

SECA-SS - COLLECTED ENERGY FROM SUNSPACE (BTU)

SECA-SS = I003 x CLAREA3 x ABSORP x 1/60

where ABSORP = 1.0

SECAMP - MEASURED ENERGY TRANSMITTED (BTU)

SECAMP = I003 x (CLAREA1 + CLAREA3) x 1/60

OTHER -- TOTAL HOUSE POWER (BTU)

OTHER = EP600 x EPCONST

TRANS - SOLAR ENERGY TRANSMITTED

TRANS = SE2/SE

HRF - AIR MASS CALCULATION

HRF = 0.244 + (0.444 x HR) where HR is a SUBROUTINE which calculates the humidity ratio

HATF - FURNACE ENERGY OUTPUT

if EP400 > 0.2

then HATF = M400 x HRF x (T419 - T402)

HEAT LOSSES

NORTH WALL OF RECREATION ROOM

HL-N-REC = N-AREA-REC x U-N-REC x (T403 - T001)/60

NORTH WALL OF EQUIPMENT ROOM

HL-N-EQUIP = N-AREA-EQUIP x U-N-EQUIP x (T430 - T001)/60

FOYER

HL-N-FOY = N-AREA-FOY x U-N-FOY x (T413 - T001)/60

NORTH WALL OF BATH1 PLUS GLASS BLOCK

HL-N-BA1 = ((N-AREA-BA1 x U-N-BA1 x (T413 - T001)) + (N-WIND-BA1 x UGLASS x (T413 - T001)) x 1/60

WEST LIVING ROOM NORTH WALL

HL-N-WLR = N-AREA-WLR x U-N-WLR x (T406 - T001) x 1/60

STAIR NORTH WALL

HL-N-STAIR = U-N-STAIR x N-AREA-STAIR x (T428 - T001) x 1/60

SDAS ROOM NORTH

HL-N-SDAS = U-N-SDAS x N-AREA-SDAS x (T411 - T001) x 1/60

PREHEAT LOFT NORTH

NL-N-PRE = (N-AREA-PRE x U-N-PRE + N-WIND-PRE x UGLASS) x (T412 - T001) x 1/60

SECOND FLOOR BATHROOM - NORTH

HL-N-BA2 = (N-AREA-BA2 x U-N-BA2 + N-WIND-BA2 x UGLASS) x (414 - T001) x 1/60

SECOND FLOOR BATHROOM - EAST

HL-E-BA2 = U-E-BA2 x E-AREA-BA2 x (T414 - T001) x 1/60

EAST BEDROOM

HL-E-BR1 = ((U-E-BR1 x E-AREA-BA1) + (E-WIND-BR1 x UGLASS)) x (T408 - T001) x 1/60

KITCHEN EAST WALL

HL-E-KIT = ((U-E-KIT x E-AREA-KIT) + (E-WIND-KIT x UGLASS)) x (T408 - T001) x 1/60

EAST PREHEAT LOFT WALL

HL-E-PRE = ((U-E-PRE x E-AREA-PRE) + (E-WIND-LOFT x UGLASS)) x (T410 - T001) x 1/60

LOFT EAST WALL

HL-E-LOF = ((U-E-LOF x E-AREA-LOFT) + (E-WIND-LOFT x UGLASS)) x (T410 - T001) x 1/60

RECREATION ROOM WEST WALL

HL-W-REC = ((U-W-REC x W-AREA-REC) + (W-WIND-REC x UGLASS)) x (T403 - T001) x 1/60

WEST LIVING ROOM

HL-W-LR = (U-W-LR x W-AREA-LR) x (T406 - T001) x 1/60

LOFT GLASS HEAT LOSS

HL-S-LOFT = (AREA-LOFT x ULOFT) x (T408 - T001) x 1/60

SOUTH WALL ABOVE TROMBE WALL

HL-S-LR = (S-AREA-LR x U-S-LR) x (T406 - T001) x 1/60

CEILING AND ROOF

HL-CEIL = ((U-CEIL-LR x AREA-CEIL-LR) + (U-CEIL-LOFT x AREA-CEIL-LOFT) +
(U-CEIL-SDAS x AREA-CEIL-SDAS) + (U-CEIL-PRE) x AREA-PRE)) x (T427 - T426)
x 1/60

FLOOR

HL-SLAB = AREA-SLAB x U-SLAB x (T416 - T417) x 1/60

TROMBE WALL

T-WALL-IN = (T207 + T205 + T203 + T201)/4

T-WALL-OUT = (T200 + T202 + T204 + T206)/4

HEAT TRANSFER DIMENSIONLESS NUMBERS

RAYLEIGH# = (1.97 x 10^6 x LENGTH**3 x ABS (TWALLIN - TROOM))

if RAYLEIGH# > 10^8 then TRANSITIONAL FLOW REGIME

if RAYLEIGH# < 10^8 then LAMINAR FLOW REGIME

NUSSELT# = 0.13 x RAYLEIGH#**0.333 if TRANSITIONAL

NUSSELT# = 0.59 x RAYLEIGH#**0.25 if LAMINAR

CONVECTION COEFFICIENT

H = NUSSELT# x KAIR/LENGTH

EQUIVALENT RADIATIVE HEAT TRANSFER COEFFICIENT

HRAD = SIGMA x 4 x 0.9 x 0.9 x ((TWALL-IN + TROOM)/2 + 460)**3/0.99 (VIEW FACTOR = 1.0)

HEAT FLUX TO/FROM WALL

HFLUX-WALL = (1/(1/H + 1/HRAD)) x (TWALL-IN - TROOM) x AREA WALL/60

if HFLUX-WALL > 0

then HG-S-TR = HFLUX-WALL

if HFLUX-WALL < 0

then HL-S-TR = HFLUX-WALL

SUMMATION OF WALL LOSS

SOUTH

HLS = HL-S-LOF + HL-S-LR + HL-S-TR

NORTH

HLN = HL-N-REC + HL-N-EQUIP + HL-N-FOY + HL-N-BA1 + HL-N-WLR + HL-N-STAIR + HL-N-SDAS + HL-N-PRE + HL-N-BA2

EAST

HLE = HL-E-BA2 + HL-E-BR1 + HL-E-KIT + HL-E-PRE + HL-E-LOFT

WEST

HLW = HL-W-REC + HL-W-LR

TOTAL CONDUCTION LOSS

HLUA = HLS + HLN + HLE + HLW + HLCEIL + HLSLAB

ESTIMATED INFILTRATION LOSS

HI = 0.018 x VOLUME x (TB - TA) x ACH

VOLUME = 15630

ACH = 0.5

HOPE = FURNACE OPERATING ENERGY

HOPE = EP400 x EPCONST

HFIRE FIRE/WOODSTOVE OUTPUT

if T419 > 100

HFIRE = FIRERATE x 1/60

DHW SYSTEM

TSW1 = M300 x T300

TSW2 = M300

THW1 = M300 x T304

THW2 = M300

HWDM = M300 x HWD (T304, T300)

HWCSM = WD300

HWSE = M300 x HWD (T303, T300)

HWAT = M300 x HWD (T304, T303)

END OF SCAN LEVEL

HOURLY CONSUMPTION

FOSSIL FUEL

HWAF = F300 x FUELCONST

HOT WATER CONSUMPTION

HWCSM = WD300

SUPPLY WATER TEMPERATURE

TSW = TSW1/TSW2

HOT WATER TEMPERATURE

THW = THW1/THW2

HOT WATER LOAD

HWL = HWSE + HWAT

ENERGY SAVINGS - HOT WATER

HWSVF = HWSE/0.6

HOT WATER SOLAR FRACTION

HWSFR = HWSE/HWL x 100

INCIDENT SOLAR - TOTAL

SEA = SE x CLAREA

INCIDENT SOLAR - TROMBE WALL

SE-TR = CLAREA1 x SE

INCIDENT SOLAR - SUNSPACE

SE-SS = CLAREA3 x SE

SOLAR TO STORAGE

STE1 = SE2 x CLAREA1 x ABSORP

SOLAR FROM STORAGE

STEO = HG-S-TR

COLLECTED SOLAR ENERGY

SECA = SECA-SS + HG-S-TR

SOLAR COLLECTED PER SQUARE FOOT

SEC = SECA/CLAREA

COLLECTION EFFICIENCY

CLEF = SECA/SEA

DRYER HEAT

HDRY = DRYEFF x F401C x FUELCONST

AUXILIARY THERMAL ENERGY

HAT = HATF + HFIRE

HOTHER - OTHER INTERNAL GAINS

HOTHER = OTHER + HDRY

BUILDING HEAT LOAD

BL = HLUA + HI

STORAGE ENERGY CHANGE

STECH = MASS-WALL x CPWALL x (TST-WALL1 - TSTWALLP)

PASSIVE SOLAR ENERGY USED

HSEP = BL - HAT - HOTHER

EQUIPMENT HEAT LOAD

EHL = HSEP + HAT

AUXILIARY HEATING FUEL

HAF = F400C x FUELCONST

BUILDING LOAD SOLAR FRACTION

BHSFR = HSEP/BL x 100

EQUIPMENT HEAT LOAD SOLAR FRACTION

HSFR = HSEP/EHL x 100

ENERGY SAVINGS - HEATING

HSVF = HSEP/0.6

AUXILIARY FUEL

AXF = HWAF + HAF

SYSTEM LOAD

SYSL = HWL + EHL

TOTAL ENERGY SAVINGS

TSVF = HWSVF + HSVF

SOLAR TO LOADS (SOLAR ENERGY USED)

SEL = HSEP + HWSE

SOLAR FRACTION

SFR = (HSFR x EHL) x (HWSFR x HWL)/SYSL x 100

SYSTEM OPERATING ENERGY

SYSOPE = HOPE

APPENDIX E

ENVIRONMENTAL PARTNERSHIP LONG-TERM WEATHER DATA

COLLECTOR TILT: 90.00 DEGREES
LATITUDE: 39.80 DEGREES

LOCATION: CREAM RIDGE, NEW JERSEY
COLLECTOR AZIMUTH: -90.00 DEGREES

MONTH	HOBAR	HBAR	KBAR	RBAR	SBAR	HDD	CDD	TBAR
JAN	1337.	557.	0.41635	1.593	887.	1042	0	31.
FEB	1801.	796.	0.44220	1.225	976.	907	0	33.
MAR	2401.	1110.	0.46228	0.868	963.	756	0	41.
APR	3024.	1442.	0.47669	0.588	848.	399	0	52.
MAY	3463.	1678.	0.48445	0.445	747.	143	47	62.
JUN	3641.	1799.	0.49417	0.394	709.	0	197	71.
JUL	3547.	1748.	0.49275	0.415	725.	0	353	76.
AUG	3189.	1567.	0.49135	0.519	813.	0	298	75.
SEP	2622.	1276.	0.48648	0.746	951.	34	118	68.
OCT	1974.	951.	0.48184	1.123	1068.	243	11	58.
NOV	1444.	612.	0.42376	1.489	911.	564	0	46.
DEC	1211.	461.	0.38072	1.652	762.	946	0	35.

LEGEND:

HOBAR ==> MONTHLY AVERAGE DAILY EXTRATERRESTRIAL RADIATION (IDEAL) IN BTU/DAY-FT2.
HBAR ==> MONTHLY AVERAGE DAILY RADIATION (ACTUAL) IN BTU/DAY-FT2.
KBAR ==> RATIO OF HBAR TO HOBAR.
RBAR ==> RATIO OF MONTHLY AVERAGE DAILY RADIATION ON TILTED SURFACE TO THAT ON A HORIZONTAL SURFACE FOR EACH MONTH (I.E., MULTIPLIER OBTAINED BY TILTING).
SBAR ==> MONTHLY AVERAGE DAILY RADIATION ON A TILTED SURFACE (I.E., RBAR * HBAR) IN BTU/DAY-FT2.
HDD ==> NUMBER OF HEATING DEGREE DAYS PER MONTH.
CDD ==> NUMBER OF COOLING DEGREE DAYS PER MONTH.
TBAR ==> AVERAGE AMBIENT TEMPERATURE IN DEGREES FAHRENHEIT.

APPENDIX F

CONVERSION FACTORS

Energy Conversion Factors

Fuel Type	Energy Content	Fuel Source Conversion Factor
Distillate fuel oil[1]	138,690 BTU/gallon	7.21×10^{-6} gallon/BTU
Residual fuel oil[2]	149,690 BTU/gallon	6.68×10^{-6} gallon/BTU
Kerosene	135,000 BTU/gallon	7.41×10^{-6} gallon/BTU
Propane	91,500 BTU/gallon	10.93×10^{-6} gallon/BTU
Natural gas	1,021 BTU/cubic feet	979.4×10^{-6} cubic feet/BTU
Electricity	3,413 BTU/kilowatt-hour	292.8×10^{-6} kwh/BTU
Wood[3]	20-25 million BTU/cord	

[1] No. 1 and No. 2 heating oils, diesel fuel, No. 4 fuel oils

[2] No. 5 and No. 6 fuel oils

[3] Energy content varies widely depending on the type of wood and the moisture content of the wood.

APPENDIX G

SENSOR TECHNOLOGY

Temperature Sensors

Temperatures are measured by a Minco Products S53P platinum Resistance Temperature Detector (RTD). Because the resistance of platinum wire varies as a function of temperature, measurement of the resistance of a calibrated length of platinum wire can be used to accurately determine the temperature of the wire. This is the principle of the platinum RTD which utilizes a tiny coil of platinum wire encased in a copper-tipped probe to measure temperature.

Ambient temperature sensors are housed in a WeatherMeasure Radiation Shield in order to protect the probe from solar radiation. Care is taken to locate the sensor away from extraneous heat sources which could produce erroneous temperature readings. Temperature probes mounted in pipes are installed in stainless steel thermowells for physical protection of the sensor and to allow easy removal and replacement of the sensors. A thermally-conductive grease is used between the probe and the thermowell to assure faster temperature response.

All temperature sensors are individually calibrated at the factory. In addition, the bridge circuit is calibrated in the field using a five-point check.

Nominal Resistance @ 25°C:	100 ohms
No. of Leads:	3
Electrical Connection:	Wheatstone Bridge
Time Constant	1.5 seconds max. in water at 3 fps
Self Heating:	27 mw/°F

WIND SENSOR

Wind speed and direction are measured by a WeatherMeasure W102-P-DC/540 or W101-P-DC/540 wind sensor. Wind speed is measured by means of a four-bladed propeller coupled to a DC generator.

Wind direction is sensed by means of a dual-wiper 1,000-ohm long-life conductive plastic potentiometer. It is attached to the stainless steel shaft which supports and rotates with the upper body assembly.

Size:	29-3/4"L X 30"H
Starting Speed:	1 mph
Complete Tracking:	3 mph
Maximum Speed:	200 mph
Distance Constant (30 mph):	6.2'
Accuracy:	± 1% below 25 mph ± 3% above 25 mph
Time Constant:	0.145 second

HUMIDITY SENSORS

The WeatherMeasure HMP-14U Solid State Relative Humidity Probe is used for the measurement of relative humidity. The operation of the sensor is based upon the capacitance of the polymer thin film capacitor. A one-micron-thick dielectric polymer layer absorbs water molecules through a thin metal electrode and causes capacitance change proportional to relative humidity.

Range:	0-100% R.H.
Response Time:	1 second to 90% humidity change at 20°C
Temperature Coefficient:	0.05% R.H./°C
Accuracy:	± 3% from 0-80% R.H. ± 5-6% 80-100% R.H.
Sensitivity:	0.2% R.H.

INSOLATION SENSORS

The Eppley Model PSP pyranometer is used for the measurement of insolation. The pyranometer consists of a circular multijunction thermopile of the plated, (copper-constantan) wirewound type which is temperature compensated to render the response essentially independent of ambient temperature. The receiver is coated with Parsons' black lacquer (non-wavelength-selective absorption). The instrument is supplied with a pair of precision-ground polished concentric hemispheres of Schott optical glass transparent to light between 285 and 2800 nm of wavelength. The instrument is provided with a dessicator which may be readily inspected. Pyranometers designated as shadowband pyranometers are equipped with a shadowband which may be adjusted to block out any direct solar radiation. These instruments are used for the measurement of diffuse insolation.

Sensitivity:	9 μ V/W/m^2
Temperature Dependence:	± 1% over ambient temperature range -20°C to 40°C
Linearity:	0.5% from 0 to 2,800 W/M^2
Response Time:	1 second
Cosine Error:	± 1% 0-70° zenith angle ± 3% 70-80° zenith angle

LIQUID FLOW SENSORS (NON-TOTALIZING)

The Ramapo Mark V strain gauge flow meters are used for the measurement of liquid flow. The flow meters sense the flow of the liquids by measuring the force exerted by the flow on a target suspended in the flow stream. This force is transmitted to a four active arm strain gauge bridge to provide a signal proportional to flow rate squared. The flow meters are available in a screwed end configuration, a flanged configuration, and a wafer configuration. Each flow meter is calibrated for the particular fluid being used in the application.

Materials:	Target - 17-PH stainless steel Body - Brass or stainless steel Seals - Buna-N
Fluid Temperature:	-40°F to 250°F
Calibration Accuracy:	± 1% (½" to 3½" line size) ± 2% (4" and greater line size)
Repeatability and Hysteresis:	0.25% of reading

LIQUID FLOW SENSORS (TOTALIZING)

Hersey Series 400 flow meters are used to measure totalized liquid flow. The meter is a nutating disk, positive displacement type meter. An R-15 register with an SPDT reed switch is used to provide an output to the data acquisition subsystem.

The output of the reed switch is input to a Martin DR-1 Digital Ramp which counts the number of pulses and produces a zero to five volt analog signal corresponding to the pulse count.

Materials:	Meter body - bronze Measuring chamber - plastic
Accuracy:	± 1.5%

AIR FLOW SENSORS

The Kurz 430 Series of thermal anemometers is used for the measurement of air flow. The basic sensing element is a probe which consists of a velocity sensor and a temperature sensor. The velocity sensor is heated and operated as a constant temperature thermal anemometer which responds to a "standard" velocity (referenced to 25°C and 760 mm Hg) or mass flow by sensing the cooling effect of the air as it passes over the heated sensor. The temperature sensor compensates for variations in ambient temperature.

Since the probe measures air velocity at only one point in the cross section of the duct, it is necessary to perform a careful duct mapping to relate the probe reading to the amount of air flowing through the entire duct. This is done by dividing the duct into small areas and taking a reading at the center of each area using a portable probe. The readings are then averaged to determine the overall duct velocity. The reading at the permanently installed probe is then ratioed to this reading. This duct mapping is done for each mode.

Accuracy:	± 2% of full scale over temperature range -20°C to 60°C ± 5% of full scale over temperature range -60°C to 250°C
Response Time:	0.025 second
Repeatability:	0.25% full scale

FUEL OIL FLOW SENSOR

The Kent Mini-Major is used as a flow oil flow meter. The meter utilizes an oscillating piston as a positive displacement element. The oscillating piston is connected to a pulser which sends pulses to the Site Data Acquisition Subsystem for totalization.

Operating Temperature:	100°C (max)
Flow Range:	0.6 to 48 gph
Accuracy:	± 1% of full scale

FUEL GAS FLOW SENSOR

The American AC-175 gas meter is used for the measurement of totalized fuel gas flow. The drop in pressure between the inlet and outlet of the meter is responsible for the action of the meter. The principle of measurement is positive displacement. Four chambers in the meter fill and empty in sequence. The exact volume of compartments is known, so by counting the number of displacements the volume is measured. Sliding control valves control the entrance and exit of the gas to the compartments. The meter is temperature compensated to reference all volumetric readings to 60°F.

Rated Capacity:	175 cubic ft/hr
Max Working Pressure:	5 psi

ELECTRIC POWER SENSORS

Ohio Semitronics Series PC5 wattmeters are used as electric power sensors. They utilize Hall effect devices as multipliers taking the product of the instantaneous voltage and current readings to determine the electrical power. This technique automatically takes power factor into consideration and produces a true power reading.

Power Factor Range:	1 to 0 (lead or lag)
Response Time:	250 ms
Temperature Effect:	1% of reading
Accuracy:	0.5% of full scale

HEAT FLUX SENSORS

The Hy-Cal Engineering Model BI-7X heat flow sensor is used for the measurement of heat flux. The sensor consists basically of an insulating wafer, with a series of thermocouples arranged such that consecutive thermoelectric junctions fall on opposite sides of the wafer. This assembly is bonded to a heat sink to assure heat flow through the sensor. Heat is received on the exposed surface of the wafer and conducted through the heat sink. A temperature drop across the wafer is thus developed and is measured directly by each junction combination embodied along the wafer. Since the differential thermocouples are connected electrically in series, the voltages produced by each set of junctions is additive, thereby amplifying the signal directly proportional to the number of junctions. The temperature drop across the wafer, and thus the output signal, is directly proportional to the heating rate.

Operation Temperature:	-50° to 200°F
Response Time:	6 seconds
Linearity:	2%
Repeatability:	0.5%
Sensitivity:	2 mv/BTU/ft^2-hr
Size:	2" X 2"

APPENDIX H

MONTHLY REPORT: MARCH 1982
SITE SUMMARY: ENVIRONMENTAL PARTNERSHIP P2803

	CONVENTIONAL UNITS
GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	4.863 MILLION BTU
	9425 BTU/SQ.FT.
COLLECTED SOLAR ENERGY	1.448 MILLION BTU
	2806 BTU/SQ.FT.
AVERAGE AMBIENT TEMPERATURE	41 DEGREES F
AVERAGE BUILDING TEMPERATURE	67 DEGREES F
ECSS SOLAR CONVERSION EFFICIENCY	0.79
ECSS OPERATING ENERGY	N.A. MILLION BTU
STORAGE EFFICIENCY	14.96 PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	* BTU/DEG F-SQ FT-HR
TOTAL SYSTEM OPERATING ENERGY	0.036 MILLION BTU
TOTAL ENERGY CONSUMED	0.000 MILLION BTU

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	1.828	7.056	N.A.	8.865 MILLION BTU
SOLAR FRACTION	16	53	N.A.	45 PERCENT
SOLAR ENERGY USED	0.230	3.715	N.A.	3.818 MILLION BTU
OPERATING ENERGY	N.A.	0.036	N.A.	0.036 MILLION BTU
AUX. THERMAL ENERGY	1.806	1.985	N.A.	3.692 MILLION BTU
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. MILLION BTU
AUX. FOSSIL FUEL	3.011	0.827	N.A.	3.838 MILLION BTU
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	N.A. MILLION BTU
FOSSIL SAVINGS	0.384	6.192	N.A.	6.363 MILLION BTU

SYSTEM PERFORMANCE FACTOR: 2.24

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 49.61

* = UNAVAILABLE; N.A. = NOT APPLICABLE; I = INVALID; E = ESTIMATED.

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, NOVEMBER 1981.
SOLAR/0004-81/18
READ THIS BEFORE TURNING PAGE.

MONTHLY REPORT: MARCH 1982
SITE SUMMARY: ENVIRONMENTAL PARTNERSHIP P2803

SI UNITS

GENERAL SITE DATA:	
INCIDENT SOLAR ENERGY	5.131 GIGA JOULES
	107027 KJ/SQ.M.
COLLECTED SOLAR ENERGY	1.528 GIGA JOULES
	31866 KJ/SQ.M.
AVERAGE AMBIENT TEMPERATURE	5 DEGREES C
AVERAGE BUILDING TEMPERATURE	19 DEGREES C
ECSS SOLAR CONVERSION EFFICIENCY	0.79
ECSS OPERATING ENERGY	N.A. GIGA JOULES
STORAGE EFFICIENCY	14.96 PERCENT
EFFECTIVE HEAT TRANSFER COEFFICIENT	* W/SQ M-DEG K
TOTAL SYSTEM OPERATING ENERGY	0.038 GIGA JOULES
TOTAL ENERGY CONSUMED	0.000 GIGA JOULES

SUBSYSTEM SUMMARY:

	HOT WATER	HEATING	COOLING	SYSTEM TOTAL
LOAD	1.928	7.444	N.A.	9.353 GIGA JOULES
SOLAR FRACTION	16	53	N.A.	45 PERCENT
SOLAR ENERGY USED	0.243	3.919	N.A.	4.028 GIGA JOULES
OPERATING ENERGY	N.A.	0.038	N.A.	0.038 GIGA JOULES
AUX. THERMAL ENG	1.906	2.095	N.A.	3.895 GIGA JOULES
AUX. ELECTRIC FUEL	N.A.	N.A.	N.A.	N.A. GIGA JOULES
AUX. FOSSIL FUEL	3.176	0.873	N.A.	4.049 GIGA JOULES
ELECTRICAL SAVINGS	N.A.	N.A.	N.A.	N.A. GIGA JOULES
FOSSIL SAVINGS	0.405	6.532	N.A.	6.713 GIGA JOULES

SYSTEM PERFORMANCE FACTOR: 2.24

INTERPOLATED PERFORMANCE FACTORS, PERCENT OF HOURS: 49.61

* = UNAVAILABLE; N.A. = NOT APPLICABLE; I = INVALID; E = ESTIMATED.

REFERENCE: USER'S GUIDE TO MONTHLY PERFORMANCE REPORTS, NOVEMBER 1981.
SOLAR/0004-81/18

MONTHLY REPORT: ENVIRONMENTAL PARTNERSHIP P2803 MARCH 1982

ENERGY COLLECTION AND STORAGE SUBSYSTEM (ECSS)

DAY OF MONTH (NBS ID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	AMBIENT TEMP DEG-F (N113)	ENERGY TO LOADS MILLION BTU	AUX THERMAL TO ECSS MILLION BTU	ECSS OPERATING ENERGY MILLION BTU (Q102)	ECSS ENERGY REJECTED MILLION BTU	ECSS SOLAR CONVERSION EFFICIENCY (N111)
1	0.266	36	N	N	N	N	0.889
2	0.248	40	O	O	O	O	0.766
3	0.407	32	T	T	T	T	0.520
4	0.005	31					27.488
5	0.224	43	A	A	A	A	0.716
6	0.000	34	P	P	P	P	0.000
7	0.000	37	P	P	P	P	0.000
8	0.338	32	L	L	L	L	0.677
9	0.069	34	I	I	I	I	-3.130
10	0.164	35	C	C	C	C	1.433
11	0.166	49	A	A	A	A	0.625
12	0.171	54	B	B	B	B	0.267
13	0.158#	41#	L	L	L	L	0.769
14	0.158#	41#	E	E	E	E	0.769
15	0.017	42					11.026
16	0.074	42					1.796
17	0.000	40					0.000
18	0.126#	41#					0.685
19	0.174#	44#					0.989
20	0.246	46					0.603
21	0.000	47					0.000
22	0.155	46					0.936
23	0.319	45					0.336
24	0.295	44					0.491
25	0.070	45					2.745
26	0.046	47					3.385
27	0.271	36					0.768
28	0.311	33					0.675
29	0.223	42					0.740
30	0.153	48					1.084
31	0.009	55					11.041
SUM	4.863	-	N.A.	N.A.	N.A.	N.A.	-
AVG	0.157	41	N.A.	N.A.	N.A.	N.A.	0.785
PFRV	0.4987	0.4987	N.A.	N.A.	N.A.	N.A.	0.0000

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY REPORT: ENVIRONMENTAL PARTNERSHIP P2803 MARCH 1982

COLLECTOR SUBSYSTEM PERFORMANCE

DAY OF MONTH (NBSID)	INCIDENT SOLAR ENERGY MILLION BTU (Q001)	OPERATIONAL INCIDENT ENERGY MILLION BTU	COLLECTED SOLAR ENERGY MILLION BTU (Q100)	DAYTIME AMBIENT TEMP DEG F	COLLECTOR SUBSYSTEM EFFICIENCY (N100)
1	0.266	N	0.080	49	0.300
2	0.248	O	0.072	44	0.289
3	0.407	T	0.110	36	0.271
4	0.005		0.016	34	2.984
5	0.224	A	0.056	41	0.247
6	0.000	P	0.007	40	0.000
7	0.000	P	0.000	40	0.000
8	0.338	L	0.087	39	0.256
9	0.069	I	0.026	37	0.372
10	0.164	C	0.042	48	0.257
11	0.166	A	0.046	58	0.275
12	0.171	B	0.049	69	0.286
13	0.158#	L	0.047#	46#	0.297#
14	0.158#	E	0.047#	46#	0.297#
15	0.017		0.017	46	0.982
16	0.074		0.023	50	0.308
17	0.000		0.002	41	0.000
18	0.126#		0.035#	43#	0.274#
19	0.174#		0.051#	39#	0.293#
20	0.246		0.067	56	0.271
21	0.000		0.010	53	0.000
22	0.155		0.043	53	0.280
23	0.319		0.087	62	0.273
24	0.295		0.085	51	0.289
25	0.070		0.031	53	0.451
26	0.046		0.021	37	0.461
27	0.271		0.075	39	0.276
28	0.311		0.089	39	0.284
29	0.223		0.069	44	0.307
30	0.153		0.051	69	0.332
31	0.009		0.010	56	1.166
SUM	4.863	N.A.	1.448	-	-
AVG	0.157	N.A.	0.047	47	0.298
PFRV	0.4987	N.A.	0.4987	0.4987	0.4987

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY REPORT: ENVIRONMENTAL PARTNERSHIP P2803 MARCH 1982

PASSIVE SYSTEM THERMAL PERFORMANCE

DAY OF MONTH (NBS ID)	BLDG SOLAR FRACTION PERCENT	BUILDING HEAT LOAD MILLION BTU	U*A*DT MILLION BTU	INFIL LOSSES MILLION BTU	AUX ENERGY FIREPLACE MILLION BTU	AUX ENERGY INTERNAL GAINS MILLION BTU	AUX THERMAL USED MILLION BTU (Q401)	PASSIVE SOLAR USED MILLION BTU	EQUIP HEAT LOAD MILLION BTU (Q402)	SOLAR FRACTION EQUIP HEAT LOAD PERCENT (N400)
1	86	0.275	0.170	0.106	0.000	0.040	0.000	0.235	0.275	85
2	76	0.232	0.143	0.088	0.000	0.052	0.002	0.177	0.232	77
3	70	0.300	0.185	0.115	0.045	0.042	0.045	0.213	0.300	71
4	45	0.277	0.171	0.106	0.000	0.048	0.083	0.146	0.277	53
5	78	0.204	0.127	0.077	0.000	0.045	0.003	0.157	0.204	77
6	-43	0.275	0.170	0.105	0.000	0.053	0.356	-0.133	0.275	-48
7	-67	0.284	0.180	0.104	0.000	0.061	0.408	-0.185	0.284	-65
8	70	0.309	0.192	0.117	0.041	0.046	0.043	0.220	0.309	71
9	-101	0.254	0.157	0.097	0.000	0.055	0.423	-0.225	0.254	-89
10	85	0.273	0.169	0.104	0.000	0.040	0.001	0.232	0.273	85
11	51	0.153	0.096	0.057	0.000	0.062	0.002	0.088	0.153	58
12	26	0.149	0.093	0.055	0.045	0.043	0.065	0.040	0.149	29
13	51#	0.228#	0.142#	0.087#	0.012#	0.044#	0.065#	0.120#	0.228#	54#
14	51#	0.228#	0.142#	0.087#	0.012#	0.044#	0.065#	0.120#	0.228#	54#
15	81	0.228	0.141	0.087	0.000	0.042	0.002	0.184	0.228	80
16	68	0.208	0.128	0.080	0.000	0.032	0.045	0.132	0.208	63
17	58	0.205	0.126	0.079	0.000	0.035	0.049	0.121	0.205	59
18	45#	0.212#	0.132#	0.079#	0.012#	0.052#	0.070#	0.091#	0.212#	45#
19	79#	0.209#	0.130#	0.079#	0.000#	0.038#	0.007#	0.164#	0.209#	78#
20	67	0.205	0.128	0.077	0.014	0.048	0.014	0.143	0.205	70
21	76	0.179	0.110	0.069	0.000	0.039	0.000	0.140	0.179	78
22	79	0.181	0.112	0.068	0.000	0.038	0.002	0.141	0.181	78
23	39	0.219	0.137	0.082	0.071	0.046	0.071	0.103	0.219	47
24	52	0.240	0.149	0.091	0.068	0.027	0.072	0.142	0.240	59
25	75	0.218	0.136	0.082	0.000	0.040	0.000	0.178	0.218	82
26	80	0.195	0.121	0.074	0.000	0.039	0.002	0.154	0.195	79
27	83	0.265	0.164	0.101	0.000	0.044	0.000	0.221	0.265	83
28	68	0.286	0.178	0.108	0.036	0.045	0.036	0.205	0.286	72
29	43	0.241	0.151	0.090	0.050	0.045	0.050	0.146	0.241	61
30	80	0.202	0.126	0.076	0.000	0.034	0.000	0.168	0.202	83
31	63	0.121	0.075	0.046	0.000	0.035	0.004	0.082	0.121	68
SUM	-	7.056	4.381	2.675	0.408	1.355	1.985	3.715	7.056	-
AVG	52	0.228	0.141	0.086	0.013	0.044	0.064	0.120	0.228	53
PFRV	0.4987	0.4987	0.4987	0.4987	0.4987	0.4987	0.4987	0.4987	0.4987	0.4987

* UNAVAILABLE; N.A. NOT APPLICABLE; I INVALID; E ESTIMATED; # <40% VALID DATA; PFRV RELIABILITY VALUE.

MONTHLY REPORT: ENVIRONMENTAL PARTNERSHIP P2803 MARCH 1982

PASSIVE STORAGE THERMAL PERFORMANCE

DAY OF MON. (NBS)	INCIDENT SOLAR ENERGY MILLION BTU	PASSIVE SOLAR USED MILLION BTU	SOLAR ENERGY COLLECTED MILLION BTU	ENERGY TO STORAGE MILLION BTU	ENERGY FROM STORAGE MILLION BTU	CHANGE IN STORED ENERGY MILLION BTU	AVG STORAGE TEMP DEG F	AVG BLDG TEMP DEG F
1	0.266	0.235	0.080	0.124	0.019	I	74	67
2	0.248	0.177	0.072	0.116	0.015		72	67
3	0.407	0.213	0.110	0.190	0.017		73	67
4	0.005	0.146	0.016	0.002	0.014		68	63
5	0.224	0.157	0.056	0.105	0.004		66	66
6	0.000	-0.133	0.007	0.000	0.007		67	65
7	0.000	-0.185	0.000	0.000	0.000		63	68
8	0.338	0.220	0.087	0.158	0.010		67	66
9	0.069	-0.225	0.026	0.032	0.010		66	63
10	0.164	0.232	0.042	0.077	0.005		66	66
11	0.166	0.088	0.046	0.077	0.008		69	66
12	0.171	0.040	0.049	0.080	0.010		73	70
13	0.158#	0.120#	0.047#	0.074#	0.011#		70#	67#
14	0.158#	0.120#	0.047#	0.074#	0.011#		70#	67#
15	0.017	0.184	0.017	0.008	0.013		72	68
16	0.074	0.132	0.023	0.035	0.006		68	65
17	0.000	0.121	0.002	0.000	0.002		63	63
18	0.126#	0.091#	0.035#	0.059#	0.006#		66#	65#
19	0.174#	0.164#	0.051#	0.081#	0.011#		72#	68#
20	0.246	0.143	0.067	0.115	0.011		72	69
21	0.000	0.140	0.010	0.000	0.010		71	67
22	0.155	0.141	0.043	0.072	0.008		69	66
23	0.319	0.103	0.087	0.149	0.014		75	70
24	0.295	0.142	0.085	0.138	0.018		77	71
25	0.070	0.178	0.031	0.033	0.016		75	70
26	0.046	0.154	0.021	0.021	0.011		72	69
27	0.271	0.221	0.075	0.127	0.013		70	66
28	0.311	0.205	0.089	0.145	0.018		72	65
29	0.223	0.146	0.069	0.104	0.018		75	69
30	0.153	0.168	0.051	0.071	0.016		76	71
31	0.009	0.082	0.010	0.004	0.008	I	71	69
SUM	4.863	3.715	1.448	2.269	0.340		-	-
AVG	0.157	0.120	0.047	0.073	0.011		70	67
PFRV	0.4987	0.4987	0.4987	0.4987	0.4987	0.6062	0.4987	0.4987

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MONTHLY REPORT: ENVIRONMENTAL PARTNERSHIP P2803 MARCH 1982

HOT WATER SUBSYSTEM I

DAY OF MON. (NBS ID)	HOT WATER LOAD MILLION BTU	SOLAR FR.OF LOAD PER. (N300)	HOT WATER DEMAND MILLION BTU (Q302)	SOLAR FR.OF DEMAND BTU	SOLAR ENERGY USED MILLION BTU (Q300)	OPER ENERGY MILLION BTU (Q303)	AUX THERMAL USED MILLION BTU (Q301)
1	0.052	4	0.004	23	0.002	N	0.063
2	0.054	23	0.050	25	0.013	O	0.048
3	0.048	26	0.050	23	0.013	T	0.066
4	0.035	2	0.003	66	0.001		0.043
5	0.038	25	0.020	17	0.005	A	0.059
6	0.091	8	0.046	13	0.008	P	0.060
7	0.050	11	0.042	14	0.005	P	0.055
8	0.052	17	0.040	13	0.009	L	0.040
9	0.096	10	0.046	15	0.009	I	0.073
10	0.052	11	0.030	12	0.004	C	0.053
11	0.073	17	0.042	15	0.013	A	0.065
12	0.068	18	0.020	15	0.009	B	0.052
13	0.060#	31#	0.031#	17#	0.007#	L	0.058#
14	0.060#	31#	0.031#	17#	0.007#	E	0.058#
15	0.065	17	0.032	16	0.009		0.175
16	0.002	100	0.010	20	0.002		0.000
17	0.322	2	0.037	7	0.005		0.279
18	0.028#	39#	0.041#	14#	0.006#		0.024#
19	0.043#	35#	0.032#	17#	0.008#		0.034#
20	0.015	59	0.033	22	0.007		0.000
21	0.003	100	0.023	28	0.003		0.002
22	0.075	6	0.021	29	0.004		0.076
23	0.045	16	0.014	16	0.005		0.028
24	0.010	44	0.014	11	0.003		0.028
25	0.031	45	0.035	20	0.012		0.061
26	0.059	8	0.022	22	0.005		0.027
27	0.025	44	0.038	17	0.010		0.010
28	0.115	4	0.021	15	0.005		0.122
29	0.051	37	0.093	19	0.019		0.024
30	0.066	13	0.034	17	0.009		0.079
31	0.040	37	0.064	23	0.014		0.043
SUM	2.040	-	1.019	-	0.230	N.A.	1.806
AVG	0.059	16	0.033	18	0.007	N.A.	0.058
PFRV	0.4745	0.4745	0.4745	0.4745	0.4745	N.A.	0.6062

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MONTHLY REPORT: ENVIRONMENTAL PARTNERSHIP P2803 MARCH 1982

HOT WATER SUBSYSTEM II

DAY OF MON. (NBS)	AUX ELECT FUEL MILLION BTU (Q305)	AUX FOSSIL FUEL MILLION BTU (Q306)	ELECT ENERGY SAVINGS MILLION BTU (Q311)	FOSSIL ENERGY SAVINGS MILLION BTU (Q313)	SUPPLY WATER TEMP DEG F (Q305)	HOT WATER TEMP DEG F (N307)	TEMPERED HOT WATER USED GAL	HOT WATER USED GAL (N308)	SOLAR SPECIFIC OPER ENERGY MILLION BTU
1	N	0.105	N	0.003	52	121	N	7	N
2	O	0.079	O	0.021	49	129	O	75	O
3	T	0.110	T	0.021	50	123	T	82	T
4		0.072		0.002	51	122		5	
5	A	0.099	A	0.009	53	125	A	32	A
6	P	0.100	P	0.013	51	132	P	68	P
7	P	0.092	P	0.009	51	128	P	66	P
8	L	0.066	L	0.015	52	128	L	62	L
9	I	0.122	I	0.016	49	130	I	68	I
10	C	0.088	C	0.007	50	125	C	47	C
11	A	0.108	A	0.021	50	126	A	66	A
12	B	0.087	B	0.014	52	124	B	33	B
13	L	0.097#	L	0.012#	53#	126#	L	48#	L
14	E	0.097#	E	0.012#	53#	126#	E	48#	E
15		0.292		0.014	50	130		48	
16		0.000		0.004	50	128		16	
17		0.465		0.008	51	125		60	
18		0.039#		0.010#	52#	123#		68#	
19		0.057#		0.013#	53#	125#		52#	
20		0.000		0.012	52	129		51	
21		0.004		0.005	53	132		35	
22		0.127		0.007	52	124		35	
23		0.046		0.008	51	127		23	
24		0.047		0.006	53	127		22	
25		0.101		0.020	51	124		58	
26		0.045		0.008	53	125		36	
27		0.017		0.017	51	128		60	
28		0.203		0.009	52	129		33	
29		0.040		0.031	50	129		141	
30		0.132		0.015	53	128		54	
31		0.072		0.023	51	131		95	
SUM	N.A.	3.011	N.A.	0.384	-	-	N.A.	1594	N.A.
AVG	N.A.	0.097	N.A.	0.012	51	127	N.A.	51	N.A.
PFRV	N.A.	0.6062	N.A.	0.4745	0.4745	0.4745	N.A.	0.4745	N.A.

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MONTHLY REPORT: ENVIRONMENTAL PARTNERSHIP P2803 — MARCH 1982

PASSIVE SYSTEM ENVIRONMENT

DAY OF MONTH (NBS ID)	MAX BLDG TEMP DEG F	MIN BLDG TEMP DEG F	BUILDING TEMP MIDNIGHT DEG F	BUILDING TEMP 6 AM DEG F	BUILDING TEMP NOON DEG F	BUILDING TEMP 6 PM DEG F	INTERIOR RELATIVE HUMIDITY PERCENT	AMB TEMP DEG F (N113)	DAYTIME AMB TEMP DEG F	INCIDENT SOLAR ENERGY MILLION BTU	AVG STOR TEMP DEG F
1	70	63	67#	65#	64#	69#	22	36	49	0.266	74
2	70	63	66#	65#	64#	68#	25	40	44	0.248	72
3	71	62	68#	65#	66#	71#	25	32	36	0.407	73
4	67	59	66#	63#	64#	63#	24	31	34	0.005	68
5	70	62	68#	65#	63#	70#	28	43	41	0.224	66
6	71	62	71#	65#	64#	65#	26	34	40	0.000	67
7	72	64	68#	65#	67#	68#	28	37	40	0.000	63
8	70	62	65#	63#	64#	68#	26	32	39	0.338	67
9	70	60	68#	65#	60#	65#	24	34	37	0.069	66
10	68	62	65#	63#	64#	68#	25	35	48	0.164	66
11	70	61	69#	65#	64#	70#	30	49	58	0.166	69
12	74	67	68#	65#	64#	74#	33	54	69	0.171	73
13	*	*	68#	65#	64#	70#	28#	41#	46#	0.158#	70#
14	*	*	68#	65#	64#	70#	28#	41#	46#	0.158#	70#
15	69	66	66#	69#	64#	68#	28	42	46	0.017	72
16	67	64	68#	65#	67#	66#	28	42	50	0.074	68
17	66	61	62#	63#	64#	62#	32	40	41	0.000	63
18	62	60	68#	65#	64#	70#	30#	41#	43#	0.126#	66#
19	71	69	68#	65#	70#	70#	29#	44#	39#	0.174#	72#
20	*	65	71#	66#	64#	73#	29	46	56	0.246	72
21	71	65	65#	68#	64#	66#	31	47	53	0.000	71
22	70	62	67#	65#	64#	69#	30	46	53	0.155	69
23	75	64	71#	65#	64#	74#	28	45	62	0.319	75
24	75	67	73#	65#	64#	75#	26	44	51	0.295	77
25	73	67	68#	65#	67#	73#	28	45	53	0.070	75
26	70	67	68#	69#	68#	69#	29	47	37	0.046	72
27	68	62	66#	64#	64#	70#	26	36	39	0.271	70
28	70	60	69#	61#	64#	70#	25	33	39	0.311	72
29	74	63	68#	65#	68#	74#	26	42	44	0.223	75
30	73	66	71#	67#	64#	73#	26	48	69	0.153	76
31	71	68	69#	65#	64#	70#	33	55	56	0.009	71
SUM	-	-	-	-	-	-	-	-	-	4.863	-
AVG	105	59	68	65	64	69	28	41	47	0.157	70
PFRV	N.A.	N.A.	0.3800	0.2051	0.1842	0.3800	0.4987	0.4987	0.4987	0.4987	0.4987

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MONTHLY REPORT: ENVIRONMENTAL PARTNERSHIP P2803 — MARCH 1982

ENVIRONMENTAL SUMMARY

DAY OF MONTH (NBS ID)	TOTAL INSOLATION BTU/SQ.FT (Q001)	DIFFUSE INSOLATION BTU/SQ.FT	AMBIENT TEMPERATURE DEG F (N113)	DAYTIME AMBIENT TEMP DEG F	RELATIVE HUMIDITY PERCENT	WIND DIRECTION DEGREES (N115)	WIND SPEED M.P.H. (N114)	HEAT DEGREE DAYS	COOL DEGREE DAYS
1	516	N	36	49	0#	0#	0#	30	0
2	480	O	40	44	0#	0#	0#	23	0
3	789	T	32	36	0#	0#	0#	32	0
4	10		31	34	0#	0#	0#	36	0
5	435	A	43	41	0#	0#	0#	20	0
6	0	P	34	40	0#	0#	0#	31	0
7	0	P	37	40	0#	0#	0#	28	0
8	655	L	32	39	0#	0#	0#	34	0
9	134	I	34	37	0#	0#	0#	30	0
10	318	C	35	48	0#	0#	0#	31	0
11	321	A	49	58	0#	0#	0#	15	0
12	331	B	54	69	0#	0#	0#	8	0
13	306#	L	41#	46#	0#	0#	0#	*	*
14	306#	E	41#	46#	0#	0#	0#	*	*
15	34		42	46	0#	0#	0#	21	0
16	144		42	50	0#	0#	0#	22	0
17	0		40	41	0#	0#	0#	25	0
18	245#		41#	43#	0#	0#	0#	30	0
19	337#		44#	39#	0#	0#	0#	14	0
20	476		46	56	0#	0#	0#	0	5
21	0		47	53	0#	0#	0#	17	0
22	301		46	53	0#	0#	0#	18	0
23	617		45	62	0#	0#	0#	19	0
24	573		44	51	0#	0#	0#	21	0
25	135		45	53	0#	0#	0#	17	0
26	88		47	37	0#	0#	0#	20	0
27	526		36	39	0#	0#	0#	28	0
28	603		33	39	0#	0#	0#	30	0
29	433		42	44	0#	0#	0#	22	0
30	296		48	69	0#	0#	0#	17	0
31	17		55	56	0#	0#	0#	12	0
SUM	9425	N.A.	-	-	-	-	-	695	5
AVG	304	N.A.	41	47	0	0	0	22	0
PFRV	0.4987	N.A.	0.4987	0.4987	0.0000	0.000	0.000	N.A.	N.A.

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