SUMMARY RESULTS FROM
THE NASA TECH HOUSE ONE YEAR LIVE-IN

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Abstract

The NASA Tech House was designed and constructed at the Langley Research Center, Hampton, Virginia, to demonstrate and evaluate new technology potentially applicable for conservation of energy and resources and for improvements in safety and security in a single-family residence. All technology items, including solar energy systems and a waste water reuse system, were evaluated under actual living conditions for a one-year period with a family of four living in the house in their normal life style. Results are presented which show overall savings in energy and resources compared to requirements for a defined similar conventional house under the same conditions. Also included are general operational experience and performance data for all the various items and systems of technology incorporated into the house design.

Tech House Description

The Tech House is a single-level contemporary style with interconnected modules which can be re-arranged to suit personal preference or a particular building lot. Other than the contemporary style, the most obvious external feature is the roof mounted solar collectors as seen in Figure 1. Solar energy is used for space heating and for heating domestic hot water. The bedroom module and the garage module are connected to the main living area by a flat-roofed foyer and hallway, respectively.

Some of the external design and appearance features are functional for energy conservation. The window overhang on the south side of the bedroom module allows the sun to help heat the south bedrooms in the winter. It shades the windows from the sun in the summer when the sun is high in the sky. Large louvered vents permit passive ventilation for the attic area of each module. External window shutters provide an added barrier against thermal heat loss as well as for security and acoustical benefits. A small panel of photovoltaic solar cells on the garage roof converts solar energy to electricity and charges the battery for an emergency lighting system. The emergency lighting is automatically activated when there is a power outage from the electric utility.

The floor plan is shown in Figure 2. The house consists of approximately 1500 square feet of enclosed living space and is intended to be representative of a typical middle-income-family residence. The foyer is provided with front and rear entry vestibules. Each has a double door air lock for energy conservation. A laundry room is provided in the rear vestibule. Both the solar pre-heat tank and the conventional domestic hot water tank are located in the connecting hallway between the dining room and the garage. The data system is located in the garage, along with the water source heat pumps and other electrical and mechanical equipment.

In addition to technology items already mentioned, the design includes special insulation for the floors, ceiling and walls; thermo-pane windows; an operable window in the foyer roof, for ventilation when needed; a programmable burglar...
alarm system; smoke detectors; and other safety items. All equipment and materials used are either new on the market or expected to be available within 5 years from time of construction completion in 1976. It is intended that the house, with all the special features, could be built commercially for approximately $50,000 (in 1977 dollars), not including the cost of the building lot.

Project Objectives

The Technology Utilization House, now referred to as Tech House, was intended to demonstrate the potential benefits of new construction techniques and new technology, including some aerospace technology, that could help to advance the home building industry. The practical demonstration of use and benefits of solar energy systems, energy and water conservation design concepts, safety, and security technology were major objectives. It was intended that additional investments for energy and water conservation systems would be cost effective for the homeowner over a 20-year period.

A committee was established to identify technology to be included, to guide in the necessary studies, and to formulate the test plan and direct construction. The committee included representatives from the Department of Housing and Urban Development, the National Association of Home Builders Research Institute, the National Bureau of Standards, the Consumer Product Safety Commission, and NASA. Tabulated below are the results of studies made to compare energy consumption in a conventional house, electrically heated and constructed by 1974 standards, with estimated energy consumption for the Tech House.

<table>
<thead>
<tr>
<th>Energy Use</th>
<th>Conventional House (kw-hr)</th>
<th>Tech House (kw-hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heating</td>
<td>29,300</td>
<td>6,000</td>
</tr>
<tr>
<td>Air Conditioning</td>
<td>3,600</td>
<td>2,100</td>
</tr>
<tr>
<td>Water Heating</td>
<td>4,380</td>
<td>1,500</td>
</tr>
<tr>
<td>Lights</td>
<td>2,000</td>
<td>1,000</td>
</tr>
<tr>
<td>Appliance</td>
<td>5,609</td>
<td>3,400</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>1,111</td>
<td>1,000</td>
</tr>
<tr>
<td>Totals</td>
<td>46,000</td>
<td>15,000</td>
</tr>
</tbody>
</table>

(66% less)

Earlier studies and developmental work by NASA determined that a significant reduction in domestic water consumption could be achieved by reusing selected waste water for toilet flush water. Water saver shower heads and low profile water closets were used in addition to the reuse system. The following tabulation shows projected water consumption at the Tech House compared to a conventional house without these features.

The major objective of the project was to evaluate performance and report actual results with a selected typical family of four living in the house for one year in their normal life style. Results would include actual system performance, what was learned for improvements in design, along with observations of the researchers and the live-in family.

Water Use

<table>
<thead>
<tr>
<th>(for a family of four; excluding lawn watering)</th>
<th>Conventional House (gal)</th>
<th>Tech House (gal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bathing</td>
<td>22,265</td>
<td>16,480</td>
</tr>
<tr>
<td>Dishwashing</td>
<td>2,920</td>
<td>2,190</td>
</tr>
<tr>
<td>Laundry</td>
<td>5,840</td>
<td>5,840</td>
</tr>
<tr>
<td>Cleaning</td>
<td>2,190</td>
<td>2,190</td>
</tr>
<tr>
<td>Toilet</td>
<td>32,485</td>
<td>0</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>7,300</td>
<td>7,300</td>
</tr>
<tr>
<td>Totals</td>
<td>73,000</td>
<td>34,000</td>
</tr>
</tbody>
</table>

(50% less)

The Live-in Test

A live-in test to determine performance of the Tech House was conducted from approximately mid-August 1977 to mid-August 1978. During the test period a family of four lived in the house. The house served as their sole residence during this time, and they were encouraged to live in their normal life style to the extent practical. Both parents were professionals and worked during the day. A teenage daughter and teenage son attended school during the normal school year.

For the test year, energy and water use and numerous other operational parameters were monitored and recorded. Daily readings were made of electrical energy and water consumption, as well as run time and performance of the components of the solar energy systems. In addition, the data system measured heating and cooling system operating parameters, water temperatures for the various systems, room and wall temperatures, air and water flow data, available solar radiation, outside temperature and numerous other parameters necessary for quantitative evaluation, to the extent practical, of all technology systems and features. In some cases, of course, only qualitative evaluation was possible. The performance has now been analyzed and compared to that projected.

Summary Results

All the technology items incorporated in the Tech House were evaluated, either quantitatively or qualitatively, during the live-in test. Energy and water conservation were monitored and analyzed more extensively than some of the other design features. Results, in some cases, were better than predicted, and in other cases below or quite different from expectations. All technical information collected, however, is considered to be useful and applicable for modifications and future design improvements. A performance summary on the major systems and technology features is given in the following paragraphs.

Energy Savings

Results from the live-in test show that significant reductions in energy and resources were realized. Total electrical energy used for all purposes, including heating and cooling, was less
than half the amount projected to have been used in a conventional all-electric home under the same conditions. A plot of actual electrical energy use at the Tech House is shown in Figure 3, along with savings compared to the projected electrical energy use in a defined comparable conventional house.

![Savings Comparison Graph](image)

Fig. 3 Electrical Energy Use: NASA Tech House vs Conventional House

A comparison of actual electrical energy usage versus projected requirements for the "conventional" home in each use category is shown in Table 1. The major energy savings were realized in requirements for space heating. Thermal design features, such as improved insulation, double door entrances and special window shutters accounted for approximately 60 percent of the total energy saved. Solar energy and the heat pump system supplied essentially all of the space heating requirements for the Tech House for the year. Although, the special fire-place system demonstrated the potential to supply an appreciable portion of the heating needs, it was infrequently used by the residents.

### Table 1 Actual Energy Use for Year vs Similar Conventional House

<table>
<thead>
<tr>
<th>USE</th>
<th>CONVENTIONAL HOUSE</th>
<th>TECH HOUSE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PROJECTED KWH</td>
<td>ACTUAL KWH</td>
</tr>
<tr>
<td>DOMESTIC HOT WATER</td>
<td>4300</td>
<td>1500</td>
</tr>
<tr>
<td>HEATING</td>
<td>29000</td>
<td>6000</td>
</tr>
<tr>
<td>AIR CONDITIONING</td>
<td>3600</td>
<td>2100</td>
</tr>
<tr>
<td>BASE LOAD (LIGHTS, APPLIANCES, ETC.)</td>
<td>8720</td>
<td>5400</td>
</tr>
<tr>
<td>TOTALS</td>
<td>46000</td>
<td>15000</td>
</tr>
</tbody>
</table>

Solar energy provided approximately 35 percent of the domestic hot water requirements. This percentage was considerably less than expected due to the fact that the use of hot water, both daily and for the year, was greater than anticipated. Energy efficient lighting, appliances and miscellaneous items accounted for the remaining annual savings in energy use.

![Water Savings Graph](image)

Water Savings

The water reuse system reduced overall source water requirements for the year by 26 percent, as shown in the tabulation below:

| Total Water Use for Year  | 72,757 Gal |
| Reuse Water Provided      | 18,787 Gal |
| Total Required Source Water | 53,970 Gal |
| Savings From Reuse System | 26%        |

Total water use for the year was very close to 73,000 gallons, as predicted. Almost 19,000 gallons of that total was supplied by the reuse system to provide about 85 percent of the toilet flush water, as illustrated in Fig. 4.

![Source Water Required for Toilet Flushing](image)

Savings in Energy Cost

Based on actual electrical energy use at the Tech House during the live-in test, compared to projected use for the defined conventional house, total energy savings for the year amounts to approximately $1125. This is based on a cost of 4.4 cents per kilowatt hour, the number currently used by the local electric utility for estimating. This equates to an average monthly savings of about $94 throughout the year.

It is important to note that the major savings result from investments in the thermal design of the house. Insulation and other design improvements to the house thermal envelope account for approximately $700 of the total annual savings as calculated above. Solar heating and the heat pump system accounted for about $325 of the savings; solar heated domestic hot water accounted for some $100 of the savings; and the remainder results from savings in lighting, appliances, and miscellaneous items.

Summary on Major Systems and Features

Some technology items included in the Tech House and described in the reference publications are not discussed in this report. Neither is there performance data on all items evaluated during the one year live-in. A comprehensive report on all technology, with both quantitative and qualitative results, is now being edited for publication in the near future. It is expected to be
available in the near future from the National Technical Information Service, Springfield, Virginia, 22161, for a nominal charge to cover the printing cost.

The following paragraphs briefly describe some of the major technology systems and design features and present some of the test results.

Solar Heating

Sixteen 3 x 8-foot flat plate solar collectors were used during the winter of the live-in test to supplement the space heating requirements. The heating and cooling system schematic (Figure 5) shows how the collectors are integrated into the overall heating system.

![Fig. 5 Heating and Cooling System](image)

The preferred mode of heating the house, and most cost effective, was with solar heated water circulating through the direct-duct heat exchanger. The blower then delivered the heat throughout the house. Available excess solar energy was stored in the underground storage tank. At other times, when solar energy could not adequately supply heating needs, the well-water supplemented water-to-air heat pump was operated. During this time any available solar energy was stored in the tank. In some cases water from the storage tank through the air duct heat exchanger adequately heated or supplemented heating requirements. A summary on the heating system performance is tabulated below. Although the fireplace is designed so that water flows through the grate to collect additional heat energy from the fire and deliver this energy to the main heating system, the fireplace was not used frequently by choice of the family. Tests showed, however, that when in use the fireplace can supply the major heat needs for the house except in very cold weather.

The tabulation above shows that the total heat requirement for the year was 13550 kilowatt hours. Of this amount, 6080 was purchased from the electric utility (45%) and the remainder (55%) was provided at no cost by the heat pump and solar collector system. Table 2 shows the winter season performance of the heating system solar collectors. Columns E and F of that table make an important distinction in the calculation of collector efficiency. Low level solar radiation frequently is inadequate to supply any heat energy to the collector flow medium. Only the available solar radiation during the time that heat is transferred to the flow medium should be used to determine the operational collector efficiency. Column F efficiency is therefore far more meaningful as a measure of collector performance.

**Table 2 Performance of Heating System Solar Collectors**

<table>
<thead>
<tr>
<th>MONTH</th>
<th>A - TOTAL AVAILABLE SOLAR ENERGY</th>
<th>B - OPERATIONAL SOLAR ENERGY AVAILABLE</th>
<th>C - RATIO OF OPERATIONAL SOLAR TO AVAILABLE SOLAR</th>
<th>D - SOLAR ENERGY COLLECTED (X 10^8 BTU)</th>
<th>E - PERCENT OF AVAILABLE ENERGY COLLECTED</th>
<th>F - PERCENT COLLECTED OF OPERATIONAL SOLAR ENERGY AVAILABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>OCT 77</td>
<td>10.85</td>
<td>4.60</td>
<td>.44</td>
<td>2.96</td>
<td>27%</td>
<td>62%</td>
</tr>
<tr>
<td>NOV 77</td>
<td>9.98</td>
<td>6.65</td>
<td>.66</td>
<td>3.99</td>
<td>40%</td>
<td>60%</td>
</tr>
<tr>
<td>DEC 77</td>
<td>7.69</td>
<td>.72</td>
<td>4.69</td>
<td>44%</td>
<td>61%</td>
<td></td>
</tr>
<tr>
<td>JAN 78</td>
<td>13.38</td>
<td>9.33</td>
<td>.70</td>
<td>5.86</td>
<td>44%</td>
<td>63%</td>
</tr>
<tr>
<td>FEB 78</td>
<td>14.16</td>
<td>11.95</td>
<td>.81</td>
<td>7.40</td>
<td>52%</td>
<td>65%</td>
</tr>
<tr>
<td>MAR 78</td>
<td>14.13</td>
<td>9.78</td>
<td>.69</td>
<td>5.96</td>
<td>42%</td>
<td>61%</td>
</tr>
<tr>
<td>APR 78</td>
<td>14.26</td>
<td>9.40</td>
<td>.66</td>
<td>4.45</td>
<td>30%</td>
<td>58%</td>
</tr>
<tr>
<td>MAY 78</td>
<td>7.38</td>
<td>1.56</td>
<td>.21</td>
<td>.83</td>
<td>11%</td>
<td>53%</td>
</tr>
<tr>
<td>TOTALS</td>
<td>95.76</td>
<td>61.16</td>
<td>.64</td>
<td>37.43</td>
<td>39%</td>
<td>61%</td>
</tr>
</tbody>
</table>

* SOLAR ENERGY AVAILABLE DURING TIME WATER FLOWING THROUGH COLLECTORS.

Monthly heating requirements during the winter season and the actual portion supplied with solar energy are represented in Figure 6. Also shown is that amount of the monthly heating requirements that would have been supplied with an idealized 100 percent tank storage efficiency. The actual portion of the total heating supplied by solar for the winter was approximately 40%; with 100 percent storage efficiency the amount would have been about 58%.

![Fig. 6 Tech House Heating Requirements](image)

For air conditioning the house in the summer months, the heat pump system was evaluated in two different operating modes. In one mode, heat removed from the house by the heat pumps was dumped into the storage tank. Then, at night, the water from the tank was pumped through the night radiators mounted on the north roof of the garage. Limited tests of this concept indicated that almost as much heat energy is added to the water by the
pump as is dissipated by the radiators. This results, in part, from a high dewpoint temperature (typical 70°F or greater) for this area in the summer, which limits effective nocturnal cooling.

The most satisfactory operation of the heat pumps for cooling was the mode in which well water was pumped through the direct-duct heat exchanger for precooling before being further used to dissipate the additional heat energy removed by the heat pumps.

Solar Domestic Hot Water

The design and operation of solar domestic hot water system is as shown in Figure 7. Two of the total eighteen roof-mounted solar collectors supply solar heated water to a 50-gallon solar preheat tank by means of an external tube-wrap heat exchanger. As hot water is used within the house, the conventional tank is replenished from the solar preheat tank.

Cumulative hot water energy usage for the year and the savings resulting from solar energy are plotted in Figure 8. Savings provided by solar was approximately 35 percent, which is considerably less than the 60 to 80 percent predicted. Factors that contributed to the lower percentage were family lifestyle and an undersized collector area and preheat tank for the greater than predicted typical daily usage of hot water (often over 100 gallons a day).

The monthly energy use and solar system performance for domestic hot water are represented in Figure 9. Although the use of hot water varied from month to month, the monthly variations in energy use result primarily from seasonal changes in temperature of the incoming tap water. The monthly portion of energy requirements supplied by solar (shaded portion of total use in Figure 9) is indicative of the amount of sunshine available for the month. November 1977, for instance, was rainy or cloudy virtually all month long.

Water Reuse System

For conservation of water use at the Tech House, smaller, low-profile toilet tanks were used in both bathrooms; flow restrictor devices were installed in the shower heads; and a gray water reuse system was provided to supply a major portion of the toilet flush water. It was estimated that the combination of these features could reduce total water consumption by 50 percent.

The design and operation of the water reuse system is schematically represented in Figure 10. Bath and laundry water is collected, filtered and purified with chlorine bleach and pumped to toilet tanks for flush water as required. Water is not collected from the kitchen and bathroom sinks because of the wide range of materials than can be disposed of in these places and the added complexity that would be required for necessary treatment.
The water reuse system operated satisfactorily, if not better than expected, throughout the live-in period. The system provided approximately 26 percent of the total requirements for water for the year. Objectives were realized in removing visible solids; preventing odors; holding turbidity, color, and foaming to aesthetically acceptable levels; and eliminating health hazards due to possible coliform organisms. There were noticeable, but not offensive, changes in the color of the water at times resulting from clothing dyes in the collected laundry water. Maintenance was within expected and predicted levels.

Fireplace

The fireplace is designed to be an integral part of the heating system. Water flowing through the wood grate captures additional heat energy for use throughout the house. A double-wall fireplace and the use of outside air for combustion also contribute to the overall performance and efficiency.

During the test the residents used the fireplace only occasionally. As a result there exists very little quantitative data on performance. It has been determined, however, that the fireplace as designed has a potential for supplying an appreciable part of the total house heating for much of the winter in this area. Further evaluation is planned after some indicated modifications are made to the control of the pump for the grate water and for more effective distribution of the heat collected by the double-wall fireplace.

Zone Control Heating

The heat duct system was provided with computer controlled dampers so that heat could be provided to various zones of the house in response to temperature sensors in the respective zones, as dictated by a programmed schedule for heat requirements. A time-of-day and day-of-week program was developed in accordance with the life style of the live-in family. Manual override or re-programming was possible as required for variations in normal lifestyle. The bedroom module of the house was divided into two zones and the living area module was the third zone. Temperatures ranged from 60°F in zones when not occupied, to 68°F when programmed to be occupied.

The house was heated both with and without zone control heating at different times of the winter season. Without zone control the house experienced uneven heating, 70°F in some rooms and 60°F in others, since the heating system was operating to satisfy any temperature sensor demanding heat. With zone control, there was a savings in energy and the house was heated evenly as required. There was, however, some problem in operation of the heat pump. Variations in air flow over the heat pump coils as zone dampers were operated caused the heat pumps to operate somewhat less efficiently, at times, and to cease to operate at other times from the operation of unit safety switches. The solution was to operate the heat pumps at reduced output capacity as air flow across the coils was reduced as a result of zone control.

Thermal Envelope

Passive features of the house include the orientation, external color, architectural features such as size and location of roof overhang, and the structural and thermal design of the external envelope. In addition to window shutters and double-door air lock entries, which have already been described, the thermal envelope includes double-pane windows, 6-inches of foam insulation in external walls, 7%-inches of foam insulation in the ceiling, and 6-inches of gypsum foam insulation under the floors. An operable skylight was installed in the foyer area which also enables "chimney effect" ventilation during certain times of the year when the temperature is suitable. Outside doors were insulated metal type with a thermal break from exterior to interior door surface. Special magnetic seals were provided for the outside doors.

Thermal envelope design features are best evaluated in laboratory controlled conditions and cannot easily be quantitatively tested with a family living in the house. Evidence of the combined performance is provided by the total energy required for cooling and heating which was less than half that projected for the defined conventional house of comparable size.

Foam Insulation

A urea-tripolymer foam was used in the ceiling, in exterior walls, and in some interior walls. The 7%-inches of foam in the ceiling and nominal 6-inches in exterior walls provided R-values of approximately 34 and 25, respectively. In addition to the thermal characteristics, the foam was selected because it was tested to be non-flammable and to provide no toxic gases or objectionable odors.

After the live-in test was completed, and about 30 months from the time it was installed, the foam insulation was examined at several locations: on the west wall of the living room, on the north wall of the dining room; and at an internal wall between the hallway and a bedroom. The examination consisted of removal of the sheetrock for visual observation of the foam insulation. At all locations examined the foam showed various degrees of shrinkage and a random pattern of cracking. In spite of the shrinkage and fracturing, the heat loss data for the test year indicated generally good insulation effectiveness for the house. The cause of shrinkage and cracking and the extent of reduction in insulation quality will require extensive additional evaluation. As viewed from the attic, the ceiling insulation also showed evidence of shrinkage and random cracking.

Miscellaneous Technology Items

Qualitative performance statements can be made about various other technology items as a result of the live-in experience. The following are general observations on use and performance of security and safety features, the external window shutters, the low voltage emergency lighting system, and the operable skylight in the foyer.

The programmable burglar alarm system was used during the year as a normal routine. When armed, or programmed, sensors at windows and under the carpet at entry locations will provide an alarm signal if someone gains entry or attempts to gain entry to the house. Fortunately, except for
novely and testing, the system was not seriously evaluated during the year. Neither were the smoke detectors and fire resistant materials evaluated. Electrical power from the local utility was lost on several occasions. During these periods the emergency low-voltage lighting system, which was constantly charged by the small panel of solar cells, performed very satisfactorily to provide low-level lighting throughout the house.

The external window shutters were used by the family to various extents. For some periods they were used effectively by the family to control heat loss or gain, both at night and during the day. At other periods they were not used extensively, except at night when they were routinely closed as an added security barrier. It is apparent from the data that use of the shutters can appreciably reduce heat loss or heat gain of the house and thereby conserve energy use.

The foyer skylight was used in the fall and spring to increase the ventilation air throughout the house. It was found, that the summer sun through the skylight produced an undesirable heat load in the foyer area. Reflective mylar film was installed on the window to alleviate this problem and still allow natural lighting for the foyer area.

Concluding Remarks

It is important to remember that the Tech House is a technology laboratory and the one-year live-in test was an evaluation of the particular technology included in the house design. The objective of the project was realized in that unique operational data and experience were obtained, comparing actual to predicted performance, for the numerous technology items under normal living conditions. Some of the incorporated systems and items performed satisfactorily as designed; others performed somewhat below expectations for various reasons. In either case, the unique information and experience gained provide valuable insight for improvements in both systems and technology.

Total energy use at the Tech House was reduced to about one-half that for the defined conventional house. It was predicted that total energy use would be reduced to about one-third. Because of available sunshine and other system design factors, solar energy systems provided less energy than expected. In addition, the actual energy required for domestic hot water was approximately 40 percent greater than projected for the conventional house due to a greater than predicted consumption.

A large percentage of the total energy saved resulted from investments in the thermal envelope, as expected, because of the method of determining projected use for space heating for the defined conventional house. Energy used for gas heating of the conventional house was converted to kilowatt hours as though it were electrically heated. No adjustment was made for the fact that the house would have, very likely, been better insulated if it had been actually heated with electricity.

Solar energy provided 41 percent (5,550 kw hr) of the total heating energy (13,550 kw hr) for the Tech House. Of the total solar energy collected and delivered to the underground storage tank, only about 49 percent was later used for space heating largely because of tank losses. It has been concluded that an above-ground storage tank, in the Hampton, Virginia area, would be more satisfactory because of the high water table and difficulty in protecting against degradation of the insulation.

Another factor contributing to the solar heating system performance was the actual percentage of possible sunshine available for the test year, compared to the normal for the area. This information is plotted in Figure 11. During the early part of the heating season, available solar radiation was considerably less than normal, as indicated. Since heating degree days were essentially normal for this same period, a large portion of the heating requirements would have very likely been supplied by solar if available sunshine had been normal. For the winter months of January and February it can be seen that available solar energy was greater than normal. Temperatures throughout these two months were abnormally low, however, and heating requirements for the house were much greater. Heating degree days for the test year, compared to the 30-year average for the area, are plotted in Figure 12.
in addition to available sunshine which was a factor as before, were the larger consumption of hot water and the family lifestyle.

Both a larger solar collector area and a larger solar preheat tank were needed to supply the percentage of hot water expected and desirable for optimum cost effectiveness of the system investment. Since all the family members were away from home most of the time when solar energy was available, the daily contribution from solar was essentially limited daily to the preheat tank capacity of 50 gallons. The use of hot water per 24-hour period was frequently over 100 gallons. If a larger portion of the hot water use had occurred during the daytime period, available solar radiation might have been used more effectively to heat a greater portion of total daily use. Under these conditions collector efficiency would have been better, also, due to lower temperature water through the collectors resulting from the addition of tap water to the preheat tank.

The water reuse system, in addition to supplying 26 percent of the overall requirements for water for the year, exceeded expectations in general operation and performance. Routine maintenance to occasionally clean the filter and replenish the chlorine bleach, used for purification, was very much as predicted. Most noticeable to the live-in family about the system was the sound of the pump when it operated and some discoloration of the water in the toilets resulting from clothing dyes. The major design information learned from the test relates to the sizing of the gray water collection tank based on family make up and lifestyle. At the Tech House, if the collection tank size had been 140 gallon capacity, instead of 110 gallon, a larger percentage of the flush water requirements would have been supplied by the system. The larger tank capacity would have enabled more of the laundry water, from numerous consecutive wash loads, to be collected and later used for toilet flushing.

Statements by the live-in family members indicated that while they were always aware that their every action was indirectly monitored and recorded, they found none of the technology intrusive. They were impressed with some of the technology to the extent that they hoped to add it at their permanent residence in Florida. Two such items, in particular, were the window shutters and the water reuse system. The family agreed that no conscious effort was made to alter their lifestyle during the year.

The actual performance of the technology items during the live-in test is perhaps not as important as what was learned that could improve systems and design features. It now appears important to customize the design of a solar energy system or a water reuse system, for example, to fit the family make up and lifestyle. It also appears that the water reuse system can be cost effective in many regions of the country and may have much greater potential than ever imagined. From the experience of the Tech House, solar energy for domestic hot water is already a cost effective investment over the expected life of the system, if sized and designed properly. Solar energy for space heating constitutes a sizable investment, and with the present cost of conventional energy, cannot be justified on an economic basis.

Whether the Tech House is the shape of things to come is not clear at this time. The project has served as a catalyst for increased interest, both locally and nationally, in new technology for the home building industry and for residential applications, in general. The next 25 years will be interesting as these and other new technology features are integrated into practical and architectural changes to homes built in the future.

References