MASTER

**PASSIVE-DESIGN CONCEPTS
APPLIED TO MULTIFAMILY CONSTRUCTION:
CHESAPEAKE, VIRGINIA**

Prepared by
The Design Collaborative

for

SOUTHERN SOLAR ENERGY CENTER

and

U.S. DEPARTMENT OF ENERGY

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SOUTHERN SOLAR ENERGY CENTER

OPERATED WITH SUPPORT FROM THE U.S. DEPARTMENT OF ENERGY
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FINAL REPORT

PASSIVE DESIGN CONCEPTS APPLIED TO MULTIFAMILY CONSTRUCTION

CHESAPEAKE, VIRGINIA

THE DESIGN COLLABORATIVE
138 SOUTH ROSEMONT ROAD
VIRGINIA BEACH, VIRGINIA 23452

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FOREWORD

The Southern Solar Energy Center, Inc. (SSEC), operates as a regional organization serving the southern United States. The Center's primary function is to support and implement regional energy programs for the U.S. Department of Energy. SSEC is currently concerned with research, development, and associated field testing of solar and renewable energy sources, including related advanced conservation techniques. Activities that support federal research and development programs and technology transfer to the region's industry are emphasized.

This project, funded by SSEC's Passive/Hybrid Solar Program, documents the design and technical assistance process for multifamily development in the Norfolk/Virginia Beach, Virginia area. It includes the energy-related alternatives considered and the process of evaluating them, site planning, building design, and thermal performance analyses. The project was conducted in a cooperative manner with the local building community in order to achieve effective technology transfer.

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PROJECT OBJECTIVES

The objective of this project was to redesign a speculative multifamily townhouse project to include justifiable energy-conserving and passive solar features. The redesign was undertaken to achieve significant energy savings without compromising first-cost and marketability criteria so that the redesigned townhouses would be built and sold by a local builder-developer. The built project was to be monitored and publicized to demonstrate the viability of energy-conserving, passive solar, multifamily housing and thus encourage other builders to adopt similar measures.

BACKGROUND

To date, there has been little activity directed toward the application of energy-conserving/passive solar principles to multifamily residential buildings. However, multifamily housing (rowhouses, townhouses, apartments, condominiums, etc.) now accounts for a significant and growing portion of the residential units being built in the Southern Solar Energy Center region.¹

PROJECT METHODOLOGY

To accelerate the practical application of passive solar and related advanced conservation techniques, this contract provided architectural design assistance to a builder-developer who was planning to build a multifamily residential project. The builder-developer was not obligated to accept our proposals. Therefore, the major focus of this project was in identifying, investigating, and evaluating energy-conserving/passive solar features that could comply with all the criteria that a volume speculative home builder must meet (cost, consumer appeal, schedules, ease of construction, codes, product availability, etc.).

Thus, the methodology insured that this would be a "real-life" project in which all decisions would reflect the actual forces that normally guide the design process of a speculative residential development.

PROJECT PARTICIPANTS

The project participants included the builder-developer, the architect, and the civil engineer. These three are normally involved on a multifamily project. The Southern Solar Energy Center, a regional organization operated for the U.S. Department of Energy (DOE), participated as a solar energy consultant.

1. The SSEC region includes the following:

Alabama
Arkansas
Delaware
District of Columbia
Florida
Georgia

Kentucky
Louisiana
Maryland
Mississippi
North Carolina
Oklahoma

Puerto Rico
South Carolina
Tennessee
Texas
Virginia
Virgin Islands
West Virginia

Because of the presence of SSEC, this project attracted the participation of several other organizations that normally would not be so actively involved in a project of this nature. These participants were the land developer, the local utility, and the local home builders' association.

All of the participants were enthusiastic about being involved in an energy-conserving/passive solar project, and all made significant contributions.

The project participants were the following:

1. Southern Solar Energy Center
Atlanta, Georgia
Project Manager: Don Abrams

The Southern Solar Energy Center is one of the four regional energy centers funded by DOE as part of its solar program. SSEC helps to complete the research and development process and accelerates the practical application of renewable energy sources.

2. Builder-Developer
The Christopher Companies
Virginia Beach and Vienna, Virginia

The Christopher Companies, an experienced and successful real estate development company, emphasizes home building. The firm is involved in land development, construction, and marketing. In 1980 the company's volume was \$10 million. Prior experience in multifamily projects includes 289 townhomes completed in the local area within the past three years.

The Christopher Companies had no prior experience with solar energy, but did have an ongoing commitment to energy conservation. For example, foamed-in-place infiltration sealant was provided as a standard item on their projects.

3. Architect (SSEC Subcontractor)
The Design Collaborative (TDC)
Virginia Beach, Virginia
Project Architect: Richard Fitts

The Design Collaborative is an eight-member architectural firm with a broad range of experience in residential, commercial, industrial, and institutional projects. In its 16 years of experience, TDC has designed thousands of units of multifamily housing. Furthermore, TDC previously designed two townhome projects for the Christopher Companies.

The Design Collaborative has had considerable experience in passive solar and energy-conscious design. TDC architects won awards in the 1978 HUD/DOE passive solar residential design competition and in the 1980 Virginia state passive solar residential competition. Since 1978, TDC has designed over 20 passive solar projects, including homes, condominiums, and office buildings.

4. Civil Engineer
Engineering Services
Virginia Beach, Virginia

Engineering Services is a civil engineering firm providing land surveying, site engineering, and land planning services. Engineering Services had provided all site engineering for the Greenbrier Planned Unit Development.

5. Land Developer
Greenbrier Associates
Chesapeake, Virginia
Partner-In-Charge: Lee McClurkin

Greenbrier Associates is a land development company responsible for the development of the 3,000-acre Greenbrier Planned Unit Development (PUD) in Chesapeake, Virginia.

Greenbrier Associates had previous experience in passive solar energy and energy conservation. The Greenbrier PUD was the subject of a 1979 case study by the Community Systems Division of DOE.¹

Lee McClurkin headed the case study research team, so he was familiar with both the opportunities and the obstacles involved in combining passive solar with speculative housing.²

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1. "Case Study of Project Planning and Design For Energy Conservation, Greenbrier, Chesapeake, Virginia," DOE Contract No. EM-78-C-01-4216.
 2. The Greenbrier Case Study recommended that residential operating energy consumption could be reduced by 54.7 percent for an additional capital investment of \$200 to \$3,150 per dwelling. Their conclusion follows:

"Although the expected energy savings is achievable within the confines of current 'state-of-the-art,' commercially available mechanical equipment and careful land planning and construction techniques, several obstacles remain in the way of implementation. Foremost among these obstacles are the highly competitive and inflationary nature of the residential construction industry, and an overwhelming lack of knowledge among the residential consumer as to what constitutes energy conservation in residential structures. Until there is demonstrable evidence that either these expected savings can be achieved at no increase in cost, or until the consuming public demands more energy efficient structures from the residential construction industry, it appears unlikely that the energy conserving options advocated in this research will be implemented in the speculative building market."
(Emphasis ours.)

6. Local Utility

Virginia Electric and Power Company (VEPCO)
Norfolk, Virginia

Representatives: G.E. Bishop, Jr., Manager Energy Service Division
James Bondurant, Director Energy Services

VEPCO is the public utility for Virginia. VEPCO had previous experience with passive solar energy and energy conservation. They participated in the Greenbrier Case Study and in the planning of a passive solar demonstration house.

7. Local Home Builders' Association

Tidewater Builders Association (TBA)

Chesapeake, Virginia

Representative: Frank Smith, Executive Vice President

The Tidewater Builders Association is the local builders' organization and is affiliated with the National Association of Home Builders.

The TBA had previous experience with passive solar through the design of a solar demonstration home.

PROJECT CONCEPT

The project was a planned townhouse-for-sale development in Chesapeake, Virginia. Chesapeake is a suburban community in the Norfolk-Virginia Beach metropolitan area of southeastern Virginia. Phase 1 of the project was planned for 162 townhouses, with the option to eventually build more than 300 units.

The builder-developer-architect team had previously produced two very successful townhouse projects. These two projects had established small townhouses as a viable housing product in this market. The builder-developer's concept for this project was to reuse the plans from the most recent project (Windmill Point) with only minor modifications.

The target market for these townhouses was the first-time buyer, so a low initial cost was imperative. The project consisted of three models, which were small two- and three-bedroom townhouses of 925 square feet, 1,126 square feet, and 1,250 square feet (gross floor area). The sales prices were to have been in the mid to upper \$40s in the spring of 1981.

The builder-developer decided to maintain a traditional "Colonial" street elevation featuring lap siding, shutters, and single-hung windows. In this area, a traditional appearance is felt to appeal to a broader market segment than any other style. The rear elevations were as simple as possible, featuring 4' x 8' panel siding, sliding windows, and a sliding glass patio door.

PROJECT SITE AND CLIMATE

The Norfolk regional area, comprised of the cities of Norfolk, Portsmouth, Chesapeake, and Virginia Beach, is known as Tidewater. The population of Tidewater is approximately 900,000. Land use varies from rural areas in parts of Chesapeake and Virginia Beach to central city in Norfolk. However, the overall land use character is suburban.

The topography of Tidewater is flat and low (near sea level).

The Tidewater climate is characterized by hot-humid summers (typical of the southeastern United States coastal areas) with mild winters. Tidewater has 3,488 heating degree-days and 1,441 cooling degree-days. The area has an average yearly temperature of 60.6 degrees F., an average winter temperature of 47.4 degrees F., and an average summer temperature of 78.3 degrees F. Heating is, thus, the first design priority with cooling second.

The Tidewater area has relatively low wind velocities both summer and winter. Average summer wind velocity is 9.5 mph, while average winter wind velocity is 11.2 mph. Average rainfall is 43.1 inches per year.

The Tidewater receives a yearly average of 1,399 Btus of solar radiation per square foot per day, or roughly 54.7 percent of possible radiation. The area receives an annual average of 2,803 hours of sunshine, or 62 percent of the maximum possible. Although a good quantity of solar radiation is present, a relatively high percentage of this radiation is diffuse, being scattered or reflected by clouds or other atmospheric constituents. The latitude is 36 degrees 51' north.

The project site was a 14.7-acre parcel in the 3,000-acre Greenbrier Planned Unit Development.

The site was flat and bounded by a man-made lake on its west side. Site access was by a secondary road on the north and east. At 162 units on 14.7 acres the project density was 11 units/acre, which is about average for small townhouses.

LOCAL BUILDING PRACTICES

Typical new home construction for houses in this area and in this price range includes the following features as normal practice:

1. 4" concrete slab-on-grade ground floor construction with 1" x 24" beadboard perimeter insulation.
2. Aluminum windows with double insulating glass.
3. Prehung, metal-faced, foam-filled insulated entry doors.
4. 2 x 4 wood stud wall construction with non-insulating sheathing, R-11 kraft-faced batt insulation, gypsum wallboard, and wood or hardboard siding.

5. Wood truss roof structure with R-19 blown ceiling insulation.
6. Air-to-air heat pump HVAC system.

LOCAL ENERGY AVAILABILITY AND RATES

Although VEPCO provides both natural gas and electricity, new homes in recent years have been all-electric because of a moratorium on new gas hook-ups.

During the course of this study, VEPCO lifted its moratorium, and natural gas became available.

Electricity rates vary with the amount used and with the season (summer rates are higher). At the time of this study rates were about 5.6 cents per kwh.

ENERGY USE CHARACTERISTICS OF TOWNHOUSES

Townhouses (also called row houses) are attached side-by-side homes, usually of two stories. Typical buildings include from four to nine townhouses. Because only the front and back walls are exposed to the weather, heat loss/gain is much less than in a detached home of equivalent size. Because energy use in townhouses is less to start with, potential savings are also small. Therefore, it is more difficult to justify additional costs for energy conservation and solar heating.

Townhouses are typically narrow and deep. Therefore, the exposed wall area available for passive solar collectors (windows, sliding doors, greenhouses) is small relative to the floor area. This limits the potential for passive solar.

End units in townhouse buildings use more energy because heat loss/gain is increased through the exposed end wall.

PROJECT STATUS AT INITIATION OF SSEC INVOLVEMENT

At the time SSEC became involved, the project team had already been assembled and initial planning had begun. The site had been selected, preliminary site plans had been approved, and site engineering was proceeding.

The owner-developer had decided to build three models based on the previous architectural plans. Therefore, many architectural decisions were already known. This was fortunate because it allowed the project participants to focus most of their attention on energy conservation and passive solar options.

The project time schedule was also set. The owner-developer planned to start construction in 90 days from the initial meeting. This short time schedule forced the project participants to proceed quickly in the redesign process.

PROJECT GOALS AND CONSTRAINTS

The goal of this project was to redesign the townhouses to reduce energy consumption as much as practicable within the constraints noted below. We endeavored to include as many justifiable energy-conserving and passive solar features as possible.

The energy redesign process was subject to the following constraints:

1. The preliminary site plan had been done and had received preliminary city approval. Some final site engineering drawings had already been begun on a small portion of the site. Therefore, any site revisions would require both a time delay (to redraw the plans and to obtain new approvals) and an additional cost for engineering fees.
2. The townhouses were to be based on three models previously built by the owner-developer. These models had sold very well. Therefore, the owner-developer was receptive to minor improvements, but not to major changes in layout, appearance, or cost. Specific constraints were as follows:
 - a. The plans must be identical on north-facing and south-facing lots. Alternate north/south plans were rejected as adding too much complexity to the construction process. Also, alternate plans suggested potential marketing problems - confusion of potential buyers.
 - b. Retain the "Colonial" appearance on the front elevations. The requirements for window shutters and a "Colonial" appearance limited our opportunity to provide larger glass areas.
 - c. Hold the 19.0' lot width. This limited the total amount of south-facing wall available for potential passive solar collection.
 - d. Hold the unit floor areas at or very close to the original plans. The units were very tight. For example, adding a masonry mass wall or a freestanding mass (e.g., water tube) would compromise furnishability noticeably. Furnishability was judged as more important than passive solar.
 - e. Retain all the successful features of the previous plans. For example, the bay window option on previous models was very popular.
3. Costs were the overriding concern. Because the target market was first-time buyers, a low initial cost was essential.
4. Due to the inherent energy efficiency of townhouses as a building type and because of the small size of these units, heating and cooling costs were not large to start with. Thus, there was reduced opportunity to make dramatic savings. The estimated total monthly utility cost for these all-electric units (with a heat pump) was \$67.50/month.

5. The owner-developer's time schedule was to start construction approximately 90 days from the initial meeting. This meant that design time was compressed and that concept development, evaluations, and decisions had to be made quickly. (Our experience with owner-developers of single-family projects in this market has been that they all expect to move their projects this fast or faster.)

EVALUATION CRITERIA

Note that the final decision on all proposed features was the prerogative of the owner-developer. The owner-developer, though interested in energy conservation and passive solar, never lost sight of the basic goal of selling homes at a profit.

This professional attitude was characteristic of all the project participants. Therefore, the realities of free market competition were never slighted or ignored in this project. The following criteria were used to evaluate proposed energy features:

1. Low-cost/no-cost criteria. Cost was the most important criterion. No-cost options were obviously preferred. Low-cost items were evaluated for payback. We looked for a simple payback in reliably estimated energy savings of no more than three to four years.

The three- to four-year payback was selected on the judgment of the owner-developer. We decided that most buyers do not own their homes long enough to directly benefit from longer paybacks. Although more involved methods of payback analysis were considered, simple payback was selected as the criterion. Simple payback is easier to explain to prospective buyers. Also, simple payback is easy to evaluate during the design process. Even though energy-saving features would undoubtedly help in future resales, low initial cost and quick payback were still judged to be more important.

2. Consumer appeal criteria. Energy-saving features must contribute to the marketability of the townhouse. If the sales price must be increased, there must be a reasonable explanation that the buyer can and will pay for the feature or that the feature can be offered as an option. Note that on production housing, options must be kept to a minimum.

The owner-developer felt that energy conservation is better understood and accepted by local buyers than is passive solar. Therefore, energy conservation features appeal to a much larger number of home buyers than do passive solar features.

Visible, tangible features such as attic fans were considered to be the most popular features. Sometimes certain features were in such demand that we included them in the project in spite of excessively long payback or questionable performance. Consumers demanded them. Therefore, not to offer them would be a noncompetitive posture relative to other projects.

Non-visible, tangible features such as increased insulation were considered somewhat less appealing, but still very marketable.

Simple direct gain passive solar was considered to be even less marketable by the owner-developer because of lack of buyer knowledge. We were not sure that buyers would believe that proper solar orientation would really save them money. More complex passive solar features such as Trombe walls were considered to be the least acceptable. Such a feature combined extra cost and unfamiliarity.

3. Low-hassle/no-hassle criteria. All features considered for production housing must work in the real world. Tricky details, hand crafting, exotic materials, and fragile products are out. Features must be reliable, proven products. They must create no problems in the construction process or for the buyers. Preferably products and materials will be locally available and will be supplied and installed by the owner-developer's normal subcontractors.
4. Appearance criteria. Appearance of the townhouses is very important to owners. All features that would be normally visible on the exterior or the interior of the unit must fit in. Realtors feel that first impressions are extremely important to sales. It is not uncommon to spend \$20,000 to have one sales model professionally decorated and furnished.

The owner-developer takes great pride in the appearance of his developments. He goes to extra lengths to create and maintain an attractive development. For example, all buyers must belong to a homeowner's organization, which zealously enforces standards of appearance. This is part of the owner-developer's long-range plan. They find that many new sales are made by referrals from previous buyers.

5. Legal criteria. All features were evaluated for compliance with applicable building codes, zoning ordinances, etc.

PROPOSED ENERGY-SAVING FEATURES

With consideration for the project goals, constraints, and evaluation criteria, the architect selected over 50 possible energy conservation and passive solar features to be evaluated by the project participants. These features were grouped into the following general areas:

1. Space heating and cooling
2. Water heating
3. Lighting
4. Appliances
5. Miscellaneous

For a detailed list of these proposed energy-saving features, see Appendix A.

PROJECT REDESIGN PROCESS

The project redesign process was essentially one of group discussion. Over the course of three months, periodic meetings were held to discuss and evaluate the proposed energy-saving features.

The various project participants contributed information and opinions according to their specialty. Costs were generally provided by the owner-developer based on actual subcontractor prices. Energy savings were estimated by SSEC or VEPCO. Marketability judgment was provided by the owner-developer. The architect acted as overall project coordinator. Overall, the process was very productive, positive, and solution-oriented.

SUMMARY OF SELECTED ENERGY-SAVING FEATURES

As a result of the redesign process the owner-developer accepted 25 of the 50 proposed features. Nineteen features were accepted as standard items, and six were accepted as options.

We were able to achieve a redesign of the site plan so that all lots had proper passive solar orientation. This resulted in maximum winter solar gain for reduced heating loads and minimum summer solar gain for reduced cooling loads. Beyond proper solar orientation, no other specific passive solar features met the evaluation criteria for payback.

The majority of the selected features were energy conservation features. In general, energy conservation features were inexpensive, easy to integrate into the construction process, marketable, and quite effective in reducing energy consumption.

Following is a summary of the energy-conserving and passive solar features selected for this project. Note that some of the features (asterisked) were already standard items for this owner-developer prior to this redesign. (For a more detailed summary of the evaluation of each of the 50 proposed features, see Appendixes D and E).

	EXTRA COST
A. STANDARD FEATURES	
1. Solar Orientation:	
All lots face true south $\pm 20^\circ$ for optimum solar gain.	0
*2. Double-Insulating Glass	0
3. Overhangs To Shade Windows:	0
Fixed roof overhangs were provided where possible to allow winter solar gain and shade windows from unwanted summer solar gain.	
*4. Insulating Entry Doors	0
5. R-19 Wall Construction	\$156

	EXTRA COST
*6. Infiltration Sealant:	\$100
Expanding foam sealant was provided at exterior walls and ceiling penetrations to reduce air leaks (infiltration).	
*7. Slab Perimeter Insulation	0
8. R-26 Attic Insulation	\$60
9. Heat Pump (Air-to-Air) HVAC System	0
10. Heat Pump and Ducts Located in Heated Space:	0
Locating the heat pump and ducts in heated space reduces losses due to duct leaks.	
11. Whole House Ventilating Fan:	\$250
A whole house ventilating fan helps cool the house without air conditioning.	
12. Attic Ventilation Fan:	\$100
An attic ventilation fan is believed to reduce the cooling load by exhausting hot air from the attic in the summer (see Appendix D).	
*13. Proper Roof Vents:	\$25
Ridge and soffit vents were sized to provide adequate relief for the whole house ventilation fan.	
*14. Energy-Efficient Water Heater	\$25
15. Water Heater Time Clock	\$75
*16. Water-Saving Faucets and Shower Heads:	0
These save energy by reducing the amount of hot water used. Also saves water.	
17. Single-Lever Type Faucet and Shower Controls:	\$50
These can save energy and water by encouraging owners to turn the water on and off rather than letting it run.	
18. Fluorescent Kitchen Light:	\$20
Fluorescent lights use less electricity than incandescent lights.	

	EXTRA COST
19. Owner's Manual:	\$30

Owners would be educated about the ways to save energy with the features provided in their new home.

\$897

B. OPTIONAL FEATURES

1. Solar Water Heater	\$2,500
2. High-Efficiency Heat Pump	\$250
3. Storm Windows:	?

Provides triple glazing when installed over standard double-glazed windows.

4. Movable Window Insulation	\$750
5. Energy Monitor:	\$250

An energy monitor encourages conservation by providing owners with constant read-out on the cost of their rate of energy use.

PLANS OF REDESIGNED PROJECT

Comparison of the original site plan and the redesigned solar site plan shows that proper solar orientation was easily accomplished for all lots. Also note that five additional lots were provided. This reduced the land cost per unit and increased the project's profit potential. Deleting the lakefront east/west-facing lots was not perceived as a great loss. The owner-developer decided that they probably could not have charged a premium price for them anyway.

Examination of the floor plans and elevations reveals how normal they are in comparison to similar townhouse projects. We did not provide appreciably more glazing (collector) area due to architectural constraints such as room size and the clearance required for the shutters. The project does not look "solar" because it does not have recognizable "solar" features, such as large south-facing glass areas, Trombe walls, greenhouses, tile floors, wood stoves, etc. This non-solar look is probably more acceptable to a majority of prospective buyers.

ORIGINAL SITE PLAN

SO .AR SITE PLAN

SECOND FLOOR PLAN

FIRST FLOOR PLAN

FRONT ELEVATION

0 10 FT

REAR ELEVATION

0 10 FT

EVALUATION OF THE REDESIGNED PROJECT

The project redesign was considered a success by all of the project participants. The goal of achieving significant energy savings was accomplished within the constraints and criteria of a real-life speculative multifamily housing project. Following is an evaluation of the redesigned project relative to the project goals, constraints, and criteria.

1. Energy use was reduced by 25 percent to 50 percent.

Thermal calculations and professional judgment indicated that the redesigned townhouses would use at least 25 percent and more likely up to 50 percent less energy. Calculations indicate a 25 percent reduction in design heat loss alone. Improvements in cooling efficiency by such features as the whole-house ventilating fan and shading are known to be effective but are not quantifiable. Due to time constraints, calculations were not done for some features.

Based on 1980 prices, a 25 to 50 percent energy savings would save the homeowner \$17 to \$34 per month or \$204 to \$408 per year. Of course, this amount will increase as energy prices escalate.

2. Real-life constraints were not barriers.

The project redesign was accomplished without compromising the constraints noted earlier in the report. Constraints on time, cost, and marketability were important but were not real barriers to achieving our energy goals.

3. Instant payback plus low cost was achieved.

The extra mortgage cost of the redesigned townhouse was less than the energy savings. The extra cost to the builder was estimated at \$891 per townhouse. This resulted in an extra cost to the buyer of \$1,158. At 12.5 percent for 30 years the owner would pay \$12.36/month in extra mortgage payments to save \$17 to \$34/month. (All of this is at Fall 1980 prices and interest rates.)

Note that for several reasons low cost is as important as payback. Initial cost must be low so that buyers can qualify for the total loan amount. We were not sure that lenders would accept our low energy costs as part of their evaluation of prospective buyers. We were also not sure if the extra costs for energy-saving features would be reflected in higher mortgage appraisals.

4. Consumer appeal was enhanced.

The energy-saving features added a market advantage to the project without compromising any other factors.

5. No "hassles" were created.

All of the energy-saving features were stock items installed by normal subcontractors. The only feature that presented much of a challenge to our ingenuity was insulating the whole-house ventilating fan in the winter.

6. Project appearance was maintained.

The exterior and interior appearance of the townhouses was essentially unchanged. Most of the features are not visible at all. Those that are visible are not objectionable nor do they attract attention.

7. No legal problems were created.

All the energy-saving features easily complied with the applicable building codes, zoning ordinances, minimum property standards, FHA, and VA requirements, etc.

PROJECT TERMINATION

Due to adverse market conditions the owner-developer decided not to proceed with this project. In the Fall of 1980 interest rates were rising and sales were falling. Furthermore, market research by the owner-developer indicated a very competitive situation in townhouses of this price range.

PROJECT RESULTS

Although no units were built, this project did achieve some positive results.

1. Market Impact

Local interest in, and awareness of passive solar energy was stimulated just by the fact that a leading owner-developer was known to be planning a passive solar project. A small owner-developer did pick up this project site and did build a townhouse project. This other owner-developer did include some of the energy-saving features in his project.

2. Application of Knowledge by Participants

Both the land developer and the civil engineer report that they learned a new respect for the importance of proper solar orientation in planning subdivisions. They now try to provide proper solar orientation on their new projects when possible. They also report that more and more builders are requesting south-facing lots.

The owner-developer has incorporated some of the energy-saving features into other projects and will plan for solar orientation in future projects.

The architect has applied the knowledge gained from this project to several other multifamily and single-family projects. In 1980-81, 150 multifamily units were planned using proper solar orientation and some of the other energy-saving features. Furthermore, the architect is publicizing the lessons of this project through local seminars.

CONCLUSION

This project did prove that achieving significant energy savings in multifamily housing is very feasible and desirable right now. The combination of proper solar orientation and effective energy conservation measures reduced energy use by 25 to 50 percent. Most important is the fact that projected energy cost savings exceeded extra mortgage costs for these features (even at mortgage rates of up to about 20 percent).

In our opinion, the basic obstacle retarding the implementation of projects like this one is the lack of knowledge in the building construction industry (builders, developers, engineers, architects, lenders, etc.). When those in the building industry learn that saving energy is basically quite simple and easy, they will do it.

APPENDIX A

PROPOSED ENERGY CONSERVATION AND PASSIVE SOLAR HEATING FEATURES

GOAL: Reduce energy consumption in townhouses by both conservation measures and use of passive solar heating.

OPPORTUNITIES TO REDUCE ENERGY USE:

1. Space heating and cooling
2. Water heating
3. Lighting
4. Appliances
5. Miscellaneous

PROPOSED ENERGY CONSERVATION AND PASSIVE SOLAR HEATING FEATURES:

1.0 Space heating and cooling options

1.1 Reduce heat loss and gain by increased insulation, especially at walls and roof.

1.10 Walls - see attached list of options.

1.11 Roof - increase amount of blown insulation. Suggested values to consider: R-26, R-30, R-38.

1.12 Slab - increase perimeter insulation below slab from 1" to 1-1/2" or 2".

1.13 Windows and sliding doors - use thermal-break frames, use night insulating shades or curtains.

1.14 Provide insulating glass with wider air gap.

1.15 Provide storm window option that gives triple glazing when used with standard double-insulating glass.

1.16 Entry door - insulating metal-faced foam-core door with magnetic weather strip.

1.2 Reduce heat loss/gain by reducing air infiltration.

1.20 Walls - seal joints in sheathing or use thermoply sheathing. Use infiltration sealant (foamed-in-place sealants).

1.21 Ceiling - use 6-mil poly vapor barrier or foil-backed gypsum wallboard.

1.22 Windows and sliding doors - use tighter units.

- 1.23 Entry door - insulating metal-faced foam-core door with magnetic weather strip.
- 1.24 Miscellaneous penetrations (dryer exhaust, range hood exhaust) - use backflow preventer-type caps that really work (if available).
- 1.3 Increase passive solar heat gain in winter.
 - 1.30 Orient units within 20 degrees of true south.
 - 1.31 Optimize south-facing glass area (balance heat gain, heat loss, appearance, and cost).
 - 1.32 Increase thermal mass inside units to store solar heat. Expose the masonry party walls. Fill block cores. Thermally expose the concrete slab (tile instead of carpet).
 - 1.33 Do not shade south-facing glass in winter (a properly designed overhang will allow low winter sun in while blocking out high summer sun).
 - 1.34 Use open planning to encourage distribution of solar heat throughout the unit.
 - 1.35 Locate living spaces on south of unit where possible.
 - 1.36 Provide solar greenhouse as option.
- 1.4 Reduce solar heat gain in summer.
 - 1.40 Orient units south $\pm$ 20 degrees.
 - 1.41 Shade south-facing glass in summer.
 - 1.410 Use properly designed overhangs.
 - 1.411 Or use removable shading screens.
 - 1.412 Or use deciduous trees/vines (the site has many existing trees).
 - 1.413 Or use operable awnings.
 - 1.42 Reduce heat gain in areas adjacent to townhouses.
 - 1.420 Study paving and landscaping materials.
- 1.5 Reduce the use of air conditioning by using more natural or fan-assisted ventilation.
 - 1.50 Plan units for cross ventilation where possible.

- 1.51 Use windows that allow more ventilation area (avoid single-hung windows).
- 1.52 Use whole-house ventilating fans (study exhaust louvers needed).
- 1.53 Use ceiling fans.
- 1.54 Raise ceiling heights and use larger windows to encourage natural ventilation.
- 1.6 Increase efficiency of heating equipment and/or distribution system.
 - 1.60 Make heat pump standard instead of optional (about 85 percent choose heat pump at Windmill Point).
 - 1.61 Locate inside unit of heat pump in conditioned space instead of in attic. HVAC subcontractor estimates about 10 percent increase in system efficiency due to eliminating duct loss and leakage.
 - 1.62 Use more efficient heat pump units.
 - 1.63 Or use water-to-air heat pump units.
 - 1.64 Provide for direct use of outside air (economizer cycle).
 - 1.65 Increase duct insulation (2" presently used).
 - 1.66 Locate return to circulate solar-heated air.
- 1.7 Provide option for heat-circulating fireplace or wood stove.
- 2.0 Water heating options
 - 2.1 Reduce temperature of water heater thermostat.
 - 2.2 Reduce time of operation of water heater.
 - 2.20 Use time clock.
 - 2.21 Use wall switch to override time clock.
 - 2.3 Reduce heat loss from water heater and/or lines.
 - 2.30 Use water heaters complying with ASHRAE 90-75.
 - 2.31 Provide insulation jacket for water heater.
 - 2.32 Insulate hot water lines.

2.4 Reduce hot water consumption.

2.40 Use flow restrictors on faucets (required by Virginia Beach code).

2.41 Use single-lever faucet controls to encourage turning off and on water instead of running the water (temperature setting is not lost).

2.5 Solar water heating.

2.50 Active solar water heating.

2.51 Qualifies for federal income tax credit to buyer.

2.52 Passive solar water heating may be viable if available; need to solve problem of freeze protection.

2.53 Provide heat reclaimer for domestic water heat pump.

3.0 Lighting

3.1 Use more fluorescent lights in lieu of incandescent (bath and kitchen are good places for fluorescent).

3.2 Use larger windows for more daylight.

3.3 Study site lighting for energy efficiency.

4.0 Appliances

4.1 Use energy-efficient dishwasher.

4.10 Use dishwasher without drying cycle or with drying cycle optional.

4.11 Use dishwasher with booster heater to allow lower setting on water heater.

4.2 Use energy-efficient refrigerator.

4.20 Extra insulation

4.21 Switched door heaters

4.3 Use energy-efficient stove.

4.30 Microwave option

4.4 Use solar clothes dryers.

5.0 Miscellaneous: Provide owner's manual

5.1 Education

Note: Studies of energy use in identical units show widely varying energy use (200 percent differences). Residents need education on how to conserve energy.

5.2 Energy monitor

A device is available that constantly reads out the cost of energy use. This lets people get instant and constant feedback on their energy use and cost. According to manufacturers, people use less energy when their awareness is raised about how much they are using.

5.3 Provide natural gas in lieu of electricity for space heating, water heating, and cooking.

APPENDIX B

WALL CONSTRUCTION OPTIONS

I. Options to Increase Wall Insulation

Note: For ease of discussion and comparison, R-value shown is for total of significant insulating materials disregarding air films, wallboard, siding, and non-insulating sheathing; therefore, the base line wall is R-11 since only the R-11 batt is a significant insulator.

A. R-17, R-19, R-21

Use R-13 unfaced batt insulation with continuous 6-mil polyethylene vapor barrier under wallboard. Use 1/2" (R-4), 3/4" (R-6), or 1" (R-8) "Thermax" type insulating sheathing. Tape joints with 3" aluminum tape or parsec tape.

B. R-19

Use 2 x 6 studs @ 24" o.c. and R-19 kraft faced batt insulation. Use "Thermoply" type sheathing.

C. R-23, R-25, R-27

Use insulating sheathing with 2 x 6 wall. Provide poly vapor barrier under wallboard.

II. Options to Increase Exposed Thermal Mass at Masonry Party Walls

Note: As normally built, the dead air space between the furred wallboard and the block effectively insulates the block from the townhouse. Exposing the heat-storing block to the townhouse will moderate temperature fluctuations inside, thus reducing peak heating and cooling loads. Excess solar heat will tend to be collected and stored in the block. Best results will be attained if block is heavy aggregate, and solid or with cores grouted solid.

- A. Use plaster, stucco, or other direct, trowel-applied decorative finish.
- B. Use decorative brick-pattern block and paint.
- C. Use "flexi-wall" rolled plaster wall covering over block.
- D. Use wallboard adhesively applied with heavy bead of glue.
- E. In all these options provision for wiring, receptables, and switches must be made.

APPENDIX C

TYPICAL CONSTRUCTION OF TOWNHOUSES PRIOR TO REDESIGN FOR ENERGY CONSERVATION AND PASSIVE SOLAR

BASELINE INFORMATION ON WINDMILL POINT TOWNHOUSES

<u>HVAC</u>	Air-to-air heat pump is optional (over 85 percent choose it). Electric furnace with central air conditioning is standard.
<u>WINDOWS AND SLIDING DOOR</u>	Aluminum frame, double-insulating glass. Windows are sliders at rear and single hung at front.
<u>FRONT DOOR</u>	Prehung metal insulating entry doors with magnetic weather strip.
<u>WALL CONSTRUCTION</u>	Hardboard siding. Sheathing - various non-insulating sheathings such as gypsum, fiberboard, "Thermoply," and "Denny Board." 2 x 4 @ 16" o.c. R-11 kraft-faced batt insulation. 1/2" gypsum wallboard.
<u>INFILTRATION SEALANT</u>	Polycel sealant (fiberglass sill sealer also).
<u>ATTIC INSULATION</u>	R-19 blown.
<u>SLAB INSULATION</u>	1", R-3.6, 12" under slab and between slab and shoe block.
<u>WATER HEATER</u>	Electric "Energy-Mizer" complying with ASHRAE 90-75, 40 gallon.
<u>APPLIANCES</u>	Electric refrigerator, stove and dishwasher. Normal builder quality.
<u>PARTY WALLS CONSTRUCTION</u>	8" lightweight concrete block, 2 x 2 furring, and gypsum wallboard both sides.

APPENDIX D

EVALUATION SUMMARY FOR SELECTED ENERGY-SAVING FEATURES

INTRODUCTION

Following is a summary of the evaluation of those proposed energy-saving features that were selected for this project. In general, the reasons for selection fell into the following categories:

1. Already Standard Features:

Some features, such as double glazing, were already standard with the owner-developer. These features were retained in the redesigned project.

2. Already Popular Options:

Some features, such as heat pumps, were already popular. Without much evaluation, these were made standard instead of optional.

3. Obviously Effective Features:

Some features such as fluorescent lights were simple, low-cost items that were obviously energy saving. These features were adopted by consensus after some discussion. Usually no quantifiable investigation of energy savings was done.

4. Highly Marketable Features:

Consumer demand for some features proved to be the overriding consideration. The owner-developer chose two features (R-19 walls and attic fans) on the basis of this demand. This choice was consciously made in spite of a lack of justifiable energy savings.

5. Justifiable Features:

Many features were fully investigated as to cost, energy savings, availability, and all of the other evaluation criteria. Those selected met the criteria.

EVALUATION SUMMARY OF SELECTED FEATURES

1. SOLAR ORIENTATION (Proposals 1.30 and 1.40)

The decision to orient all the lots within 20° of true south was made without any quantifiable energy analysis. SSEC's expert status made an impact on the project participants. Once the benefits and principles of passive solar orientation were explained, a consensus was quickly reached.

The decision to provide orientation was also made easier because 75 percent of the lots already had acceptable solar orientation. Having 25 percent of the lots facing the wrong way would have hurt the project's credibility and its marketability. The redesigned solar site plan also achieved an increase of five lots for the project.

Fortunately, the final site engineering drawings had not been completed. Also, the subdivision had only received preliminary approval from the city. Revisions to the site plan involved extra costs for revised site engineering drawings. The revisions also necessitated a 30-day delay in the project to obtain preliminary approval of the site plan. SSEC provided funds to have the site plan revisions accomplished. The land developer was able to work around the time delay. Problems involved with the location of site utilities were solved by the site engineer and the land developer.

The opportunity to change the site plan for this project was somewhat unusual. Quite often the land developer subdivides the site long before the owner-developer and the architect (if any) get involved. The costs in money, time, and trouble to make revisions to the site plan at that point are prohibitive.

2. DOUBLE GLAZING (Proposal 1.14)

This feature is generally accepted as a basic feature in any energy-efficient home. Since double glazing was already standard with the owner-developer, it was retained.

SSEC suggested that double glazing with an air gap wider than the normal 1/4" would improve performance somewhat. The owner-developer found no reliable, local source for such windows, so this feature was not selected.

3. OVERHANGS TO SHADE WINDOWS (Proposals 1.33 and 1.410)

Fixed roof overhangs were designed to allow maximum winter solar gain while minimizing summer solar gain. This was very easy at the second floor windows, where a roof overhang is normally provided. Fixed overhangs at first floor windows were provided only where it was expedient. Overhangs for first floor windows on the front elevations were generally not acceptable in appearance or cost. Studies of an additional overhang for the first floor windows and sliding door on the rear elevations indicated very little savings (less than \$1.50/month).

4. INSULATING ENTRY DOOR (Proposals 1.16 and 1.23)

Prehung metal-faced, foam-core entry doors were standard with the owner-developer. They are very effective and were thus retained.

5. R-19 WALL INSULATION (Proposal 1.10)

R-19 wall insulation was selected in order to remain competitive with other projects. The energy saving over an R-11 wall was only \$10/year. The extra cost was \$156. The 15.6-year payback was not acceptable. However, the owner-developer decided that R-19 walls are expected by buyers in any house that is advertised as energy-efficient.

R-19 walls were achieved with R-4 insulating sheathing over 2 x 4 studs with an R-13 kraft faced batt. Poly vapor barriers (at \$0.10/s.f.) were not provided. No conclusive data supported the need for a poly vapor barrier in this climate. The infiltration sealant alone was deemed sufficient by the owner-developer in reducing infiltration.

6. INFILTRATION SEALANT (Proposal 1.20)

Infiltration sealant is a well recognized energy-saving feature among energy-conscious builders and architects. The owner-developer already provided "Polycel" infiltration sealant as a standard feature, so it was retained. The cost is \$100/unit. Savings were not estimated.

7. SLAB PERIMETER INSULATION (Proposal 1.12)

1" x 24" beadboard slab perimeter insulation is required by code and was therefore a standard feature. Raising the insulation value above the normal R-3.6 was not justifiable by energy savings versus cost.

8. R-26 ATTIC INSULATION (Proposal 1.11)

R-19 attic insulation was the owner-developer's standard. This was in line with other local projects. Energy savings of R-26 over R-19 were estimated at \$6/year. Extra cost was \$60. However, this analysis became academic when V.A. raised its insulation requirements to R-25. Obviously, R-26 was then selected.

9. HEAT PUMP (AIR-TO-AIR) HVAC SYSTEM (Proposal 1.60)

New homes in this area are almost exclusively all electric. Therefore, the choice is between electric resistance heat with central air conditioning or a more efficient heat pump system. The owner-developer had previously offered heat pumps as an extra cost option. Eighty-five percent of all buyers recognized the energy saving superiority of the heat pump and took that option. For this project the owner-developer made the heat pump standard.

10. HEAT PUMP AND DUCTS LOCATED IN HEATED SPACE (Proposal 1.61)

Energy savings due to this feature are attributable to the fact that the inevitable air leaks in the duct system and in the heat pump will not cause a net loss if the system is inside the house. Energy savings are not quantifiable but were estimated to be about 10 percent of the HVAC operating costs.

Due to the very tight plans for these small townhouses space was at a real premium, and we only achieved this feature on one of the three models. In two models they were in the attic.

11. WHOLE-HOUSE VENTILATING FAN (Proposal 1.52)

Savings achieved by this feature were not quantifiable. However, the concept of fan-forced ventilation is obviously sound, and these fans were common before the acceptance of air conditioning. Several of the participants had whole-house ventilating fans in their homes and recommended them highly. These fans do not substitute for air conditioning in the hottest months. However, they do reduce the need for air conditioning in less hot weather.

On the basis of those recommendations the owner-developer selected this feature as a standard, even though it was the single most expensive feature selected. Additional strong points in favor of these fans are that their visibility (a ceiling louver) makes them marketable and that their operation is a simple concept for buyers to understand. Also they can easily be converted to an extra-cost option if necessary to maintain a lower base price.

12. ATTIC VENTILATION FANS (Miscellaneous Proposal)

These fans exhaust air only from the attic. In contrast, the whole-house ventilating fan exhausts air from the house out through the attic. Savings due to this feature were not apparent in SSEC studies. However, they were selected by the owner-developer for their marketability. Rightly or wrongly, other builders were pushing these fans as energy savers. They were included in this project primarily to maintain a competitive position with other builders.

An unexpected benefit from this feature was gained by wiring them to run whenever the whole-house ventilating fan is on. This assists in removing air being blown into the attic by the whole-house fan. Thus the size of roof and soffit vents could be reduced.

13. PROPER ROOF VENTS (Proposal 1.52)

Roof ridge vents and soffit vents were required to be upsized in houses not equipped with attic ventilation fans to allow for the air exhausted through the attic by the whole-house ventilating fan.

14. ENERGY-EFFICIENT WATER HEATER (Proposals 2.30 and 2.32)

Electric water heaters complying with ASHRAE 90-75 were standard features with the owner-developer. SSEC studies indicated that the majority of the pipe heat losses occur in the first two to three feet from the tank. Therefore, the owner-developer decided to insulate the hot water lines from the tank to the wall.

15. WATER HEATER TIME CLOCK (Proposals 2.20 and 2.21)

This timer would limit the time of operation of the water heater. The local utility estimated a savings of \$42/year for an 80 gallon/day use. This is with the timer on two hours in the morning and two hours in the evening. Savings on this project would be less because a lower water usage is expected. However, this feature looked very desirable due to low cost (\$75), simple operation, substantial energy savings, and appeal to the consumer.

A wall switch in the hallway would be provided to override the time clock. The water heater could be easily turned on if hot water were needed during an "off" period or if larger than normal usage was expected. This is a convenience feature. It was provided because access to the water heater and time clock is difficult.

16. WATER-SAVING FAUCETS AND SHOWER HEADS (Proposal 2.40)

The local code requires these for water conservation reasons. They also save energy by reducing hot water use.

17. SINGLE-LEVER-TYPE FAUCETS AND SHOW CONTROLS (Proposal 2.41)

With this feature the water can be turned on and off without losing the temperature setting. These can save hot water (and therefore energy) by encouraging owners not to let the water run.

18. FLUORESCENT LIGHT IN KITCHEN (Proposal 3.1)

This feature was recognized as an energy saver. However, only the kitchen was considered an acceptable location for fluorescent lighting. The owner-developer expected buyer resistance to fluorescents anywhere else.

19. OWNER'S MANUAL (Proposal 5.1)

We recognized that the actual energy savings for these homes would depend on the owners' proper understanding and use of these energy features. Studies of energy use in other housing projects show as much as 200 percent variation between identical homes. Obviously the owner is the big variable.

We conceived of the Owner's Manual as a marketing device for prospective buyers as well as a guide for owners. Because the project was terminated, we did not produce the Owner's Manual.

OPTION 1. SOLAR WATER HEATER (Proposals 2.50 and 2.51)

The owner-developer felt that the appearance of the collector panels for a solar water heater would be very detrimental to the project. However, he agreed that they should be allowed as an option to be consistent with the project's commitment to energy efficiency. In order to control the appearance, rack-mounted collectors would be prohibited. Also, only glass collector covers would be allowed. These rules would be enforced by the Home Owner's Association.

Payback analysis for solar hot water is very good chiefly because of the federal tax credit. When the cost of the solar water heater is mortgaged with the house, the owner makes several hundred dollars the first year.

However, the justification for a solar water heater on these small townhouses is questionable without the tax credits. SSEC estimates only a \$120 total annual water heating cost. (This is without the clock.) Even an 80 percent savings due to solar would save only \$8/month. The extra mortgage payment for \$2,000 at 12.5 percent - 30 years is \$21.36/month.

OPTION 2. HIGH-EFFICIENCY HEAT PUMP (Proposal 1.62)

Analysis by the local utility indicated an estimated annual savings of \$30 to \$50 for a higher efficiency heat pump (2.0 tons). All of this saving was in the cooling mode. The extra cost was about \$250.

OPTION 3. STORM WINDOWS (Proposal 1.15)

"Piggyback" storm windows can easily be supplied by the window manufacturer. Thus triple glazing can be provided. The owner-developer felt this option might appeal to a significant market segment.

OPTION 4. MOVABLE WINDOW INSULATION (Proposal 1.13)

No energy savings estimates were done for this feature. However, insulating shades were felt to be effective. It was hoped that buyers would purchase these shades in place of normal non-insulating shades or drapes. Then payback would not be a major factor.

This option would also help marketability. By attracting attention in the sales models, these shades would help to convince buyers of the energy-efficient aspects of this project.

OPTION 5. ENERGY MONITOR (Proposal 5.2)

This option was also popular with the owner-developer for marketing reasons. Like the insulating shades, an energy monitor would attract attention in the sales models. It would be an interesting "gimmick," and it would reinforce the energy efficiency theme of the project.

This option is based on the Fitch Energy Monitor and experience with it. This device continuously displays the rate of electrical consumption in cents per hour. By giving the homeowner a constant reminder of energy costs, this device would encourage energy savings.

An experiment with this monitor showed a 12 percent reduction in energy use. These monitors were installed in 25 of 101 energy-efficient, all-electric homes. Savings were attributable to the fact that the monitors prompted more energy conservation by increasing awareness of costs.¹

1. "Energy Conservation Effects of Continuous In-Home Feedback in All-Electric Homes," McClelland and Cool, Institute of Behavioral Science, University of Colorado, Boulder, CO 80309, 1978.

APPENDIX E

EVALUATION SUMMARY

· FOR NON-SELECTED ENERGY-SAVING FEATURES

Following is a summary of those proposed energy-saving features not selected for this project.

1. THERMAL BREAK FRAMES AT WINDOWS AND SLIDING GLASS DOORS (Proposal 1.13)

Much too expensive for the savings in our climate. Cost \$30-\$50 more per window (\$200 - \$400 per house). The energy savings were not quantified, but they would definitely not be sufficient to justify this cost.

2. SEAL JOINTS IN SHEATHING (Proposal 1.20)

This would be overkill since the infiltration sealant is believed to be sufficient in preventing air leaks.

3. VAPOR BARRIER AT ATTIC CEILING (Proposal 1.21)

This was not justifiable by cost. The infiltration sealant is believed to be sufficiently effective in preventing air leaks. The walls had vapor barriers inside (kraft-faced batt insulation) and outside (foil-faced sheathing). Therefore the consensus was that not having a vapor barrier at the ceiling was desirable. Thus potentially damaging water vapor had a route out of the house.

4. PROVIDE BETTER WEATHERSTRIPPED WINDOWS AND SLIDING GLASS DOORS (Proposal 1.22)

This option is not available in the price range of windows and doors used. Commercial grade units would be too expensive.

5. PROVIDE EFFECTIVE BACKFLOW PREVENTER-TYPE WALL CAPS AT DRYER AND EXHAUST HOOD EXHAUSTS (Proposal 1.24)

At the time the project was designed none was found that appeared very effective. Normal wall caps with hinged flaps are often stuck open, bent, etc. At the time this report was written a new wall cap with mini-louvers was available. It is made by "De-Flecto" and appears to be effective.

6. OPTIMIZE SOUTH-FACING GLASS AREA (BALANCE HEAT GAIN, HEAT LOSS, APPEARANCE, AND COST) (Proposal 1.31)

As previously designed the units had small amounts of south-facing glass by passive solar standards. Typically south-facing glass was about 5 percent of the floor area (about 50 s.f. per unit). We set a goal of 75 s.f. of south-facing glass. This was based upon criteria developed by TEA for low-mass, direct-gain homes.¹

This amount of south-facing glass would optimize solar gain and heat loss while also reducing overheating.

1. "Restraint in Sizing Direct Gain Systems," Daniel Lewis and Winslow Fuller, Total Environmental Action, Inc., Solar Age, December 1979, pp. 28-32.

However, due to architectural constraints, we were not successful in appreciably increasing the glass area. Small room sizes, placement of rooms, required clearance for shutters, and furnishability problems conflicted with using larger windows or sliding glass doors.

SSEC calculations showed an estimated energy savings of only about \$12/year to go to 75 s.f. of south-facing glass. Therefore, the architectural constraints took precedence over increasing the glass area to achieve such a small saving.

7. INCREASE THERMAL STORAGE MASS INSIDE UNITS TO STORE SOLAR HEAT (Proposal 1.32)

The normal party wall construction for local townhouses is a lightweight concrete block masonry wall that is furred and drywalled. This masonry would be useful thermal mass if it were to be exposed. However it is isolated by the furred drywall. See Appendix B for a discussion of this feature and proposals.

The owner-developer rejected all the proposals on this matter because of cost or unsatisfactory appearance. SSEC calculations (DEROB) were unable to quantify a savings due to this feature. We believe that thermally exposing the masonry would be beneficial, but we could not prove it so.

Exposing the slab-on-grade concrete floor with tile was rejected for high cost and poor marketability. Wall-to-wall carpet is the industry standard.

8. USE OPEN PLANNING TO ENCOURAGE DISTRIBUTION OF SOLAR HEAT THROUGHOUT THE UNIT (Proposal 1.34)

This was not feasible between floors due to the very small size of the units. First floors were quite open. Second floors were bedrooms.

9. LOCATE LIVING SPACES ON SOUTH OF UNIT WHERE POSSIBLE (Proposal 1.35)

This was not feasible. We had to use the same plans on both north- and south-facing lots.

10. SHADE WINDOWS WITH REMOVABLE SHADE SCREENS, DECIDUOUS TREES, OR OPERABLE AWNINGS (Proposals 1.411, 1.412, 1.413)

Use of trees was discussed, but landscape plans were not done. Screens or awnings were rejected for cost and appearance.

11. REDUCE HEAT GAIN ADJACENT TO TOWNHOUSES BY JUDICIOUS CHOICE OF PAVING AND LANDSCAPING (Proposal 1.420)

Cost constraints made standard paving the choice. Landscaping plans were not done.

12. PLAN UNITS FOR CROSS VENTILATION WHERE POSSIBLE (Proposal 1.50)

This was considered a very low priority relative to other constraints and criteria. Little opportunity to achieve this was found. The whole-house ventilating fan was selected partially to compensate for the poor natural ventilation of townhouses.

13. USE SLIDING WINDOWS INSTEAD OF SINGLE-HUNG WINDOWS TO ALLOW MORE NATURAL VENTILATION (Proposal 1.51)

For appearance, single-hung windows were required by the owner-developer on front elevations.

14. USE CEILING FANS (Proposal 1.53)

Rejected for cost.

15. RAISE CEILING HEIGHTS AND USE LARGER WINDOWS TO ENCOURAGE NATURAL VENTILATION (Proposal 1.54)

Raised ceilings rejected for cost. Larger windows rejected for architectural constraints. See Item 6 above.

16. USE WATER-TO-AIR HEAT PUMPS (Proposal 1.63)

Rejected due to high cost and potential hydrology problems.

17. PROVIDE FOR DIRECT USE OF OUTSIDE AIR IN THE HVAC SYSTEM (Proposal 1.64)

Rejected for cost. This is not really needed in a residence.

18. INCREASE DUCT INSULATION OVER 2" (Proposal 1.65)

Rejected for cost. 2" is standard. Other is special.

19. LOCATE HVAC RETURN HIGH TO CIRCULATE SOLAR-HEATED AIR (Proposal 1.66)

This was actually accomplished on two of the three models. However, it was done because the location was expedient.

20. PROVIDE OPTION FOR HEAT-CIRCULATING FIRE PLACE OR WOOD STOVE (Proposal 1.7)

Fireplaces are a normal option. Because the project was terminated, we did not investigate whether a heat-circulating type presented any problems. We believe that a heat-circulating fireplace with glass doors and outside combustion air could be offered as an extra-cost option. Wood stoves were rejected because they require too much floor area for clearances.

21. REDUCE TEMPERATURE OF WATER HEATER THERMOSTAT (Proposal 2.1)

This would save energy, but it is not controllable by owner-developer. This would have been discussed in the proposed owner's manual.

22. PROVIDE INSULATION JACKET FOR WATER HEATER (Proposal 2.31)

This was considered overkill on the energy-saving water heaters. No calculations of savings were done.

23. PROVIDE PASSIVE SOLAR WATER HEATER (Proposal 2.52)

No reliable, commercially available unit was known at the time the project was designed.

24. USE LARGER WINDOWS FOR MORE DAYLIGHTING (Proposal 3.2)

Architectural constraints limited window sizes. Possible savings by this feature are not quantifiable.

25. STUDY SITE (STREET) LIGHTING FOR ENERGY EFFICIENCY

Because the project was terminated, this feature was not evaluated. When street lights are provided by the city, there is probably little or no opportunity to influence the design.

26. PROVIDE ENERGY-EFFICIENT KITCHEN APPLIANCES (Proposals 4.10, 4.11, 4.20, 4.21, and 4.30)

Because the project was terminated this feature was not evaluated. Normally the owner-developer selects appliances during bidding. Cost is very important.

27. USE SOLAR CLOTHES DRYERS (CLOTHES LINES) (Proposal 4.4)

This feature was not evaluated. Presumably homeowners will provide their own clothes lines in their fenced-in back yards.

28. PROVIDE SOLAR GREENHOUSE OPTION (Proposal 1.36)

Solar greenhouses presented problems of cost, building code compliance, and appearance. However, a solar greenhouse on a sales model was considered very desirable to impress buyers. Energy savings were not evaluated.

The cost of a prefab aluminum frame greenhouse was \$3,000 - \$4,000. We felt that such an expensive option was inappropriate on this low-price project.

The greenhouse presented problems of building code compliance. The end walls were required to be of one-hour fire-rated construction to meet the building code.

The appearance of the greenhouse was not compatible with the "colonial" front elevations.

29. PROVIDE HEAT PUMP HEAT RECLAIMER (Proposal 2.53)

This device uses waste heat from the heat pump to provide domestic hot water. This was not selected because of cost (\$500) and the inability to estimate energy savings accurately.

30. USE NATURAL GAS INSTEAD OF ELECTRICITY FOR SPACE HEATING, WATER HEATING, AND COOKING (Proposal 5.3)

This was not selected because of cost and design problems. Extra costs are required to vent gas appliances. Also the plans would have to be redesigned to accommodate gas appliances. For space heating and cooling, gas energy costs were equal to those of electricity (heat pumps) in 1980. With gas prices being deregulated, heat pumps will probably save more in the future. Gas water heating did show an annual savings of \$116 over electric water heating. However, we felt a combination of the electric water heater timer and deregulated gas rates would reduce or eliminate the differential.