ENERGY-EFFICIENT COMMUNITY DEVELOPMENT TECHNIQUES

Five Large-Scale Case Study Projects from U.S. Department of Energy's Site and Neighborhood Design (SAND) Program—Phase I

ULI

The Urban Land Institute
Washington, D.C.

ENERGY-EFFICIENT COMMUNITY DEVELOPMENT TECHNIQUES

FIVE LARGE-SCALE CASE STUDY PROJECTS

from

U.S. DEPARTMENT OF ENERGY'S

SITE AND NEIGHBORHOOD DESIGN (SAND) PROGRAM--PHASE I

Edited by

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The Urban Land Institute is an independent, nonprofit educational and research organization incorporated in 1936 to improve the quality and standards of land use and development.

The Institute is committed to disseminatng information which can facilitate the orderly and more efficient use and development of land; conducting practical research in the various fields of real estate knowledge; and identifying and interpreting land use trends in relation to the changing economic, social, and civic needs of the people.

ULI receives its financial support from membership dues, sale of publications, and contributions for education, research, and panel services. The Institute's members include land developers/owners, builders, architects, planners, investors, public officials, financial institutions, educators, and others interested in land use.

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This report was assembled and prepared by ULI-the Urban Land Institute based on the five case studies involved in the Site and Neighborhood Design for Energy Conservation Program. In many cases, text has been taken directly from the project reports. The reports have been edited in order to conform to the uniform style and format of this publication. Full credit and responsibility for the case study research and documentation should be given to the respective team members.

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* All case studies contain project background, team response, impediments to implementation, summary and recommendations, project data, and a list of team participants.

FOREWORD

ULI's objective in publishing this report is to disseminate to the development community information about community management systems and design techniques that work in the marketplace and improve overall energy-use efficiency. Although this segment of the SAND program may not have direct applicability to all development projects, it does provide a beginning to understanding energy-conscious land use planning. We hope that this report will help to increase the incorporation of energy-efficient measures into future development projects.

The improved energy-efficient systems and techniques which comprise the energy plans of the five SAND projects generally are based not only on energy performance but also on criteria such as availability, least cost, market acceptance, and few or no institutional constraints. As editors, we have attempted to report on SAND Phase I experience by summarizing salient points of the final technical reports of the five projects and by presenting them in a consistent format. In most instances the case studies were supplemented with background information and project data about the project so that the reader could better understand the project and, therefore, the context in which the energy decisions were made. In order to present the national energy context in which the cases were undertaken, they are preceded by an overview of the entire SAND program. Also supplementing the case study material is energy resource information, comprised of a glossary of energy-related terms, an energy bibliography, and a list of energy information sources.

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The Editors

Metric Conversion Table

Meters	= feet x 0.305
Kilometers	= miles x 1.609
Square Meters	= square feet x 0.093
Square Kilometers	= square miles x 2.590
Cubic Meters	= cubic feet x 0.028
Cubic Meters	= cubic yards x 0.765
Hectares	= acres x 0.405

(a hectare is 10,000 square meters)

PART I

OVERVIEW

THE SAND PROGRAM

The U.S. Department of Energy's (DOE) program in Site and Neighborhood Design (SAND) is based on the assumption that substantial energy efficiency improvements can be achieved in new developments and in redevelopment by considering energy efficiency a matter of first priority as key project decisions are made during the planning and design stages of project development. Achieving general acceptance and implementation of this priority will not be easy. Planning criteria and institutional arrangements that date from an era when energy was inexpensive and believed to be inexhaustible have acquired the tenacity of bad habits; they will have to be changed. The entire project planning and design process will have to be modified to integrate not only concepts of reduced energy consumption but also improved delivery systems which can depend on renewable resources. It will also be necessary for land use options to incorporate natural site systems and new energy-efficient mechanical systems such as solar, water-source heat pumps, cogeneration, and district heating.

To promote these changes, DOE's Division of Community Systems has been engaged in a series of activities that has the following overall objectives:

- to provide exemplary models of successful energy-sensitive approaches and techniques;
- to identify and/or create (in cooperation with local governments) models of regulatory procedures that enhance energy efficiency in new development and redevelopment; and
- to propose new DOE policies and legislative initiatives for energy practices in community development.

As one of DOE's several programs in community development, the SAND program has three particular technical objectives:

- to create models of energy-conscious interdisciplinary planning teams and to improve the competence of such teams to deal with technical problems of energy efficiency;
- to develop and demonstrate techniques for identifying and choosing between energy options for a given site; and
- to demonstrate effective procedures for carrying out energy-efficient site designs.

Since 1977, when the SAND program was launched, a number of state-of-the-art reviews have been completed in anticipation of site-specific case studies, which are being presented here. In one, ULI-the Urban Land Institute assessed the types and incidence of energy-related measures in real estate development, basing its findings on a survey of builders, designers, planners, and public officials (Urban Land, September 1979, the Urban Land Institute). ULI also prepared two separate lists of energy-efficient projects. In another, the Center for Landscape Architectural Education and Research compiled a 112-page compendium of existing techniques for improved energy efficiency through site selection, building orientation, planning, and design. Finally, the American Planning Association surveyed and reported on 13 communities with development regulations to foster improved energy-use efficiency.

In 1977, DOE issued a request for proposals (RFP) to designers or developers who were in the preliminary design phases of a mid/large-scale (50- to 500-acre), multi-building site-development project. In 1978, five developments were chosen from 31 applicants to participate in the SAND planning study. A total of $998,000, or about $200,000 for each project, was allocated for this phase of the program. By June 1979, concurrently with the preparation of the conventional development plan, each project team had prepared an energy efficiency plan for its site which became the basis for determining energy savings. Final submission of all of the project reports occurred in the summer of 1980.

DOE's overall objective in this phase of the SAND program has been to collect and disseminate information that will help reduce energy consumption in residential and commercial projects without reducing services, and overcome a number of constraints currently faced in achieving this goal. Among the constraints are

- a lack of documented case studies that could serve as design and construction guidelines;
- state and local regulatory procedures which inhibit the incorporation of improved energy-efficient techniques; and
- the financial risk associated with the construction and marketing of something different from the accustomed norm.

Is is hoped that this summary report will assist in overcoming these constraints. The full SAND project reports in printed copy or microfiche are available from the National Technical Information Service.* These and other SAND program materials, which include slide presentations, are available from DOE's Community Energy Program.**

PROJECT DESCRIPTIONS

The five developments chosen for the SAND demonstration program encompass a variety of climates, site conditions, development objectives, building costs, and state and local regulations. A brief description of each follows:

- Burke Centre, Virginia, is 17 miles west of Washington, D.C., in a rapidly developing suburban area. The planned population for the entire project is 15,000; the SAND study areas encompass over 210 acres for mixed residential and major commercial development. The energy objective in this temperate climate was to discover how to create an energy design while responding to the daily changing development pressures of a major metropolitan area. The DOE contractor was a project consultant, Land Design/Research of Fairfax, Virginia.
- Greenbrier, Virginia, is located in the Norfolk-Portsmouth-Virginia Beach area, which has a humid-temperate climate. Greenbrier, planned for a population of 14,000, is primarily a residential community. The SAND study area is 719 acres to be developed for single-family residences. Energy considerations included siting, infrastructure, and home heating and cooling systems, as well as groundwater heat pumps as an alternative to traditional heating and cooling. The DOE contractor was the project developer, Greenbrier Associates of Chesapeake, Virginia.
- \+ Radisson, New York, is 12 miles northwest of Syracuse, which has a cool temperate climate. With an estimated population of 18,000, Radisson is a planned community being built by the Urban Development Corporation of the State of New York. The SAND study sites, totalling over 140 acres, include a town commercial center and mixed residential developments. Primary energy considerations focused on passive siting options to reduce high winter energy demands. The DOE contractor was a project consultant, Reimann-Buechner Partnership of Syracuse, New York.
- \+ Shenandoah, Georgia, is located 25 miles southwest of Atlanta. It is a mixed residential/commercial development with a planned population of 45,000. The SAND study area is a 235-acre site to be developed as a residential neighborhood. The area's climate is considered humid subtropical. Major energy interest was in the potential of a large-scale application of site design and solar technology within existing financial and marketing constraints. The DOE contractor was the project developer, Shenandoah Development, Inc.
- \+ The Woodlands, Texas is 28 miles north of Houston and is planned for a population of 150,000. The development plans for the 500-acre SAND study area included a major regional center for mixed commercial, office, and light industrial uses. The climate is hot and humid. Energy concerns included long-range development needs over the 20-year build-out period,

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* NTIS, U.S. Department of Commerce, 5285 Port Royal Road, Springfield, Virginia 22161; (703)487-4600.

** Community Energy Program, Community Energy Management Branch, U.S. Department of Energy, Forrestal Building, Mail Stop CS 111.3, 1000 Independence Avenue, S.W., Washington, D.C. 20585.

\+ Radisson, Shenandoah, and The Woodlands are Title VII new towns.

balancing energy, infrastructure, and support requirements of a primarily nonresidential area. The DOE contractor was the project developer, The Woodlands Development Corporation,

CURRENT ENERGY CONTEXT *

Development patterns and land planning practices in the U.S. have proceeded for several decades on the presumption that gasoline, natural gas, fuel oil, and electricity would continue to be available at bargain prices. The compact, linear, streetcar suburbs of past decades have long been replaced by suburban sprawl as the prevalent form of urban expansion. Highways, rather than transit lines, have become the connectors between residential neighborhoods and employment centers. Convenience goods and services are consigned to strips along arterials, most often at the very fringe of their market area. Mass retailing and single-family detached tract housing dominate the development industry. Water and sewer systems determine the direction and pace of suburban growth. Zoning laws segregate land uses while subdivision regulations standardize most of the flexibility out of neighborhood planning. Until the initial gasoline shortages of the early 1970s, little attention was given to the amount or type of energy that would be needed to support the community structures which had evolved.

The average American family consumes large amounts of energy carrying out its daily routines. The typical "local" trip for work or shopping is usually more than a few miles, and, because the automobile is the only convenient travel mode, the routes are congested and gasoline efficiency is impaired. The decentralization of commercial and public facilities, combined with large lot, low-density subdivisions, adds additional driving time at each end of a typical trip.

Generally, it is assumed that transportation of all types accounts for 25 percent of U.S. national energy consumption. In most breakdowns of national energy use by components, between 35 and 40 percent of U.S. energy use is attributed to the construction and operation of buildings. This includes the energy embodied in construction materials (but not that used in transporting these materials) and that required for building operation and maintenance (ULI, "Focus on Energy Conservation, A Project List," p. 8, the Urban Land Institute). One breakdown of energy use in the U.S. produced the following figures (Housing, mid-May 1980, p. 12),

Use		Percent
Residential		19.2
space heating	(11.0)	
water heating	(3.0)	
cooking	(1.0)	
refrigeration	(1.0)	
air conditioning	(1.0)	
lighting and all other	(2.2)	
Commercial		14.4
Industrial		41.2
Transportation		25.2
		100.0

The SAND program, then, by focusing on energy-efficient techniques in the residential, commercial and transportation sectors encompasses the areas that currently use almost 60 percent of the energy consumed in the U.S.

Although Americans are responding to a changed energy situation by curtailing energy usage, the amount of savings still to be realized is substantial. The siting and configuration of most structures ignore the impact of sun and winds and the long-understood techniques for cooperating with nature. Mechanical systems within structures also often waste much of the energy they consume.

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* Includes edited sections from Burke Centre's final report, p.2.

FIGURE 1

SAND ENERGY-EFFICIENT TECHNIQUES BY PROJECT

o considered
● used
◐ recommended but not included in energy plan savings

	Energy-Efficient Technique	BURKE CENTRE	GREEN-BRIER	RADISSON		SHENANDOAH			THE WOODLANDS
				residential	town center	passive	dispersed systems	central util.	town center
LAND/SITE PLANNING	Building/lot orientation (max south)	●	●	●	●	●	●	●	●
	Pavement width/length reduction	●	◐		o	●	●	●	◐
	Efficiency of lot to infrastructure	o	o	●		o	o	o	
	Vegetation screening	●	◐	●	●	●	●	●	●
	Landform screening	●		●	●	●	●	●	
	Building arrangements (clustering)	●		●	●	●	●	●	
	Increased building densities			●					●
	Central location of public uses	●				●	●	●	o
	Pavement shading					●	●	●	
	Humidity control					●	●	●	
	Shared parking	o			●				●
	Exterior space locations					●	●	●	
	Reduced parking				●				●
	Compatability between uses								●
	Separation of through & local traffic								●
	Pathways to encourage non-motorized travel	●							●
	Decreased number of intersections	●	o						●
	Micro-climate modifications								◐
	Multi-use/MXD buildings	●			o				
ARCHITECTURAL	Internal space reconfiguration		o	●		o	o		
	Solar screening		o	●		●	●	●	
	Arkansas construction		●	◐					
	Double/triple glazing/storm windows		o	◐					
	Roof overhang		o	o		●	●	●	
	Slab vs. crawl space		●						
	Greenhouse		◐		o		●		
	Air infiltration reductions		o	●	●				●
	Trombe wall (thermal storage)		o			o	◐	o	
	Reflective exterior materials & paint colors		◐	o		o	o	o	●
	Berming			◐		●	●	●	
	Window-placement (N-min)			●	●	●	●	●	
	Solar window						o		
	Convective loop collector						o		
	Solar chimney						o		
	Increased insulation & use of thermally efficient building materials			●		●	●	●	●
	Reduced exterior glass								●
	Building form alteration				●				●
	Reduced HR wall orientation to winds			o	●				
	Building entries protected from winds			◐	●				
	Entry vestibules			◐	o				
	Energy-efficient fireplaces			●					
	Roof pitch to deflect winter winds			●					
	Avoidance of excessive interior spaces			●	o				
	Daylighting			●	o				
	Natural ventilation			●					

(continued)

FIGURE 1 (cont'd)

SAND ENERGY-EFFICIENT TECHNIQUES BY PROJECT

o considered
● used
◐ recommended but not inlcuded in the energy plan savings

	Energy-Efficient Technique	BURKE CENTRE	GREEN-BRIER	RADISSON residential	RADISSON town center	SHENANDOAH passive	SHENANDOAH dispersed systems	SHENANDOAH central Util	THE WOODLANDS town Center
MECHANICAL	Heat pump-air to air		o	◐					◐
	-water to air	●	●	o			o		
	Active solar hot water		o	o		o	●	o	
	Hot water heat reclaimer		●						
	Active solar heating-air			o		o	o	o	◐
	-water						o		
	Solar absorption cooling						o		◐
	Solar heat engine						o		
	Photovoltaics						o		
	Woodburning devices						o		
	Low wattage fluorescent lights								●
	Return of air through light fixtures								●
	Computer thermostat control								●
	Variable-volume fans & control								●
	Desiccant dehumidification								◐
	Gas heating								◐
	Solid waste steam								◐
	Water saving devices	●		o					●
	Zone HVAC			o					
	Vented attic			o					
	Dryer heat recovery			◐					
	Hot water tank insulation			◐					
CONSUMER/COMMUNITY SYSTEMS & OPERATIONS	Total solar community system		o					o	
	Wind energy production		o					o	
	Central thermal plant		o					o	
	Waste recycling		o	o					
	Energy monitoring device		o						
	Multi-use of schools (day/night)					●	●	●	
	Central utility							o	◐
	TES							o	
	MIUS + variations			o				o	
	TIES (6 alternative fuel sources)				o			●	
	Transportation:								
	park & ride facilities	●							●
	van pool								●
	bus	o							◐
	carpooling	o							◐
	rail commuter service	o							
	Embodied energy reduced	●	◐	●					●
	Heat recovery systems			o					
	Aggressive employment program	o							
	Expanded central function of town center	o							
	Increased efficiency of solid waste collection	●							

Potable water is treated as a natural resource with little regard for the energy needed to purify and move it and to treat the resultant waste leaving the home.

Planning and building today to improve energy productivity for tomorrow is not a simple proposition. Available knowledge and technology are sufficient, if applied, to make our communities substantially more energy-efficient. However, to achieve this goal will require changes in consumer expectations and lifestyles, public agency administration, and building industry practices that are currently in operation as a result of and in response to public demand.

TEAM RESPONSES

All five case studies generally followed a two-step approach of initial energy-efficient option screening followed by more detailed analysis of the more promising options. All of the analyses were based on a thorough survey of site conditions (for example, climate, topography, etc.). Several project teams used computer programs to simulate the effects that the various energy-efficient options would have on the project's energy consumption. The options that the teams finally chose were based on criteria such as good energy performance given the cost, market acceptance, and few or no institutional constraints. The promising options taken as a whole then became the energy plan, which expressed many of the options in the physical land use plan (for example, east-west street orientation). In some projects the energy plan appears radically different from the conventional plan. Although all of the project energy plans have similarities to the conventional plans, these similarities are usually in appearance only; elements in the conservation plan such as landscaping, will not be used arbitrarily or solely for aesthetic purposes but will usually be used to ensure maximum energy efficiency.

The study teams included the usual experts needed for large new community development--planners, engineers, architects, and landscape architects. If one of these traditional development team members did not have computer analysis skills or technical energy capability, a new member had to be added to the traditional technical team to provide this capability. In the cases of Greenbrier, Shenandoah, and The Woodlands, technical energy capability was provided by a research arm of a nearby university. In each case, the decision-making authority for the team rested with the project's developer. In some cases, (Radisson, Shenandoah, and The Woodlands) the local public utility provided technical expertise and was tied to some decision-making aspects of a project. In some cases, an advisory group comprised a mix of lenders, utility officials, local government officials, and existing project residents met to review the energy plans.

The SAND study area for each project was only part of the total project and was selected for analysis because of its potential for immediate development at the end of the SAND study period, possibly under the SAND energy plan. The study examined a variety and mix of land uses in the five case projects. Low-density residential uses were studied in Burke Centre, Greenbrier, Radisson, and Shenandoah; higher-density residential and commercial uses were considered in town center segments of the Burke Centre, Radisson, and The Woodlands studies.

ENERGY ALTERNATIVES AND TECHNIQUES

Figure 1 lists all of the energy techniques that were considered in the five case study projects. For any given project, all of the options that the project's study team considered are shown with those that were used in the project's energy plan. In some projects, techniques that appeared promising were recommended but not included in the energy-saving calculation, usually because of a single remaining constraint to implementation of the technique.

The energy techniques in this figure are grouped by general type--land/site planning, architectural, mechanical, and community system. The land/site planning and architectural types generally represent the passive options or those that have no moving mechanical parts to improve energy productivity. In contrast, the mechancial options generally require active mechanical devices such as fans and pumps to improve energy productivity. The community-level energy options are those systems that improve energy efficiency because of the economies of scale and efficiency in meeting multi-building needs from a shared system or more efficient community arrangement than is now in general practice. In many cases, the study teams have summarized their energy savings in terms of the passive, active, and/or community cooperative levels of systems.

Details about each project's conventional plan and energy plan(s), including the land use plan sketch,can be found in the respective project reports and in the edited versions that follow in Part II of this report.

ENERGY SAVINGS

Substantial energy savings are achievable through modifications made to site designs within the development process. In the SAND program, it has been estimated that dramatic reductions of over 50 percent can be achieved in annual energy consumption in buildings in The Woodlands and Greenbrier, where sophisticated mechnical systems such as water-source heat pumps or community energy systems appear practical. The other case studies, Burke Centre, Radisson, and Shenandoah have reported more modest potential annual savings on the order of 20 to 35 percent of the project's conventional usage. In the latter cases, however, this saving would be accomplished with a simultaneous reduction in site development costs, primarily stemming from improved sensitivity in working with rather than against the natural systems on the site. In those cases where net initial costs have increased--due mainly to more sophisticated mechanical systems--the eventual savings in energy costs to the owner/operator will pay back the capital investment within three years.

Particulars regarding each project's energy savings are as follows:

Burke Centre

If the energy plan was implemented as proposed, land development costs would be reduced by as much as 18 percent, while yielding the same densities. The added costs for the proposed heating and cooling systems would be returned in two years. Total energy consumption by the buildings in the community would be reduced by at least 33 percent. Implementation of this plan should cause no negative impact on either the price of homes or on the present sales pace of the developer and his homebuilders.

Greenbrier

Initial calculations applied to the base or conventional plan found that end-use energy consumption projected over a 30-year mortgage period was considerably higher than energy embodied in the materials and building of the site infrastructure and project structures. Since, over this period, operating consumption would be six times greater than the original embodied energy used to construct the community, the scope of the research was narrowed to those energy options which would most affect operational usage.

Greenbrier's study team found that for relatively small increases in capital expenditure, developers, and especially residential builders, can substantially decrease end-use energy consumption. For a capital investment of $200 to $3,150, operating energy consumption can be reduced by 54.7 percent in residential development; at the then current energy cost of 3.5 cents per kWh (this represents $744.60 annual savings per house or energy savings to each homeowner of 21,275 kilowatt hours (kWh) per year) and over a 30-year conventional mortgage period, this reduction represents a savings of $22,330 per house.

Radisson

Energy-efficient plans developed for a residential site and the town center focused on passive measures to reduce energy use for space heating. Utility systems options were identified for both sites but require further study as to feasibility and cost. Based on use of the computer modeling, the following design loads were developed for the conventional and the energy plans.

- The annual design load for the 201 single-family dwelling units in the conventional plan is 6,737 Mbh. This load represents an annual cost of $77,163 for the total plan and $383 per single-family dwelling unit.

- The annual design load for the 259 single-family dwelling units in Energy Plan 1 is 9,835 Mbh. This load represents an annual cost of $95,101 for the total plan and $367 per single-family dwelling unit.

- The annual design load for the 220 single-family dwelling units in Energy Plan 2 is 7,112 Mbh. This load represents an annual cost of $81,688 for the total plan and $371 per single-family dwelling unit.

Modeling of reduced heating load due to wind protection identified potential annual savings of between 6 percent and 9 percent on both energy plans for single family detached units and up to 13 percent for townhouse units. This reduction represents a savings in annual operating costs of $27 annually for single-family detached units and $44 annually for townhouse units. When projected on a total plan basis, the annual savings in operating costs for protected dwelling units is $6,792 for Energy Plan 1 and $5,454 for Energy Plan 2. In addition, a comparison of the conventional and the energy-efficient plans identified a savings in the energy embodied in site development. Energy Plan 1 saves 25 million Btu and Energy Plan 2 saves 15 million Btu over the conventional plan. These savings represent respective decreases of 22 percent and 17 percent over the conventional development plan.

Factors that were qualitatively evaluated for the town center are the potential for annual heat gain through south oriented windows and potential winter heat loss reduction. While the exact amount of yearly heat gain varies with climate conditions and building design, potential annual heat gain per square foot of glazing can be identified. Based on comparison to comparable sites, a potential yearly heat gain of 76,517 Btu per square foot of double glazed window is assumed possible at Radisson. A comparison of the energy and the conventional plans indicated that the energy plan doubles the amount of south-facing glass while minimizing undesirable east, west and north glazed surfaces. In addition to maximizing the potential for annual heat gain, the energy plan reduces the potential winter heat loss by siting structures to protect and minimize windward wall exposure.

A conceptual integrated utility system has been proposed for the town center. The proposed system would be capable of supplying electric power and fuel, using ground water and natural gas on site, and would replace a conventional system. Estimates of energy savings due to reduction in line loss and elimination of conventional fuel requirements for this system have not been calculated. However, reviews of comparable systems (i.e., systems using cogeneration techniques with diesel-engine-driven generation) have identified potential energy savings of up to 46 percent.

Shenandoah

The Shenandoah SAND project team developed and evaluated three alternative plans as well as a conventional (base) plan. The Level 1 (passive) plan focused on passive site design. The Level 2 (dispersed systems) plan added to the Level 1 plan active and passive decentralized heating and cooling systems for the residential structures. The Level 3 (central utility) plan examined the possibility of a central plan system for electricity and thermal needs. The estimated fuel savings that would be realized under these alternative plans are as follows:

Passive Plan--When compared to energy expenditures under the conventional plan, total annual savings under the passive plan would be 496.25 Mwh (5.5 percent) for electricity and 8.91 billion Btus (29.9 percent) for natural gas.

Dispersed Systems Plan--Under the dispersed systems plan, the total annual savings that would be realized over the conventional plan are 335.42 Mwh (3.8 percent) on electricity and 19.56 billion Btu (65.6 percent) for natural gas. While the amount of electricity used under this plan would be 160.82 Mwh more than that used under the passive plan, a difference of 1.9 percent, the amount of natural gas used would be 10.65 billion Btu less than under the passive plan--a saving of 51 percent.

Central Utility Plan--Because of the chilled water cooling used under this plan, a substantial amount of the electricity load would be reduced. The central utility plan would use 2,499.40 Mwh (29.6 percent) less electricity than the passive plan and 2,995.65 Mwh (33.5 percent) less electrical energy than the conventional plan. Because of the hot water distribution, 100 percent of the natural gas used for space and water heating is replaced by the thermal energy generated at the central plant. Offsetting these benefits is the necessity of generating 33.78 billion Btu of thermal energy from energy sources like wood for the heating and cooling of buildings on the site.

The Woodlands

Analysis of the energy-efficient modifications to a 0.9-square-mile section of The Woodlands' Metro Center indicates that the following magnitude of savings could be achieved: (a) embodied energy, 4.9 percent, and (b) annual energy, 16.7 percent (50 percent in buildings). In overall terms, application of the methods described for the energy-efficient plan seemed likely to yield annual energy savings on the order of 17 percent. Under less pessimistic projections of travel behavior, where the average length of external trips to and from the study area was reduced by 50 percent, a 23 percent reduction in annual energy consumption was estimated. Such reductions in vehicle miles of travel seem plausible as The Woodlands moves closer to becoming a place where people can live and work in the same environment and as more development occurs in the northern corridor leading out of Houston. Finally, with reduced demands for energy and with the use of on-site power generation, a 30-percent reduction in the use of external sources of prime fuels can be achieved.

IMPEDIMENTS TO IMPLEMENTATION

Many of the passive energy principles which were considered or incorporated into the case project energy plans have been known for centuries and many of the active and central utility options are proven technologies today. Despite this availability of techniques and technologies and despite the optimistic outlook of the SAND program's general findings, several factors remain to temper expectations, at least in the near future.

Marketability

In each of the case studies, marketability, or consumer reluctance to accept innovative options, and consequent builder resistency to include them, was found to be the paramount concern regarding options that were considered technologically feasible and cost-effective. Uncertainty as to the exact energy savings, coupled with the lack of a performance guarantee to the owner, are seen as the two largest obstacles to marketing energy-efficient plans. If, however, these obstacles could be overcome in demonstration projects related to particular situations, the SAND project developers have expressed confidence that such proven efficiency would, in fact, enhance the saleability and marketing image of their developments.

Role of Leadership

No firm consensus exists regarding who should assume a leadership role in implementing an energy efficient plan. SAND developers, skeptical of regulation and wary of additional regulatory delays, nevertheless recognized that the public sector may have to assume a larger role in mandating improved development practices, so that competing projects would not have unfair competitive advantage. The primary incentives for this posture were: (a) the need to remain competitive with other developments in the marketplace, and (b) the inability of a single developer to absorb additional front-end costs that would place him or her at a price disadvantage given the perceived marketability risks. SAND developers also expressed a general concern that whatever the developer might accomplish in the way of facilitating energy savings, the actions of the builder would have to be consistent with this aim if the energy-saving potential were to be realized.

Cost/Benefit Accrual

The developers perceived a disparity between costs and benefits inherent in the energy-efficient plans. The risk and costs all were viewed as accruing to the developer and/or builder, while the benefits were seen as accruing to the consumer (renter or owner), the public utility, and the public at large. Only in the case where the developer would assume the builder responsibilities or where he would remain on the site as an owner/operator would these benefits be internalized.

Development Regulations

Local development restrictions did not play a major role in the five case studies because all were in current phases of multi-phase development within a relatively flexible regulatory environment. This context was intentional to identify what was possible within the present development state of the art. In many areas, local development restrictions may present unintentional barriers to the application of specific energy techniques suggested in the five energy plans. Some local governments have adopted new development regulations or amended existing ones to promote improved energy productivity, more efficient generation and distribution, or a switch to renewable resources (Figure 2).

Technical Know-How

Each of the five case studies created a rather specialized technical "team" approach that sought to identify, screen, and evaluate means of achieving increased energy efficiency at each of the sites. There is not yet a single generic approach to energy efficiency at the site level, although a general list of options has emerged. (Figure 1).

In the past, energy performance of specific structures and of various building and mechanical systems has not been a formal criterion for the developer; neither the developer nor the design team is generally in a position to evaluate the savings of a proposed innovation. Preliminary design estimation procedures for energy use do not currently exist, and the use of computer simulation is far beyond the means of most development projects. The five case studies have all generally used a two-step approach of initial option screening followed by more detailed analysis of the more promising options. Until an efficient screening technique or option application directory is established, and in light of the impediments described above, it is unrealistic to anticipate a large degree of experimentation by developers or builders.

CONCLUSIONS

The Site and Neighborhood Design (SAND) program in Phase I has studied the manner in which increased energy efficiency can be incorporated into project design and development. DOE contractors compared standard development plans to energy-efficient ones in five actual projects. The five case studies have shown the energy-efficient development options available, methodologies for arriving at the options, and implementation strategies and related difficulties to make the energy plans a reality. The projects that were discussed used a variety of energy-efficient approaches, including

- passive techniques such as siting buildings for maximum southern exposure and vegetative screening of the hot summer sun and cold winter winds;
- active systems such as the water source heat pump or solar hot water collector system; and
- community systems such as biomass cogeneration plants and central solar facilities.

The case studies showed that significant amounts of energy--from 20 percent to over 50 percent--could be saved through these approaches. As the thermal efficiency of building envelopes improves, the marginal energy contribution of correct siting becomes increasingly significant. With higher densities, development costs are about the same and lower costs per unit can be achieved. In addition, development costs for passive energy-conserving design are the same or less than those for conventional plans. In the SAND case studies, the maximum energy savings were achieved in the energy plans when passive design and active energy systems were conceived as mutually supportive.

Besides demonstrating energy savings, the five SAND case studies show the following:

- Passive/energy efficient techniques can generally be readily implemented.

FIGURE 2

COMMUNITIES WITH ENERGY-EFFICIENT DEVELOPMENT REGULATIONS*

CATEGORY AND COUNTY	TYPE OF REGULATION	DATE ACCEPTED	PROVISION
Reducing Heating and Cooling Needs			
1. Port Arthur, TX	Subdivision requirements for passive solar orientation	Sept. 1979	Mandatory
2. Sacramento County, CA	Resolutions and administrative procedure for passive solar orientation	1977	Voluntary
3. Dade County, FL	Site plan review criteria for energy-efficient site design	1975	Voluntary
4. Boulder, CO	Incentives for energy-efficient site design	Aug. 1977	Incentive
5. Douglas County, KS	Zoning amendment to permit underground housing	March, 1979	Removes regulatory barrier
6. King County, WA	Regulations to permit and encourage town-house development	Dec. 1979	Removes regulatory barrier/encourages
7. Davis, CA	Zoning amendment to permit flexible siting of fences and hedges for solar heating	1979	Removes regulatory barrier
8. Davis, CA	Zoning amendment to permit greater use of shade control devices	1979	Removes regulatory barrier
9. Davis, CA	Landscaping requirements for energy conservation	1979	Mandatory
Reducing Transportation Needs			
10. Boulder, CO	Incentives for energy-efficient location of development	Aug. 1977	Incentive
11. Windsor, CT	Incentives and requirements for energy-efficient location of development	1976	Incentive/ mandatory
12. Davis, CA	Zoning amendment to expand use of home occupations	Apr. 1979	Removes regulatory barrier
Reducing Embodied Energy			
13. Windsor, CT	Reduced subdivision standards for street widths	1974	Removes regulatory barrier
14. King County, WA	Reduced subdivision standards for street widths	Proposed	Removes regulatory barrier
15. Davis, CA	Reduced subdivision standards for street widths	Proposed	Removes regulatory barrier
Using Alternative Energy Sources and Systems			
16. San Diego County, CA	Mandatory use of solar water heaters in new development	1979	Mandatory
17. San Diego County, CA	Protection of solar access in new development	1979	Mandatory
18. Albuquerque, NM	Zoning provisions to protect solar access	1976	Mandatory
19. Los Alamos, NM	Zoning provisions to protect solar access	1977	Mandatory
20. Lincoln, NB	Incentives for protecting solar access	Oct. 1979	Incentive
21. Imperial County, CA	Overlay zoning provisions to manage geo-thermal energy development	1972	Manages and facili-tates
22. Davis, CA	Deregulation of clotheslines "solar dryers"	1977	Removes regulatory barriers

* Within each category the examples are not listed in any particular order, except that similar techniques are grouped together.

* Source: American Planning Association, "Energy-Conserving Development Regulations: CURRENT PRACTICE," (ANL/CNSV-TM-38) U.S. Department of Energy and Argonne National Laboratory, Chicago, Illinois, May, 1980, p. 14.

- The effect the developer can have on energy use for transportation even within a project the size of The Woodlands Metro Center, is negligible. It now appears that (a) this substantial component of community energy use is more sensitive to overall density, modal availability, and development location than was previously suspected, and (b) a facilitative role between the developer and the local unit of government is required to coordinate decision-making.

- Despite the high degree of awareness of embodied energy costs, which usually reflects development infrastructure costs to the developer, the annual operating energy over three to five years usually equalled the embodied energy. Thus, over a 30-year project life, a reduction of from 6- to 10-Btu in embodied energy would be required to offset a 1-Btu reduction in annual operating energy.

- A stronger, more innovative role for the public utility in the development decision-making process appears to be likely to achieve efficiencies of supply and distribution beyond the building level. In the two case studies (Radisson and Shenandoah) where this interaction has occurred, the developer and the utility were able to identify a mutual benefit for proceeding to a second phase of sizing the community energy system and examining its efficiency and operational characteristics. The involvement of the utility in the eventual ownership and maintenance of the energy system is seen as a key factor in overcoming questions as to the system's reliability and saleability.

- The development industry does not have ready access to design teams with sufficient expertise for the design of total energy communities. Assembling such a team requires the massing of numerous participants with varied skills. Even when a design team is operating efficiently, however, other factors inhibit execution of the energy-conscious design. These inhibiting factors include (a) the complexity of acheiving consensus among multiple decision makers (for example, designers, developers, lenders, public officials, utilities, and consumers) in a fragmented and decentralized process; (b) lack of examples to demonstrate the practicality of previous efforts; (c) little or no incentives to developers to undertake the risks necessary to test consumer acceptance of innovative alternatives; and (d) public regulations and regulators, which restrict energy-efficient techniques or offer no incentives for using them.

Much can be done today to increase the energy efficiency of tomorrow's communities. Improved energy productivity has not necessarily proved to be more costly, and it does not require exotic departures from the products developers currently are marketing. It will, however, require additional consideration in developers' decision-making criteria, and, to be most effective, it should include new roles for both the public utility and the local government in the development process. Although this segment of the SAND program concentrated on new suburban development to the exclusion of energy rehabilitation and retrofit in older suburban and inner city areas, it does provide a beginning to understanding energy-conscious land use and development.

SAND PROGRAM PHASE II

Currently under way is the next phase of the SAND program which encourages local governments to assume a larger role in energy efficiency. The eight communities listed below have been awarded contracts by DOE to develop by the autumn of 1981 regulations to foster energy efficiency:

- Schaumburg, Illinois, a growing suburb with substantial commercial and industrial as well as residential development.

- Bellevue, Washington, a growing suburb with primarily residential development. The city is representative of the energy problems of the Pacific Northwest.

- Boston, Massachusetts, an example of New England's dependence on foreign oil. The city has substantial planned development and a strong interest in community energy systems.

- San Antonio, Texas, an expanding southwestern city with a redevelopable core and a municipal electric utility.

- St. Petersburg, Florida, a growing city with the hot, humid climate characteristic of the Gulf Coast.

- Fairfax County, Virginia, a rapidly growing metropolitan county with energy problems characteristic of the Atlantic Seaboard.

- Sacramento County, California, a rapidly growing county with a substantial interest in utilizing solar energy. The Sacramento Municipal Utility District (SMUD) supports the county and will supply technical assistance.

- City and County of Honolulu, Hawaii, an island (Oahu), which has an urgent need for improved energy productivity because all of its energy is derived from imported oil.

These communities will analyze and evaluate energy-efficient techniques used in site and neighborhood design, propose modifications to their regulations (other than building codes) to accommodate those techniques, and submit proposed modifications to the local decision-making bodies for approval. Model guidance ordinances will be published based on the experience of the eight communities in order to assist and encourage other communities in the removal of impediments to energy efficiency.

PART II

CASE STUDIES

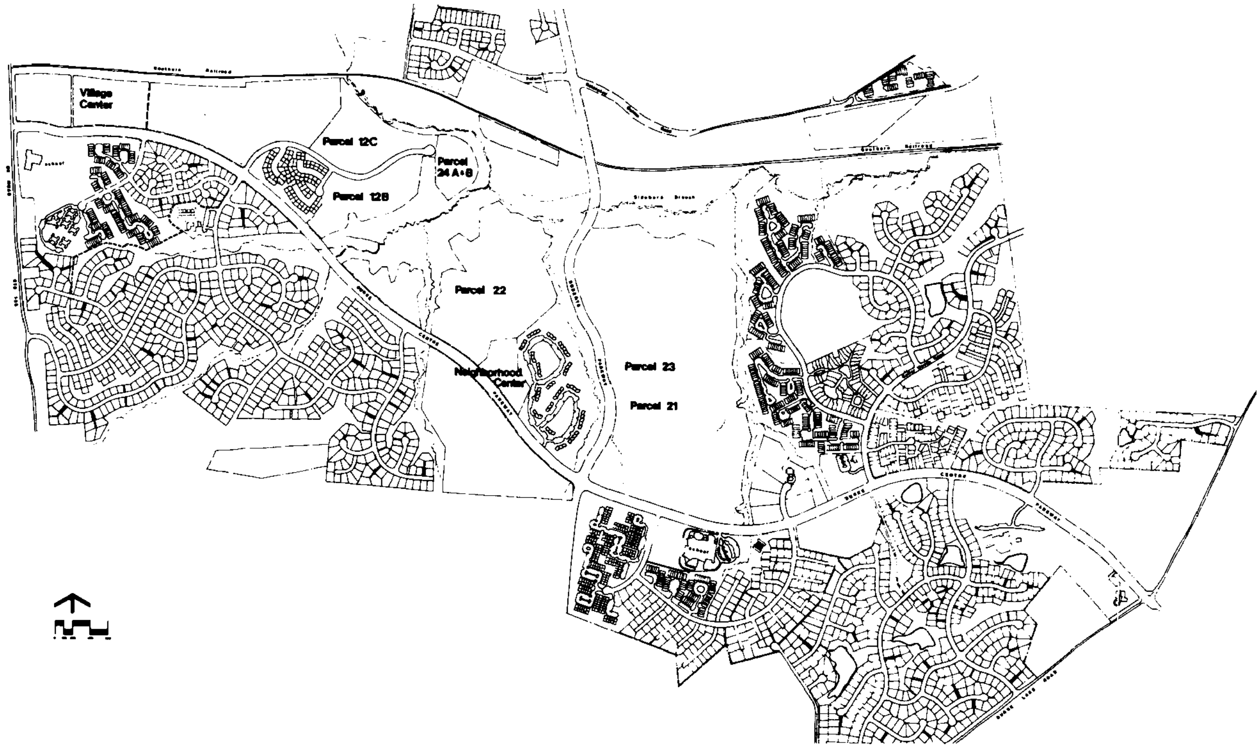

Figure BC-1

BURKE CENTRE DEVELOPMENT PLAN
Source: Burke Centre Report Figure 4

BURKE CENTRE

BACKGROUND

GENERAL DESCRIPTION

Burke Centre is a 1,390-acre planned unit development with a mix of single-family houses, townhouses, patio and other zero-lot-line units, and garden and mid-rise apartments at 3.92 dwelling units per gross acre. Although within commuting distance (17 miles southwest) of Washington, D.C., Burke Centre has allocated 62 acres for light industrial use and will also include commercial and retail uses in a neighborhood center and a town center. The areas studied for the SAND program total 218 acres and include the town center, neighborhood center, and a variety of residential parcels of different sizes and unit mixes.

The project's development plan (Figure BC-1) was approved in August 1975 under Fairfax County's RPC (residential planned community) zoning category for over 5,700 dwelling units. Development of Burke Centre began in May 1976, and the first resident moved in during February 1977. The increasing pressures on Fairfax County, primarily brought about by the growth of the federal bureaucracy, have generated a rapid pace since opening day. As of May 1980, over 2,040 units were occupied, while another 350 units had been sold by builders and were under construction. An additional 500 units had been sold by the development group to the builders, and the remaining units were under contract to builders or in sales negotiation. The last residential unit should be occupied by 1985 at the latest.

The development of the commercial components of Burke Centre will be by members of the development group, the Burke Centre Partnership (under other business structures). The village centre will contain a convenience shopping facility of 80,000 square feet, and the town center will be a larger complex of retail office and recreational uses.

PROJECT MARKET

Burke Centre is located in Fairfax County, Virginia, one of the fastest growing areas in the Washington, D.C., metropolitan region. As of the 1970 census the three predominant occupations in the region were professional-technical, clerical, and manager-administrator, comprising 67 percent of the work force. Although service and light industry sectors are both increasing, the federal influence remains strong, and the stability of government-related employment has proven to be the determinant of growth.

In 1970 Fairfax County had 127,000 households. As of June 1979, the county had 195,600 households, an increase of over 68,000 homes or more than 8,000 units per year. (Source: Fairfax County PLUS Program and Fairfax County Statistics Department.) The county's Pohick planning area, in which Burke Center is located, was the focus of much of the county's growth. Most development in the Pohick area has been in the form of single-family detached (large-lot) homes with townhouses becoming more popular in recent years.

The area immediately around the project has been extensively zoned for commercial use. Much of it has already been developed into strip convenience centers, free-standing retail and eating establishments and office space for personal and professional service businesses. A number of major shopping malls are in operation within a 20-minute drive of the project, and downtown Washington is less than an hour away. In some respects Fairfax County has been over developed with commercial uses in anticipation of continued population growth through the 1980s.

THE SITE

Burke Centre is adjacent to the existing communities of Lake Braddock (a Planned Unit Development) and Kings Park West (a large subdivision). Burke Centre is the largest consolidated tract in the Pohick Watershed that has sewer and water available for development at the time of this study. The Virginia Electric Power Company (VEPCO) provides electric service to Burke Centre. At the time of the study VEPCO had installed the main service trunks throughout the project and was serving the community with power. Gas service is not available to new users in this section of Virginia and none is provided at this time to Burke Centre. As with all development in Northern Virginia, road access lags behind the influx of new residents. Improvement is planned for four major roads serving Burke Centre, and the project's own road construction will provide several cross-country links. At present, express buses run from the site to Washington, D.C., and to the Pentagon, the subway connection point to downtown Washington.

Much of the site was farmed at one time but had grown back to a forested state. Topography varies from gently rolling land to moderately steep slopes; most slopes greater than 20 percent are in the form of narrow ridges overlooking the streams. Soils are generally silty loams and drain fairly well; with the exception of the floodplains, most areas are suitable for development.

Location in the middle latitudes (lat. 38-39^{o} N), where the general atmospheric flow is from west to east, favors a continental type of climate with four well-defined seasons. Summers are warm and at times humid, and winters mild; generally pleasant weather prevails in spring and autumn. The coldest period, when minimum temperatures average 23^{o}F, occurs in mid-January; the warmest, with a mean maximum of 87^{o}F, comes in the last half of July. Precipitation is rather evenly distributed throughout the year. Prevailing winds are from the south, except during the winter months when they are from the northwest.

RESPONSE

TEAM AND METHODOLOGY

An interdisciplinary group was assembled for the energy study to provide the perspective of the builder-developer, architect, engineer, planner, buyer/tenant, utility, regulatory/code inspector, and financier. Burke Centre as a real estate business venture is a partnership, comprised of a former home builder who directs development activities, a local attorney who handles the relationships with the County, and a Washington corporation that has extended the necessary credit to the enterprise. Known as the Burke Centre Partnership, this group is concerned primarily with land development--the creation of value by consolidating and improving raw acreage into a planned and fully serviced community.

At the outset of the study the team held discussions with VEPCO officials concerning energy conservation programs and VEPCO policies. VEPCO expressed a desire to work with the team as needed during the study process and to provide available data for the study team's research. VEPCO also was willing to undertake more direct participation such as metering model energy homes. Because the study team, concerned about the potential adverse impact on the project, declined to pursue such issues as on-site energy generation, the need to involve VEPCO directly in the program was diminished. None of the recommendations made in this report require specific action or approvals by the utility company.

With the exception of the town center parcel, each study parcel was schematically planned to determine its capacity and basic development criteria. Development of the energy conservation plan began with a thorough analysis of these undeveloped study parcels. The studies were conducted in

Figure BC-2

CONVENTIONAL PLAN OF STUDY AREAS
Source: Burke Centre Report Figure 8

an effort to identify and understand those elements which cause the use of energy and to identify opportunities for improvement in the layout of the various building programs. A full understanding of the physical characteristics of these study sites allows them to be modified sensitively through grading and retention of vegetation and natural drainage systems. Manipulation of these physical features can have an impact on microclimates and significantly affect site development costs.

The climatic and topographic features were studied to determine their impact on the community layout plans and building types and the opportunities they offered for energy conservation through modification of the base plan. The various building types were then analyzed to determine what additional energy saving opportunities were available at the individual unit level.

Together with screened conservation options, an energy plan was systematically developed in order to take advantage of as many of these identified opportunities as possible. The physical layout of the various neighborhoods and building groups evolved through the influence of a combination of factors, such as costs, marketability of the final product, good site planning techniques, and regulatory restraints.

CONVENTIONAL (BASE) PLAN OVERVIEW

The cluster concept is the key to Burke Centre's conventional development plan (Figure BC-2). The extensive open space network uses streams and wooded buffers to give each cluster a separate identity. Streets often follow ridge tops, allowing houses to be constructed with walk-out basements--an amenity perceived valuable by area homebuyers. Private streets are planned in many clusters to avoid grading and sight distance criteria imposed by state and county standards that are higher than nationally accepted standards for service and safety. In two clusters, for example, 70-foot private rights-of-way have been designed without the imposition of public standards, in order to permit a wooded streetscape rather than one which is clear cut. The developer has had the responsibility for major grading of roads and the built environment. When raw parcels have been sold to builders, they have remained subject to the developer's comprehensive engineering plans. The development plans include a major east-west road, Burke Centre Parkway, from which arterials and then cul-de-sacs will run. A north-south collector, Roberts Parkway, is also planned. The town center will be located near the intersection of the two parkways.

Specifics on each study parcel will be discussed as a part of the conservation plan sections. Figure BC-3 below summarizes the annual energy use of the base plan.

Figure BC-3
BASE PLAN ENERGY USE
(in 10^9 Btu/yr)

Use		Annual Energy Use at the Fuel Source	Percent	Annual Site Energy Use	Percent
HVAC, lighting, appliances and hot water		457.1	43.2	137.1	21.0
Transportation:	on-site	96.2	9.1	96.2	15.0
	off-site	361.2	34.1	361.2	57.0
Potable water treatment		50.3	4.8	15.1	2.0
Wastewater treatment		90.3	8.5	27.1	4.0
Refuse collection and disposal		2.9	0.3	2.9	1.0
Total conventional plan energy use		1,058.0	100.0	639.6	100.0

CONSERVATION OPTIONS

Based on the detailed analysis of the study area, a generic options listing was developed and categorized by systems, site, and operations. Approximately 300 option combinations were defined and developed for five distinct levels of potential application: community; neighborhood; sub-neighborhood; building grouping; and unit.

The study team then applied a screening process to establish a base list having an optimistic chance of success. In order to simplify the handling of the large list of energy conservation options, a rough pass/fail screening was conducted according to the following criteria:

- energy conservation potential
- technological state-of-the-art
- economic feasibility
- institutional marketing and other considerations

This screening decreased the list to more manageable proportions.

The limits of the study and the testing methodologies available prevented the study team from testing every option. Many of the site options incorporated into the plan are recognized climate modifiers and were included as a matter of course. Many of the specific building modifications, operations, and systems options suggested in this list were not tested as part of the study. Testing focused primarily on community-wide and neighborhood-wide conservation and the use of water-source heat pumps, transportation, community layout (orientation), water, sewer and solid waste disposal. The following options were applied and tested:

Land Planning Techniques

Building orientation was a fundamental consideration in the layout of each of the parcels. It is well known that the effects of solar radiation and winds vary with the surface area and angle of exterior building walls. Given the conventional plans for the 1,624 residential units and the commercial space, it was estimated that 55 percent of the total energy usage associated with buildings would go to heating and cooling--ample reason to give considerable attention to building orientation.

Clustering and consolidation of building space was practiced, particularly in the community and neighborhood centers and elevator residential projects. Proper grouping of structures can take advantage of sun and wind screens created by one structure on another. By consolidating various uses in one building shell the amount of exterior wall area is reduced and greater efficiencies in space conditioning can be achieved.

Road patterns were adjusted where possible to shorten distances from access roads to parking lots. Intersections were redesigned or eliminated to reduce the number of stops. Since 17 percent of gasoline usage occurs as a result of interruptions to movement, this aspect is especially important. A side, but usually direct, benefit of shortening on-site streets is the reduction in the length of utility lines, curbs and gutters, sidewalks, and, often, drainage systems.

Natural screening with earth berms and vegetation contributes to the control of both sun and wind effects on buildings. The rolling terrain and abundant vegetation offered many opportunites to re-site buildings to take advantage of these "free" features; in other cases berms created by regrading were called for.

Development standards were investigated in certain instances where variances produced important energy savings with little disruption to safety considerations. For instance, county road-width minimums for local streets were modified in some cases, parking requirements were slightly reduced, and, in the community and neighborhood centers, parking sharing between uses was practiced. These variations contributed to greater site planning flexibility and reduced the amount of asphalt used.

Building Systems and Hardware

Water-to-air heat pumps using groundwater can contribute significant savings in the heating and cooling of buildings. Preliminary evidence indicates that the Burke Centre site has adequate groundwater at acceptable depths to make wells a reasonable proposition for the savings obtained. This system was employed throughout most of the study area.

Figure BC-4

ENERGY-CONSERVING PLAN OF STUDY AREAS
Source: Burke Centre Report Figure 9

Water saving devices were tested to attack energy use for hot water and for producing potable water and treating waste water. Those devices tested included flow restrictors on water taps and shower heads, low-volume flush toilets, mixing valves on showers and water-conserving appliances.

Community Planning and Services

A park-and-ride system was tested to help reduce the off-site transportation energy use by project residents going to work or to major shopping areas and by nonresidents traveling onto the site to use its services and facilities.

A path system for bikes and pedestrians was included in the energy plan where reasonably close connections existed between residential areas and activity centers. The consolidation of buildings in the town center made this path system an especially effective solution to excessive on-site auto trips.

A more efficient solid waste collection system was tested. Although collection trips consume less than one percent of the project's total energy consumption, major reductions can be realized by the use of modern compactor vehicles.

While this may appear to be a modest list of options, most of the major energy-consumption features of a community such as Burke Centre are positively affected by one or more of the techniques. More importantly, every method used in the study can be employed today by community developers and builders in most sections of the country. They are generally compatible with most local regulations and policies, with utility company operations and are--or are becoming--acceptable to the American homeowner. Nevertheless, a few of the plans do contain siting features that may prove difficult to market.

TOWN CENTER CONSERVATION PLAN

Site Conditions

The town center site of approximately 124 acres is located in the geographical middle of the Burke Centre development. It is bounded on the south by the major collector for the community, Burke Centre Parkway, and on the west by the proposed Roberts Parkway.

Its physical characteristics are typical of all of the parcels chosen for this study. The land slopes generally from south to north, with a vertical drop of 140 feet from the highpoint along Burke Centre Parkway to the Sideburn Branch stream on the north. Minor drainage courses and small streams further subdivide the parcel flowing to the northeast and northwest from a centrally located ridgeline. Several sites are suitable for the creation of ponds. A very small portion of the site is level, with the majority of the slopes in the 5 to 15 percent range. Approximately 7 percent of the slopes have a gradient of over 20 percent.

Base Plan

At the time the study began, no site planning had been done on any portion of the town center. Therefore, a plan was produced employing typical siting standards for suburban commercial centers. In this plan, the retail space was arranged in an L-shaped strip configuration with the cinema located at one end and the major tenant at the other. The required 1,043 parking spaces were put into a large, single lot facing the shops with access off a service drive from the parkway. Additional parking for the cinema was sited behind the facility to avoid conflict with retail patrons.

The office space was distributed in three buildings, each with its own parking lot. The buildings were grouped to provide the opportunity for a common exterior plaza or other amenity. The dinner theatre site was placed on the parkway to increase its visibility and to allow it to share some of the office parking. Each of the major recreation facilities was sited in a separate building but in the same general area, with the apartments located in a conventional manner.

The base plan presented few opportunities for walking from one activity to another. For instance, the offices were at a distance from the retail center that made walking to lunch reasonable only on nice days. No more than 10 percent of the residential units were within walking distance of the retail and office space.

The configuration and siting of the buildings created substantial exposure to summer heat gain and only modest opportunities for solar gain in winter. The large number of single-use, individual buildings called for by the plan would produce excessive exterior wall space, thereby increasing heating and cooling costs.

The separation of uses would require that each building have its full share of parking spaces, despite the fact that periods of peak use would vary considerably among them. The large areas of service roads and lots would force the full utilization of the 124.4 acres requiring substantial earthwork to level out the terrain and the subsequent removal of most of the existing vegetation.

The internal road system would provide direct access to each building and would work well with the site. Of necessity, a large number of stops and yields would be created. These conditions would add to the consumption of gasoline.

Conservation Solutions

Building consolidation was explored, particularly for the commercial space. Coincidental to the study team's attempts to reconfigure the office, retail, and recreation uses into a compact cluster of buildings, the developer's design consultant produced a similar schematic plan. The developer expressed a strong opinion in favor of the marketing advantages inherent in this approach. He believed that the resulting larger buildings and massing effect would improve the center's visual impact on the public and produce greater comfort and convenience for the consumer.

The consolidation included putting the office space into two larger structures and siting them on the same court that serves the retail space. The bowling alley, racquetball courts, and roller rink were consolidated into one large building with a multilevel format and were also placed on the central court. As a result, all commercial space would be within easy walking distance of each other. This consolidation allowed the parking to be massed around the commercial uses on three sides, giving more flexibility to its use. Initially, no spaces were removed since county regulations do not recognize parking sharing at this time. County planning officials have indicated a willingness to consider the possibility of allowing sharing in circumstances such as this in the future.

Arranging the parking on three sides of the commercial center freed a fourth edge for siting some of the residential units. Two-high rise structures were sited in this area, giving these 336 units a comfortable walking distance to the center. The developer was in favor of this scheme because he felt both the commercial leasing and apartment leasing programs would benefit. This type of convenience is especially important to the high-rise apartment market which generally includes singles and couples seeking urban conveniences. A path system for bicycles and pedestrians was provided to connect most of the town center garden units to the commercial center. Where appropriate, the paths were aligned to connect to the community system.

During the early phase of the study an attempt was made to site the commercial complex in a central location in the town center. A site on the eastern stream valley and midway between Burke Centre Parkway and the northern boundary was selected for testing. This location offered a natural "bowl" within which to place the buildings, thereby reducing excavation work and providing natural screening from winds. It also allowed for the placement of the high density housing around the complex, so that a larger number of the units were within walking distance of the commercial complex.

This suggestion was considered unworkable by the developer. The retail and office space were located too far from the main road to make it marketable. He believed that not only the prospective merchants but also the professionals who would occupy the offices would shy away from a low-visibility location. The extensive development of competitive commercial space in the Burke Centre market area mitigated against, in the developer's opinion, moving the complex away from the parkway. He further pointed out that the additional housing units that were brought within walking distance of the center represented less than one percent of its potential market. The energy savings of placing a large, sub-regional commercial center near several hundred units is, in fact, too small to be a site location criterion.

Just over 100,000 square feet of land was removed from parking coverage by a variety of paving reduction techniques, among them the inclusion of compact car spaces and the shortening of those spaces on the perimeter of the lots by utilizing curb overhangs. The service road system was also reduced substantially (22 percent) through the consolidation of the parking areas. The 211,000 square feet of land removed from paving coverage was replanned as a 277-space lot for local commuters. These spaces were sited at the far end of the main parking lot from the commercial buildings and would be available for overflow, evening, and weekend shopping needs. Since public bus service is already planned for the Burke Centre Parkway, the provision of a park-and-ride lot immediately adjacent to it should work well in future regional transit programs. As a final transportation note, the road network was redesigned to reduce the number of interference points in traffic flows.

All of the commercial buildings, totalling 400,000 square feet, were sunk a half level below grade to reduce the surface wall exposure. Nearly all of the town center structures, commercial and residential, were oriented for southern exposure. As a result, the amount of wall surface exposed to winter sun was increased by 24 percent. Conversely, the wall exposure to summer heat gain was reduced by 50 percent. The resulting increase of wall area facing winter winds was minimized by the retention of an additional 9 acres of natural vegetation in strategic locations north and west of many of the buildings. Further, the savings realized in various site development costs allowed an increased budget for shade and evergreen trees of $84,000 or 46 percent.

Finally, each of the buildings in the town center was provided with a water-to-air heat pump system. Initial inquiries have indicated the presence of adequate groundwater to support the combined systems. There are no county or other regulatory restrictions that would prohibit the use of ground water for this purpose.

Energy Savings Potential

Figure BC-5 shows the total energy consumption for the commercial space in the town center, assuming the base plan is used. Figure BC-6 indicates the usage for the same space, provided the energy-conserving features are employed. The difference in annual energy consumption is about $7,000 \times 10^6$ Btu or a savings of 27 percent. The savings in costs for energy are over $50,000 annually from using the energy conserving plan. Hot water savings account for $26,100 of this reduction. The remainder comes from the reduction of heating and cooling costs through the use of the water-to-air heat pumps, the proper orientation of buildings, the sinking of the lower levels and the reduction of total wall surface.

Several areas of transportation savings are associated with the commercial center energy plan. First, the reduction of friction points (stops and lights) in the service road system results in a daily savings of 43 gallons of gasoline or 25 percent of the gas consumed at stops and lights in the base plan. Second, the path system connecting the center to the adjacent

Figure BC-5

CONVENTIONAL PLAN TOTAL ENERGY PER COMMERCIAL/RECREATIONAL TYPE
(in 10^6 BTU/Year)
Source: Burke Centre Report Table 1

	Neighborhood Center					Town Center						
	Community Meeting Bldg.	Pool Bathhouse	Bowling Alley	Health & Racquet Club	Roller Skating Rink	Dinner Theatre	Office Bldg. #1	Office Bldg. #2	Office Bldg. #3	Com-mercial Retail Bldg. #1	Com-mercial Retail Bldg. #2	Com-mercial Retail Bldg. #3
Total Floor Area (Sq. Ft.)	4,000	1,600	28,000	24,100	24,000	9,500	30,000	50,000	120,000	20,000	44,400	50,000
Heating	78	27	762	757	1,262	382	346	414	913	146	219	307
Cooling	40	15	1,447	1,206	958	164	505	848	2,090	468	981	1,233
Lighting	26	5	811	812	150	26	198	330	793	373	723	932
Appliances & Equipment	1	2	281	152	4	35	135	226	546	15	27	37
Hot Water	20	150	280	2,250	145	50	146	243	581	190	368	475
TOTAL	165	199	3,581	5,177	2,519	657	1,330	2,061	4,923	1,192	2,318	2,677
Cost/yr.	$3,524	$1,482	$33,157	$44,394	$24,280	$8,155	$14,892	$21,838	$49,042	$13,306	$24,853	$31,260

[1] *All have air-to-air heat pumps except Office #1, 2, 3 which have electric resistance heat*

Figure BC-6

CONSERVATION PLAN TOTAL ENERGY PER COMMERCIAL/RECREATIONAL TYPE
(in 10^6 BTU/Year)
Source: Burke Centre Report Table 2

	Neighborhood Center	Town Center							
	Community Meeting & Pool Bathhouse Bldg	Retail	Retail/ Office	Retail	Retail/ Office	Movie Theatre	Office/ Retail/ Dinner Theatre	Recreational	Mall
Total Flr. Area (Sq. Ft.) x 10^3	5,600	45,300	103,500	20,200	75,900	9,500	69,500	76,100	53,200
Heating	12	21	320	23	250	275	432	532	521
Cooling	34	826	1,103	321	767	114	790	1,255	1,804
Lighting	31	803	816	358	678	75	645	1,773	1,586
Appliances & Equipment	3	31	14	283	39	230	437	19	
Hot Water	40	150	377	67	272	32	222	675	0
Well Pumps	1	1	6	1	1	1	2	1	2
TOTAL	121	1,832	3,046	784	2,251	536	2,321	4,673	3,932
Energy Cost	$3,292	$20,075	$35,067	$9,887	$25,097	$7,083	$27,764	$44,728	$40,788

[1] All have water-to-air heat pumps

Heat pump C.O.P.: Heating 4.0
Cooling 3.0

Distribution efficiency: 0.95

housing areas should shift some trips from the car to walking or biking. If up to 20 percent of the trips were shifted to walking, the savings would amount to 5 gallons of gasoline per day or 1,500 gallons per year. Third, by compacting the center it can be assumed that certain trips to it would have at least two destinations. Further, no vehicular trips would be involved in moving from one use in the center to another, since all buildings are closely related to each other. These features would produce a savings in gasoline usage on-site and off-site of 26 percent or about 40 gallons per day. Taking all of the transportation savings into account, the total annual savings of gasoline for the same level of usage would be an estimated 26,400 gallons. The cost savings realized would of course vary with the cost of a gallon of gasoline. It is probably safe to assume that a minimum of $23,000 would be saved during the study period.

The residential program proposed for the town center would be significantly affected by the energy measures as well. The high-rise units would consume 20×10^6 Btu/unit/year less as a result of the use of the water-to-air pumps and the water conserving equipment and as a result of the proper site orientation, which would amount to a cost savings of $220 per year for each of 336 units. Similar savings would be obtained in the garden apartment units.

Conservation Cost

Figure BC-7 summarizes the development costs for land improvements for both the base plan and the energy plan. The bottom line for site development costs is an overall reduction of $1.2 million, or just under 20 percent if the energy plan were used. As for many of the other parcels in Burke Centre, the largest part of these savings would stem from reductions in the amounts of earth moving and paving and utility construction required. In the town center these reductions would be made possible by clustering the commercial complex to the extent that the elevator apartment units could be included within the original land bay that held only the commercial space. This clustering would add flexibility to the garden apartment site plans and would provide for greater retention of natural features. It should be noted that the reduced site development estimate for the energy plan included the addition of $85,000 for new tree plantings to help screen the buildings.

The overall added costs for the wells, pumps, and piping to serve the town center were $122,000 for the high-rise units ($363 per unit); $348,000 for the garden units ($580 per unit); and $124,000 for the commercial space ($.40 per square foot).

NEIGHBORHOOD CENTER CONSERVATION PLAN

Site Conditions and Base Plan

The 6.2-acre neighborhood center lies adjacent to the southeast corner of Parcel 22 along the Burke Centre Parkway. The wooded site is dominated by a high, level plateau which occupies the western third of the site. The remainder of the site slopes to the northeast towards a tributary of Sideburn Branch adjacent to Roberts Parkway. Several areas in the northern portion of the site have slopes of 20 percent or more with the balance of the parcel having slopes of between 5 percent and 10 percent.

A conventional recreation center that many developers have included in their residential projects, the center would encompass a full-size community swimming pool with an 1,800 square foot bathhouse, a small community building of 4,000 square feet, four tennis courts, and a parking lot for 50 cars.

A schematic site plan for the center was prepared by the developer and was used as the base plan for this study. This plan contained several features that potentially involved excessive energy consumption. The pool, bathhouse, and community building were fairly remote from the access

Figure BC-7

PARCELS 21/23 SITE DEVELOPMENT COSTS
Source: Burke Centre Report Table 4

	Base Plan		Energy Plan	
Item/Description	Quantity	Total Price ($000)	Quantity	Total Price ($000)
Site preparation	107 ac.	$ 268	110 ac.	$ 275
Earthwork	C.Y.	1,754	C.Y.	1,402
Erosion control	Lump Sum.	16	Lump Sum	13
Site drainage	11,040 L.F.	472	11,200 L.F.	414
Sanitary sewer	14,900 L.F.	285	12,125 L.F.	230
Waterline	20,260 L.F.	389	12,160 L.F.	233
Pavement	204,500 S.Y.	2,831	178,540 S.Y.	2,471
Curb	68,340 L.F.	547	25,000 L.F.	200
Shade trees	1005	176	1457	255
Evergreen trees	76	6	138	10
Shrubs	936	19	936	19
		$6,762		$5,522

Figure BC-8

NEIGHBORHOOD CENTER SITE DEVELOPMENT COSTS
Source: Burke Centre Report Table 8

	Base Plan		Energy Plan	
Item/Description	Quantity	Total Price ($000)	Quantity	Total Price ($000)
Site preparation	4.8 A.C.	$ 12	4 A.C.	$ 10
Earthwork	7130 C.Y.	11	6100 C.Y.	9
Erosion control	Lump Sum	3	Lump Sum	2
Site drainage	80 L.F.	5	40 L.F.	4
Sanitary sewer	920 L.F.	19	570 L.F.	15
Waterline	550 L.F.	15	300 L.F.	12
Pavement	4815 S.Y.	72	3080 S.Y.	47
Curb	1460 L.F.	12	800 L.F.	6
Shade trees	42	7	85	15
Evergreen trees	—	—	12	1
		$154		$120

road to the site. This created a long service drive to the parking lot. The community center and bathhouse were shown as two individual buildings producing extensive exterior wall area for the amount of enclosed space. In addition, the buildings were poorly oriented for prevailing solar and wind conditions.

Conservation Solutions and Energy Savings Potential

Although the site contains some pronounced slopes, it was possible to relocate the center closer to the access road without incurring additional earthwork costs. The building space was combined into one structure with reduced exterior wall area, and the building was located on the service road side of the pool to further shorten the distance to the parking lot. It was a simple matter to align the small structure on a north-south axis. Finally, a tree planting program was used to increase wind screening. In addition to the site planning modifications the use of water-conserving devises was employed, as was the assumption that a water-to-air heat pump would be used.

The gasoline savings realized from shortening the service road would, of course, be small in terms of overall consumption by the community. Nevertheless, even the reduction of 100 feet in the road length should produce a savings of 50 gallons or more of gasoline a year, given the anticipated use of the center.

The use of the water-to-air heat pump and the consolidation of the building space with proper solar/wind orientation would produce an estimated savings of 114×10^6 Btu/yr. or $949 in energy costs for heating and cooling operations. The use of the water conserving devices, particularly in the bathhouse, would lower the cost of hot water by as much as $1,250 per year. The amount of water used would be cut in half by the shower heads and restricting valves which, of course, have a substantial effect on water and waste treatment costs.

Conservation Costs

Figure BC-8 summarizes the comparative cost for land improvements in the two plans. The shortening of the service road and reduction in the utility line runs would result in a savings of $42,000 in total costs, a reduction of 27 percent from the conventional (base) plan. An add-on of about $8,500 was made for additional shade and evergreen trees to help control the environmental impact on the buildings, thereby reducing the net savings to $34,000 or about 22 percent.

Additional possibilities for cost savings were achieved by reducing the unit cost of the space conditioning equipment, thereby reducing the total installation price from $8,800 to $5,600. In addition to the trees, the other direct cost associated with the energy conserving plan would be for the well ($3,500) and the piping ($500) associated with the water heat exchange system in the building.

PARCEL 22 CONSERVATION PLAN

Site Conditions and Base Plan

This site exhibits many of the same qualities as the town center site. Its 39.3 acres are bounded on the south by the Burke Center Parkway and on the north by the Sideburn Branch stream valley. Its western boundary is the shore of the new lake. The totally wooded site slopes from south to north with a vertical drop of nearly 100 feet. Large areas of the site are in slopes of between 10 percent and 20 percent gradient. The parcel is bisected by a major drainage course running southeast to northwest that divides the site into nearly equal halves.

Parcel 22 had not been conveyed to a builder when the SAND study was conducted. The Partnership, however, had prepared a schematic plan for the site. The program called for a combination of garden and townhouse units. The yield reflected in the developer's schematic site plan was 252 garden units and 172 townhouses. The parking ratios used (1.68/d.u. for gardens and 2.10/d.u. for townhouses) resulted in approximately 785 parking spaces overall.

The developer's base plan attempted to place as many units as possible on the site. The building pads were pushed as close to the perimeter of the site as possible and little or no consideration was given to the amount of tree cover that was sacrificed or the amount of earthwork required to handle the road and building arrangement. The resulting fill requirement was nearly 7,000 cubic yards per acre, of which 3,700 cubic yards would have to be borrowed.

The building pads were arranged in relationship to the road alignments which produced a low percentage of north-south building orientation (long side). In addition, less than one acre of the existing tree cover was preserved, removing most of the natural shade and screening potential of the parcel.

Conservation Solutions and Energy Savings Potential

A fundamental problem with the base plan was the excessive fill requirements needed to produce the high dwelling unit yield. This was especially a problem in the townhouse section where topography was being severely altered. Before attempting to adjust the base plan to deal with energy issues, the site plan was tested; it was found that by reducing the number of townhouse units slightly, considerable earthwork costs would be saved. It was decided to settle for a reduced dwelling unit yield in the energy plan in the belief that overall development economics would support this approach.

The energy-conserving plan would substantially change the orientation of the buildings. All but one of the garden buildings and 75 percent of the townhouses were given a north-south exposure. Overall paving was reduced by slight reductions in parking ratios, some road shortening, and a reduced width for road paving. As many buildings as possible were sited for solar advantage, and a full acre of existing vegetation was retained in strategic locations to protect the units from winter winds and summer sun.

As was done with other study parcels, water-to-air heat pumps and a variety of water-saving devices were tested for their energy-savings potential.

The reduction in gasoline usage that can be projected for the energy plan is almost entirely related to the few stops required by the altered roadway system. Just the removal of 3 of the original 11 stopping situations would cause a 25 percent reduction in fuel consumption at intersections. On a site of this size and with the density involved the savings could amount to as much as 6,500 gallons of gasoline per year.

The water usage of Parcel 22 could be cut as much as 40 percent (15,000,000 gallons of potable water per year, or 40,000 gallons daily) with the use of the various inexpensive devices discussed elsewhere. Hot water use in a site the size of Parcel 22 can consume as much as 10×10^9 Btu/year. The cost of providing this service will approximate \$119,000 per year or about \$280 per unit per year if conventional plumbing fixtures are used. This cost could be dropped to about \$176 per unit per year with a nominal investment in special showerheads and faucets.

Heating and cooling of the Parcel 22 dwellings would cost \$158,000 annually (about \$370 per unit) without an efficient heat pump system and proper building orientation. This could be reduced to about \$75,000 a year (about \$180 per unit) with the planning techniques and equipment tested in the study.

Conservation Costs

When a development parcel is conveyed based on its dwelling unit capacity, which is typical in the industry, the seller will obviously presume the maximum number of lots or units allowed by zoning. Zoning densities, in turn, are usually established on the assumption of a flat and featureless site. When developing a site such as Parcel 22 the builder/developer, reasoning that he has "paid" for the full number of units allowed, usually instructs his engineer to achieve the full yield. The result, not surprisingly, can be extensive abuse of the land's natural features. As it was discovered in the study of this parcel, maximum yield and maximum profit are not always the same.

The base plan with 424 units required over 250,000 cubic yards of fill (over half from off-site), costing $900,000,--more than $2,100 per unit. By pushing development to the site's maximum allowable density, the cost of roads, utilities, and drainage added $3,400 per unit to the land development process. The total cost of all land improvements was estimated to be in excess of $2.5 million (Figure BC-9). That amounts to $5,900 per dwelling unit or $64,000 per gross acre. The conservation plan sited the buildings and roads to relate to the terrain and kept away from the more difficult slope conditions. The development pattern grouped the buildings closer to the central service road, staying away from the perimeter of the site. In some cases, particularly in the townhouse areas, parking lots were sited to further shorten the service roads.

The conservation plan could not yield the full 424 units intended for the parcel. This plan called for the full garden apartment program but fell short on the townhouse yield by 14 units. Although only a 3 percent reduction in yield, this shortfall would frequently be considered unacceptable in the industry. This view is challenged by the development economics. Earthwork would be reduced to only $329 per unit (a savings of $1,770 per unit) by cutting into existing slopes rather than using borrowed fill to level the site. Road, utility, and drainage costs would be reduced to $2,900 per unit, a savings of $500 each. Total site development costs are estimated at just under $1.6 million or $3,900 per unit ($41,000 per acre).

What does this discussion of land development practices have to do with energy conservation? Surprisingly, quite a bit. The conservation plan was designed to reduce not development costs but future energy consumption by the project's residents. The projected savings of $966,000 in earthwork, roads, and utilities was largely incidental to the exercise. It was not accidental, however, since shortened roads (and, consequently, utility lines) and retained slopes and vegetation were the goals of the energy plan. Planning to this criteria inevitably reduces improvement costs. It also tends to reduce the site's dwelling unit yield. There is no formula for predicting the relationship between costs and yield, nor are the results always likely to be as impressive as in Parcel 22. It appears from this test case, however, that developers and builders would benefit from using energy-associated criteria when directing their site planning consultants.

The other cost factors related to reducing energy costs on Parcel 22 are well within the budget of homebuilders and buyers. The water-saving devices required in each dwelling are all on the market and their cost per unit over conventional fixtures is nominal. The water-to-air heat pump system would require on-site wells (a closed system using potable water could also be used) and would add an estimated $290,000 to the overall cost of the project or approximately $700 per unit. Partially off-setting this cost would be a $100 per unit savings in space equipment conditioning costs.

PARCELS 12 and 24 CONSERVATION PLANS

Several small bulk parcels designated for residential use were available for our study purposes. These were replanned in similar fashion to Parcel 22 and analyzed to determine the cost impact and

Figure BC-9

PARCEL 22 SITE DEVELOPMENT COSTS
Source: Burke Centre Report Table 8A

	Conventional Plan		Energy Plan	
Item/Description	Quantity	Total Price ($000)	Quantity	Total Price ($000)
Site preparation	33 ac.	$ 83	35 ac.	$ 83
Earthwork	263,000 C.Y.	897	90,000 C.Y.	135
Erosion control	Lump Sum	39	Lump Sum	36
Site drainage	4590 L.F.	197	2960 L.F.	131
Sanitary sewer	13,925 L.F.	241	13,950 L.F.	194
Water line	7,950 L.F.	146	8350 L.F.	139
Pavement	49,838 S.Y.	716	38,988	574
Curb/gutter	17,500 L.F.	140	18,150 L.F.	145
Shade trees	401	70	686	120
Evergreen trees	50	4	59	5
Shrubs	424	8	424	8
		$2,540		$1,575

potential energy savings. The configuration of the building type programmed for Parcel 12C, the four-plex unit, would limit the benefits from solar orientation. The four-plex units were sited so that the maximum glazing of the building would occur on the south to take advantage of the warming winter sun. The building overhangs on the east and west would reduce the intensity of the summer sun on those walls. The four-plex structures were sited to reduce land development costs through shortened road and utility runs and minimized cut and fill operations.

Generally, the results that would be obtained in these smaller sites reinforced the findings in Parcel 22 which is discussed at some length in the proceeding section. Land improvement costs would be cut by 10 to 20 percent while potential savings in heating and cooling costs would be about 44 percent. The inclusion of water-to-air pumps and water-conserving devices within the homes would have a similar impact on a per-unit basis.

IMPLEMENTATION

FAIRFAX COUNTY POLICY

Fairfax County, in an effort to keep up with growth pressures, has enacted a variety of policies designed to manage and direct development, encourage a diversified land use pattern, provide adequate public services, establish reasonable development standards, and maintain the fiscal integrity of the community. Fairfax County policies have had much to do with the Burke Centre plan and program and are responsible for many of the development practices in effect on the project. The county officials responsible for administrating public policy in Burke Centre were involved in the study from the outset and contributed invaluable assistance to the formulation of our energy program.

County General Plan

The county's plan encourages the concept of planned development projects, clustering commercial uses, and increased reliance on mass transit. As a growth management policy the plan promotes ".....the use of planned Development Centers as focal points for future growth. As an alternative to sprawl this concept was designed to ..... decrease reliance on the private auto by reducing the length of work trips and making mass transit facilities more easily accessible....".

Although the General Plan is only a guide to development in the county, it does clearly define the local commitment to use growth patterns to reduce future energy consumption. In general, the plan is a supportive document of the policies advocated in this study.

Zoning Ordinance

Burke Centre is being developed under the "Planned Residential Community" provisions of the county zoning ordinance. These require a minimum of 750 contiguous acres and require an approved comprehensive plan before construction begins. The PRC provides for a balanced community by allowing a variety of housing types, employment areas, and commercial services. It encourages a balanced transportation system including mass transit and separate paths for bikes and pedestrians. The PRC also encourages intermixing uses and taking advantage of the natural environment in site planning. In the early years of development under the PRC provisions, the Burke Centre Partnership obtained approval for reduced road widths in residential areas and for variances to side yard requirements. It has proven to be a very flexible development tool.

Public Facilities Program

Many of the public facilities required to serve the Burke Centre area have already been committed to a specific location. Although the consideration of the project's town center as a potential commercial-community complex was urged, the county is not in a position to designate many new facilities at this time. The possibility of placing various county services, such as a library, community center, and elderly center, in leased space in the town center should be considered.

Economic Development

The county has lagged in building an employment base comparable to its residential growth. Recently the Fairfax Economic Development Authority has expanded its program to attract new business and industry. The authority's director was approached during the study to determine his views on marketing the town center area for office and other compatible business uses, stressing the desirability of combined business and commercial space in a compact center immediately adjacent to a variety of housing types. The direction expressed a positive attitude towards promoting the town center even though road access to Burke Centre is still in need of upgrading. The county's promotion of multi-use centers is a major step in reducing overall transportation needs, and the cooperation of agencies such as the Economic Development Authority is essential to carry out that policy.

Parking

In the energy conservation plan for the town center a reduction in total parking below the minimum required by the county occurred. The rationale was based on the sharing of parking by the individual uses that have differing peak demand times. By reducing the total parking for the center, the remaining land will accommodate a park-and-ride lot. Although the county regulations do not acknowledge sharing as a valid argument for reducing aggregate parking requirements, the officials reviewing the plan indicated a willingness to consider seriously the proposal.

Energy Policy

A commission was appointed by the county in 1978 to study measures related to energy conservation that could be implemented by local government. The commission completed its work and submitted a lengthly list of actions for consideration. Many of the site and community planning recommendations made in the study were mentioned in the commission's report.

DEVELOPER/BUILDER CONCERNS

As with Radisson, the U.S. Department of Energy (DOE) contractor for the Burke Centre study was a consultant to the project, not the actual project developer. The developer's role was advisory, providing input, information, and feedback to initial drafts and materials until July 1979. The developer was not, therefore, as deeply involved in the SAND program as the other SAND project developers who were DOE contractors. The following two major topics that particularly interested the Burke Centre Partnership are

The improved use of public transit (particularly commuter rail) in conjunction with increasing the intensity of the town center to eliminate some of the trips that would otherwise go off-site. Since the Burke Centre Partnership cannot make final decisions with respect to the public transportation system, it is their understanding that the Department of Energy is not interested in further investigating these issues, at least not with Burke Centre Partnership. In the event it becomes a Fairfax County policy to intensify development at Burke Centre to provide a subregional node (at the scale that was originally anticipated in the 1958 and 1969 County Master Plans) which will make other trips in the subregion shorter, then the assumption is that Burke Centre would respond to this county policy.

The water/air heat pump system which the SAND study included as a conservation option, was much more significant than further investigation supports. There now seems to be a question about the cost of testing the availability of groundwater and other aspects which make the water/air heat pump less desirable than was originally portrayed.

SUMMARY

The Burke Centre Site and Neighborhood Design case studied a number of parcels totalling 218 acres within a 1,390-acre planned community. The chosen parcels were committed to a development program which included a mix of dwelling unit types, retail, office, and recreational space. The project is located in a continental type climate with 5,010 heating degree days and 940 cooling degree days.

The energy conservation techniques applied and tested in the study can be employed today by community developers and builders in most sections of the country. They are generally compatible with most local regulations and policies and with utility company operations, are (or are becoming) acceptable to the American homeowner, and, most importantly, are all cost-effective today. The major techniques used to come up with the energy-efficient development plan were the following:

- consideration of building orientation for sun and wind effects in the layout of each parcel;
- clustering and consolidation of structures wherever possible for sun and wind screening and for overall reductions in exterior wall areas;
- adjustment of road patterns to shorten trips and to reduce the number of stops inovlved in travelling;
- natural screening with earth berms and vegetation;
- modification of development standards to minimize street widths and parking requirements;
- respect for marketing considerations- -for the tastes of the buying public;
- water-to-air heat pumps;
- water-saving devices;
- a park-and-ride system to help reduce the tremendous off-site transportation energy consumed in journeys to work and shopping;
- a bike and pedestrian path system; and
- a more efficient solid waste collection system.

Taking these considerations into account resulted in significant changes in the physical parameters of the base plan. The energy conserving plan shows a 20 percent reduction in primary energy consumption over the base plan (Figure BC-10). The Energy Use Index (Figure BC-11) of the buildings for the total study area of the conservation plan shows a 33 percent reduction in Btu/square foot/year over the base plan. The building energy reduction is comprised of a 35 percent reduction for residential uses, a 58 percent reduction for recreational uses, and a 17 percent reduction for commercial uses.

Figure BC-10
CONSERVATION PLAN ENERGY USE
(in 10^9 Btu/yr)

	Annual Energy Use at the Fuel Source	Percent	Annual Energy Site Use	Percent
HVAC, Lighting, Appliances, Well Pumps and Hot Water	314.1	37.1	94.2	16.0
Transportation On-site	93.4	11.1	93.4	16.0
Off-site	355.3	42.1	355.3	63.0
Potable Water Treatment	28.6	3.4	8.6	2.0
Wastewater Treatment	51.6	6.1	15.5	3.0
Refuse Collection and Disposal	1.7	0.2	1.7	1.0
Total Conservation Plans Energy Use	844.7	100.0	568.7	100.0

Figure BC-11
ENERGY USE INDEX*
(in Btu/sq.ft./yr)

	Residential Energy Use Totals	Recreational Energy Use Totals	Commercial Energy Use Totals	Total Study Area Energy Use Totals
Base Plan EUI	48,042	139,935	47,237	50,710
E/C Plan EUI	32,507	58,752	38,982	35,170
Percent Reduction	35	58	17	33

*Includes HVAC equipment, lighting hot water heating, and pumping energy uses.

RECOMMENDATIONS

A summary of the study's major findings with recommendations for further action are presented below:

OF THE TOTAL ENERGY CONSUMED BY THE BURKE CENTRE COMMUNITY, 34 PERCENT WILL GO TO OFF-SITE TRANSPORTATION NEEDS.

Burke Centre, like most residential suburbs, depends on its parent city, Washington, D.C., for employment and for many retail, cultural, and recreational needs. The lack of adequate mass transit means that most of these trips, averaging over seven miles in length, will be made by automobile.

- A park-and-ride system should be instituted using a section of the town center parking lot when it is constructed. Two and one-half percent of the total residential transportation energy use of the community could be saved by utilizing a coordinated service to Washington and other key employment centers. This suggestion has been well received by both the developer and the county officials.

- In the long term, the county and the community should pursue the expansion of local bus service connecting the town center with other commercial centers and with the residential neighborhoods of the area. The town center has a potential market area extending up to 10 miles and will therefore be a major trip generator within the region. A public subsidized local bus shuttle service, such as the one provided in Montgomery County, Maryland, would reduce off-site transportation energy use.

- In the long term, the county and area residents should also explore the use of the existing Southern Rail line as a commuter service to the Washington area. This prospect has received some attention in the past. If implemented, it would be the largest contributor to reducing energy consumed for off-site travel.

- The county should consider pursuing an aggressive employment program for its heavily populated sections, such as the Burke Centre area. Bedroom communities are high energy consumers, regardless of available transit systems. Total suburban communities like Columbia, Maryland, that integrate employment with housing have the greatest potential for energy savings in the future.

- The county should consider expansion of the town center into as broad an activity area as possible. Since the center is intended to have a subregional draw, the more needs that can be served at that one location the greater the potential for energy conservation.

ENERGY-CONSERVING SITE PLANNING GENERALLY COINCIDES WITH COST EFFECTIVE SITE PLANNING.

Planning to produce a more efficient circulation system and to utilize the sun and winds to reduce building energy usage also reduces the basic land improvement costs. Overall, the test parcels produced an 18 percent savings in land development costs when planned for energy conservation. The principal cost savings were in paving, earthwork, and utility line extensions.

- Local zoning and subdivision controls should encourage flexible site planning by providing real incentives for retaining natural features and for properly orienting structures.

- Development standards such as road widths and parking requirements should be seriously reviewed to insure they have not become overdesigned for today's needs.

- The direct relationship between cost-effective site planning and future energy savings, as portrayed in this study, should be broadly disseminated to the development industry and local public officials. This is one of the few areas where cost savings are associated with the reduction of energy consumption.

WATER-TO-AIR HEAT PUMPS, IF PROVEN TO BE FEASIBLE, ARE THE MOST EFFICIENT AND COST-EFFECTIVE METHOD AVAILABLE TODAY IN THE BURKE CENTER STUDY AREA FOR REDUCING HEATING AND COOLING COSTS IN BUILDINGS.

The total projected heating and cooling energy consumption was reduced 44 percent for the combined study areas at a cost that is retrievable within two years. About 90 percent of the energy reduction is attributable to the use of the water-to-air system; about 10 percent is due to passive and other building modifications.

- Water-to-air systems can use ground water, if available, or they can operate on self-contained systems. Since the former is often the cheaper of the two, developers and public agencies should investigate the availability of adequate and suitable ground-water prior to development.

- Research should be conducted into the creation of water storage systems, such as natural aquifers. The availability of ample water for heat pump operations can reduce the cost to the developer and make the system economically feasible over a broader part of the country.

CERTAIN PUBLIC SERVICES SUCH AS THE COLLECTION OF SOLID WASTE, MAIL PICK-UP AND DELIVERY, AND OTHER ROUTINE ACTIVITIES CAN BE MADE MORE ENERGY EFFICIENT.

For example, the total trips associated with solid waste collection could be reduced by up to 40 percent with the use of more efficient packer trucks.

- Public officials associated with the provision of services to low- and medium-density areas such as Burke Centre should consider the cost-benefit margins of utilizing equipment and systems that reduce the number of vehicular trips.

- The support of research and development in this field by agencies such as the Department of Energy may produce handsome results, and should be continued.

THE USE OF AVAILABLE WATER SAVING DEVICES IN RESIDENTIAL AND COMMERCIAL BUILDINGS CAN REDUCE A COMMUNITY'S TOTAL UTILITY ENERGY CONSUMPTION BY AS MUCH AS 20 PERCENT.

The use of flow restrictors, mixing valves, low-volume flush toilets and water-conserving appliances can cut total water consumption by 42 percent. The treatment of potable and waste water consumes 24 percent of all community energy supplied by the utility company; implementation of the recommended water-saving devices would reduce the amount of energy used in water treatment by 43 percent. The reduction in hot water energy consumption is equally significant. Hot water production consumes 22 percent of the energy delivered by the utility. The use of the devices studied would reduce hot water usage by 44 percent.

- Builders can play an important role in educating the homebuyer to the advantages of installing water saving devices in a new residence.

- Communities should consider making certain devices mandatory in new homes while encouraging the use of those that are less cost-efficient but still important conservers of water.

- Further research and development in the field of water conservation in the home promises substantial energy savings and should, therefore, be supported.

SAND STUDY TEAM

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Alexandria, Virginia

Governmental Jursidiction:
Fairfax County, Virginia
Gary W. Blanchard
Energy Management Staff

BURKE CENTRE
PROJECT DATA
(Conventional Plan)

Land Use Information

Site Area: 1,390 acres (563 hectares)

Dwelling Units:
- Completed.......................... 1,500
- Total Planned...................... 5,452

Gross Density: 3.92 d.u./acre

Parking: Each dwelling (including garden and mid-rise units) has 2 off-street parking spaces.[1]

Land Use Plan

	Acres	Percent
Residential	1,045	75
Industrial	62	4
Commercial	51	4
Schools	15	1
Major Open Space[2]	217	16
Total	1,390	100

Economic Information

Site Cost: Approximately $9,500/raw acre
Site Improvement Cost:[3] $25,000,000
Construction Cost:[4] $20 to $35/sq ft.
Amenities Cost: $550/unit[5]
Homeowner Association Dues: $240/yr[6]

Climate Information

General: Continental

Degree Days
- Heating 5,010
- Cooling 940

Average Temperature:
- Yearly .... 54°F
- Winter .... 31°F
- Summer .... 82°F

2.5 Percent Design Temperature:
- Winter 19°F
- Summer 91°F dry bulb and 74°F wet bulb

Average Wind Velocity:
- Winter 10 mph (NW)
- Summer 8 mph (W-S)

Average Rainfall: 35 in./yr.

Average Snowfall: 24 in./yr.

Solar Gain: 1,250 Btu/sq. ft./day

Annual Average Sunshine: 2,280 hr. (52 percent of possible)

Residential Unit Information

Unit Type	No.	Unit Size (Sq. Ft.)	Lot Size (Sq. Ft.)	1980 Price	Bedrooms	Bathrooms
SFD	1,193	1,800-3,000	5,600-8,000[7]	$71,000-134,000	3-5	1½-3
Patio/Duplex	2,450[8]	1,200-2,200	4,000-8,000	$63,000-89,000	2-4	1½-2½
Townhouse[9]		1,100-2,200	3,000-7,000	$58,000-90,000	1-4	1-2
Garden[10]	1,509	---	---	---	---	---
Mid-Rise[10]	300	---	---	---	---	---

Notes:

1. Standard required by Fairfax County.
2. Includes the major open space and stream valley system. Additional open space is contained in the above gross parcels, bringing the total to approximately 300 acres.
3. Includes planning, engineering, streets constructed by developer, grading for these streets and for amenities, and water and sewer lines to finished lots and to parcels in which unfinished lots are sold.
4. Varies widely because of the different builders involved.
5. This fee paid by builders to Burke Centre Partnership includes all amenities and recreation development.
6. Includes use of all community-wide open space, administration, and garbage collection, but not private street and cluster open space management.
7. The 5,600 sq. ft. lot fronts on a 70-ft private street space and backs on a 40-ft wooded common buffer.
8. Includes units under "Townhouse," the following item in the table.
9. Townhouse units are included in total for "Patio/Duplex," the preceding item.
10. As of this study, no garden or mid-rise apartments have been constructed.

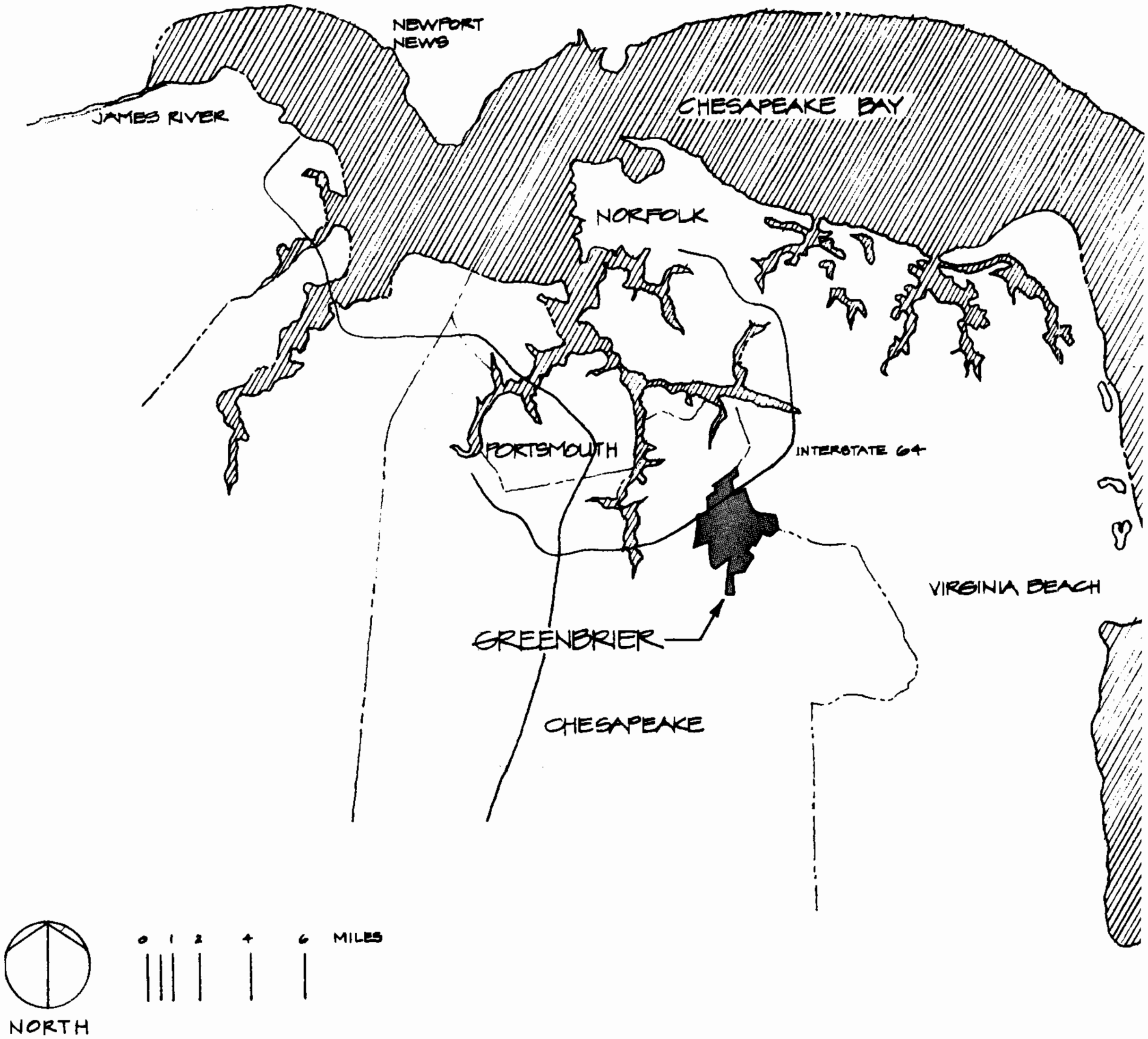


Figure G-1

REGIONAL LOCATION OF GREENBRIER
Source: Greenbrier Report Figure 4

GREENBRIER

BACKGROUND

GENERAL DESCRIPTION

Greenbrier, a 3,000-acre Planned Unit Development (PUD), is located approximately 25 minutes south of downtown Norfolk, Virginia, in the City of Chesapeake and contains residential, industrial, office, retail, and institutional uses. The Site and Neighborhood Design (SAND) study areas are in two different sections of the project, one a 415-acre initial-phase parcel and another 719-acre parcel now under development. The project contains 2,758 predominantly single-family, detached dwelling units priced in 1979 between $45,000 to $125,000 and located on relatively small lots (5,000 to 12,000 square feet).

Greenbrier is expected to have a 15- to 20-year development cycle. Unlike a prior owner, Greenbrier Associates has concentrated solely on project land development and has not engaged in the construction business. Since the project is near a major market, industrial and commercial uses were developed before residential ones. Several residential neighborhoods, however, have been completed. Since the project was acquired in 1977 by Greenbrier Associates, approximately 800 acres have been sold for a variety of uses.

The developer participated on the SAND study in the interests of conserving energy and of possibly receiving a short-term marketing edge. The conservation recommendations resulting from this project could, if implemented, give Greenbrier an advantage in energy efficiency over the rest of the market.

PROJECT MARKET

The Standard Metropolitan Area (SMSA) of Norfolk-Portsmouth-Chesapeake-Virginia Beach is often referred to as Tidewater, Virginia. The population within the SMSA is approximately 800,000. Demographic trends over the last 20 years show that the area has had moderate but consistent growth of 2 percent, although substantial demographic shifts have occurred in residential construction and other economic activity. Chesapeake contains most of the area's open land and will logically achieve the benefit of the population growth in the Norfolk area.

The U.S. government, principally the Navy, is the largest single employer in the SMSA accounting for approximately 17 percent of the total local payroll. All government payrolls constitute 60 to 65 percent of the total payrolls in the Norfolk market. While unemployment is not a major problem, the median income for Norfolk is slightly below the national average.

An important factor in developing Greenbrier has been the favorable political climate. Incorporated in 1967, the city of Chesapeake absorbed all land masses in Washington County not contained within the surrounding communities of Norfolk, Portsmouth, or Virginia Beach. As a relatively young political subdivision, those departments of Chesapeake which were most directly concerned with the development process within the property were created under progressive enabling legislation. The city government is vitally interested in the project's development and has been involved in the evolution of the general plan from its inception.

Chesapeake is a rural community with a local bias to one acre home sites. To the east are residential areas containing densities of no fewer than three homes per acre and with a generally low aesthetic quality. The Norfolk housing market has been consistent even during 1974-75, with lot prices averaging $10,000 to $15,000 for 9,000 square feet in a less desirable portion of nearby Virginia Beach. The project's competition at the time of this study came from three active

PUDs located in Virginia Beach, considered generally a more prestigious address. Otherwise, there was no competition from golf course communities or waterfront communities. The beachfront at Virginia Beach has become highly commercial. The median price for new housing in the Norfolk region was slightly below the national average.

The effect of high interest rates, particularly for the Greenbrier single-family homebuyer, has been to reduce the amount of home he can afford to own as his fixed monthly payments are increased by high interest. As personal income in the Tidewater area has not kept pace with the inflation rate of residential contruction costs, the average homebuyer can afford less house than in the recent past. Increasing construction costs, high interest rates, increasing property taxes, and rapidly increasing utility rates are all forcing the developer's principal customers, the home builders, to seek less expensive lots in order to produce an end product the homebuyer can afford to buy and operate.

The demand for small lots at Greenbrier has been excellent, and Greenbrier has been responding to this market shift. Some of the builders have been successful in responding to this market change. The I-64 interchange at Greenbrier Parkway has been a key factor among the components that add value to Greenbrier, and the importance of this interchange to Greenbrier cannot be overstressed. The interchange makes Greenbrier the most accessible PUD in the Tidewater area. With the opening of the interchange (Sping 1979), the project, almost overnight, became more attractive to residential, commercial, and industrial users.

THE SITE

Because of its strategic location near the center of the region (Figure G-1), Greenbrier has excellent access to all major employment, recreational, and shopping facilities. The interchange on I-64 is located in the center of the project, being intersected by US-13, an east-west military highway, and the main commercial strip in the Norfolk/Virginia Beach area. Rail access is provided by Southern Railway's main north-south line, which is located on the western boundary of the project. Natural gas was not available to the site at the time of the study. In early 1981, the local natural gas supplier indicated that natural gas could be made available to the site.

The topography is essentially flat with a natural elevation change of only 3 feet throughout the site. Geological characteristics can generally be described as a 2-foot cover of high-quality top soil overburdening a sand base for a depth of 15 to 50 feet. Occasional layers of deposits of silty clay/clay sand with high-moisture, low-bearing characteristics occur throughout the site. The site has abundant groundwater at a year-round fixed temperature of 62° F available at levels of 30 feet and below. Generally the water table is 9 feet below grade.

The Greenbrier climate is characterized as hot-humid, typical of the southeastern United States coastal areas. Greenbrier has 3,499 heating degree days and 1,441 cooling degree days. The area has an average yearly temperature of 60.6° F, an average winter temperature of 47.3° F, and an average summer temperature of 78.3° F. The Greenbrier area has relatively low wind velocities both summer and winter. Average rainfall for the Greenbrier area is 43.1 inches per year. The Greenbrier area receives a yearly average of 1,399 Btu of solar radiaiton 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 possible. While receiving a good quantity of solar radiation, a relatively high percentage of this radiation is diffuse (scattered or reflected by clouds or other atmospheric constituents).

TEAM AND METHODOLOGY

Greenbrier Associates, an affiliate of Realty Capital Incorporated of Washingotn, D.C., and the primary contractor to the U.S. Department of Energy, organized an interdisciplinary team to develop an effective and implementable energy-conserving plan. The research team consisted of a group of specialized enterprises, each having a unique expertise essential to the effort. The disciplines represented included land planning, advanced energy technology, architecture, engineering, landscape architecture, development economics, finance, marketing, and management. Greenbrier Associates, as the prime contractor, had complete responsibility for the Greenbrier project and retained its parent company, Realty Capital, Inc., to supervise the planning, financing, and marketing. The College of Architecture and the Engineering Experiment Station of the Georgia Institute of Technology provided technical input and analysis and served as coordinators of the technical team. The firm of Lewis Clark Associates provided critical land planning and landscape input in addition to preparing the alternative plan. The firms of Thompson, Ventulett, and Stainback (architects) and Brady, Anglin (Engineers) were active in developing conservation design methods and solar energy systems.

The Greenbrier team divided its research effort into two major tasks. The first task was to document the Greenbrier development program as it would have proceeded under a conventional development program and to project from this conventional plan the total energy that would be consumed in construction and operation of the development. Operating energy consumption was projected over a 30-year period, the normal mortgage period for conventionally financed housing.

The second major task was to propose and evaluate energy conservation options that could conceivably contribute to a conservation development plan (Figure G-2). Initially, the research team developed the following set of four conservation categories:

- land planning applications,
- architectural applications,
- mechanical applications, and
- community systems.

The conservation options that were identified within these categories were then independently appraised according to a common set of evaluation criteria.

For example, site orientation was listed as a conservation option within both the architectural and land planning categories. Once such an option was proposed, it was assigned to the appropriate members of the technical research team for documentation of design, materials, and costs. Any option proposed by any team member would be fully reviewed by both the technical and management teams at the regularly scheduled monthly review sessions. This two-stage process allowed for review of all options without initial bias as to the "appropriateness" of any option.

At the technical and management review sessions, an initial evaluation of each of the options was conducted to determine if the proposed option conformed to the team's predetermined evaluation criteria. These criteria included whether the option was (a) within the scope of the developer's role, (b) technically feasible, and (c) legally possible. Once an option was considered to have been within the scope of the developer's role and to be technically and legally feasible, the option was advanced to a second stage of evaluation.

Through computer simulation and standard manual analytic techniques, the technical and management review teams were able to assess the relative quantifiable costs and benefits at each option within each category. In this way, the most efficient options were developed for each construction problem. Over and above the quantifiable dollar costs and benefits of each conservation option,

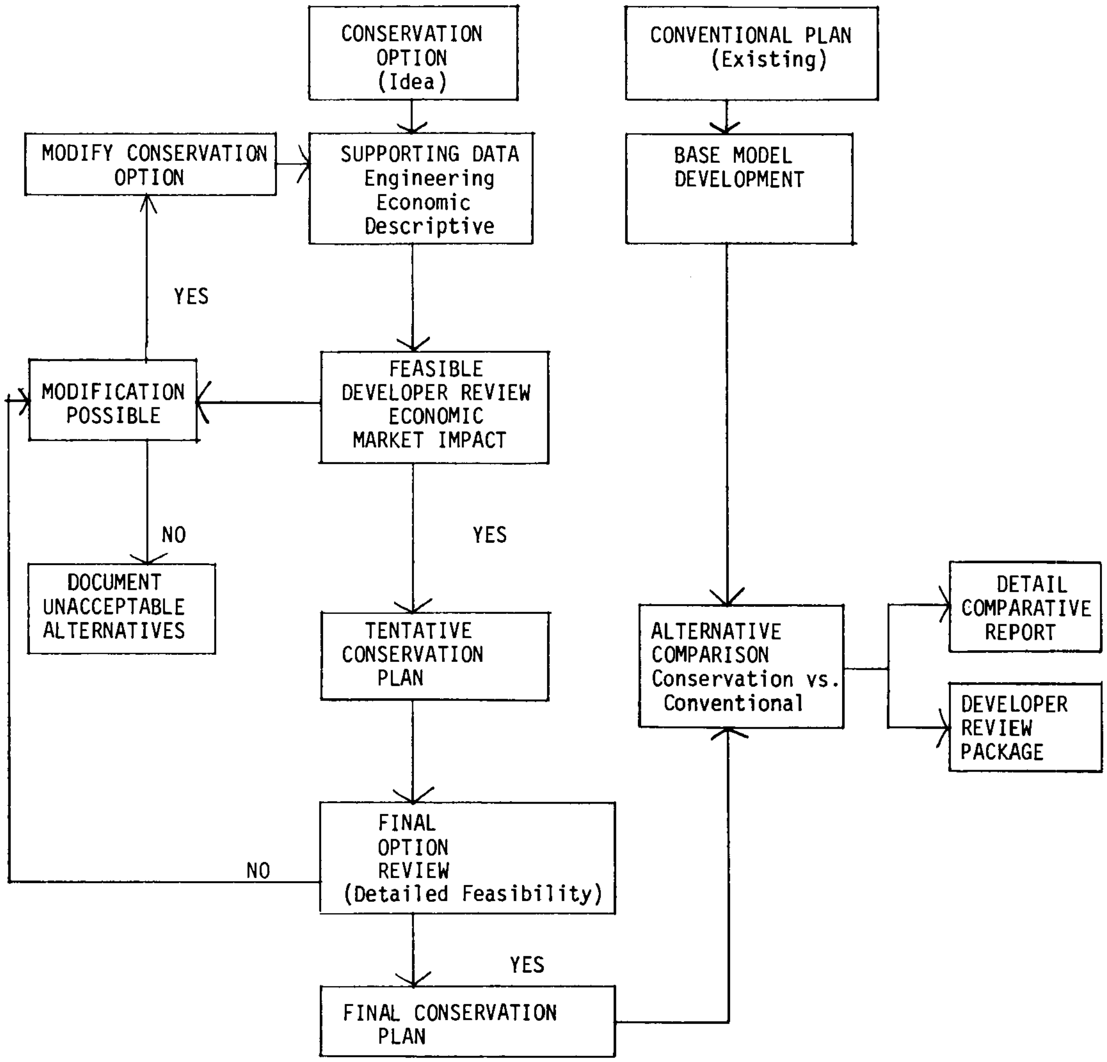


Figure G-2

CONSERVATION OPTION EVALUATION PROCESS
Source: Greenbrier Report Figure 2

every option was evaluated according to its marketability. While extensive market surveys were well beyond the scope of this research effort, Realty Capital, Inc.'s extensive experience in real estate development, management, and marketing served as the final sieve through which an option had to pass before its incorporation into an energy-conserving plan.

An understanding of the limitations of the developer's role and the incremental nature at the development process can provide some insight into the evaluation of energy-conservation options. As the developer, Greenbrier Associates can determine the overall land-use development and design strategies within the confines of the marketplace and within the confines of the developer's own financial and managerial resources. While the developer may have a commitment to larger societal purposes, these are usually not primary motives for development. The developer must ascertain his or her ability to assume risk as measured by cash outlays and expected returns over time. The developer, at Greenbrier and elsewhere, is dependent on the builders and the consumer to determine the actual end products. While building and land use design principles can be significantly influenced, their ultimate manifestation is a product of market demand and usually becomes a function of negotiation between what the developer would like to achieve and what the builder can actually sell. Such negotiations must also function within a larger governmental framework. These limitations are basic to an understanding of what energy conservation options are practical and desirable.

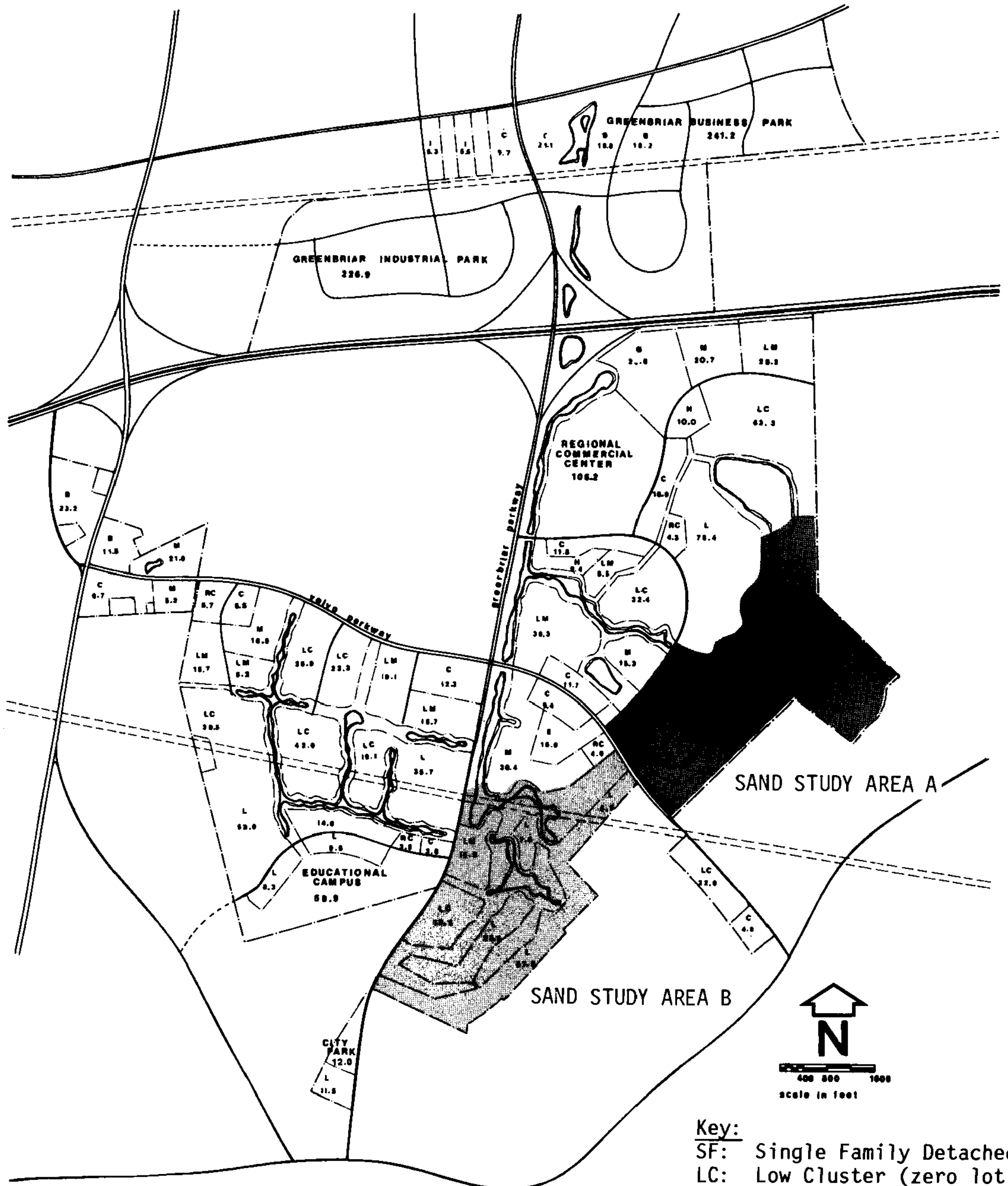
CONVENTIONAL PLAN

Greenbrier land use plans function in two principal ways: (a) as a zoning document with the city and (b) as a preliminary planning tool. As imperfections in the plans become obvious, changes in the land use plan are made. In the two years after acquisition, the developer went through four iterations of the land use plan. The January 1978 plan (Figures G-3 and G-9) was used as a base plan to evaluate the performance of the proposed conservation options.

Common threads through all the land use plans were the network of impoundment lakes and the collector road system. In addition to being an amenity, the man-made lakes were planned to handle stormwater runoff resulting from the site's high water table. The collector roads and the lakes would help define a series of villages, thereby avoiding conflicts created by differences in style and price of various builders. In addition to lakefront lots, parks were located next to the lakes so that all people could view and use the lakes as amenities. Where they were needed, 6.5-foot high berms would separate the streets from adjacent uses.

Embodied Energy

Because of the community-oriented nature of the research, the study team felt obligated to look at the total community and the energy that was conserved in the production of that community. The embodied energy that was contained in the conventional plan was analyzed in terms of the infrastructure that was required to be constructed by the developer. The above-ground construction is not necessarily directly controlled by the developer; rather, it is usually controlled by people who buy land from developers and then build on it. By taking the quantitative estimates of each linear foot of pipe and curve and each square foot of wall section, built-up roof, etc., the study team estimated that the total site infrastructure in the business, commercial, and residential sectors required 31×10^{10} Btu of embodied energy. The above-ground construction required 146×10^{10} Btu, which gave a total of 177×10^{10} Btu needed during construction.



Key:
SF: Single Family Detached
LC: Low Cluster (zero lot line)
LM: Low Medium (SF detached)
M: Medium (townhouses)
H: High (apartments)
C: Commercial
B: Business

Figure G-3

GREENBRIER LAND USE PLAN
Source: Greenbrier Report Figure 6

On the operating side, loads were calculated in three ways. A manual calculation was performed using the standard ASHRAE procedure (Manual J calculation) to determine the loads on each existing unit type. These estimates were then checked with load simulations programs from the Air Force (AFM 88-8 method) and the University of Wisconsin (TRNSYS). The figures were acceptably close but were nevertheless verified with estimates from Virginia Electric Power Company (VEPCO) and cross-checked with estimates from Georgia Power.

After the study contract was granted, the builders at the site began installing air-to-air heat pumps (GE Weatherton 2 1/2 ton units). Base-case figures were therefore adjusted for the introduction of the air-to-air heat pumps rather than electric resistance heat. This is important in considering the savings that were achieved, because the savings were related to the improved base-case.

The total projected end-use operating consumption of Greenbrier was 36 x 10^{10} Btu (Figure G-6); this figure was based on a day-to-day, hour-by-hour simulation and an average weather-year reconstructed over a 30-year period (chosen simply because it is the normal amortization period of current conventional financing). In five years the operating consumption measured at the end-use, would equal the total amount of energy consumed in the production of this development. Assuming that line losses and transmission from production to end-use is a ratio of approximately 3:1, the total Btu production requirement for operating the conventional plan for one year and seven months would equal the embodied energy. Over the 30-year period, end-use consumption would be six times greater than the embodied energy. Including losses and production, the energy required to reach that end-use would be 18 times greater.

THE CONSERVATION OPTIONS AND ALTERNATIVES

For the purpose of presentation and analysis, the proposed conservation options are separated into four categories, each representing a different level of control on the part of the developer.

Land Planning Applications

Land planning applications include those conservation options which are controlled most directly by the developer and his agents. These options may be employed at any point in the development process, from raw land conversion through site infrastructure development and lotting to the point where the land is sold to a builder or commercial developer. The following options were considered under this category:

- reduction in street widths;
- improved efficiency in lotting;
- reduction of curbs, gutters, and sidewalks;
- lot orientation;
- transportation; and
- vegetative cooling.

Architectural Applications

Architectural applications include those options which are not in the direct control of the developer or his agents but rather are controlled by individual builders and/or individual commercial developers. Greenbrier Associates, for example, does exercise limited, indirect control over much of the architectural development, mostly in the form of published guidelines and review. The options considered under this category were

- reconfiguration of internal living space;
- solar screening, window location, and house orientation;
- double glazing;
- slab and crawl space;
- roof overhang;
- greenhouse; and
- trombe wall.

Figure G-4
SUMMARY OF EXPECTED RESIDENTIAL ENERGY CONSUMPTION AT BAYBERRY
(in kWh)

Type of Housing	Sq. Ft.	Annual Heat	Annual Cool	Total Load H & C	Miscellaneous Load plus Hot Water	Total Load per Unit	Number of Units	Total Overall Consumption
Single-Family Detached 2-story	2400	14,357	7912	22,269	18,754	41,023	436	17,886,028
1-Story	2100	14,357	7200	21,557	17,880	39,437	149	5,876,113
Single-Family Detached	1600	10,939	4876	15,815	14,460	30,275	742	22,464,050
Cluster Home	1800	11,075	6566	17,641	16,200	33,841	352	11,912,032
Townhouse*	1450	7,038	4216	11,299	12,540	23,839	856	20,406,184
Apartments	11000	4,512	3663	8,157	10,290	18,465	223	4,117,695
TOTALS		62,278	34,478	96,738	90,124	186,880		82,662,102

*Average of center and end units in a 4-unit block.

Figure G-5
SUMMARY OF EXPECTED ANNUAL OPERATING ENERGY CONSUMPTION
FOR COMMERCIAL, OFFICE AND INSTITUTIONAL USES, CONVENTIONAL PLAN
(in kWh)

Type	Number of Units	Annual Heating	Annual Cooling	Fans	Lights	Water Heat	Misc.	Number of Units	Gross Consumption
Shopping Center fully a/c 89,548 sq. ft.	4	14,128	622,323	382,346	1,203,403	-	876,000	4	3,098,200 x 4= 12,392,800
Office Bldgs. each 5 stories fully a/c total 100,000 sq. ft.	4	35,160	369,177	193,378	773,513	-	386,756	4	1,757,984 x 4= 7,031,936
Secondary School 36 classrooms 1080 students air conditioned	1	555,376	238,826	679,448	392,617	-	0	1	1,866,267
Elementary School 20 classrooms 600 students not a/c classroom	1	262,840	43,400	169,864	197,100	146,250	0	1	819,454
Church 4860 sq. ft. limited use	1	40,833	10,850	51,683	14,688	1,350	-	1	119,404
Fire Station 1 bay, 2 engines limited a/c 1360 sq. ft.	1	14,033	9,757	0	5,000	1,000	-	1	29,790
Clubhouse 9100 sq. ft. fully air conditioned	1	245,130	126,000		97,200	-	-	1	468,330

Figure G-6
SUMMARY OF ALL EXPECTED CONSUMPTION AT GREENBRIER

Base Case/Conventional Plan
Aggregate Energy Consumption
(in Btu x 10^{10})

	Embodied Energy		Operating Consumption
	Site Infrastructure	Above Ground	End Use
Business & Commercial	9.9197	21.854	7.7916
Residential	21.0317	124.432	28.213
Total	30.9514	146.286	36.0046

In 4.92 years, the end use operating consumption equals the total embodied energy. If it is assumed that line losses in transmission from production end use is a ratio of approximately 3:1, then the total Btu production requirement for operating the conventional plan for one year and seven months equals the embodied energy.

Over a 30-year period, end use consumption is 6.09 times greater than embodied energy. Including transmission losses, operating consumption is 18.28 times greater than embodied energy over the same 30-year period.

(also in Btu x 10^{10})

	Embodied Energy (Btu)	End Use Consumption	Consumption W/Losses
First Year	177.3740	36.0046	108.0138
Fifth Year	177.3740	180.023	540.069
Thirty Years	177.3740	1080.138	3240.414

Mechanical Applications

Mechanical applications are normally within the direct control of the builder in residential development, and of mechanical engineer or commercial developer in the nonresidential sectors. Heating, ventilating, and air conditioning equipment is selected by the builder or the HVAC subcontractor. Equipment is usually selected on the basis of initial purchase price alone, although consumer demand for air-to-air heat pumps has created recent shifts in equipment purchases at Greenbrier. Mechanical systems considered were

- groundwater heat pump,
- domestic-hot-water heat reclaimer,
- active solar domestic hot water, and
- active solar residential heating systems.

Community Systems

Community systems are those which involve the community itself as the primary agent of energy conservation, either through on-site alternate energy production, or through such practices as organized car pools. Options falling within the first subcategory may, in fact, require control by the developer and have considerable impact on the manner in which the land plan is evolved. Normally, the primary developer does not control any form of energy production but rather ties into the existing grid of the local utility company. Options which were considered in this category included

- wind energy systems,
- solar total energy systems, and
- central thermal plants.

These options involved either on-site energy production or cogeneration with VEPCO, the local utility company. These options would substantially change the role of the developer in that the developer would have to accept more risk and expend a greater amount of his financial resources early in the development process.

Together, these categories helped synthesize the options examined in a specific energy conservation plan. Each category represented a different tier of control from which the developer could have an input into the decision making process. The site orientation option was clearly within the scope of the developer's control, while causing the individual consumer to keep thermostat settings low was clearly beyond the developer's sphere.

CONSERVATION PLAN

The conservation plan is a development strategy consisting of those options deemed feasible and appropriate for implementation by the review team, according to the established criteria. A comparison between the conventional plan and the conservation plan was made to determine the relative costs and benefits. The conventional plan used in the comparison was one prepared for a section of Greenbrier containing 719 acres of residential development, including an 18-hole golf course. The conventional plan section was not used for comparison purposes. Because of the advanced stage of infrastructure development, proposed options could not be implemented within that section. Since there is virtually no difference in the development program of the 719-acre site and the conventional plan section, the research team developed the conservation plan for possible implementation on the 719-acre site.

Options included in the conservation plan include

- maximum number of south-facing lots (orientation),
- "Arkansas" construction,
- insulated slab on grade foundation,
- groundwater source heat pump, and
- domestic-hot-water heat reclaimer.

In the conservation plan, energy consumption was reduced two ways. First, by reducing the heating and/or cooling load, thereby reducing the energy required to maintain internal comfort within the dwelling unit. Second, by heating or cooling the remaining loads more efficiently. Because the total effect of each option is not necessarily cumulative, all options were added prior to simulation of the performance of the conservation plan. The conservation plan options are further described below.

Options Included

Lot Orientation--The first test in preparing the conservation plan was a revision of the existing land plan for the 719-acre site, to obtain maximum southern orientation in lotting. The conservation plan reduced east-west facing lots from 65.4 percent of the total lots to 55.6 percent of the total. North-south facing lots were increased from 34.6 percent to 44.4 percent of the total lots. In addition to the increased optimum orientation, the conservation plan yielded 25 more lots than conventionally planned, which increased the lot-to-infrastructure efficiency.

Figure G-7
LOT ORIENTATION SUMMARY

	Conventional Plan		Conservation Plan		Differences	
Facing	Number	Percent	Number	Percent	Number	Percent
N	85	15.7	114	20.2	29	34.1
S	102	18.9	137	24.2	35	34.1
E	162	30.0	170	30.0	8	4.9
W	192	35.4	145	25.6	(47)	(24.5)
TOTAL	541	100.0	566	100.0	25	4.6

Arkansas Construction includes reduced air infiltration from one air change per hour to .3 air changes per hour. This is achieved primarily by sealing and caulking all joints and the foundation and toe plate connection and weatherstripping all doors, windows, and other openings.

Arkansas construction also includes 2-inch x 6-inch (R-23) studwalls, and double glazed windows. This package of options has the greatest cost impact of any option included in the conservation plan. Experience with 2-inch x 6-inch framing indicates that once the framing subcontractors are familiar with it, the expense is less than conventional 2-inch x 4-inch framing. This is due primarily to the decrease in board feet of lumber, resulting from 24-inch center spacing in the studwalls. The increased size of the wall cavity does increase insulation costs approximately $100 to $200 per unit. Increased costs can also be expected from caulking and sealing all joints. This is not normally done in conventional construction. Added cost from sealing is approximately $450 to $500.00. Double-glazed windows would add an additional $500 to $1,000 over conventional single glazing. As a package, Arkansas construction can be expected to increase construction costs from $1,050 to $1,750.

Insulated Slab on Grade Foundation--This option allows the house to use the earth as insulation. If the outer 24 inches of the slab perimeter are insulated, heat is not transferred through the slab to the exterior of the structure. Compared to continuous footing and pier foundations commonly in use at Greenbrier, the slab foundation is $1,500 less expensive. When compared to conventional slab on grade foundations, however, the insulation would increase the cost approximately $600 because the perimeter of the slab must be poured in two stages.

Groundwater Source Heat Pump--This option yielded the highest performance in energy conservation with virtually no known impediments to implementation. The high efficiencies of the heat pump (Coefficient of Performance 3.5) were not matched by any other heating and cooling option, except for a 100-unit central thermal plant. Data obtained from two manufacturers show that the groundwater source heat pump costs the same as an equivalent air source heat pump. Two wells, at a total cost of $300 would be required for operation.

Domestic-Hot-Water Heat Reclaimer--The base case revealed that the heating of domestic hot water is the largest consumer of energy in the dwelling, other than space heating and cooling. The heat reclaimer captures "waste" heat from the heat pump and uses it to heat domestic hot water. It provides approximately half of the total hot water needs of the average Greenbrier house at an initial cost of $500. Widespread use of this device should reduce the price considerably.

Cost differentials for these options are summarized in Figure G-8.

Figure G-8
SUMMARY OF COST DIFFERENTIALS FOR ENERGY-CONSERVING OPTIONS

Option	Cost Differential (Conservation Plan Over Conventional Plan)		
South facing lots	0		
Arkansas construction (2 x 6 studwalls; double glazing; sealing and weatherstripping)	+$1,050	to	+$1,750
Insulated slab on grade construction	-$1,500 (compared to continuous footing and pier foundations)	to	+$600 (compared to conventional slab on grade)
Groundwater source heat pump	+$150	to	+$300
Heat reclaimer for domestic hot water	+$500		
TOTAL	+$200	to	+$3,150

Some Excluded Options

Several options which proved to be promising were not included in the conservation plan either because of their questionable legal status (reduction in sidewalks, curbs, and gutters and reduction in street widths) or because the option was considered to be an add-on feature controlled by the builder (greenhouse) or a modification controlled by the consumer (vegetative cooling).

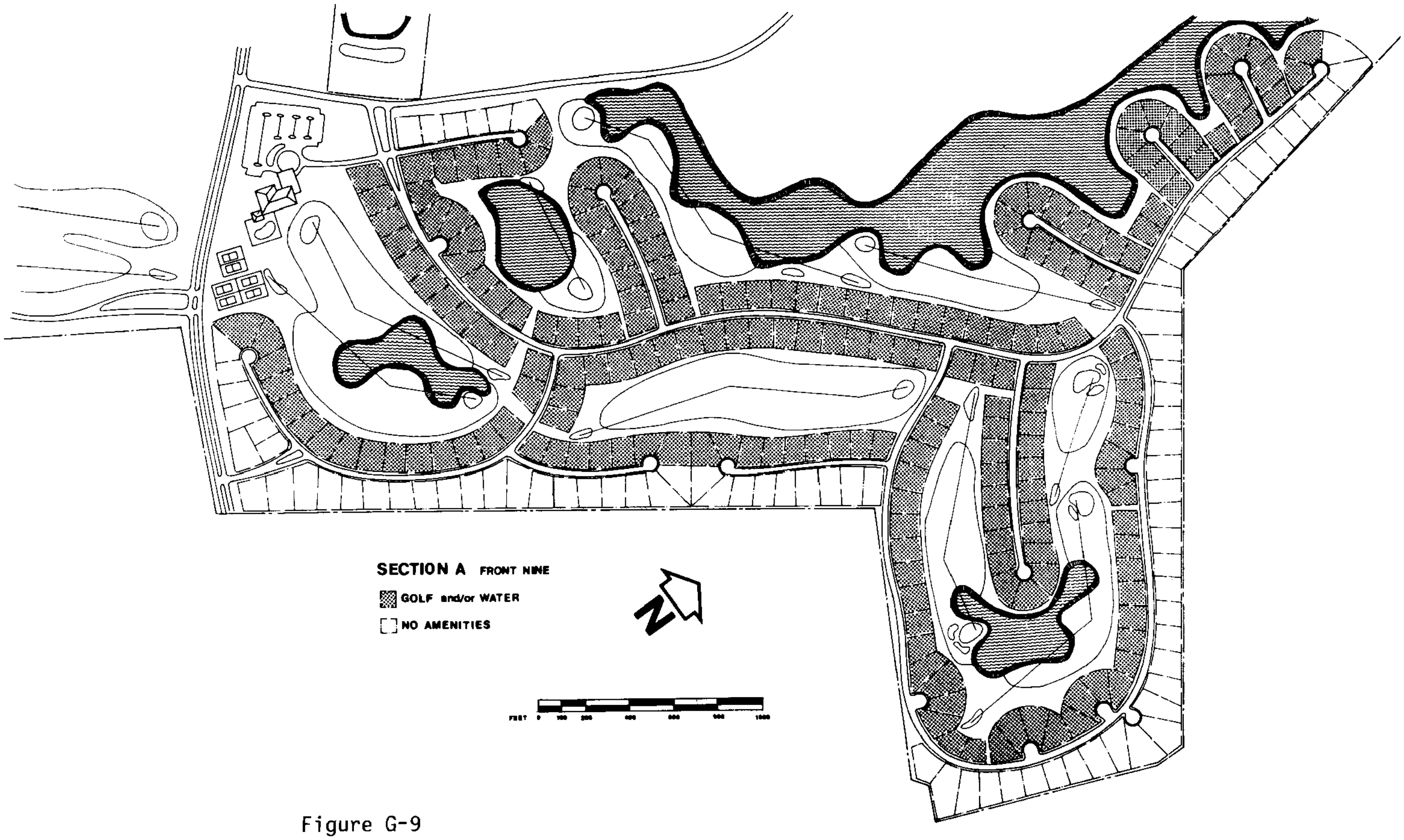
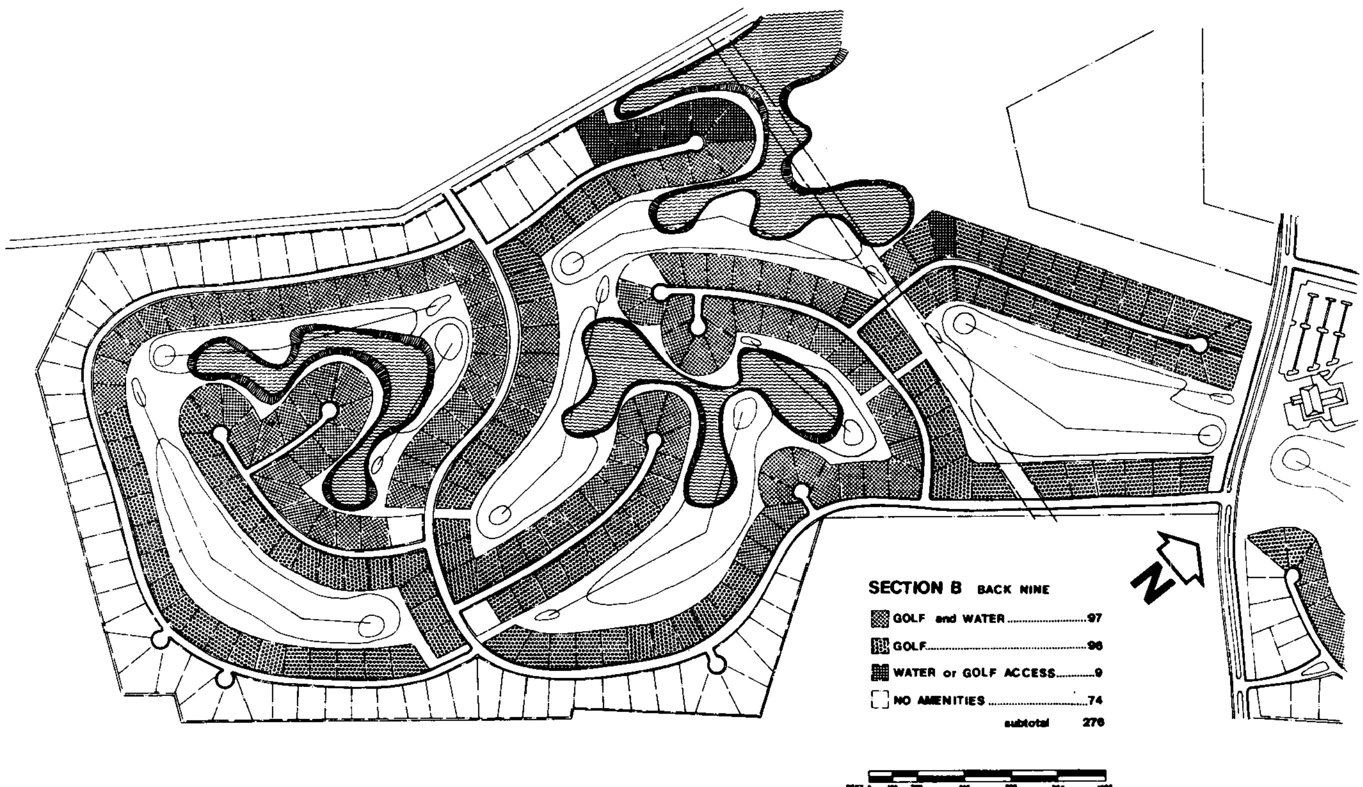


Figure G-9

CONVENTIONAL PLAN FOR SAND STUDY AREA
Source: Greenbrier Report Figures 14A and B



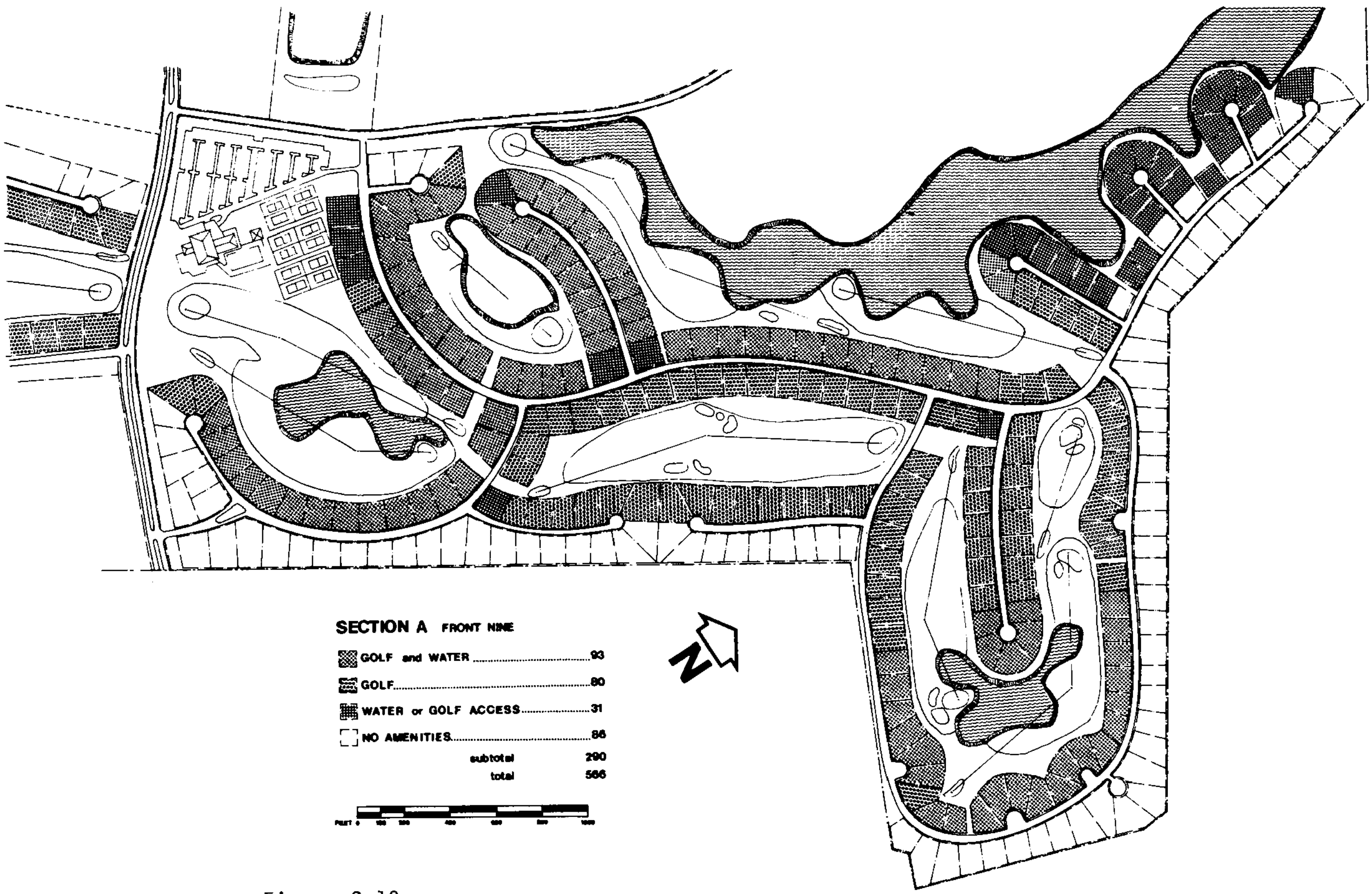
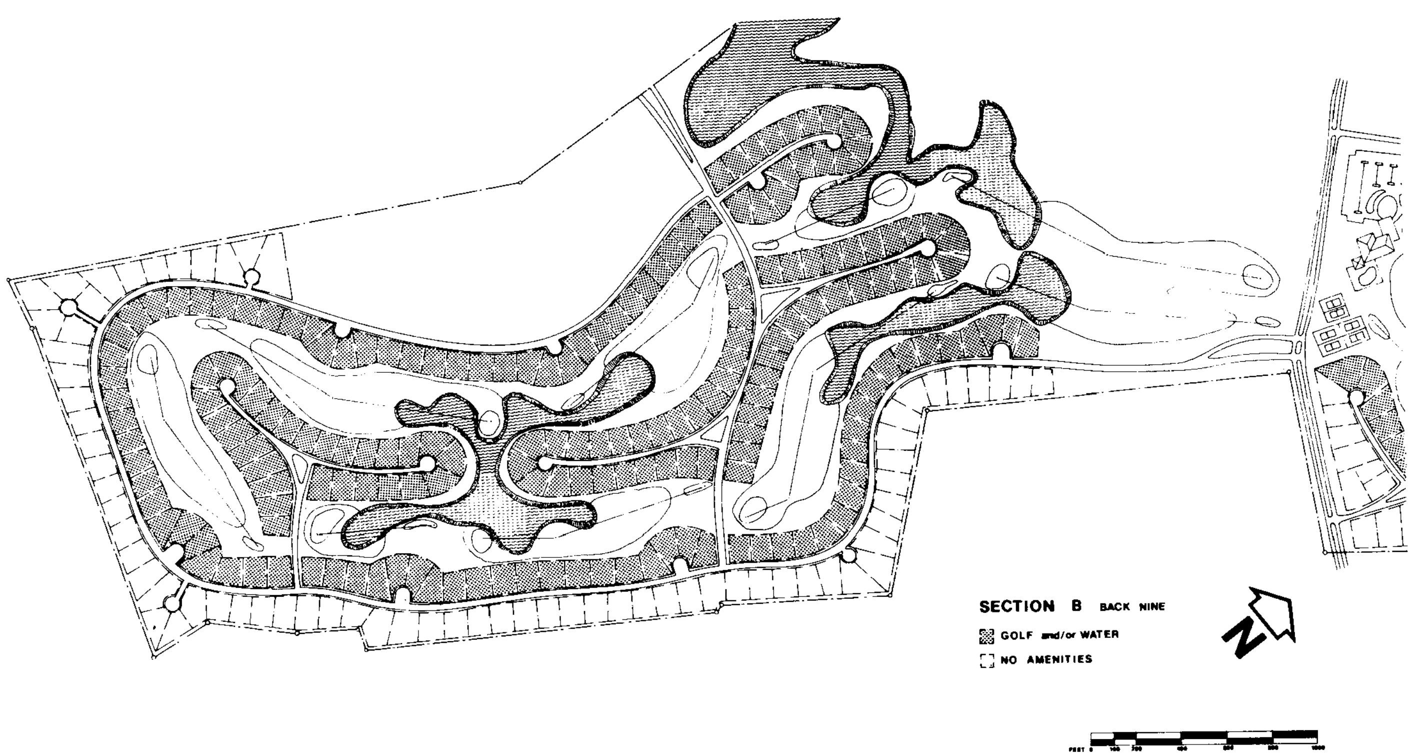


Figure G-10

CONSERVATION PLAN FOR SAND STUDY AREA
Source: Greenbrier Report Figures 15A and B



A description of these options and their savings is as follows:

Reduction in Street Widths--Directly controlled by the developer, this option is subject to the subdivision regulations established by the City of Chesapeake. Current subdivision regulations require that streets be 28 feet in width curb to curb. Residential streets are two inches of asphalt over six inches of crushed stone, over an adequate bed of select backfill material. Arterial roads vary in width, depending upon the requirement sof the City of Chesapeake. In place, residential streets consume 13,264 Btu per square foot. Embodied energy could be saved by reducing either the thickness of the slab or the width of the pavement.

Reducing the thickness of the slab would require either a change in the minimum construction specifications by the City of Chesapeake or permanent maintenance by Greenbrier Associates. Preliminary discussions with the city indicated that it would not be willing to modify its construction specifications in any area which would increase maintenance costs in the long run. The City of Chesapeake requires street construction to conform to the State of Virginia Standards so that it will receive from the State annual maintenance funds. Greenbrier Associates is not in a position to maintain site infrastructure once the development is sold out. To do so would not only require the addition of a permanent maintenance crew but also a change in the property tax laws of the City of Chesapeake and the State of Virginia. As a result of this preliminary evaluation, reduction in slab thickness was excluded from further consideration.

Reduction in street widths, however, did not face the same obstacles. Although current subdivision regulations require widths of 28 feet, reductions to 24 feet might be acceptable to the city. The average square footage of street in the low density residential sectors is 1,008 per lot. By reducing the width of the street 4 feet, the total square footage per lot is reduced by 144 square feet. From the base case it was estimated that the savings achieved by reducing the street widths would be 3.8 million Btu. Converting this to the dollar value of the embodied energy in the asphalt, the gross savings per lot would be $19.48. This option was also excluded because it would require the changing of Virginia road standards or mean the loss of state maintenance funds by Cheasapeake.

Reduction in Embodied Energy in Curbs and Sidewalks--Current subdivision regulations require poured-in-place concrete curb and gutter on all residential streets and 4-foot-wide concrete sidewalks 4 inches thick on each side of the street. While reduction in street widths and changes in lot-to-infrastructure relationships would not affect these items to a significant degree, the research team did expect some savings could be obtained by either changing material or changing the quantity of material per linear foot.

Studies in the base case showed that embodied energy contained in asphalt is 55 percent less than in poured in place concrete. By changing the concrete sidewalks from 4-inch concrete slab to 2-inch asphalt slab, 4.0×10^{10} Btu could be saved. (On a per unit basis, the average saved in all residential types would be $88). Changing the curb and gutter from concrete to asphalt represents an energy savings of 2.9×10^{10} Btu. While these changes would require modifications of existing subdivision regulations, the predicted savings may be sufficient to warrant such a change, particularly in the case of the sidewalks.

Vegetative Cooling--Manual calculations were performed for reduction in direct gain through glass surfaces on a 2,100 typical-square-foot Greenbrier residence. Using a shading coefficient of .10, deciduous shade on the east and west facades could reduce the cooling load by 85,500 Btu per day. This is the equivalent of 25.06 kWh or $0.87 per day. Over the cooling period, this reduction results in a gross savings of $78.30 per year.

There are two ways to achieve shading. One is to site each structure carefully so that shade is provided from existing trees on the site. This would require additional effort from the builder. Normally, an effort to control the cutting of trees is made by the developer and land planner through the layout of streets and lots and by the use of restrictive covenants attached to the lot at time of sale to the builder. Those trees saved by the builder, however, are normally saved only for their aesthetic appeal to the potential consumer. While the developer could restrict the cutting of trees on east and west facades, the staging requirements of the builder and his or her subcontractors during the construction period would probably make enforcement difficult. Individual siting of structures normally is done by the builder. To insure the preservation of trees in the correct location, the developer or his agent may have to control the siting of each structure.

The second way of achieving these results is to plant trees, after construction, in the desired location. This does not have the advantage of immediate results and requires additional capital expenditures on the part of the builder. In order to qualify for FHA financing, the builder must have landscaping equivalent to 1½ percent of the selling price. At Greenbrier, this averages $984 per residence. Again, the developer can influence the location and type of plantings through restrictive covenants, but only to the extent that the builder feels the marketability of his or her product will not be diminished.

These modifications are controlled exclusively by the consumer. Since there is no reasonable method of modeling consumer behavior, this option was not included in the estimate of savings in the conservation plan. The research team believed that vegetation could have a very significant impact on energy conservation and prepared, as part of the ocnservation plan, a consumer-oriented brochure on the potential benefits of careful use of vegetative screening.

Greenhouses--Several configurations of greenhouses were tested for their energy production capabilities. While those tested all yielded positive energy flow to the primary structure, the relatively high costs in relation to energy production capabilities make the greenhouse option difficult to justify on energy costs alone. Because of the "add-on" capability of this option, however, there is reason to believe that the greenhouse is a viable option. Since the decision to "add-on" a greenhouse is primarily the choice of the consumer, this option was not included in the estimated energy savings of the conservation plan. A consumer-oriented brochure, outlining the costs and energy benefits of this option was prepared.

Transportation -- Energy consumed in transportation was considered briefly but was eliminated from consideration because of the limited impact of Greenbrier Associates on trip generation. Trips to work and to other destinations beyond the Greenbrier site could easily account for over 70 percent of the total trip origins at Greenbrier. The remaining trips could conceivable be altered by careful location of commercial and institutional facilities. A cursory investigation found, however, that the central location of these facilities in the conventional plan produced the most efficient distribution of internal trips and could not be substantially improved upon without a change in transportation modes. In order to achieve this change, retail and institutional facilities would have to be located within 1 mile of all trip origins. To support such a dispersement of retail facilities with the site, the overall density of the residential sector at Greenbrier would have to be increased five times. Since the current densities reflect market demand (to the best estimate possible), increasing the density substantially was not feasible. As a result, transportion-related energy consumption was dropped from further consideration.

CONSERVATION PLAN SAVINGS

In the Greenbrier conservation plan, nothing new technologically was achieved. A very efficient device that has been around for 20 years, the groundwater source heat pump, was married to more efficient development and construction. With increased incremental costs of $200 to $3,150 per dwelling unit, energy consumption at Greenbrier could be reduced by 54.7 percent in residential development with an average annual savings of 21,2750 kWh per residential unit.

These savings could be achieved through reduction in heating and cooling loads and application of more efficient heating and cooling of the remaining loads. The reduction in loads could be achieved by redesign of the land plan to include a higher percentage of south-facing lots, use of vegetation to modify microclimate, decreased air infiltration, the use of 2-inch x 6-inch framing for better insulation, and the use of an insulated slab-on-grade foundation. Further energy savings could be expected by increased efficiencies in the groundwater-source heat pump, used for space heating and cooling, and the domestic-hot-water heat reclaimer.

When applied to a 716-acre section of Greenbrier containing 541 dwelling units, these options would reduce the total end-use energy consumption by over 50 percent and would represent an annual savings of $402,850 on an initial capital investment between $108,000 and $1.7 million. While the conservation plan would require alteration of certain procedures normally followed in the process of development and construction, it would require only minimal increases in capital expenditures. By contrast, however, using a 30-year conventional mortgage life, implementation of this plan would result in a savings of $22,338 per house at an energy cost of 3.5¢/kWh. (Since the completion of the study, power cost in the area now averages 4.5¢/kWh producing a life cycle savings of $28,720.)

Figure G-11
SUMMARY COMPARISON OF ENERGY CONSUMPTION
CONVENTIONAL PLAN AND CONSERVATION PLAN

For 2,100 sq. ft. Greenbrier Base Case House

Conventional Plan (541 dwelling units)

Direction	No. of Units	Heating & Cooling	DHW*	Misc	Total/Unit	Total
N	85	20048	9000	8800	39008	3.230×10^6 kWh
S	102	19401	9000	8800	37361	3.812×10^6 kWh
E	162	21557	9000	8800	39517	6.402×10^6 kWh
W	192	21557	9000	8800	39517	7.587×10^6 kWh
TOTAL						21.031×10^6 kWh

Average per unit = 21.031×10^6 - 541 = 38,872 kWh/yr.
@ 3.5¢ per kWh = $1,360.52 per unit/yr. ($1360.52 x 541 = $736,041.32)

* DHW: Domesting Hot Water

Conservation Plan (566 dwelling units)

Direction	No. of Units	Heating & Cooling	DHW*	Misc	Total/Unit	Total
N	114	5383	3150	8800	17413	1.985×10^6 kWh
S	137	5209	3150	8800	17239	2.362×10^6 kWh
E	170	5788	3150	8800	17818	3.029×10^6 kWh
W	145	5788	3150	8800	17818	2.584×10^6 kWh
TOTAL						9.960×10^6 kWh

Average per unit = 9.960×10^6 - 566 = 17,597 kWh/yr.
@ 3.5¢ per kWh = $615.90 per unit/yr. ($615.90 x 541 = $333,201.90)

Energy Saved (For 541 Units)

	kWh/yr.	Dollars/yr.	Capital Cost
Per Unit	21,275 kWh	$ 744.63	$ 200.00- $3,150.00
Total	11,509,775 kWh	$402,842.12	$108,200.00-$1,704,150.00

IMPLEMENTATION

ROLES

Developer

Greenbrier Associates' role as a developer at Greenbrier is slightly at variance from that of the typical developer. Greenbrier Associates acquired the property from the Ervin Company. Therefore, the property acquisition, initial land use plan, zoning approvals, much of the major infrastructure and some of the actual sales had already been at least partially completed when Greenbrier Associates acquired the site. Of course the land use plan and zoning approvals on a site as large as Greenbrier are constantly being revised and fine-tuned to keep pace with changes in the marketplace and the economy.

Promotion of Greenbrier had already occurred among builders prior to Greenbrier Associates' assuming control, so that the first residential lot sales to builders at "Bayberry Place" went rather quickly. The initial 135-lot subdivision generally had 10,000 square foot lots with a minimum of 1,750 square foot homes. Bayberry Place was Greenbrier Associates' first attempt to develop an inventory of residential properties for sales since the former owner. Ervin had focused primarily on launching industrial and commercial sales.

As an inventory of residential sites became available, builders approached Greenbrier Associates to expand the residential inventory. The most important characteristic of the developer's role at Greenbrier or elsewhere is the dependence of the developer on the market demand to set the pace of the development process. The size and nature of those lots are dictated by the builders and, ultimately, by the consumers, in conjunction with the developer's own long-term objectives and market analysis. While it is in both the developer's and the builder's interest to create inventory and raise the level of activity at the project, the developer usually is a drag on the development pace since it is his funds or loan commitments which are being used in infrastructure construction. Until the builders purchase the sites that are served by the developer's roads and utilities, the developer realizes no return on his investment and yet must continue to repay the loans which were required to make the improvements. The developer, therefore, attempts to minimize the time between infrastructure development and sales to minimize his financial exposure and to maximize his flexibility to develop other portions of the project.

The developer's role in marketing the project is generally one of institutional selling to the builders, brokers, and, to a much lesser degree, the actual buyers themselves. The developer tries through his marketing effort to create a positive ambiance surrounding the project. The builder usually markets a specific home to the buyer. The developer, then, has limited, if any, contact with the end buyer of most of his property. The developer, by and large, functions merely as a producer of inventory for the builder. The developer can strongly influence the overall direction of the development but usually does not get as site-specific as the builder does on individual residences. On the other hand, the builder is dependent on the developer for his product, and the developer can strongly influence the quality standards he is attempting to achieve. The developer is dependent on the builder to communicate those standards to the potential buyers.

Builder

Residential construction consists of either speculative building or custom building. Custom building represents less than 10 percent of the market. A custom buyer predetermines his/her individual requirements for the builder and architect, including any energy conservation characteristics such as Trombe walls, roof overhangs, or glass placement.

Speculative building results in higher volume, lower margin products. A large builder may construct 50 to as many as 5,000 units a year, although nationally 80+ percent of all housing is constructed by builders who build ten or fewer homes in a year. The industry is highly decentralized, fragmented, and parochial. The builder is constantly balancing cash flow between cash needs for construction and income from actual sales. Usually, the builder is undercapitalized and cash poor. Educating large numbers of small builders to accept changes in building techniques for energy conservation is a slow process.

PROBLEMS

Four impediments generally limit the acceptance of energy conservation building techniques.

Cost

The large builder attempts to achieve economies of scale such that will keep his costs lower than those of the small builder. He attempts to build sales by passing on a reduced price to the consumer. The large builder will not entertain a more costly product unless he feels comfortable that it will not deter from his competitive advantage in the market place. The smaller builder is obviously even more sensitive to his costs since he has less diversity of product and weaker lender relations.

Resistance to Change

Home building construction has changed very little in recent decades. Many builders begin as carpenters or other tradesmen and are usually grounded in generations of traditional building techniques. New building methods, therefore, require extensive and often costly retraining for the builder and his crews. The builder has developed his own methods over the years and will rarely stray from them unless a new idea becomes a prerequisite to continuance or survival in the marketplace. The builder is extremely reluctant to change methods unless consumers or code requirements dictate a change from tradition.

Consumer Acceptance

The consumer is usually limited in his ability to influence the builder before the beginning construction. While the consumer may be sensitized to the costs of energy and the need for energy-conservation building techniques, the constraints or changes he can impose on the builder are limited; most homes are prebuilt before the ultimate buyer is located. To create an energy-efficient home after most of the construction is complete is costly and acts as another deterrent to sales.

Financing

Lenders become particularly critical in attempting to change building methods. Added product costs for energy conservation effectively limit the amount of the builder's product and the ability of the consumer to meet his/her payments. The lender attempts to minimize risk by diversifying his portfolio with as much product and with the highest caliber of customer as possible. If the lender is not interested in paying for added insulation or heat pumps, the buyer is limited further on what he can demand. If the lender perceives that building methods will add to the product's resale value, he/she will be more willing to consider a higher loan if the consumer's income level can justify more borrowing. With the builder, the consumer, and the lender, energy conservation in building methods requires a significant education process.

The improvement of the efficiency for most power delivery systems to a site is beyond the purview of the developer today. In terms of proven systems, a site of 500 acres is inadequate to support any kind of a delivery system or to economically justify a change in the manufacturing of energy. A developer would have to build, own, operate, and maintain a power system and to arrange for a reliable backup system at his or her own risk.

Problems also arise in the manufacture and commercial availability of mechanical equipment. For example, the use of variable speed groundwater-source heat pumps and increased evaporator sizes of heat exchangers could substantially increase energy savings. Although it is expected very shortly, water-source heat pump manufacturers have not incorporated these innovations on commercially available models because the demand has not been large to justify production. As an indication of what could be realized, a manufacturer now has on the market a two-speed air conditioner with an Energy Efficiency Rating (EER) of about 9, which is 3.4 times the co-efficient of performance in the standard operating mode. When the outside temperatures are relatively low and there is not a high demand on it, it switches to a lower speed and the EER jumps to 13.

In summary, while the research indicates that energy conservation is achievable, several obstacles must be overcome. The nature of the residential construction industry is highly fragmented and competitive. In 1977, 86 percent of all new housing in this country was constructed by individual builders who produce fewer than ten houses per year. These builders take considerable personal financial risks in a speculative market and are not in a position to increase those risks by implementing construction practices and energy-conserving features that are currently "unproven." Until there is demonstrable proof that these techniques save energy without increasing costs or until the consuming public demands widespread energy conservation practices, it is unlikely that the small builder will implement most of the conservation options advocated. Currently only those conservation options, such as storm windows, air-to-air heat pumps, and insulation, which are "visible" to the consumer are immediately achievable within the larger market. Conservation options yielding significant energy savings, such as 2-inch x 6-inch construction, domestic hot water heat reclaimers, and orientation, are little understood by consumers and are subsequently not promoted by the builders.

The land developer's role in the residential market is, in many important aspects, similar to the builder's. The builder is the consumer of the product or improved lots offered by the land developer. The developer's success or failure, therefore, depends at least in part on his or her ability to offer individual builders a product that is competitively priced and that the builders' experience indicates will sell to the potential homebuyer. If and when consumer demand places a premium on south-facing lots, for example, builders will respond accordingly in their purchases, and land developers will make every effort to provide as many lots with southern orientations as the market can reasonably absorb. Similarly, energy-conservation practices or power generation at a community scale, which require the developer to make a significant role change, are likely to be met with considerable resistance.

SOLUTIONS

Many Greenbrier builders are already conservation sensitive as shown by their use of double glazing, heat pumps, and reasonably good vapor barrier systems around windows. Greenbrier currently is experiencing some schedule delays due to the increased interest rates and associated downturn of new construction starts. Use of the conservation plan and developer efforts to induce improved construction practices are anticipated when the economy picks up. Public educational brochures developed as an outgrowth of the conservation recommendations have been favorably received by both local lending institutions and builders still active on the site, although it is too early to judge their impact. A very favorable local indicator is the increasing use of "Energy Costs Per Year" figures in sales promotions by the area realtors.

SUMMARY

Greenbrier, a 3,000-acre Planned Unit Development, is located near Norfolk, Virginia, in the City of Chesapeake and is expected to have a development cycle of 15 to 20 years. The Site and Neighborhood Design (SAND) study area is a 719-acre parcel that is programmed for residential, office, retail, recreational, and public uses. The area has 3,488 heating degree days and 1,441 cooling degree days and average temperatures of 60.6 degrees F annually, 47.3 degrees F in the winter and 78.3 degrees F in the summer.

The objective of this Department of Energy research contract was to produce a case study of energy conservation at a major private sector Planned Unit Development which could serve as a model for similar developments to follow. The research was divided into three major parts:

- Development of a base case energy model, which established the total energy consumption for the community, developed in a conventional manner.
- Systematic evaluation of a series of conservations options, which were evaluated for their cost, energy-conserving performance, legality, marketability, and their impact on the developer's role as community builder.
- Development of a conservation plan, a set of feasible conservation options, which was compared to the conventional plan for its relative costs and energy saving benefits.

Initial calculations applied to the base or conventional plan found that end-use energy consumption projected over a 30 year mortgage period would be considerably higher than energy embodied in the materials and building of the site infrastructure and project structures. Because operating consumption over this period would be six times greater than the original embodied energy used to construct the community, the scope of the research was narrowed to those energy options which would most affect operational usage.

The research indicates that for relatively small increases in capital expenditure, developers and, especially, residential builders can substantially decrease end-use energy consumption. For a capital investment of $200 to $3,150 operating energy consumption could be reduced by 54.7 percent in residential development; at a current energy cost of 3.5 cents per kWh, this represents $744.62 annual savings per house, an energy savings to each homeowner of 21,275 kilowatt hours (kWh) per year and, over a 30-year conventional mortgage period, a savings of $22,330 per house.

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 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.

RECOMMENDATIONS

The public must become aware of the many energy-conserving products and techniques. One of the approaches proposed to DOE is simply to enter into a contract with one of the local builders to install 50 of the water-source heat pumps in houses. The remarkable results would be readily available and could be distributed in the market. More general use of the infrared scanning device would be highly desirable; builders would be able to see where energy was leaking in the structures they had just built. The scanning device also has implications for retrofitting older homes. The building industry also needs the ability to measure the energy efficiency of a house as is done with the "miles per gallon" rating for automobiles.

SAND STUDY TEAM

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Utility:
Virginia Electric Power Comany, VEPCO

GREENBRIER
PROJECT DATA
(Conventional Plan)

Land Use Information

Site Area:
Total....... 3,000 acres (1,215 hectares)
Developed... 1,000 acres

Total Dwelling Units: 5,000±
541 Conventional Plan
566 Conservation Plan

Overall Gross Density: 0.92 dwelling/acre

Gross Density by Type:

	d.u./acre
Single-Family Detached	2.0-4.0
Cluster	6.5
Townhouses	11.5
Garden Apartments	11.5
Mid-rise Apartments	11.5

Parking: 2 spaces/dwelling unit
1.5 spaces/apartment unit

Land Use Plan

	Acres	Percent
Residential	981	32.7
Single-Family Detached	(451)	(15.0)
Cluster (zero lot line)	(268)	(8.9)
Townhouse	(130)	(4.3)
Garden Apartments	(113)	(3.8)
Mid-rise Apartments	(19)	(0.7)
Open Space	259	8.6
Commercial[1]	112	3.7
Industrial[2]	945	31.5
Public	437	14.6
Institutional[3]	101	3.4
Golf Course[4]	165	5.5
TOTAL	3,000	100.0

Economic Information

Site Cost: $7,500/acre
Site Improvement Costs: $12.5 million[5]

Amenity Costs: $350 per dwelling unit[6]

Association Costs: $6.00/month
$12.00/month for common areas

Climate Information

General: Hot-Humid

Degree Days:
Heating 3488
Cooling 1441

Average Temperature:
Yearly . . . . . . 60.6°F
Winter . . . . . . 47.3°F
Summer . . . . . . 78.3°F

2.5 Percent Design Temperature:
Winter . . . . . . 22.0°F
Summer . . . . . . 91.0° F dry bulb and 78.0°F wet bulb

Average Wind Velocity:
Winter . . . . . . 11.2 mph
Summer . . . . . . 9.5 mph

Average Rainfall: 43.1/inches/year

Solar Gain:
1,399 Btu/sq.ft./day[7]
(54.7 percent of possible radiation)

Annual Average Sunshine: 2,803 hours
(62 percent of possible)

Unit Information

Type	Unit Size (Sq. Ft.)	Lot Size (Sq. Ft.)	Number	Sales Price	Lot Price
Single-Family Detached	1,600 -- 2,400	10,000 -- 12,000	937	$ 75,000 -- $ 125,000	$17,000
Cluster (patio homes)	1,800	5,000	742	$ 45,000 -- $ 55,000	$ 8,000
Townhouses	1,450	7,500	856	$ 55,000 -- $ 65,000	$11,000
Garden Apartments or Mid-rise Apartments	1,100	-	223	-	-

Notes:
1. Includes to date 650,000 sq. ft. retail and 400,000 sq. ft. in a 45.6-acre office park.
2. Includes Volvo's 500-acre site.
3. Includes one medium-sized church, one public elementary shcool, one private secondary school and a fire station.
4. Includes a 10,000 sq. ft. clubhouse.
5. Value of improvements such as roads and utilities dedicated to the City of Chesapeake as of 1980.
6. For common areas--lakes, walks, trees, shrubbery and grass.
7. A relatively high percentage of this radiation is diffuse, scattered, or reflected by clouds or other atmospheric constituents.

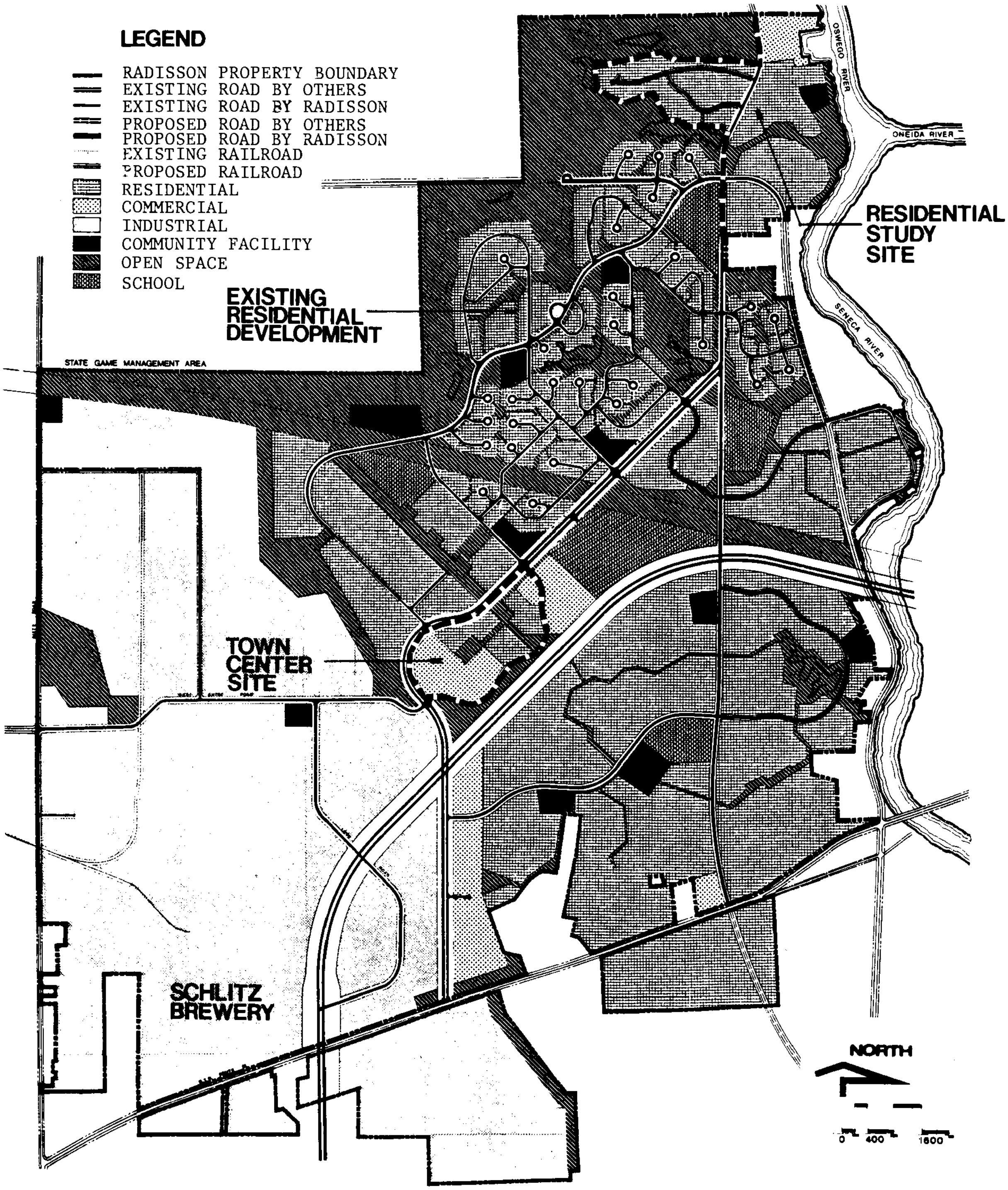


Figure R-1

RADISSON LAND USE PLAN
Source: Radisson Report Plate 7

RADISSON

BACKGROUND

GENERAL DESCRIPTION

Late in 1968 the New York State Urban Development Corporation (UDC) staff and its consultants began to study the feasibility of building a new community on a vacant 2,800-acre site in the Town of Lysander, north of Syracuse. In June 1969, UDC had acquired a majority of the site acreage for development of a new commmunity. In April 1971, the Urban Development Corporation filed a general project plan for development of the new community of Radisson on this site. The development plan for Radisson provides a framework extending over 20 years for a balanced new community. At completion Radisson will contain approximately 4,300 dwelling units for an estimated 18,000 persons and the related public and community facilities to serve such a population.

In February 1978, with 30 percent of the new community under construction, the town center site and a residential subcenter were selected for a Department of Energy case study. Because the site characteristics and the program requirements of the town center site and the residential site are distinctly different, they will be presented as separate components of the plan. Existing development at Radisson basically included the area between the two SAND study sites. As of the spring of 1979, approximately 500 units had been built, housing a population of roughly 1,175. Most of these were single-family units; some were multifamily units; and a few townhouse units were being developed.

PROJECT MARKET

Development forecasts for Radisson are dependent on (a) the project's market share of regional growth and (b) the replacement of substandard units in the surrounding metropolitan areas. The brewing of beer is a major industry in the region. Construction of the Joseph Schlitz Brewery at Radisson added a major employer to the region. Construction of a Miller brewery and a can manufacturing plant in nearby Oswego County have provided additional stimulus to the local economy.

Aside from the many jobs created in construction and related economic sectors, a permanent employment base of up to 12,000 jobs could be created in the industrial park of Radisson. On the basis of projected employee densities, on-site employment could range from 10,000 to 16,000 persons at full employment. Industrial development was to be encouraged by preparation of sites by UDC and possible assistance in financing the construction of industrial buildings for sale or lease to private firms.

About 25 percent of the 4,300 housing units projected for Radisson by the end of a 20-year development period would be special assistance housing. Based upon regional population forecasts the major source of Radisson growth would occur from the anticipated development in the northern part of the county. The statutory requirement for UDC to provide 30 percent of the total housing for low-income groups (10 percent for elderly and 20 percent for other groups) are reflected in the mix of incomes and building types. The remainder of the unit mix will be 20 percent moderate-income and 25 percent each middle- and upper-income.

THE SITE

The site is located 12 miles northwest of Syracuse. The planning and design considerations relevant to Radisson are representative of the conservative attitudes of upper New York State. The immediate site boundaries of Radisson are formed by the village of Baldwinsville to the southwest. The Town of Lysander, on the western boundary of Radisson, is responsible for all planning approvals.

On the west and southwest, the site is bounded by a 3,200-acre state game management area. The eastern border is defined by the Seneca River, part of the New York State Barge Canal System. The site's southern border is marked generally by New York State Route 31.

The primary site features were formed geologically under glacial floodplain conditions. The site's primary natural feature is a centrally located drumlin which results in a division of the site. The western side drains toward the northwest and, except for a promontory in the southwest corner, is generally flat and, in places, wet. The eastern half of the site drains toward the Seneca River, and the swales which contain these drainage channels give the landscape along the river a corduroy effect. The presence of the Seneca River creates a substantial floodplain condition in the east along the flowage easement, where no alterations to the ground form can be effected. Construction in the floodplain area would require modifications to the site.

The climate of the Syracuse area can be described as humid continental by virtue of its latitude and continental location. The area is near the average track of most of the major low pressure systems that move across the country. The interaction of the warm and cold air masses during the winter and spring season results in a marked increase in cloudiness. Heavy snowfall is associated with outbreaks of arctic air as the cold air becomes saturated by passage over Lake Ontario. Counties to the lee of the lake experience average annual snowfalls in excess of 100 inches.

Wide seasonal swings of temperature are not uncommon. Summers are usually cool with relatively high humidities; winters are cold and sometimes severe. Winter daytime temperatures average about 35° F with nighttime lows of about 18° F. Rainfall is derived primarily from cyclonic storms and thunderstorms which occur on an average of 30 days a year. The predominant wind direction is from west-northwest at average annual speeds of 9.9 mph, but during the winter months there are many days with higher winds causing blowing and drifting snow.

Imposed upon the macroclimatic conditions are the effects of the intermediate-scale factors such as lakes and uplands. The most evident of these factors in the Syracuse area is the effect of Lake Ontario on snowfall. During the fall and winter months, the temperatures over the lake will normally be much warmer than the cold continental air masses moving over it. The air crossing the lake is warmed from below and picks up much additional moisture in the process, creating a condition in which heavy snowfall occurs to the lee of the lake and producing the snowbelt of the region. Cloudiness, fog, and light rain can result for the same reasons.

Hills and river valleys can cause a channeling effect of the wind. In hilly areas, local downslope winds develop at night as a result of differential heat loss. The slopes of the hills cool more rapidly than the air and the cooler denser air accumulates in the valley floor. These factors could influence the area around the drumlin and the river within Radisson.

RESPONSE

TEAM AND METHODOLOGY

The responsibilities and input of the SAND study were organized around a decision-making team and a technical team. The New York State Urban Development Corporation and the Town of Lysander Planning Board were the major decision-makers. Both groups served in an advisory and approval capacity and reviewed and suggested revisions to preliminary and final plans of the technical team. A third group, private builders then developing housing at Radisson, also served in an advisory capacity and reviewed residential energy plans from the point of view of marketability and developer acceptability. These builders also reviewed both energy performance analyses of units which they were then building and preliminary builder guidelines.

The members of the technical team were selected for their expertise and previous consulting experience at Radisson. Team members' working familiarity with the regulatory constraints, development practices, physical characteristics, and planning objectives of the new community and the Syracuse area was considered to facilitate project development and lend a credibility to proposals developed for the case study project. It was felt that this credibility would favorably influence review and acceptance of the proposals by the Urban Development Corporation, the Town of Lysander Planning Board, and private builders and developers at Radisson.

The Radisson study team phased its work over 10 months with 5 months of that time being given to development of energy-conserving plans. During the initial phases of investigation, project data on Radisson's past development studies, existing program requirements, and existing site conditions were reviewed by the technical team. The purpose of this review was to determine the best strategy for development of energy-conserving plans for the residential and town center study sites. Analysis of these data indicated that the potential for development of integrated systems options (i.e., district heating; solar heating and cooling; and on-site energy sources such as natural gas, ground water, waste incineration and hydropower) was limited but that the potential for development of passive energy-conserving plans is both realistic and could result in significant energy savings. Selection of a passive approach was based on the following considerations:

- A previous state-of-the-art review by the Reimann Buechner Partnership had indicated that significant energy savings could be realized through site planning based on passive techniques.
- Quantification available at the outset of this project indicated that reduction of base load energy consumption in a range of 6 to 14 percent was possible through the use of passive site planning.
- Passive conservation strategies could be incorporated into the Radisson development within the project time frame and would result in immediate energy savings. In addition, they would require minimal cost for operation without requiring a long-term write-off period.

Based on these considerations, the initial project approach of the Radisson study team emphasized reduction of end use energy consumption through the use of passive conservation measures. The two primary areas identified for energy conservation were the reduction of energy consumption for the heating of structures and the reduction of embodied energy consumption for the site development. These two areas of conservation provided the basic project criteria for the identification and evaluation of energy conservation options and the development and evaluation of energy-conserving plans.

Due to the focus on conservation of energy for space heating and site development, emphasis was placed on identifying options for the planning and design of structural groupings, roadways, site utilities, and individual structures which could potentially reduce heating demand and site construction operations. Because of the extreme winter climate and high winter heating demand associated with the project location, emphasis was also placed on identification of climate related options. These options were considered to include any technique for modifying air infiltration and heat loss associated with winter winds and for capitalizing on available solar radiation and heat gain during the peak winter heating season. All options identified were evaluated in terms of their potential either to reduce winter heat loss or to increase winter heat gain.

Subsequent to identification of conservation options, a preliminary analysis was made of existing single-family housing at Radisson to identify variation in winter heating requirements associated with wind protection or solar orientation. The purpose of this analysis was to provide a preliminary project baseline. The results of this analysis indicated that the sheltering of buildings from winter winds and the reduction of cold air infiltration resulted in the most significant reduction of winter heating requirements.

During the following phase of plan development, options which would result in wind sheltering and reduced air infiltration were weighed more favorably than options for increased solar orientations. The energy-conserving plans for the residential and town center study sites were developed based on this approach. Estimates of energy savings for heating of structures and estimates of embodied energy savings for site development were calculated after plans were completed.

During the course of project review, concern was expressed by DOE staff regarding the degree to which emphasis was placed on space conditioning requirements. For the remaining portion of work, all case study participants were directed to expand their focus from end-use service demand to include a more generalized view of systems requirements. Based on this directive, the Radisson study team undertook a further investigation of utility systems options applicable to the residential and town center study sites.

CONVENTIONAL PLANS--OVERVIEW

The town center will be built on high ground slightly to the southwest of the center of the development and will be the focus of the new community because of the location of principal community services and activities. The center will be designed to concentrate the life of the new community in a small, lively pedestrian complex including shops, offices, community facilites, and residences. In addition, it will include the higher density residential development, including a central common and apartments and townhouses for the elderly, small families, and families without children.

Major school facilities will be adjacent to the town center. Industrial research and office facilities may also be included in the town center or developed nearby. A subcenter with minor commercial facilities will be located in the northeast quadrant of the development.

Residential areas will be located to the north, east, and southeast of the town center. Additional school facilities and natural area parks will be developed as part of the residential area. In general, residential densities will be greatest in the town center and decrease toward the boundaries of the site.

Estimates of energy consumption were calculated by comparative analysis to existing development at Radisson and by use of a load estimate model. Both types of calculations were used for the residential study site; however, <u>the absence of existing commercial development at Radisson prevented comparative analysis for the Town Center site</u>. The purpose of both types of energy estimation was to identify the potential reduced load demand which would be attributed to building siting characteristics.

The CLIC program, developed by the Carrier Loan Information Center, was used for estimating building loads on both study sites. Separate CLIC programs were used for residential and commercial structures. The following basic features are common to both programs:

<u>Data Base</u> -- Both programs contain climatic data and design factors for the Syracuse region. Criteria for acceptable design parameters for building latitude, room humidity, dry and wet bulb temperatures, etc. are based on the ASHRAE Handbook or Carrier System Design Manual. Factor data for window, wall, roof, and ceiling insulation; people and appliance loans; outdoor air and ventilation; equipment selection; and heating and cooling estimates is provided in the Carrier User Instructions Handbook.

<u>Input Data</u> -- Data input to the program includes design data, unit data, building data, and fuel rates and calculated energy operational expenses. Building data on size, construction, and fenestration were derived from the following sources:

- Residential building data were based on construction drawings for existing single-family and townhouse units at Radisson. Buildings were selected based on the size of the unit and quality of construction which were felt to be most representative of the building types which would be constructed on the site.

- Commercial building data were based on schematic commercial building types developed for the town center. Maximum insulation factors and standard building construction were assumed. Fenestration, circulation, and entranceways were provided by architectural consultants based on standard practice.

Output Data -- Data produced by this program take the form of annual operating costs for heating and cooling. Consideration should be given to the following characteristics of the CLIC program relevant to its application to the SAND project:

- The program is designed to identify peak loan heating and cooling requirements. For this reason, the program primarily responds to factors which can optimize building design, such as changes in building insulation, orientation and glass area in new buildings (for heat loss only, not solar heat gain), or the effect of the addition of exterior awnings or partition insulation in existing buildings.

- The climate base for the program is derived from regional climate data. For this reason, site-specific modifications of climate impacts, such as the use of windbreaks or the location of structures for wind sheltering, cannot be directly put into the program. Impacts of this nature must be related to air infiltration factors. In addition, the program does not account for the year-round effects of solar heat gain. While the program does recognize increases in summer cooling load due to solar heat gain, it does not recognize reductions in winter heating load due to solar heat gain.

Therefore, after review with the Carrier Corporation's research staff and experimentation with the CLIC program, the Radisson team determined that the program should be used for identification of reduced air infiltration coefficients to compensate for the inability of the CLIC program to take these design modifications into account.

RESIDENTIAL SITE

Conventional Plan

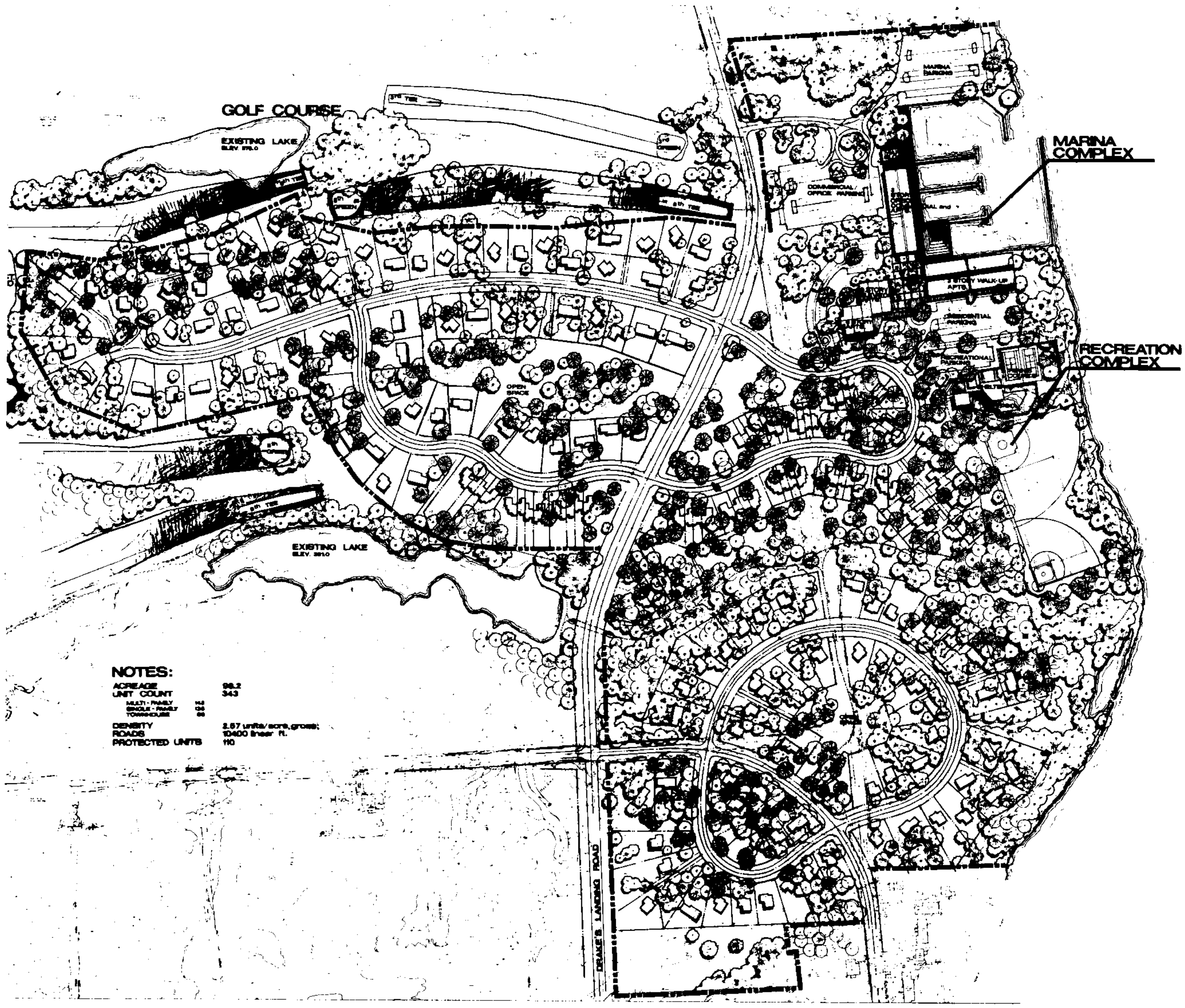
The residential study site consists of 92.1 acres located along the Seneca River on the northeast corner of Radisson. The site is bordered by residential development to the south and a golf course to the south, north, and west.

Programmed for the site are approximately 520 dwelling units, a 62-boat marina, and a recreation complex, (Figure R-2). Based on existing development practice, a 1:2 ratio of townhouses to single-family detached (SFD) dwelling units applies to the conventional plan. (One energy-conserving plan which assumed an equal split of SFD, townhouse, and multi-family units was tabled because it was felt to be unresponsive to the local market conditions.) The marina development will include a 2,400-square foot marina building, parking for more than the 80 cars and trailers, a picnic area, and an area for possible marina expansion. The recreation complex will have parking for 80 cars and will include a swimming pool, four tennis courts, two handball courts, a baseball field, a playground and three ballfields.

The existing physical factors for the SAND residential study site are the following:

- Slope Percentage
  60 percent of the site: 0 to 5 percent slope range
  25 percent of the site: 5 to 10 percent slope range
  15 percent of the site: excess of 10 slopes

- Drainage
  Major drainage flow toward existing north/south drainage swales. A drainage easement must be maintained from the outlet of the impoundment near the center of the residential study area to the Seneca River.



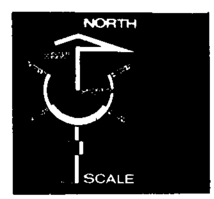


Figure R-2

CONVENTIONAL PLAN--RESIDENTIAL
Source: Radisson Report Plate 14

- Slope Aspect
  25 percent of the slopes: southern orientation
  25 percent of the slopes: northern orientation
  45 percent of the slopes: eastern orientation
  5 percent of the slopes: western orientation

- Vegetation
  40 percent of the site: dense deciduous vegetation
  30 percent of the site: sparse deciduous vegetation
  30 percent of the site: open
  General vegetative cover is mixed deciduous second growth of ash, maple, and oak with mixed deciduous shrub growth.

- Wind
  Prevailing winter wind ranges over a 60° northwest arc with a mean annual speed of 9.9 mph.

Existing conditions impose the following development constraints:

- A major north/south connector road bisects the site. Design speeds (45 mph) on this road limit the area for the intersection of "minor collector" roads to a spacing of 530 lineal feet.

- Existing utilities easement limits circulation system.

- The Seneca River flood plain as defined by F.I.A. flood studies limits residential development along the entire eastern border of the study site.

- Existing and planned storm drainage and sanitary facilities impose restrictions on the location of housing units.

- Marketing considerations necessitate maximizing residential frontage and views to golf course and river.

- Town planning standards require a minimum of 1.8 parking spaces per dwelling unit.

- The location and number of multi-family dwelling units are to be fixed elements on all plans developed.

- Exposure of open portion of site to northwestern winds with no existing vegetative wind buffer requires modification through siting of structures and windbreaks.

The conventional site plan proposed by the developer responds primarily to the program requirements and development constraints outlined above; minimum consideration is given to site planning options to conserve energy, and no consideration is given to site systems options to conserve energy. The major feature of this plan is development of single-family detached and townhouse units on fee simple lots, fronting on dedicated public streets.

For the purpose of this analysis the team examined approximately 186 existing single-family dwelling units, developed in a 330-acre area to the south of the residential study site. The development pattern for this area is characterized by low-density, single-family housing with an infrastructure of cul-de-sacs and collector streets. Units are sited to front directly on public streets. Average spacing between units is 100 feet side-to-side and 75 to 100 feet back-to-back. Spacing between housing fronts is between 100 and 180 feet. Housing in this area is heated by electricity, gas, or oil, with the predominant number utilizing electricity.

In an effort to establish a correlation between unit siting characteristics and heating energy consumption, the study team obtained meter reading data for existing development at Radisson. The data were made available on a confidential basis by the Niagara Mohawk Power Corporation. These data were sorted by the consulting team according to heating source and street. Average summer and winter fuel consumption was then calulated and recorded for each residence. In reviewing these data, the decision was made to limit the analysis to 75 electrically served units.

Analysis of mean averages for heating consumption in the sample indicate the following conslusions:

- Existing protected units with either north/south or east/west orientations consume 28 to 33 percent less energy than unprotected existing units.

- Statistical analysis of data verifies that wind protection is a significant factor in reduction of winter heating load and that study data are reliable, independent of the fact that analysis of user characteristics was not a study parameter.

- Percentages of energy savings due to wind protection are comparable with data cited in a survey of recent research data on the effects of wind sheltering on reduction of air infiltration (Princeton University; Hastings & Crenshaw; Olgyay).

- Field data on energy consumption have been found to have high acceptability with developers, builders, and the lay public during the project review process. Field testing should be included during the implementation phases of the project.

Conservation Options

Conservation options discussed are grouped according to passive site, building, and utility systems options.

Passive site options include techniques for modification of seasonal climate effects on structures which do not require the use of hardware technology. Data gathering in this area was the responsibility of the team's architects, landscape architects, and climatologists.

Major criteria for identification of passive site options were response to winter design conditions (6,678 heating degree days) affecting heating requirements and natural site features. More limited consideration was given to summer design conditions (551 cooling degree days) affecting cooling requirements. The options considered were the following:

- building orientation at a 90° angle to the prevailing winter wind;
- buffering of winter winds by vegetation, unit clusters, and solid fences;
- selection of sites on slopes that maximize solar radiation (northern being considered least desirable and southeastern most desirable).
- orientation of the largest window area on the structure so that sun exposure minimizes combined mechanical heating and cooling needs; and
- clustering of single-family attached and detached units on private drives to optimize wind protection and solar orientation.

Building options were considered to include techniques for modification of seasonal climatic impacts on structures, including design of buildings, insulatory and structural systems, and mechanical and HVAC systems. Residential building options were developed in order to provide builders with energy-saving improvements to existing residential building types. These options were based on an evaluation of the energy-conservation strengths and weaknesses of prototypical building types and a determination of optimum building orientation based on physical configuration, floor layout, and construction details. Evaluations were made on such building types as two- and three-bedroom townhouses, two-story single-family detached homes with a deck, and two-story traditional single-family detached units.

A comparative analysis of buildings was made using an energy conservation performance matrix for each building type in relation to its orientation and siting. Four general front (or entry) elevations were assumed: north, south, east, and west. Performance ratings were given for all evaluation criteria based on building and climatological data.

In addition to specific building recommendations, builder options for improvements of single-family building design were compiled and revised in accordance with the newly enacted New York State Energy Construction Code.

Utility systems options for the residential study site were identified by the Niagara Mohawk Power Corporation. The energy recovery systems described would be built upon, and integrated into, the energy systems hardware located in individual homes, apartments, commercial, and industrial units. Recovery and reuse of energy would be accomplished through the use of alternate natural sources of heating and cooling available on the site and recovery of excess energy within dwelling units.

Energy recovery systems were selected to cover the full range of possibilites: recovery within individual dwelling units, cluster systems providing recovery options for several units of individual houses or apartment and commercial buildings, and central recovery systems providing benefits to every structure within Radisson. The systems described were based upon the use of hardware then available in the marketplace. Systems were developed from engineering practices that were then in use or that could be adapted for use in energy recovery systems.

Future study of the systems will define the economic benefits of each system and develop information that can be used to make choices between the systems that are based on sound technical and economic feasibility.

The systems which would heat and cool and provide domestic hot water were divided into three specific categories:

- Individual - Individual buildings would house independent systems, such as air-to-air and groundwater heat pumps with domestic hot water and/or solar panel and thermal storage options.
- Cluster - A number of individual buildings consisting of either residential (10 units), commercial, or a mixture, would have all heating/cooling and domestic water requirements provided from a centralized source located as near the center of the cluster as practical. Various types of hydronic heating/cooling systems were considered.
- Central Plant - All buildings located in the community of 1,200 people would have their heating/cooling and domestic hot water requirement generated from a centralized source, utilizing waste incineration and a high pressure steam or hot water loop distribution for heating with solar heating and thermal storage alternatives.

It would also be possible to use any number of various schemes in combination, such as a centralized plant with individual or cluster system.

A basic heating/cooling and hot-water generation system for individual buildings, consisting of separate electric, oil, or gas-fired equipment was not included. These particular systems vary widely in design and were not considered effective in terms of heat recovery.

No attempt was made to analyze the trade-offs associated with the various systems other than energy. Future detailed studies can identify the most efficient energy recovery systems that make economic sense and could serve as a model for development of similar systems throughout the country.

All systems, whether individual, cluster, or central plant, can be designed to utilize alternative energy sources. The central plant and cluster systems offer the best opportunity for alternate energy uses. They also have significant load management potential. Alternate energy sources will allow a flexibility for the reduction of primary fuel demands. These alternate sources could also serve the project during a shortage of primary fuel. Utilization of on-site energy sources, such as the river, water wells, and gas wells, could be incorporated into the equipment design to reduce demand on off-site sources. An economic study is necessary to assess the impact of on-site energy sources on the financing structure of the various systems.

Conservation Plans

Two energy conserving plans for the residential site have been developed based on the following critiera:

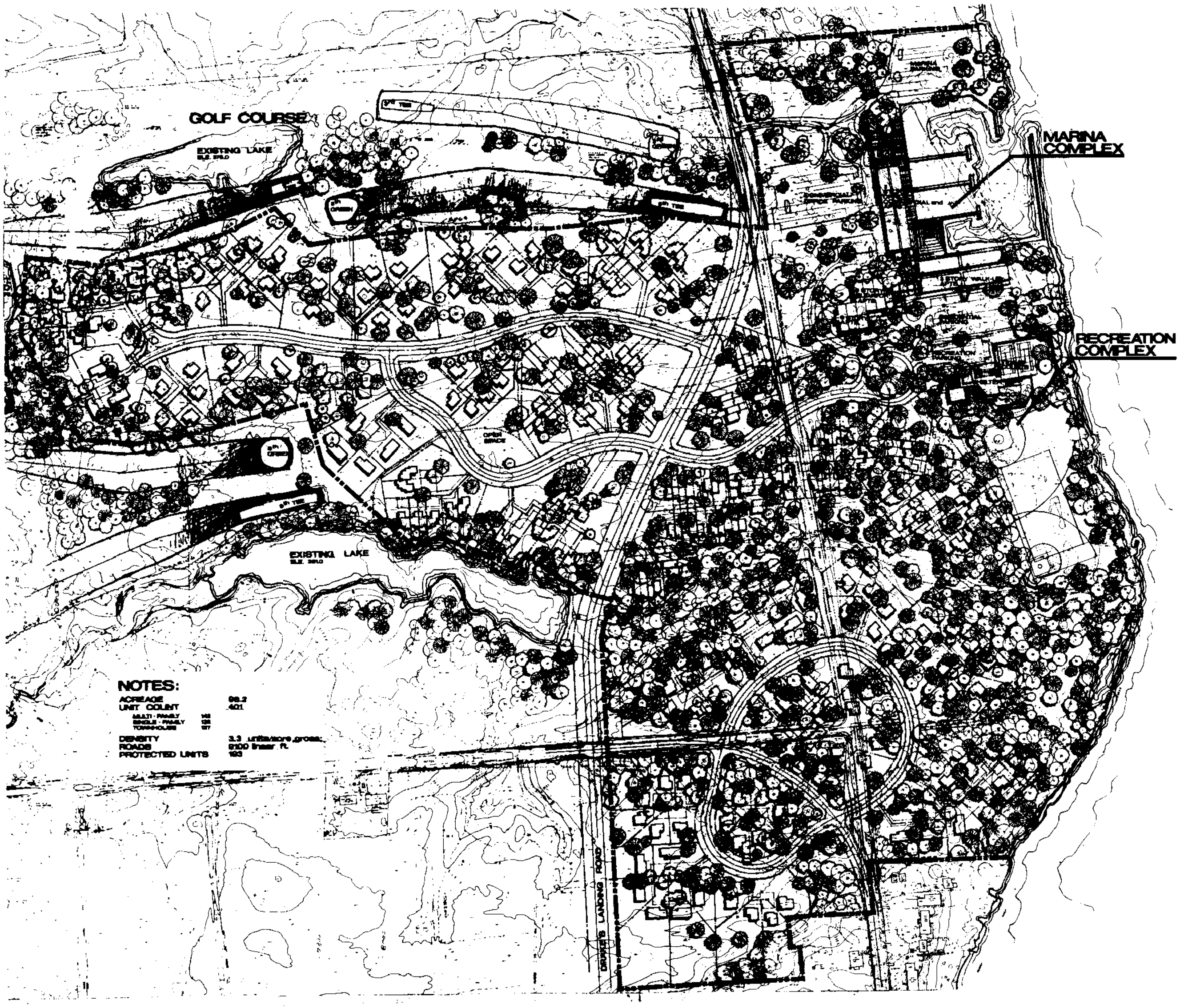
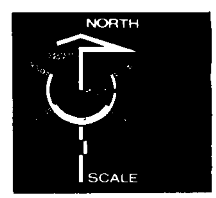


Figure R-3

CONSERVATION PLAN 1--RESIDENTIAL
Source: Radisson Report Plate 15



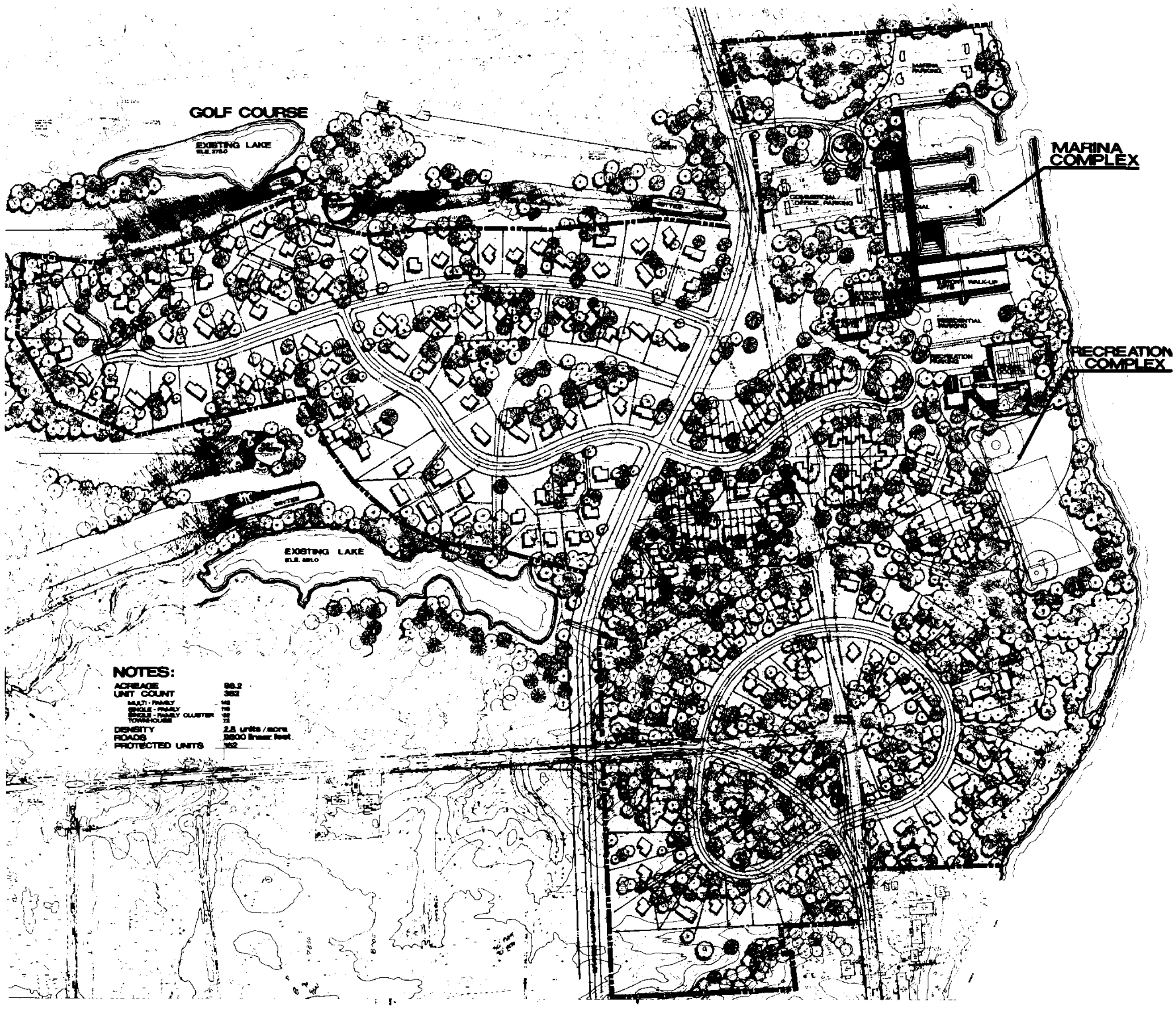
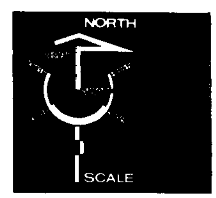


Figure R-4

CONSERVATION PLAN 2--RESIDENTIAL
Source: Radisson Report Plate 16



- selection of building sites utilizing climatological data whenever possible;
- structures sited and grouped for maximum winter wind protection and solar orientation in order to reduce heating loads; and
- roads and utilities designed to reduce embodied energy costs and financial cost for site development.

Since site energy systems options for the residential site were still the subject of detailed analysis at the time of this report, this section will deal primarily with passive energy-conserving plans and their energy and cost analysis.

Energy Conservation Plan 1 developed a single-family detached and townhouse cluster housing along a system of private drives and auto courts to provide flexibility in unit orientation to the sun and for wind protection. Densities were increased over the traditional plan to reduce site development costs and embodied energy per unit.

A second energy plan (Energy Conservation Plan 2) was formulated because of developer concern about the marketability of an extensive cluster housing plan in an untested market area. (As of this report, cluster housing had been built in only one development in the Syracuse area.) Plan 2 incorporated the major site planning features of Plan 1, with the difference that only single-family detached housing is clustered and the number of clusters is limited. Plan 2 could provide a test sampling for later field comparison of a built project with traditional housing patterns on site.

Conservation Plan Savings

Two estimates of energy savings gave been developed for comparison of the Conventional and Energy Conservation Plans 1 and 2. The first is a qualitive estimate of anticipated energy savings based on annual energy consumption of existing single-family housing at Radisson. This estimate is derived from a comparative analysis of two years of the meter reading data provided by the Niagara Mohawk Power Corporation as well as field identification and air photo analysis of unit siting characteristics. This estimate is limited to single-family detached housing.

The second estimate of energy savings includes both single-family detached and attached townhouse units. This estimate is a comparison of heating load and operating costs for the conventional and energy-conserving plans, based on differences in air infiltration due to building siting. Savings per building type according to the second estimate, when projected against the total number of protected dwelling units, are shown in Figures R-6a and R-6b. Cost/benefit analysis of traditional versus energy conserving plans is based on consideration of the following development and energy factors:

Development Costs -- Cost per dwelling unit calculations are based on the number of single-family dwelling units, which varies per plan. Multifamily dwelling units, which are constant on all plans, are not included. The overall site development costs are 6 percent higher for Energy Plan #1 and less than 1 percent lower for Energy Plan #2, when compared to the developer's traditional plan. However, on a per-dwelling-unit basis, development costs for Energy Plan #1 are 17 percent less and development costs for Energy Plan #2 are 9 percent less than for the developer's traditional plan (See Figure R-7).

In addition to the development cost savings per unit basis, a comparative evaluation was made of total land value and income per lot affected by Energy Conserving Plans # 1 and #2. A summary of the land value comparison for the Traditional and Energy Plans is provided in Figure R-8.

Embodied Energy Costs -- In spite of the increased number of dwelling units on Energy Plans #1 and #2, these plans consume approximately the same amount of embodied energy (±5 percent) as the base plan. However, on a per dwelling unit basis, Energy Plan #1 saves 25.29 million Btu per unit (22 percent) and Energy Plan #2 saves 14.58 million Btu per unit (12 percent) over the Traditional Plan (See Figure R-9)

Annual Operating Costs -- Comparative savings in annual operation costs, based on the number of protected dwelling units, assumes a savings of $27 annual per single-family detached unit and $44 annually per townhouse unit (See Figure R-10)

Figure R-5

DEVELOPMENT CHARACTERISTICS OF RESIDENTIAL STUDY SITE

	Conventional Plan	Energy Plan #1	Energy Plan #2
Total Number of Dwelling Units	201	259	220
Gross Site Density (Units/Acre)	2.57	3.3	2.8
Unit Distribution:			
Single-Family Detached	135	--	116
Single-Family Cluster	--	132	32
Town House Conventional	66	--	72
Town House Cluster	-	127	--
Total No. of Protected Units	64	193	168
Public Road Length (Linear Foot)	9,200	7,800	8,700
Private Roadways (Linear Foot)*	1,750	4,030	2,200

* Private Roadway includes roadway developed for flag lots on conventional plan, as well as cluster housing.

Figure 6a

COMPARISONS OF LOAD AND COST
(Figures include both single-family
detached and attached townhouse units)

	Traditional Plan	Energy Plan #1	Energy Plan #2
Design Load	6737 Mbh	9835 Mbh	7112 Mbh
Annual Operating Cost	$77,163	$95,101	$81,688
Average Cost per Dwelling Unit	$ 383	$ 367	$ 371

Figure 6b

OPERATING COSTS BY BUILDING TYPE

	Exposed		Protected	
	No. of Units	Cost	No. of Units	Cost
Traditional Plan				
SF Colonial	54	$25,758	13	$ 5,850
SF Contemporary	55	$17,930	13	$ 3,887
Townhouse	28	$10,780	38	$12,958
	137	$54,468	64	$22,695
Energy Plan 1				
SF Colonial	16	$ 7,632	50	$22,500
SF Contemporary	16	$ 5,216	50	$14,950
Townhouse	34	$13,090	93	$31,713
	66	$25,938	193	$69,163
Energy Plan 2				
SF Colonial	17	$ 8,109	57	$25,650
SF Contemporary	17	$ 5,542	57	$17,043
Townhouse	18	$ 6,930	54	$18,414
	52	$20,581	168	$61,107

Figure R-7

RESIDENTIAL DEVELOPMENT COST COMPARISON

	Traditional Plan 201 D.U.	Energy Plan 1 259 D.U.	Energy Plan 2 220 D.U.
Roads/Driveways	$593,000	$530,000	$577,000
	$ 2,950	$ 2,046	$ 2,622
Water	$238,000	$236,000	$231,000
	$ 1,184	$ 911	$ 1,050
Sanitary Sewers	$425,000	$462,000	$420,000
	$ 2,114	$ 1,784	$ 1,909
Drainage:			
Piping	$160,000	$291,000	$177,000
	$ 796	$ 1,124	$ 804
Ditching	$ 52,000	$ 52,000	$ 52,000*
	$ 258	$ 258	$ 258
Walkways	$225,000	$225,000	$225,000
	$ 1,119	$ 1,119	$ 1,119
Contingencies	$253,950	$269,000	$252,300
	$ 1,263	$ 1,038	$ 1,146
TOTAL	$1,946,950	$2,065,000	$1,934,300
PER D.U.	$ 9,686	$ 7,972	$ 8,793

* Difference in cost between piping and ditching operations is due to increased pipe size for energy plans required because of increased density.

Figure R-8

SUMMARY OF INCOME PER LOT

	Conventional (201 D.U.)	Energy Plan #1 (259 D.U.)	Energy #2 (220 D.U.)
Income Per Lot Type			
Single-Family	$1,620,000	$1,584,000	$1,776,000
	(135)	(132)	(148)
Townhouse	396,000	762,000	432,000
	(66)	(127)	(72)
Total Site Income	$2,016,000	$2,346,000	$2,208,000
Average Income Per Lot	$ 10,029	$ 9,057	$ 10,036
Total Site Income Increase	(n.a.)	$ 330,000	$ 192,000
Profit Per Lot Increase	(n.a.)	$ 1,274	$ 872

Figure R-9

RESIDENTIAL EMBODIED ENERGY COMPARISON
(in million of Btu)

	Traditional Plan 201 D.U.	Energy Plan 1 259 D.U.	Energy Plan 2 220 D.U.
Roads/Driveways	7,975.60 39.67	7,550.81 29.15	7,885.60 35.84
Water	4,277.50 22.28	3,700.00 14.28	4,217.70 19.17
San. Sewers	3,435.00 17.09	3,500.00 13.55	3,319.30 15.09
Drainage:			
Piping	3,688.30 18.35	4,700.00 18.14	3,053.60 13.88
Ditching	28.00 .14	28.00 .11	28.00* .13
Walkways	600.00 2.99	600.00 2.12	600.00 2.73
Contingencies	3,000.00 14.92	3,011.00 11.60	2,865.00 13.02
TOTAL PER UNIT	23,004.00 114.44	23,090.00 89.15	21,970.00 99.86

* Difference in cost between piping and ditching operations is due to increased pipe size for energy plans required because of increased density.

Figure R-10

RESIDENTIAL ANNUAL OPERATING COST SAVINGS

	Traditional Plan	Energy Plan #1	Energy Plan #2
SF Colonial	$ 351	$1,350	$1,539
SF Contemporary	$ 351	$1,350	$1,539
Town House	$1,672	$4,092	$2,376
TOTAL	$2,374	$6,792	$5,454

TOWN CENTER

Conventional Plan

The town center study site consists of approximately 51 acres located at the center of Radisson. Major land uses surrounding the town center are high-density residential development to the north and south, major educational development to the east, and industrial development to the west. Major areas of low-density single-family housing exist to the north and are proposed to the east and west. Immediate boundaries of the site are formed by an existing four-lane divided road (Willett Parkway) to the north and a four-lane expressway, scheduled for construction around 1985, to the southeast.

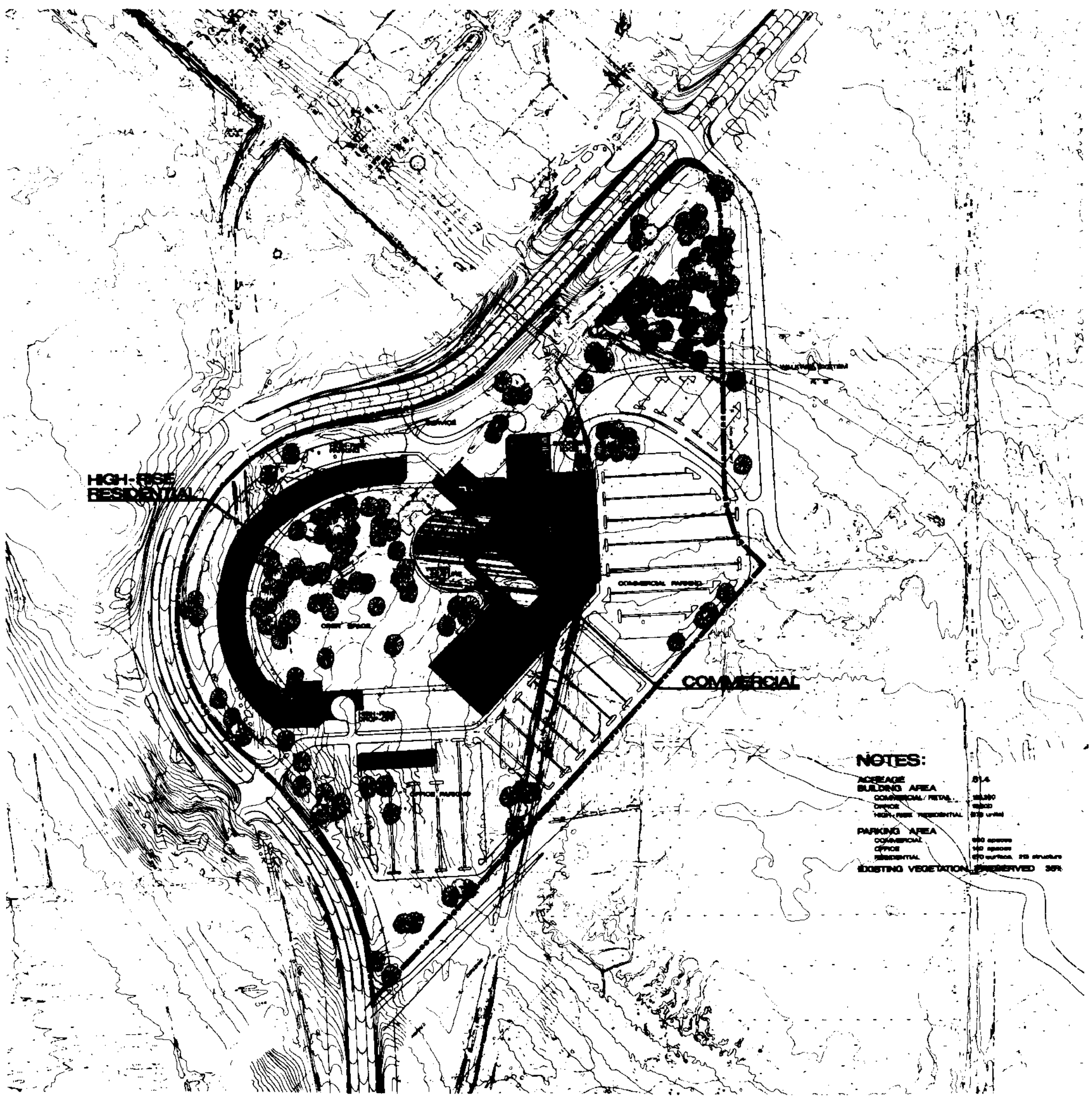
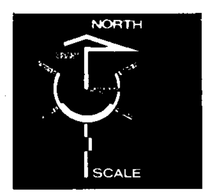


Figure R-11

CONVENTIONAL PLAN--TOWN CENTER
Source: Radisson Report Plate 25



The developer has programmed for the town center 350 to 400 apartment units, 125,000 square feet of convenience stores, and 19,000 square feet of office space. In addition, an urban plaza, open space walkway system, and public commons are planned. Current parking standards require one car per 100 square feet of gross leasable commercial space and will result in 13 acres or 25 percent of the town center site being devoted to parking.

Existing physical factors are as follows:

- Soils
  Wet sandy silt
  Fine sand (little silt) predominant
  Silty fine sand (wet)

- Slope Percentage
  70 percent of site: 5 to 10 percent slope range
  30 percent of site: slopes in excess of 10 percent
  Major topographic feature in north/south dirt road will be removed.

- Drainage
  Major drainage flow is east to seasonally wet areas and drainage swales.

- Slope Aspect
  35 percent of the slopes: southern orientation
  50 percent of the slopes: eastern orientation
  10 percent of the slopes: northern orientation
  5 percent of the slopes: western orientation
  The existing low point at the northern end of the site is likely to create a major frost and snow pocket.

- Vegetation
  40 percent of site: dense deciduous
  35 percent of site: sparse deciduous
  25 percent of site: open
  General vegetative cover is mixed deciduous second growth, ash, maple, and poplar with mixed deciduous shrub growth.

- Wind
  Prevailing winds range over a northwest 60° arc with a mean speed of 9.9 mph. The existing drumlin to the west is likely to alter this wind flow pattern.

The existing conditions impose the following restraints:

- The existing major four-lane road borders site to the north and creates major traffice flow to the site.
- Vehicular access to site is limited to two points north and south due to gradient and site lines.
- Proposed four-lane expressway to southeast creates potential noise instrusion.
- Location of proposed pedestrian overpass fixed due to existing gradient establishes the major pedestrial access point.
- Location of existing water and sanitary facilities.

Conservation Options

Given that many principles of the residential passive site and utility system options apply to the town center site, the town center option concentrated on building design types for high-rise apartments and the pedestrian shopping mall. The high-rise residential options included modifications to the traditional double-loaded corridor building and single-loaded corridor building.

Four systems for enclosure of the pedestrian shopping mall were identified, each based on a building mass along a 30-foot double-loading pedestrian corridor. The systems varied in terms of type and degree of overhead enclosure, from permanent overhead structure to mobile canopy systems modulated on a seasonal basis. The following recommendations were made for all systems:

- Incorporate double-door entry vestibules which create an air lock but still provide an opportunity to use natural ventilation when climatic conditions are not severe.

- Orient all glazing and appropriate shading to the south, southeast, or southwest.
- Design service access in such a way as to avoid direct northwest winter winds.
- Use service and storage areas as buffers to wind chill.
- Reduce standard 18-, 14-, and 12-foot commercial ceiling heights to 10 feet.
- Use double-loaded pedestrian systems.
- Provide a market flexibility for second floor office or retail use.

The following mall enclosure systems were considered:

- enclosed mall clerestony,
- enclosed greenhouse mall,
- enclosed mall with skylights, and
- seasonally enclosed mall.

Conservation options for parking areas were also considered:

- Use of energy efficient high pressure sodium lighting with color correction in parking areas and other site lighting applications.
- Implementation of energy-incentive parking plan, which gives priority to compact and generally efficient automobiles.
- Use of grass-block overflow parking to minimize need for additional asphalt paved areas.
- Programming of space so as to share parking wherever possible.

In addition, an alternative utility system was considered for the town center. This integrated utility approach would use existing natural gas and ground water on the site to supply heating, cooling, and electrical needs.

Conservation Plan

The energy-conserving plan for the town center site was developed in response to the same climate-related site planning criteria used in site selection and building orientation. Extensive consideration was given to the selection and planning of residential building types which would permit optimum orientation for sun and wind for the greatest number of dwelling units.

Major site planning features of the energy-conserving plan are the following:

- Residential and commercial structures would be sited in open pockets where vegetation or topography offers potential for building protection.

- Three-story garden apartments would comprise approximately 60 percent of the residential units. Due to its reduced height, this building type is less susceptible to wind eddying and turbulance and eliminates the need for vertical transportation systems. In addition, this building type offers greater potential for optimum solar orientation and wind protection for a greater number of dwelling units than do high-rise structures.

- Although space limitations in the site would require the use of high-rise residential structures, they would be orientated so as to reduce wall surface exposure to prevailing winds.

- Commercial structures were planned with a seasonally enclosed pedestrian access and walkway system to provide an air lock and sun shade as required.

As compared to the conventional plan, the conservation plan has 48 fewer dwelling units but has preserved more site vegetation and has shaded more parking areas. The conservation plan has slightly more office and retail space (See Figure R-13).

Conservation Plan Savings

Estimated energy savings for the town center site are based on the comparison and evaluation of qualitative differences between the conservation and the conventional plans. Plan characteristics evaluated are the differences in the siting and orientation of structures in relation to their impact on maximizing winter heat gain and minimizing winter heat loss. In the absence of

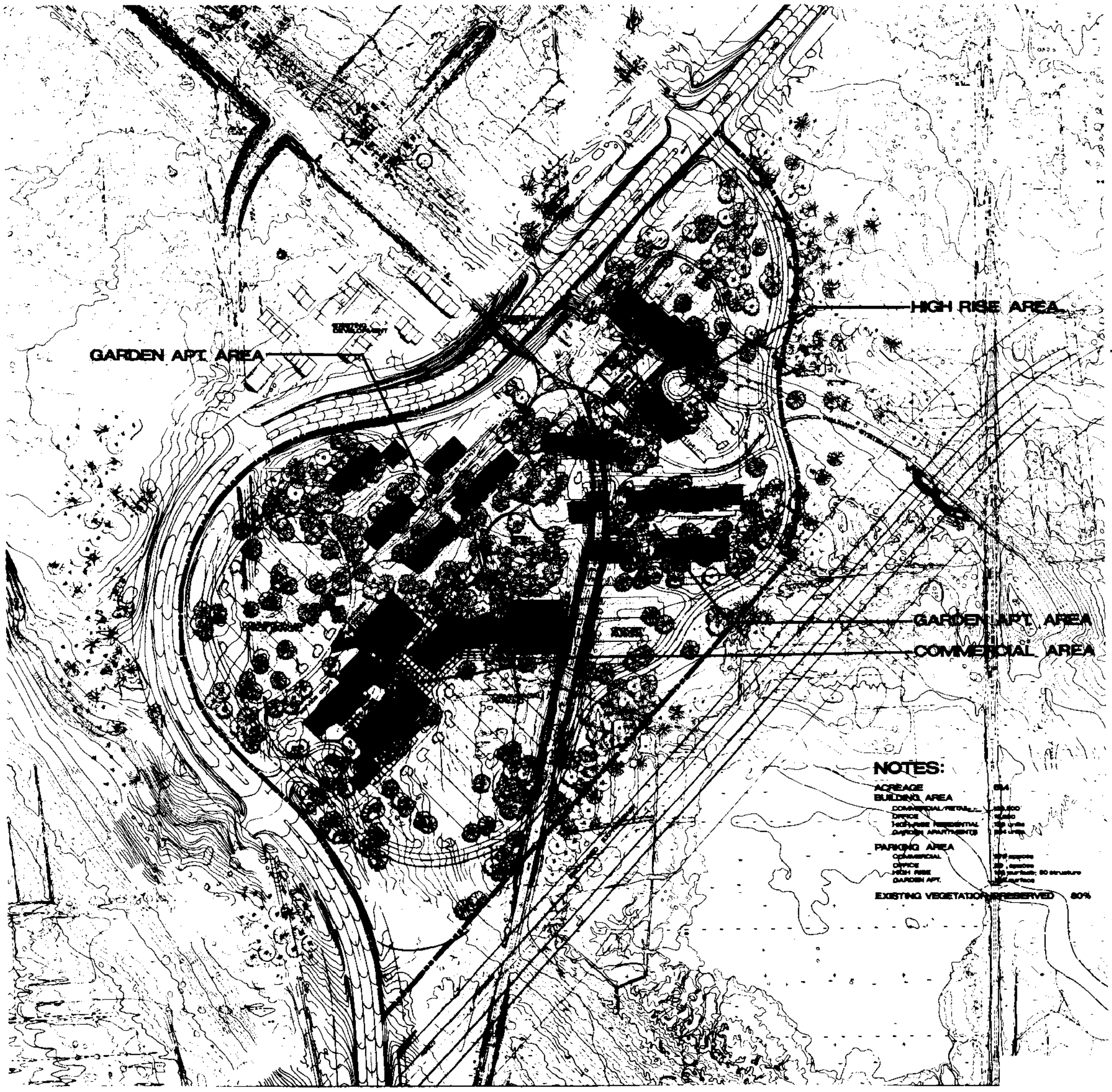


Figure R-12

ENERGY CONSERVATION PLAN--TOWN CENTER
Source: Radisson Report Plate 26

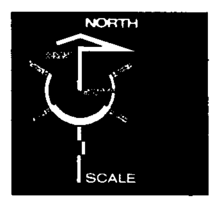


Figure R-13
RADISSON TOWN CENTER PLAN COMPARISON

	Town Center Plans	
	Conventional Plan	Conservation Plan
Building Area:		
Commercial/Retail	125,350 sq. ft.	126,500 sq. ft.
Office	19,200 sq. ft.	19,800 sq. ft.
High-rise Residential	378 dwelling units	126 dwelling units
Garden Apartments	0	204 dwelling units
Parking Area (percent shaded):		
Commercial/Office	9 acres	10 acres
(percent shaded)	(7 percent)	(43 percent)
Residential	6 acres	5 acres
(percent shaded)	(16 percent)	(38 percent)
Existing Vegetation		
Preserved:	9 percent of gross site	30 percent of gross site

specific data on building configuration, structural and window design and material types, insulation, and HVAC systems it is difficult to provide a detailed assessment of the impact of passive design features such as building siting and orientation on reduced load requirements. Potential energy savings for various passive design features can be evaluated in a qualitative manner, but are difficult to quantify. Comparative analysis of the town center plans to existing development at Radisson was not possible due to the absence of existing commercial and apartment structures at Radisson. In addition, the Carrier Load Information Center (CLIC) Model was not suited for analysis of multi-family dwellings and was, therefore, limited to analysis of commercial structures.

In any case, the conservation plan doubles the amount of south-facing glass over the conventional plan while minimizing undesirable east-, west-, and north-facing glazed surfaces. Based on data which show that the potential annual heat gain for south-facing windows is triple that for north-facing windows, the potential for increasing direct annual heat gain is significantly greater on the energy-conserving plan. Furthermore, the conservation plan significantly reduces total wall surface exposure and undesirable north, east, and west wall exposure in comparison to the conventional plan. By reducing north, east, and west wall surface area, as well as reducing the percentage of window glazing on these surfaces, the conservation plan minimizes potential cold air infiltration. In addition to siting structures to reduce north, east, and west surface wall area, the conservation plan uses existing vegetation and building spacing to provide wind sheltering on north and west wall surfaces. An overall comparison of the two plans indicates that in the energy-conserving plan 70 percent of the north and west wall surface is sheltered from the wind, while in the conventional plan the figure is only 20 percent.

Use of the Carrier Commercial Load Program did permit modeling of heat load for commercial/office structures. Because the Carrier program does not take solar gain or wind buffering into account, the program was used on a limited basis to identify the basic heating load and rate of air infiltration (3/4 of an air change per hour) on a medium/tight commercial structure. Heat load estimates derived from this calculation indicate a 5 percent increase in heat load for the energy-conserving plan (5,965,486 Btuh) over the conventional plan (5,612,994 Btuh).

As the differences in wall and glass surface identified above indicate, the increased heating load on the energy plan is due primarily to differences in the character of building surface with no account made for solar gain or wind buffering. As previously stated, town center building types are conceptual in nature and require more detailed development of solar gain factors, building design and climate impacts in order to quantify the potential benefits of heat gain and winter heat loss reduction identified in this section.

IMPLEMENTATION

PROBLEMS

Residential Site

Impediments to the implementation of the residential energy plan primarily pertain to single-family clustering and are as follows:

Ownership and maintenance of roads and utilities--Under the proposed clustering scheme, all utilities would be located in a right-of-way easement. Repair of utilities, which is the responsibility of individual homeowners in conventional development, would become the joint responsibility of all residents in a cluster. Snow plowing and road maintenance, ordinarily the responsibility of the Town of Lysander, would also become the joint responsibility of all residents in a cluster for the length of the cul-de-sac. Maintenance of road surface and utilities in a four-house cluster is comparable to overall maintenance of four conventional single-family houses on fee simple lots.

In meetings with U.D.C., the Town of Lysander Planning Board, and Radisson residents and builders, another impediment was identified. Residents in cluster housing would be required to enter into a maintenance agreement at the time of purchase of their homes. However, residents in cluster developments would in addition still be assessed for taxes for road repair and maintenance in the same manner as owners of housing fronting on dedicated public streets.

Development Guidelines and Controls--At the time the study was conducted, builders at Radisson purchased land developed by U.D.C. and were subject to guidelines restricting building setback, materials, color, facade, alignment, site fencing, and landscaping. These guidelines were established primarily for visual control. If the energy-conserving benefits of cluster planning, in terms of climate response, are to be achieved, Radisson must develop builder guidelines to insure that buildings are sited for sun and wind response as planned.

In addition to guidelines, a method of control must be established in order to guarantee that units as built can achieve the potential energy savings indicated. This type of control is particularly necessary to provide potential purchasers of new homes with a means of assessing claims of energy efficiency.

Public Awareness and Marketability--Because cluster housing patterns are not currently used in central New York State, an educational effort must be made to inform consumers of the advantages of the benefits (cost, environmental, and energy) to be realized by cluster housing.

Sampling of Radisson residents indicates that data as to actual energy savings of housing units as built are required before cluster housing can be marketed in terms of its energy conserving benefits. It is assumed that a one-year monitoring of use, relative to siting conditions, would be required to obtain this data.

Efficient Utility Distribution--Under existing regulatory constraints, utilities are required to be placed in public right-of-way. Under standard electrical design for single-family residences (Figure R-14), primary electrical line follows the public right-of-way and drops off at transformers which feed across the road to houses in a secondary system. When applied to eight prototypical residences, this system would require 400 lineal feet of primary distribution (156 ft/d.u.) and 540 feet of secondary (67 ft/d.u.). Extending this to 48 houses, which is what one feeder would normally supply in an electrically heated development of 76 to 80 amps, the line losses amount to 23.5 kWh/per year, or $940 per year based on 4¢ per kWh electricity. This averages out to $19.60 per house. The customer does not see this cost except as indirectly reflected on all utility bills. However, it is a real energy cost to the system.

In order to service cluster housing under existing constraints, the utility company has identified the need to loop in and out of each cluster grouping, increasing the length of primary line to 850 feet or 106 feet per dwelling unit (Figure R-15). The line losses in this system amount to 48 MWH per year which is approximately $1,920 or $40 per dwelling unit. The additional energy used annually under this distribution system would be sufficient to produce free service to one of the 48 conventionally served houses.

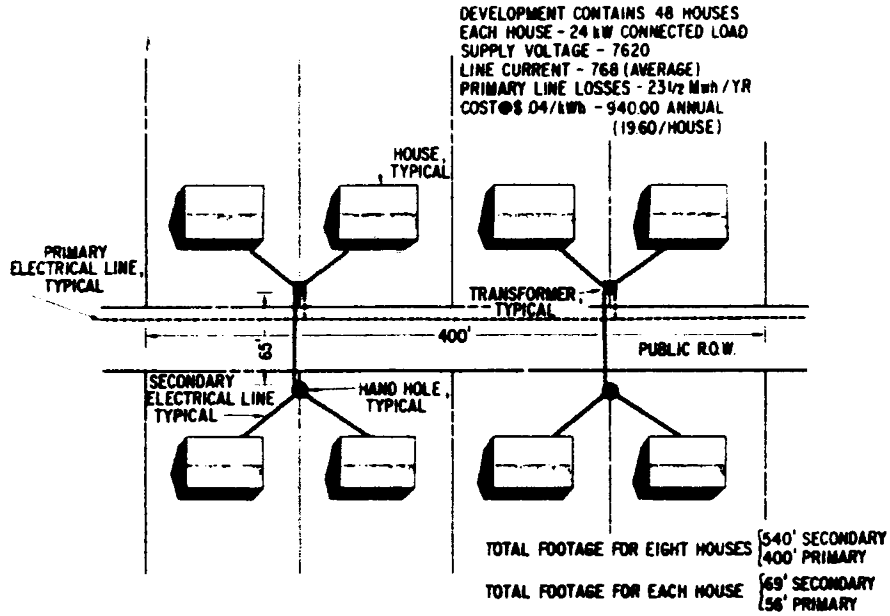


Figure R-14

STANDARD DESIGN OF PRIMARY ELECTRICAL LINES FOR CONVENTIONAL HOUSING
Source: Radisson Report Plate 44

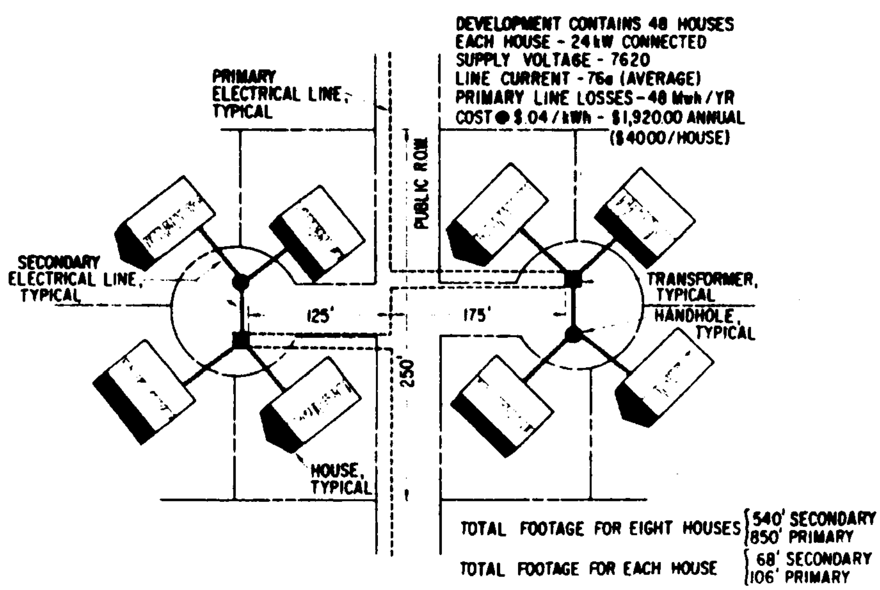


Figure R-15

UTILITY DESIGN OF PRIMARY ELECTRICAL LINES FOR CLUSTER HOUSING
Source: Radisson Report Plate 45

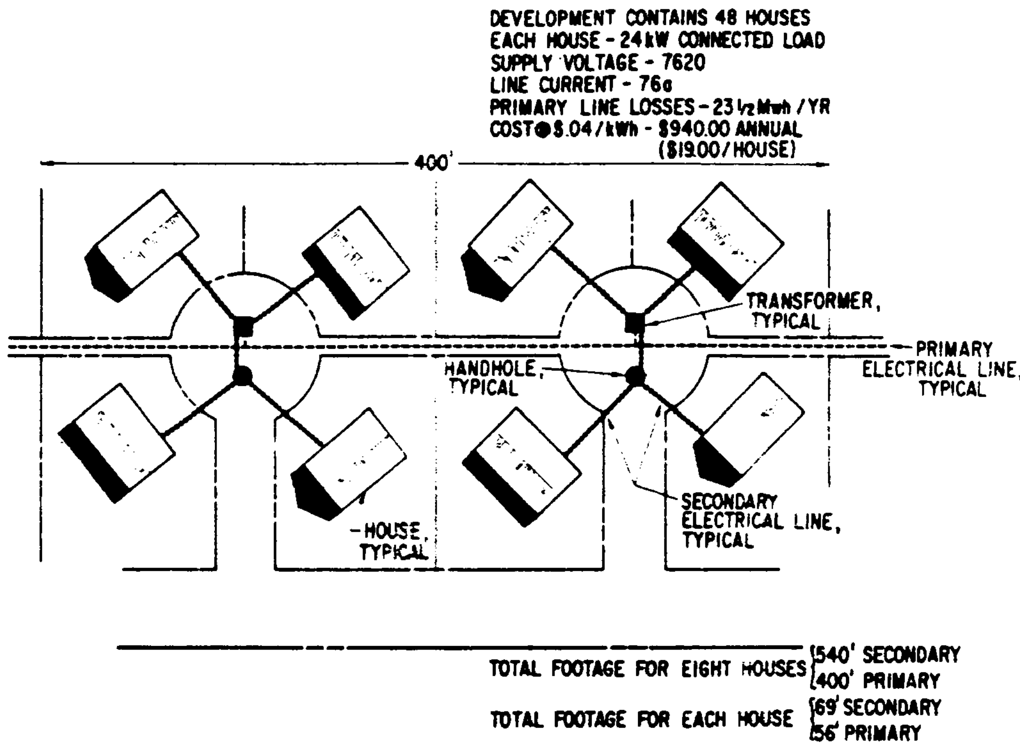


Figure R-16

PROPOSED DESIGN OF PRIMARY ELECTRICAL LINES FOR CLUSTER HOUSING
Source: Radisson Report Plate 46

In light of the undesirable line loss entailed in the servicing scheme identified above, an alternative servicing scheme for cluster housing using utility easements has been proposed (Figure R-16). This scheme results in the same distribution pattern and line requirements as the conventional pattern. In fact, tightening of clusters is likely to reduce line requirements over conventional patterns.

The following steps are required to insure that cluster housing can be implemented with efficient distribution patterns.

- Meetings with the Public Service Commission and Niagara Mohawk Power Corporation are required in order to establish special utility easements.
- Design development of cluster housing is required in order to produce the tightest pattern possible for reduction of line loss and to insure year round service accessibility to transformers.

Town Center

Impediments to the implementation of the town center energy-conservation plan pertain primarily to the following marketing and development concerns:

Developer Commitments--At the time the study was conducted, Radisson did not have the commitment of a commercial developer for the entire town center site. Due to the flexibility for phasing which has been incorporated into commercial development, it is most likely that commercial development will be implemented in stages by a group of developers. In order to insure that the objectives of climate response incorporated into the energy plan are implemented, Radisson must develop building guidelines for the town center. Such guidelines would control building orientation, spacing, and facade controls so as to insure that wind sheltering, solar access, and shading would be incorporated into the plan as built.

Parking Requirements--Under the zonging in effect when the study was conducted, the town center must conform to parking requirements of a regional shopping center [10 parking spaces per 1,000 square feet of grass leasable area (GLA)]. The increased surface parking area required by these standards increases development and maintenance costs and associated energy use. The findings of the study team led to the following general conclusions: off-street parking needs have been overestimated by shopping center developers, lenders, and tenants; similarly, off-street parking requirements being asked for are excessive in many zoning ordinances. Accordingly, for shopping centers of all sizes it is currently recommended that a standard of 5.5 parking spaces per 1,000 square feet of gross leasable area be established generally.

Project engineers have suggested an integrated utility system for the town center. As indicated earlier, the proposed system would utilize existing natural gas and industrial waste heat sources on site. Major impediments to the implementation of the utility system are as follows:

- It is unlikely that, with the cost of energy today, anything but a conventional energy system would be designed and installed to serve the proposed commercial development of 144,000 square feet. While inclusion of a 350-unit residential development proposed for the town center would make an integrated system cost-effective, it is unlikely that these units would be built earlier than 1985.
- In addition, further engineering studies are required for the following: (a) investigation of the availability, quality and cost of development of natural gas, waste heat, and other potential energy sources; (b) analysis of the feasibility and cost of energy storage systems and the potential environmental impact of such storage systems.

IMPLEMENTATION PROGRAM

Residential Site

At the time this report was written, the western portion of Conservation Plan 2 was scheduled for design development and implementation. As part of the plan implementation, a study of heat pump applications on the residential site was being prepared by New York State ERDA (Energy Research and Development Authority) and the Niagara Mohawk Power Corporation. In particular, the study was being conducted to determine if water source heat pumps using individual wells, common wells, or river or lake water can supplement fossil fuel. Standard heat pumps operate using outdoor air. This experiment was designed to attempt to extract heat or cold from water, depending on the season, to demonstrate the commercial feasibility of such pumps.

The Niagara Mohawk Power Corporation has provided the services of its Research and Development Department since the inception of this project. At present, Niagara Mohawk has proposed a two-phased assessment of a community based energy system for space heating and cooling equipment, as well as selected individual heating and cooling systems. This assessment would entail detailed investigation of the options for individual, cluster and central plant systems. The assessment would build on site and design data developed under the case study and would include detailed on site investigation of energy sources. Niagara Mohawk's Howard Phillips expresses the company's attitude toward development of energy systems at Radisson in the following words:

> "Utilities have in recent years become increasingly attracted to the load management potential of certain customer loads. Time of Day or Time of Use rates are emerging in several parts of the country. Real time control is felt by most to be essential to meaningful implementation of customer load management. Hardware is now offered by several manufacturers for providing this type of control, however there are implementation problems. There are not enough controllable loads to make board based installation attractive, consequently, the coordinating effort necessary for installing the control hardware, and insuring that there would be enough load to be attractive would be monumental."

> "Community based thermal plants could provide a very attractive load management tool while still offering the customer an attractive energy-conserving tool."

At present, the major impediment to development of community utility systems for the residential site is the need for further study of the cost benefit and feasibility of systems options identified to date.

The researchers also planned to study other possible methods of increasing the heat content of water circulated by heat pumps by capturing low-grade heat sources within the community. In Radisson's case this could include industrial waste heat, methane gas found on the site, wood, solid waste or other local resources. The entire utility study is to be phased over a 3-year period to be coordinated with Radisson's construction schedule. The study will include management and monitoring of systems as built.

Town Center

At the time of the case study, Radisson did not have a definite developer commitment for implementation of the town center conservation plan. The effort toward implementation would require Radisson to solicit a commercial developer. At that point, design development of the passive measures and detailed study of utility options can proceed realistically.

SUMMARY

Radisson is a 2,852-acre new community currently being developed by the New York State Urban Development Corporation. The new community is located in central New York, 12 miles northwest of Syracuse. Case study sites selected for this project are a 92.1-acre residential site and the 51-acre town center of the new community. Development on the residential site is a low-density mixture of single-family, townhouse, and multifamily dwelling units. Development on the town center site is a mixture of small-scale commercial use (approximately 144,000 sq. ft.) and about 330 multifamily dwelling units. The central New York area has cool summers and cold winters, with 6,678 heating degree days and 551 cooling degree days.

Energy conserving plans developed for both sites have focused on passive measures to reduce energy use for space heating. Utility systems options have been identified for both sites but require further study as to feasibility and cost. For the residential study area, two conservation plans were formulated. Conservation Plan 1 envisioned development of single-family detached and townhouse cluster housing along a system of private drives and auto courts, with an increase in site density over the base plan in order to decrease site development costs and embodied energy use on a per unit basis. Conservation Plan 2, developed in response to the developer's concern over the marketability of an extensive cluster housing plan in an untested market area, clusters only single-family units and limits the number of housing clusters.

The design load calculations identified for the two conventional and the two energy-conserving plans are based on the net heating requirements for all proposed single-family housing. These calculations were derived from the Carrier Load Information Center Program (CLIC) using existing developer's building plans and specifications. Operating costs are based on the Carrier Air to Air Heat Pump, Model 38 BQ 008 and 40 BA 009.

Estimated energy savings for both of the energy plans are based on the effect of passive measures, such as the siting and orientation of dwelling units to reduce cold air infiltration and winter heating loads.

Based on use of the CLIC model, the following design loads were developed for the conventional and energy plans.

- The annual design load for the 201 single-family dwelling units on the conventional plan is 6,737 Mbh. This load represents an annual cost of $77,163 for the total plan and $383 per single-family dwelling unit.
- The annual design load for the 259 single-family dwelling units on Energy Plan 1 is 9,835 Mbh. This load represents an annual cost of $95,101 for the total plan and $367 per single-family dwelling unit.
- The annual design load for the 220 single family dwelling units on Conservation Plan 2 is 7,112 Mbh. This load represents an annual cost of $81,688 for the total plan and $371 per single-family dwelling unit.

Modeling of reduced heating load due to wind protection identified potential annual savings of between 6 percent to 9 percent on both energy plans for single-family detached units and up to 13 percent for townhouse units. This reduction represents a savings in annual operating costs of $27 annual for single-family detached units and $44 annually for townhouse units.

When project on a total plan basis, the annual savings in operating costs for protected dwelling units is $6,792 for Conservation Plan 1 and $5,454 for Conservation Plan 2.

In addition, a comparison of the conventional and the energy conserving plans identified a savings in the energy embodied in site development. Conservation Plan 1 saves 25 million Btu, and Conservation Plan 2 saves 15 million Btu over the conventional plan. These savings represent respective decreases of 22 percent and 17 percent in embodied energy.

Estimated energy savings for passive measures on the town center plan are based on an evaluation of the qualitative differences between the energy-conserving and conventional plans. Factors evaluated are the potential for annual heat gain through south-oriented windows and potential winter heat loss reduction.

While the exact amount of yearly heat gain varies with climate conditions and building design, potential annual heat gain per square foot of glazing can be identified. Based on comparison to comparable sites, a potential yearly heat gain of 76,517 Btu per square foot of double-glazed window is assumed possible at Radisson. A comparison of the conservation and conventional plans indicates that the conservation plan doubles the amount of south-facing glass while minimizing undesirable east, west, and north glazed surfaces.

In addition to maximizing the potential for annual heat gain, the conservation plan reduces the potential winter heat loss through siting structures to protect and minimize windward wall exposure. An overall comparison of the two town center plans indicates that 70 percent of the north and west surface wall exposure on the energy-conserving plan is sheltered from the wind compared to 20 percent of the north and west wall surface on the conventional plan. A comparison of the distribution of surface wall by orientation indicates that the energy-conserving plan reduces north and east/west wall exposure by 2 percent and 37 percent respectively.

A conceptual integrated utility system has been proposed for the town center. The proposed system would be capable of supplying electric power and fuel by using ground water and natural gas on site and would replace a conventional system. Estimates of energy savings due to reduction in line loss and elimination of conventional fuel requirements for this system have not been calculated. However, review of comparable systems (i.e., systems utilizing cogeneration techniques with diesel engine driven generation) have identified potential energy savings of up to 46 percent with the use of an integrated approach.

Since a developer had not been identified for the town center further definition implementation of conservation options was limited to the residential study area. UDC is proceeding with the development of the residential study site under Conservation Plan 2. Implementation of passive measures should be accomplished in two phases. Phase one would entail more detailed design studies; phase two would entail all site construction. Concurrently, the developer and the utility are undertaking a feasibility analysis to attempt to bring a demonstration water-source heat pump system to serve some of the clustered units. If found feasible, the final engineering of the heat pump system will be co-ordinated with the development schedule.

RECOMMENDATIONS

The major recommendations of the SAND study team are as follows:

- Based on the changes in project emphasis and the expertise offered by the Niagara Mohawk Power Corporation, the project should be initiated with the power corporation as a key technical team member with responsibility for the identification and analysis of utility systems options.

- Due to the limited capacity of computer models available for this study to account for the effects of climate modifications on space conditioning requirements, greater reliance should be placed on hand calculation techniques and qualitative analysis.

- A simulation model should be used in similar planning efforts to help in evaluation of the climate impacts. (A joint endeavor by all case study participants to develop a simulation model would have facilitated quantification of plans and eliminated duplication of efforts.)

SAND STUDY TEAM

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RADISSON
PROJECT DATA

Land Use Information

		SAND Study Areas		
	Developed	Residential	Town Center	Total
Site Area in acres (hectares):	1,319.0	92.1	51.0	2,852.0 (1,155)
Dwelling Units [1]:	967	343	378	4,300
Gross Density in d.u./acre:	3.48	3.72	10.8	1.51
Parking Spaces:	--	1.8 per d.u.	1 per 100 GLA sq. ft.	--

Unit Information

Type	Unit Size in Sq. Ft.	Lot Size in Sq. Ft.	Number	Lot Price	Sales Price
Single-Family Detached	1446-2280	9,000-11,000	135	$12,000	$70,000-$90,000
Townhouse	1374	4,500	66	$ 6,000	$45,000-$80,000
Multifamily	--	--	142	--	--

Land Use Plan

	Acres	Percent
Residential		
Low Density	476.5	16.71
Medium/High Density	244.3	8.57
Commercial	81.8	2.87
Major Right of Ways	450.7	15.80
Schools	78.8	2.76
Community Facilities	47.1	1.65
Open Space and Recreation	571.2	20.03
Industrial Development [2]	901.6	31.61
Total	2,852	100.00

Economic Information

Site Cost: $500/acre (1968)
$1,000/acre (1979)

Site Improvement Costs: Approximately $9,600/unit (conventional)

Construction Costs: $38/sq.ft. (residential)

Climate Information

General: humid continental

Degree Days:
Heating 6,678
Cooling 551

Mean Temperature:
Annual .... 48°F
Winter .... 27°F
Summer .... 71°F

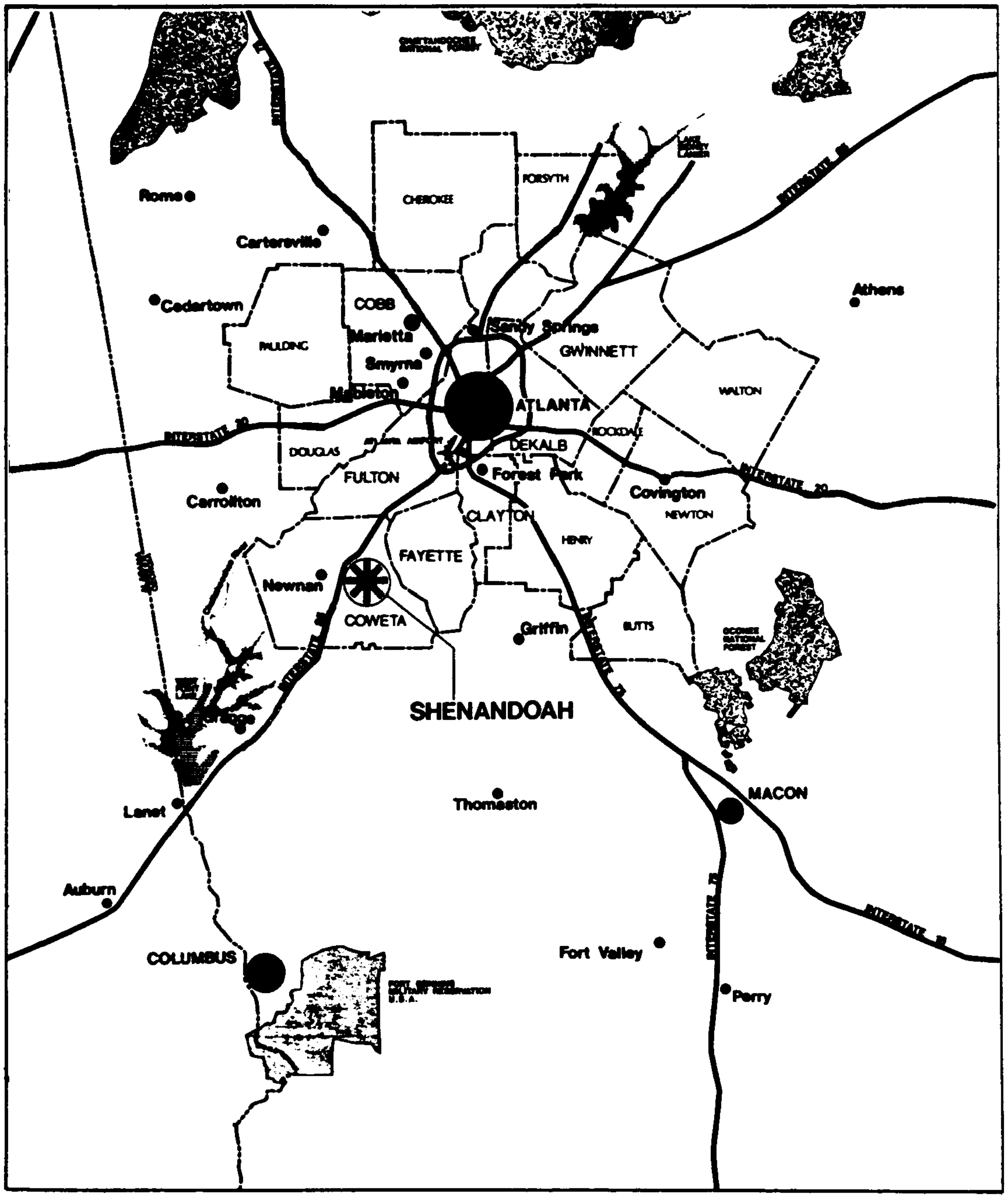
2.5 Percent Design Temperature:
Winter .... 0°F
Summer ....90°F

Average Wind Velocity: 9.9 mph ranging over a 60°north/northwest arc (in winter)

Mean Rainfall: 36.4 inches [3]
Solar Gain: 300 Langleys

Annual Average Sunshine:
November through March--less than 40 percent
May through August--up to 65 percent

Notes:
1. In the Syracuse area, typically the mix of single-family detached units to townhouses has to be 2 to 1. In study area, the unit mix is 1/3 single-family detached, 1/3 townhouse, and 1/3 multifamily units.
2. Includes a 188.2-acre Joseph Schlitz Brewery.
3. Rainfall is distributed evenly throughout the year, averaging about 3 inches per month. On about 168 days a year precipitation exceed 0.01 inches. The mean annual snowfall is 100 inches, and monthly amounts in excess of 24 inches are not uncommon.



SHENANDOAH

Figure S-1

SHENANDOAH REGIONAL LOCATION MAP
Source: Shenandoah Report Map 1.1

SHENANDOAH

BACKGROUND

GENERAL DESCRIPTION

The new town of Shenandoah, Georgia, is situated in Coweta Couty on 7,400 acres surrounding the Newnan exit of Interstate 85, 25 miles southwest of Atlanta's Hartsfield International Airport (Figures S-1). Shenandoah is a balanced community planned for homes, business, and industry and is in the early stages of a 20-year development program aimed at creating a community of 18,000 people. The SAND study site is located in Village One, which covers approximately 235 acres and which will ultimately include residential areas, high school, church, fire station, commercial, and recreational facilities (Figure S-2). Shenandoah also contains a 55,000-square-foot solar-heated and -cooled recreation center and several active and passive solar homes. Commercial energy-conservation applications at Shenandoah include plans for solar-power manufacturing plants for knitware products and flat plate solar collectors.

The overall Shenandoah development plan is based on a loose grid of primary roads and infrastructure facilities. Two four-lane divided roadways, Shenandoah Boulevard and Road "C," provide access throughout the site and ensure smooth and efficient traffic flow. A network of local streets, primarily cul-de-sacs within subdivisions, connects to these loop roadways and provides access to individual lots within the project. Regionally oriented activities, including the industrial park and commercial uses, have been located around the I-85 interchange with State Highway 34.

Residential development has been located in a series of seven separate village clusters, each with its own character, elementary school, and convenience shopping facilities. By clustering housing, open space has been maximized and the length and cost of utility and service lines have been minimized. Densities vary from cluster to cluster, and a wide selection of homes in every price range, varing from single-family homes to medium-rise apartment buildings, will be provided. Home sites have been concentrated mainly on the heavily wooded upland ridges of the site. Bike and walkway paths link the residential areas with the recreational amenities and the linear open space network, which has been located primarily along the wooded valleys. Pedestrian underpasses separate vehicular and pedestrian traffic. All utilities have been placed underground.

All plans for the construction or alteration of any structure must be submitted to and approved by the Shenandoah Development Review Committee (DRC). The DRC is managed by a seven member board of directors which contains at least two members who are property owners or residents. It is responsible for reviewing plans, establishing the procedure for the submission of plans, and establishing guidelines for design features, architectural styles, exterior colors and materials, details of construction, location and size of structures, and related items.

Solar tax incentives have also been provided. All solar equipment is exempt from Georgia sales and use taxes. In addition, Coweta County was the first county in Georgia to pass a local option property tax exemption for residential, commercial, and industrial solar systems and a property tax exemption for equipment used in the manufacture of solar systems. Exemptions extend through July 1, 1986.

Shenandoah's application was accepted in 1971 by the U.S. Department of Housing and Urban Development under Title VII guidelines of the Urban Growth and New Community Development Act of 1970. The HUD loan guarantee was issued in March 1974 and the first home was sold in December

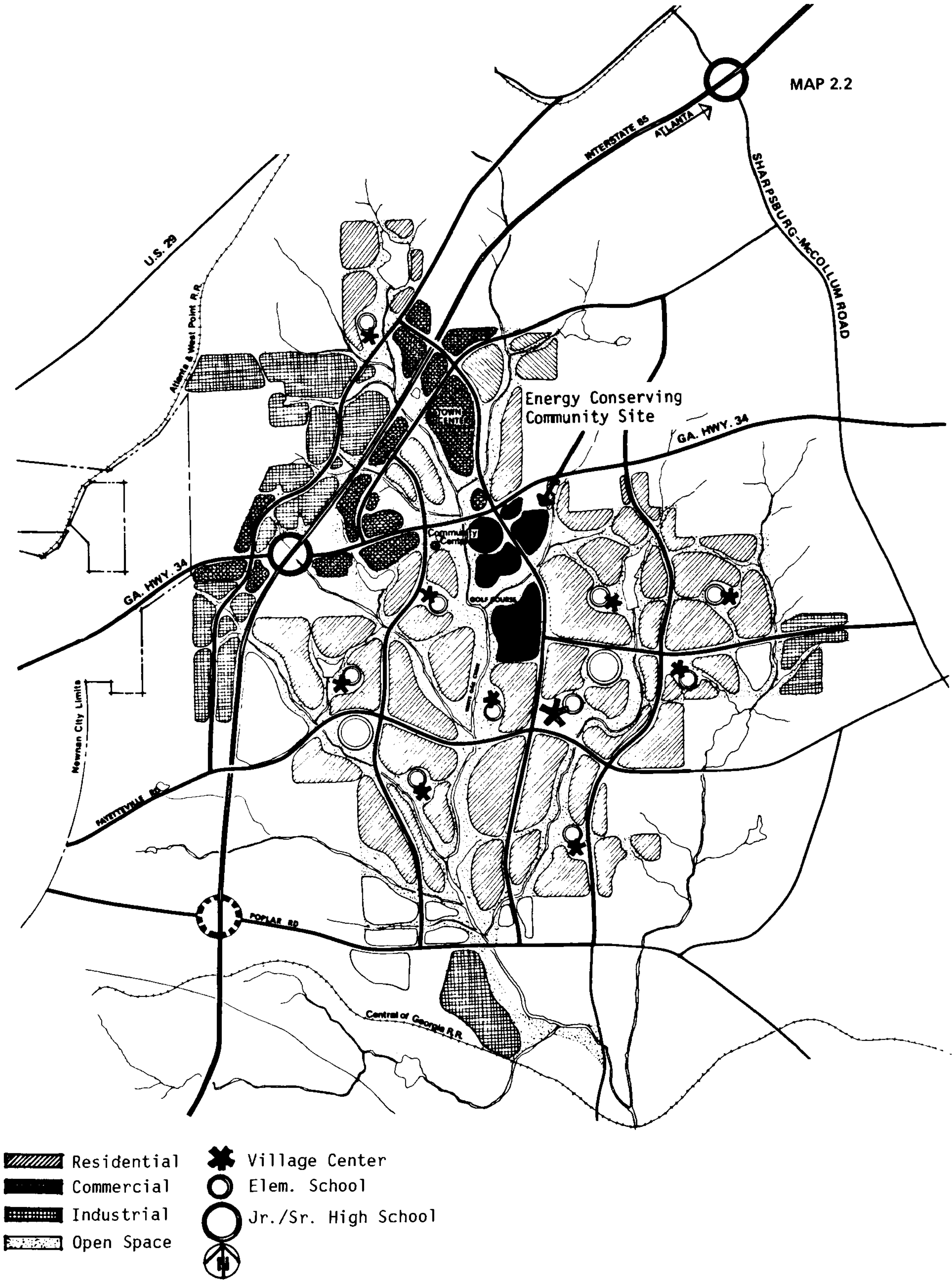


Figure S-2

SHENANDOAH TOWN PLAN
Source: Shenandoah Report p 2-8

1976. At the time of the SAND study there were approximately 275 units in Shenandoah housing an estimated population of 825.

PROJECT MARKET

In the 1950s and 1960s, Atlanta's growth was mainly to the northwest and northeast, following the expressway system. Twenty miles northwest of Atlanta, in Marietta, was Lockheed Aircraft, then Georgia's largest employer. Construction on Interstate 85 began in the late 1960s to move southeastward into one of the last major corridors of undeveloped land in metropolitan Atlanta, and in 1968 it reached the northern portion of Coweta County.

Employment opportunities are now provided within the 600-acre Shenandoah Industrial/Business Park. To date, seven industries, one office, and one bank have purchased land in the park; five companies have begun operations, one of them on three shifts. Approximately 1,000 people are now employed in the park, with eventual total employment projected for more than 4,000 persons. Shenandoah has built two warehousing facilities of 50,000 square feet for rental to companies needing storage space. The park contains a 33-acre Foreign Trade Zone, which enables domestic and foreign companies that import goods or materials to defer, reduce, and in some instances, totally eliminate customs duties.

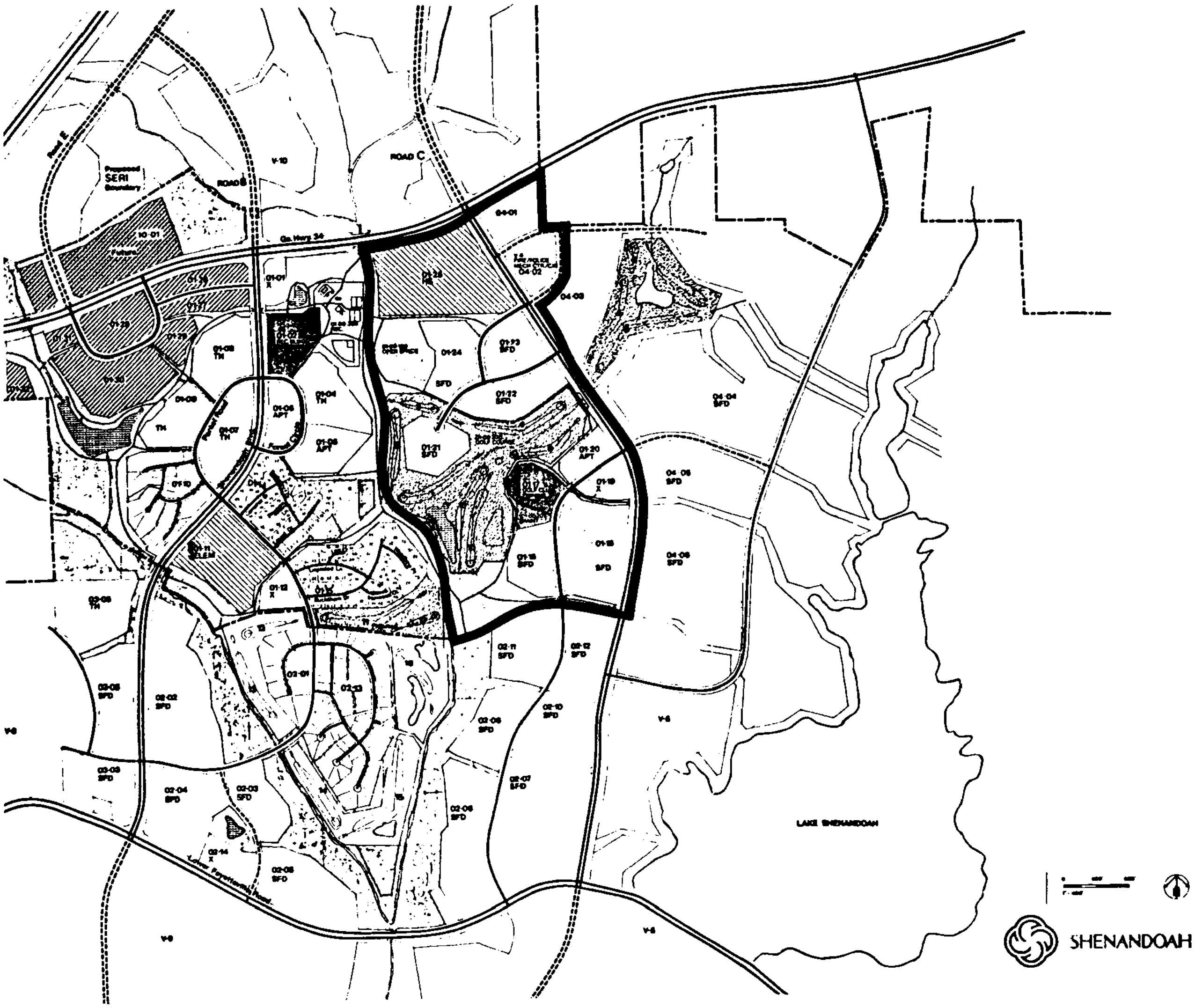
The basic objective of providing housing for those employed in the industrial park has not been fully realized. Only a small percentage of those working in the industrial park also live in Shenandoah. The project's image as an upper-income, white collar community, rather than the actual price of housing, has deterred industrial park employees from purchasing there. To alleviate this problem, the housing marketing program has recently been directed more toward the market created by the industrial park.

THE SITE

The western boundary of Shenandoah is contiguous to the city of Newnan, the county seat of Coweta County. Coweta County and the area to the south is still predominantly rural, and Newnan, with a population of 13,000, serves as the industrial, commercial, and administrative center of a six-county area.

The site is characterized by gently to moderately sloping terrain containing stands of pine, mixed hardwood woodlands, and abandoned agricultural fields. About one-half of the site is composed of slopes ranging from 0 to 8 percent and less than 5 percent of the site contains slopes of greater than 16 percent. A large drainage swale runs east and west, dividing the site equally. White Oak Creek runs along the site's western boundary and is the main drainage corridor for the surrounding area. The 100-year old flood elevation for White Oak Creek encompasses about one-quarter of the project site; constraints for high-intensity development within this flood area have been imposed.

The climate of this section of Georgia is classified as subtropical humid. Summers are warm, but long periods of excessive heat are rare. Winters are not severe, but moderately cold temperatures are common, with freezing temperatures occuring on about one-half of the days from December through February. However, the abundance of solar radiation greatly modifies maximum winter temperatures, normally resulting in high temperatures in the fifties and sixties, with 70° Fahrenheit temperatures not unusual even in mid winter.



OPEN SPACE/RECREATION
COMMUNITY FACILITIES
GOLF COURSE
EDUCATIONAL
COMMERCIAL
RESERVE SITE
TRACT No.
RESIDENTIAL
Single Family Detached
Single Family Attached
Townhouses
Apartments
ARTERIAL ROAD 4 Lanes Divided
COLLECTOR ROAD 2 Lanes
FUTURE ROAD EXTENSION
MAJOR PEDESTRIAN/BICYCLE PATH
GRADE SEPARATED CROSSING
BOUNDARY
Study Area

Figure S-3

SHENANDOAH SAND STUDY AREA
Source: Shendandoah Report Map 1.2

RESPONSE

TEAM AND METHODOLOGY

Technical Team Organization

The general program plan involved Shenandoah Development Corporation (SDC) as the prime contractor and five subcontractors--Georgia Insititute of Technology Engineering Experiment Station (GT); Finch, Alexander, Barnes, Rothschild, and Pascal (FABRAP); Newcomb & Boyd (NB); Williams-Russell and Associates (WR); and Laubmann-Reed and Associates (LR). These six team members provided expertise in land development practices, energy engineering, central utility system, landscape planning, mechanical engineering, architecture, civil engineering, and program management.

Shenandoah Development Corporation, as the prime contractor, chose the study site, determined the land uses, and was involved in the conventional development process. In addition, Shenandoah aided in coordination of the subcontractors and the advisory committees. The Financial and Marketing Advisory Committees were most important to the study team as a screening system for ideas to be implemented in each of the three conservation plans studied. In joint meetings the study team and each committee discussed the various options and plans under consideration and eliminated those which were not financially feasible or were not marketable--thereby helping to assure the marketability of the plans. The Financial Advisory Committee was composed of bankers, both commercial and savings and loan, which were local and nonlocal. The Marketing Advisory Committee was composed of builders, government agency personnel, and real estate and market research people.

The three utilities located in Shenandoah are Georgia Power Company, Oglethorpe Power Corporation, and Atlanta Gas Light. Each electrical supplier has a specific territory to serve within although one may bid against the other to serve a particular customer where electrical loads exceed a specific limit. The 235-acre SAND study site lies in the Oglethorpe territory. All three utilities have offered and supplied their expertise where needed as well as their reactions to various aspects of the study. Consequently the overall approach has been basically unaffected by the necessities of dealing with more than one utility company; rather, the utility companies have been a welcome resource for the project.

METHODOLOGY

During a one-year period, the Shenandoah SAND program developed three alternative energy-conservation plans in conjunction with a base (or conventional) plan and the necessary data to permit evaluation of each plan. The final conservation plan was formulated from the alternatives, based on the criteria of lowest life-cycle cost. Through the study process, two main objectives became clear:

- to provide long range passive energy conservation design measures and guidelines which
  - (a) must be compatible with normal construction costs on the base plan, and
  - (b) could be used for immediate implementation.
- to implement these long-range energy measures.

Initial research began with the selection of a study site within Shenandoah. Site selection was based upon an area intended for development over the succeeding five years. Once selected, the site was analyzed for topography, vegetation, physiography, zoning, and existing land use and climate. Following the analysis, maps were developed showing results of each phase of the analysis. At the same time a conventional plan was developed to provide base values for construction costs and energy consumption levels. These values served as comparison values for the later plans to determine the changes in costs and energy consumption.

Along with development of the three conservation plans, other research involved determining the institutional barriers to utilizing solar energy and development of solar rights solutions. Other research also undertaken at this time included developing a life-cycle cost model (which was used in determining the central utility system alternatives and energy supply alternatives available and their costs) and developing a central utility design.

The conventional plan, as its name implies, reflects the traditional form of development familiar to the American subdivider for the past two decades. Streets are wide and curvilinear, lots generally large, and houses oriented toward the street. The conventional plan offers heating with natural gas in the winter and air conditioning by electricity in the summer. Window glass is single-glazed and insulation conforms to FHA minimum requirements.

The first alternative plan to the conventional plan to be developed was the Level 1 (passive) Plan. As its name implies, the major emphasis of the plan was on energy conservation through passive site design. In the passive plan, streets would be generally oriented along an east-west axis, and the structures would be oriented to the south to achieve maximum solar heat gain. In addition to the southern exposure, the majority of the window area would be moved to the southern wall and the window glass would be double-glazed to reduce heat loss in the winter and heat gain in the summer. The residential structures would also be designed with increased insulation in the roof and walls and Arkansas construction, which is a tighter construction. The passive site plan also featured higher density and some smaller lot sizes. In addition, the passive plan utilized other beneficial characteristics of the site, such as vegetative shading in the summer, natural stormwater drainage systems, and natural wind screens. The analysis which follows compares this plan with the conventional plan.

The Level 2 (dispersed systems) plan was designed to take the process one step beyond the passive plan by adding decentralized systems, both active and passive, to the residential structures. Again, both conventional and improved construction techniques were analyzed with the decentralized system.

The Level 3 (central utility) plan examined the possibility of using some form of cogeneration plant to generate electricity for use in the study area and for sale back to the local utility. Cogeneration would permit hot and chilled water to be distributed throughout the study site to provide the needed thermal loads. A number of central plant systems were studied, including solar, coal, and wood systems.

A common methodology was used to compare all three alternative plans with the conventional plan. Infrastructure costs, energy consumption and price levels, building costs, and energy end-use systems were all examined for differences and changes from plan to plan. For additional consistency and for ease of calculation the same number of single-family, apartment, and townhouse units was used in each of the plans; calculating costs and energy usage per square foot would have been more difficult. Consequently, even though the passive plan (Level 1), for example, shows more apartments and single-family dwellings, the energy and dollar figures are for the same number as are indicated for the conventional plan.

Given all of these plans, the economic analysis was made to determine the life-cycle costs of each plan. The final results of this analysis determined the total costs of the 235-acre development over 25 years, including site development costs, lot development costs, construction costs, and energy costs. By comparing the present value of additional investments in each alternative level to the present value of savings (primarily from reduced energy consumption), a final savings-investment ratio was calculated for each plan in relation to the conventional plan.

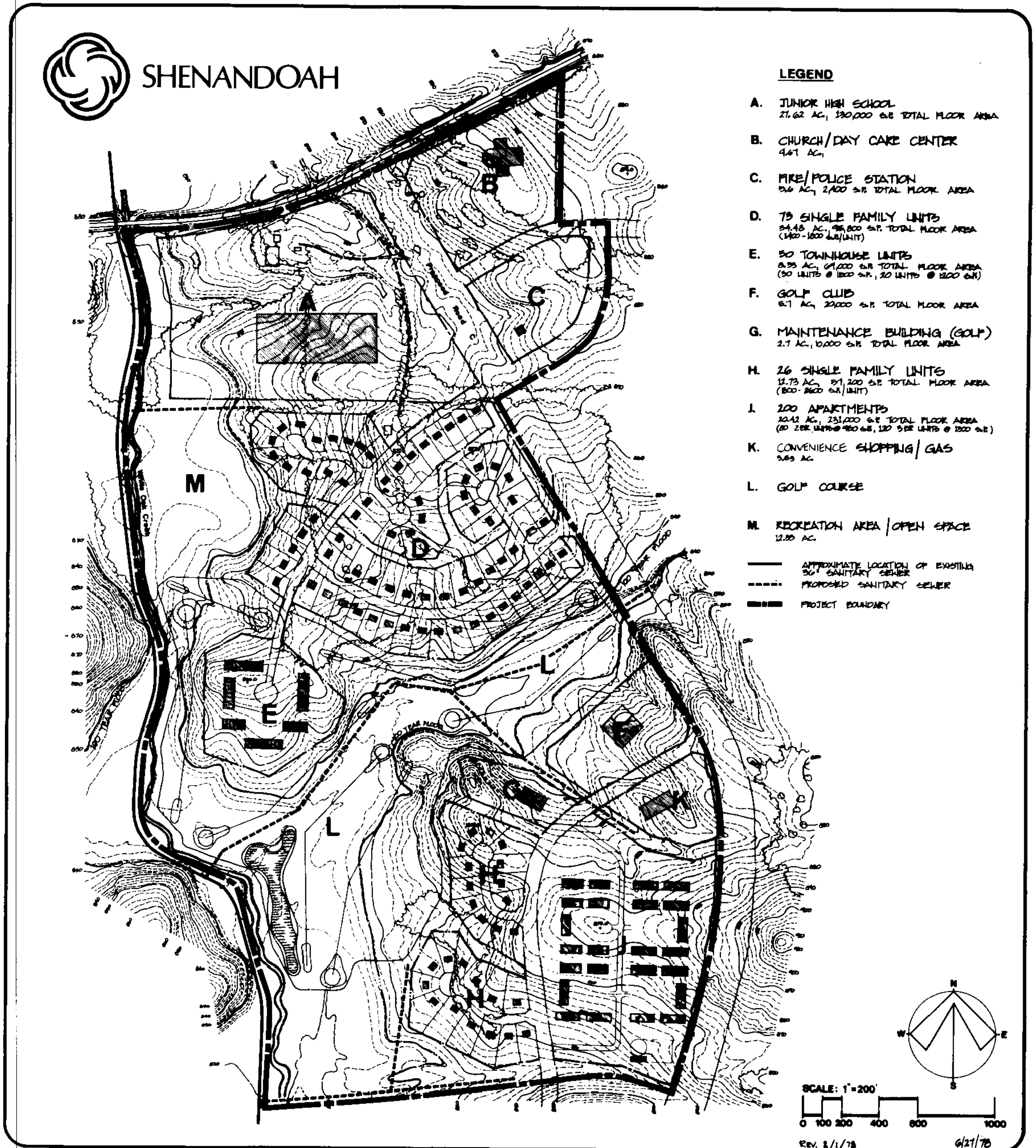


Figure S-4

SHENANDOAH CONVENTIONAL PLAN
Source: Shenandoah Report Map 1.3

The L3Model, a community-level life-cycle cost model, was used for project analysis and evaluation. The analytical technique employed was a computer coded application of the familiar total net present value of costs method. Automated data processing and formated input/output techniques were used to produce a variety of analytical reports for evaluation.

For this project, the ESP-1 program developed by APEC (Automated Procedures for Engineering Consultants) was used to predict energy consumption. This program uses hourly weather data and information about a building's architecture, occupancy, and internal loads, such as lights, to calculate the thermal building loads for each hour. The program then simulates the action of a space conditioning system in response to each hour's loads.

Traditionally, predictions of building energy consumption have been based on empirical "rule-of-thumb" numbers, such as degree-day calculations. These methods are not accurate or sensitive enough to adequately evaluate the kinds of changes involved in community planning. An example of this problem is a typical passive solar building. On a sunny day, the total daily solar heat gain through the windows can be more than the daily heat loss from the building. The problem is that the solar heat gain does not occur at night, when it is needed most. As a result, only an hour by hour analysis of the interaction of the building, solar transmission, and internal loads with the space conditioning system can provide a reliable estimate of a building's designed energy consumption. Due to the number of calculations required to analyze a building for 8,760 hours of the year, a computer simulation is a necessity.

Finally, the study team both analyzed the potential barriers to the implementation of the plans with regard to solar access and with regard to institutional, legal, developer, builder, consumer, and financing impediments and suggested possible solutions.

CONVENTIONAL PLAN

The conventional site plan (Figure S-4) was designed from, and the buildings was sized and oriented in accordance with, standard development practices. As summarized below, the conventional plan primarily contains residential units, including single-family detached, garden apartments, and townhouses, along with a high school, a fire and police station, a golf club, and a shopping/gas store.

Figure S-5
SUMMARY OF CONVENTIONAL PLAN

Use Type	Building Area (in Sq. Ft.)	Percent
Single-Family Detached		
(1,600 x 73 units)		
(2,200 x 26 units)	174,000	26.5
Townhouse		
(1,200 x 20 units)		
(1,500 x 30 units)	69,000	10.6
Apartment		
(950 x 80 units)		
(1,300 x 120 units)	232,000	35.4
Senior High School	160,000	24.3
Fire/Police Station	2,400	0.4
Golf Clubhouse	14,700	2.2
Commercial Space	4,000	0.6
Total	656,100	100.0

The land use allocated for a church/day care center is within the study area; however, the team decided to omit the center from the study because essentially no changes would be made on it throughout the study and the energy consumption was negligible. A maintenance building is also omitted from the analysis because it does not change throughout the analysis and is neither heated nor cooled.

The construction cost per square foot with lot and site development costs for each building type is presented below. The costs include the energy end-use systems and represent the costs associated with the standard construction. Standard construction implies: (a) single-glazing in residential units, double-glazing in nonresidential units; (b) R-11 insulation in walls, R-19 insulation in ceilings; (c) standard 2 x 4 frame construction in residential units, golf club, and convenience store; and (d) brick veneer with interior concrete block in the school and fire/police station.

The conventional plan as described in Figure S-6 would use both electricity and natural gas. Natural gas would provide space heating, water heating, and cooling needs and electricity would apply cooling, lighting, and miscellaneous needs except in the high school, where heating would be provided by electricity. The total annual projected electrical energy consumption for the conventional plan is 8932.5 MWH. The total annual projected natural gas consumption for the conventional plan is 29,790.2 MMBtu. Figure S-7 summarizes these total annual costs; Figure S-8 describes the total construction, development, and energy costs; and Figure S-9 indicates the present value of all conventional plan costs by cost centers, including construction, development, energy, and interest on construction.

THE CONSERVATION OPTIONS

Level 1 (Passive) Plan

The types of architectural passive systems geared for a particular building type often create a framework from which the site design may begin. For example, the types of solar collection systems will often dictate the size and length of adequate solar access corridors in the site plan. The following summarizes passive options that were considered applicable for the Shenandoah site plan.

Solar Access -- Solar access depends on the means by which the solar collection takes place. It is obvious that many different collection systems will give direction to land use density and layout. Stein (1977) devised three methods in which solar access would work. The first method which he described allows the sun to penetrate a target wall within a 30 degree angle off the perpendicular of due south. The second method assures solar access between certain hours of the day, for example, between 8 a.m. and 4 p.m., for all seasons where the sunlight would be unimpeded. At all other times, partial sunlight would hit part of the wall. The third method provides all sunlight where the sun is 15 degrees altitude above the highest part of the wall. When comparing the three methods, the results of solar availablity are quite different. Each method will result in different percentages of efficiency.

Building Orientation--Olgyay (Design with Climate, 1963) conducted tests which involved optimum building placements for energy conservation. In his method, known as the "Sol Air" approach, he found that for buildings within the hot-humid region an orientation at 5 degrees east of south was an optimum building position for human comfort. In some cases living areas of buildings might face orientations other than the optimum when restricted by grade.

Cluster and Group Layout Responses to Sun and Wind -- The climatic conditions which prevail in the Shenandoah area dictate slightly greater heating requirements than in Olgyay's illustration. The goal here is to provide adequate solar access to each building unit and create protection from winter winds by the arrangement of the buildings and yet provide adequate air ventilation and protection from solar loads by relieving some of the adverse weather impact.

Figure S-6
CONSTRUCTION, LOT DEVELOPMENT, AND SITE
DEVELOPMENT COSTS, CONVENTIONAL PLAN

Building Type		Units	$/sf	$/unit	Total $	Lot Development	Site Development
Single-Family Detached	(1,600)	73	23	$ 36,800	$2,666,400	$ 113,600	$ 383,202
	(2,200)	26	24	52,800	1,372,800	39,910	186,806
Townhouuse	(1,200)	20	23	27,600	552,000	20,039	79,446
	(1,500)	30	24	36,000	1,080,000	37,711	148,157
Apartment	(950)	80	20	19,000	1,520,000	51,673	243,075
	(1,300)	120	20	26,000	3,120,000	105,867	511,034
Senior High School		1	32	5,120,000	5,120,000	152,588	521,770
Fire/Police Station		1	40	96,000	96,000	34,367	8,589
Golf Clubhouse		1	48	705,600	705,600	44,770	47,238
Commercial Space		1	24	96,000	96,000	40,980	12,883
Total					$16,348,800	$641,505	$2,141,200

Figure S-7
SUMMARY OF TOTAL ANNUAL
ELECTRICITY AND NATURAL GAS CONSUMPTION, CONVENTIONAL PLAN

		Annual Electricity Consumption Total (MWH)	Annual Natural Gas Consumption Total (MMBtu)
Single Family	(1,600)	1,285.64	8,253.86
	(2,200)	633.22	4,065.34
Townhouse	(1,200)	302.47	1,352.54
	(1,500)	614.11	2,746.06
Apartment	(950)	1,446.36	4,522.84
	(1,300)	2,686.10	8,399.56
Senior High School		1,532.70	220.30
Fire/Police Station		66.70	31.10
Golf Clubhouse		287.10	156.10
Commercial Space		78.10	42.50
TOTAL		8,932.50	29,790.20

Figure S-8
TOTAL CONSTRUCTION DEVELOPMENT,
AND ENERGY COSTS

		Base Construction Cost	Base Development Cost	Base Energy Cost	Total Cost
Single Family	(1,600)	$3,290,822	$ 585,716	$1,879,685	$5,756,224
	(2,200)	1,616,006	288,488	925,741	2,830,235
Townhouse	(1,200)	691,152	120,855	396,577	1,208,583
	(1,500)	1,283,566	244,407	805,276	2,313,251
Apartment	(950)	1,852,752	366,388	1,909,344	4,128,474
	(1,300)	3,761,696	744,005	3,545,280	8,050,981
Senior High School		6,195,200	815,973	1,395,291	8,406,464
Fire/Police Station		116,160	51,977	79,793	247,930
Golf Clubhouse		853,776	111,330	336,161	1,301,267
Commercial Space		116,160	65,174	88,953	270,287
TOTAL					$34,513,696

Figure S-9
PRESENT VALUE OF COSTS, CONVENTIONAL PLAN*

Cost Center	Base Contruction Cost	Base Development Cost	Base Energy Cost
Detached Dwelling Units	$ 4,906,828	$ 874,204	$ 2,805,426
Cluster Dwelling Units	7,589,168	1,455,654	6,656,467
Institutional Facilities	6,311,360	867,950	1,475,084
Community Facilities	969,936	176,504	425,114
Total	$19,777,293	$3,374,312	$11,362,091
Interest	$ 988,865	0	0

TOTAL NET PRESENT VALUE - $35,502,561

The assumptions behind this analysis are:+

Analysis Information	
Analysis Period	22 years
Construction Period	3 years
Annual Interest Rates	
Construction Financing	5.00 percent
Discount Rate	10.00 percent
Return on Investment Capital	20.00 percent
Annual Escalation Rates	
Construction	10.00 percent
Energy	
Electricity	7.50 percent
Gas	10.00 percent
Thermal	5.00 percent

* All Costs Are Present Value Dollar, Jan. 1, 1981, the projected starting date for construction to begin at the SAND study site.

\+ All changes in cost for construction and energy, unless otherwise stated, refer to these figues and assumptions.

Microclimate Evaluation--Microclimates are extremely difficult to measure with accuracy because of the high number of variables involved in creating them. The variables which make up a microclimate are air temperature, sun and radiation intensity, winds, precipitation, humidity absorption of heat from sky and ground, topography, aspect, surface cover, and ground material. (Foster, Landscaping that Saves Energy Dollars, 1978).

The site at Shenandoah, because of its sloping terrain, soil and vegetation diversity, and abundance of water has many different microclimates. In order to locate and accurately define the microclimates which exist on site, a detailed inventory and site analysis of natural site factors was carried out and provided direction for the development of the passive plan by qualifying potential microclimatic areas that are most favorable for intense development and limiting development of unfavorable microclimatic areas. To be most energy-effective, the highest energy-using land uses must be sited in microclimates that, for the most part, contain air temperatures, humidity, and wind levels near the "human comfort zone" as stated by Olgyay (1963).

When siting for microclimate control, certain trade-offs must be made. Although many areas may be favorable for certain development, different land uses may not be compatible with one another. Or, certain sites may have difficult access requiring extensive site preparation costs, which in itself requires additional energy for the construction of roads. Use of this option also requires evaluation of proximity, accessiblity, and land use compatibility.

Shading and Cooling--Reducing heat build-up during the summer involves three design objectives, according to Egan (Concepts in Thermal Comfort, pp. 23-53): (a) reduce penetration of solar radiation; (b) improve evaporative cooling condition by proper building layouts; and (c) lower the heat gain from reflectant surfaces.

Reduction of solar radiation gain involves planting or preserving trees on east and west exposures of structures, since the low sun angles are closer to perpendicular to the building in early morning or mid/late afternoon. Another way of lowering direct solar gain is to reduce east and west wall areas and to eliminate most of the windows in those areas. Egan shows that mature hardwood trees allow about 20 to 25 percent of radiation to pass through.

Proper placement of excessive heating surface away from cool air openings in buildings is an important consideration in the planning process. Deciduous shrubs might be used to protect dwellings from radiant heat by providing a buffer zone of absorption where in winter, when loss of leaves occurs, the radiant heat from the parking lots may be absorbed by the dwelling. However, improper shrub placement may result in air stagnation.

Shrubs and trees may be used to buffer the reflectivity of a hard surface. Plumbley reports that ground reflectivity during midday significantly increases solar radiation on vertical surfaces ("Metropolitan Physical Environment," USDA, 1977, pp. 152-169). By proper location of trees and shrubs and the correct selection of such species, or the maximum preservation of existing species, a significant reduction in energy for space cooling would occur.

Berming--Partial earth berming on north and west exposures of the building was also a consideration in the overall site planning of the project. Although berming may not be suitable for some buildings, the plan was allowed the flexibility of providing berming for all structures on site. The cost effectiveness of berming involves a study of soil nature, grade, and structural requirements of the building. It is known that partial berming creates a reduction in heating and cooling loads by eliminating wall exposure and using the thermal lag in the heating and cooling cycle of the soil.

The Reorientation of Existing Planning Codes and Policies--At Shenandoah enforcing builders to comply with passive site design standards was also a consideration. The planning policies might require adequate sun access and breeze channelization, yet be flexible on setback and minimum lot size requirements.

Proper north-south lot orientation with lower side-lot setback distances would provide some protection from low summer sun and winter winds by allowing shading. Setback distances from the street might be made more flexible where optimum building orientation is needed for maximum sun access or where air circulation is needed.

Another planning reorientation consideration in the site design was the reduction of street widths from 24 feet to 20 feet and right-of-ways from 50 feet to 40 feet. It is obvious that a considerable amount of energy and money expended in the construction of the roads can be saved. The reduction of right-of-way (R.O.W.) widths saves more valuable land and reduces sprawl, not to mention a reducing pollution from nonpoint sources. Narrow streets bring the scale down to a pedestrian level and can be shaded more easily.

Level 2 (Dispersed Systems) Plan

The study team considered an assortment of dispersed energy options for the Level 2 (dispersed systems) Plan. Dispersed energy options are devices that can be incorporated into individual buildings. Options such as district heating were not considered. A preliminary screening used technical feasibility, cost effectiveness, and marketability as criteria to select specific alternatives for further analysis. In the screening process for the Level 2 Plan, the study team considered installation of the dispersed options mainly in single family units. The options selected for inclusion in Level 2 were evaluated in other land use settings to determine their total potential for implementation.

Level 3 (Central Utility) Plan

In the case of the Shenandoah development, it was felt that a central plant could conserve energy through the more efficient use of primary fuels, stabilize energy costs, and accrue savings to the residents of the community in the areas of capital outlay cost and maintenance and operating costs. To do this, the plan had to be feasible within the constraints of financing, current technology, phased construction, and marketability to the end-user.

Two levels of central utility plant schemes were considered. The first level considered the total 7,400-acre Shenandoah development as being the ultimate build out and service area of the central utility plant. It was anticipated that a central power plant in the capacity range of 30 to 60 megawatts could be constructed on a site adjacent to the Shenandoah Industrial park. The design of the plant would include provision for district heating, cooling, and process steam for industrial customers. Electricity from the plant would be congenerated with the steam and thermal energy uses and tied into the Georgia Power Company electrical distribution grid in a Total Integrated Energy System (TIES) mode of operation. This option was eventually abandoned because of site-specific technical considerations and Shenandoah's long build-out period.

A second plan considered a small central utility plant, located within the 235-acre SAND study site which would be phased to serve the site and, possibly the adjacent sites which were still available. The small site central utility plant would be designed to provide thermal energy for heating and cooling and electric energy which could be sold into the electric utility company's power grid.

The six fuel alternatives for a small utility plant are as follows:

- fuel cell Integrated Community Energy System-Total Integrated Energy System (ICES-TIES) mode,
- internal combustion engine with heat recovery ICES-TIES mode,
- wood-fired thermal/electric ICES-TIES mode,
- photovoltaic ICES-TIES mode,
- solar thermal central plant, and
- solar thermal/electric ICES-TIES mode.

It appears that the wood-fired cogeneration system is the most suitable of the central plant schemes. The first costs and operating costs are relatively low when compared to other central plant options of this size. One important favorable point of the wood-fired cogeneration plan is the use of a nondepletable fuel. Present research and development work and funding is wary of systems based on scarce fuels, while much effort is being placed into alternative fuel use.

CONSERVATION PLANS

Level 1 (Passive) Plan

The concept for the development of mixed land uses at Shenandoah as a passively sited, energy-conserving community is based on a plan that would use the natural site characteristics, maximize on passive energy siting requirements, and allow flexibility for the changing needs of the Shenandoah Development Corporation (Figure S-10).

The northern portion of the site would be developed primarily for public facilities. The high school, church/day care facility, and police/fire station would be developed here, because each facility requires direct accessibility and visiblity from Georgia Route 34 and each facility is centrally located to future developments. The convenience store would also be developed here to take advantage of the central location and high visibility provided by this site.

Apartments and townhouses would be developed in the central portion of the site since slope, aspect, and soils are most favorable for this high intensity development. These land uses would be serviced by a loop road from Road "C." This site has close proximity to open space and goods and services. Single-family development would also be located in this area, with adequate separation from the proposed high density residential by the loop road and an open space corridor.

The southern portion of the site would be developed primarily for single-family detached residential units. This area, in addition to having good soils and slope exposures, is removed

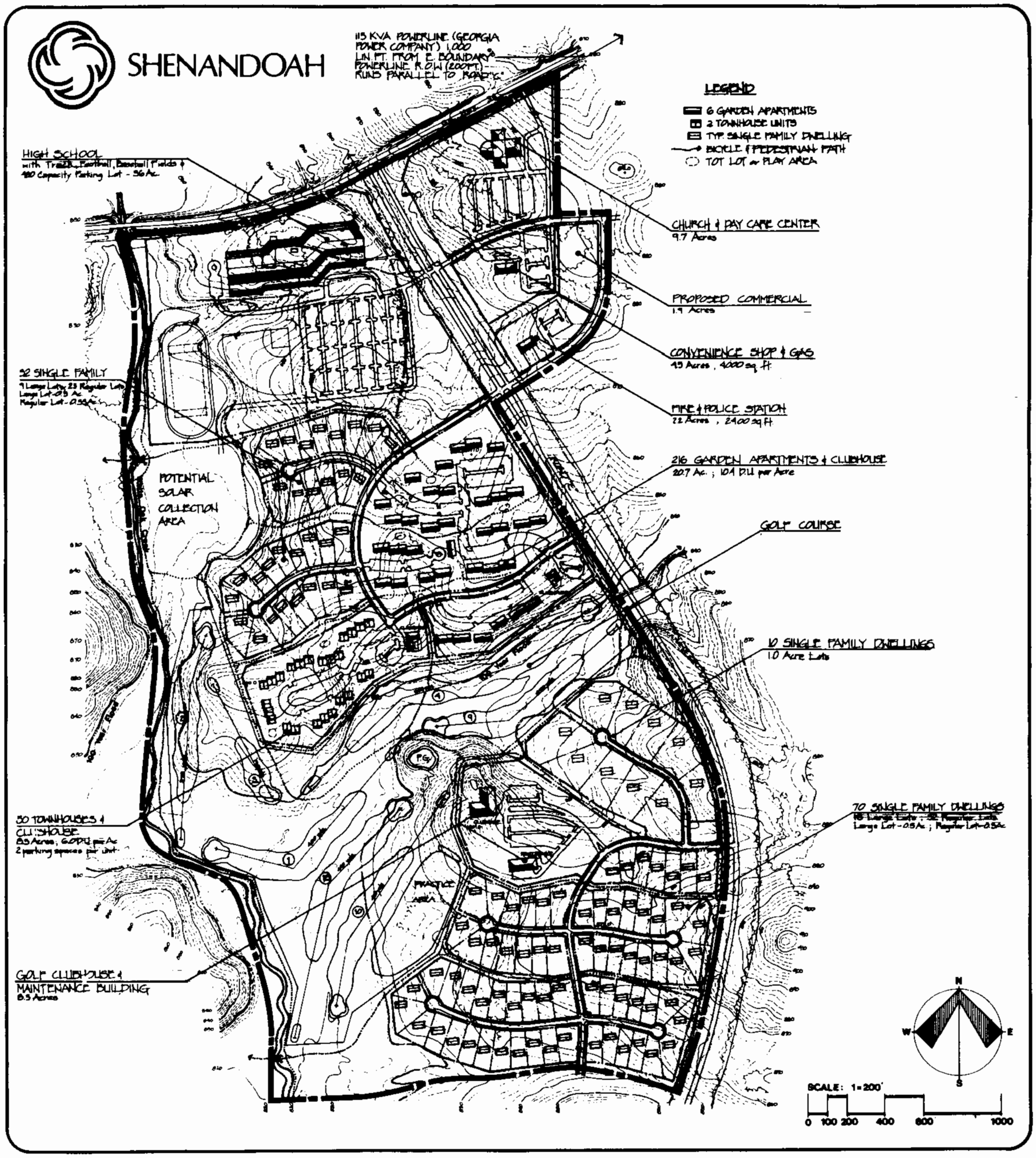


Figure S-10

CONSERVATION PLAN FOR PASSIVE/DISPERSED SYSTEMS
Source: Shenandoah Report Map 1.4

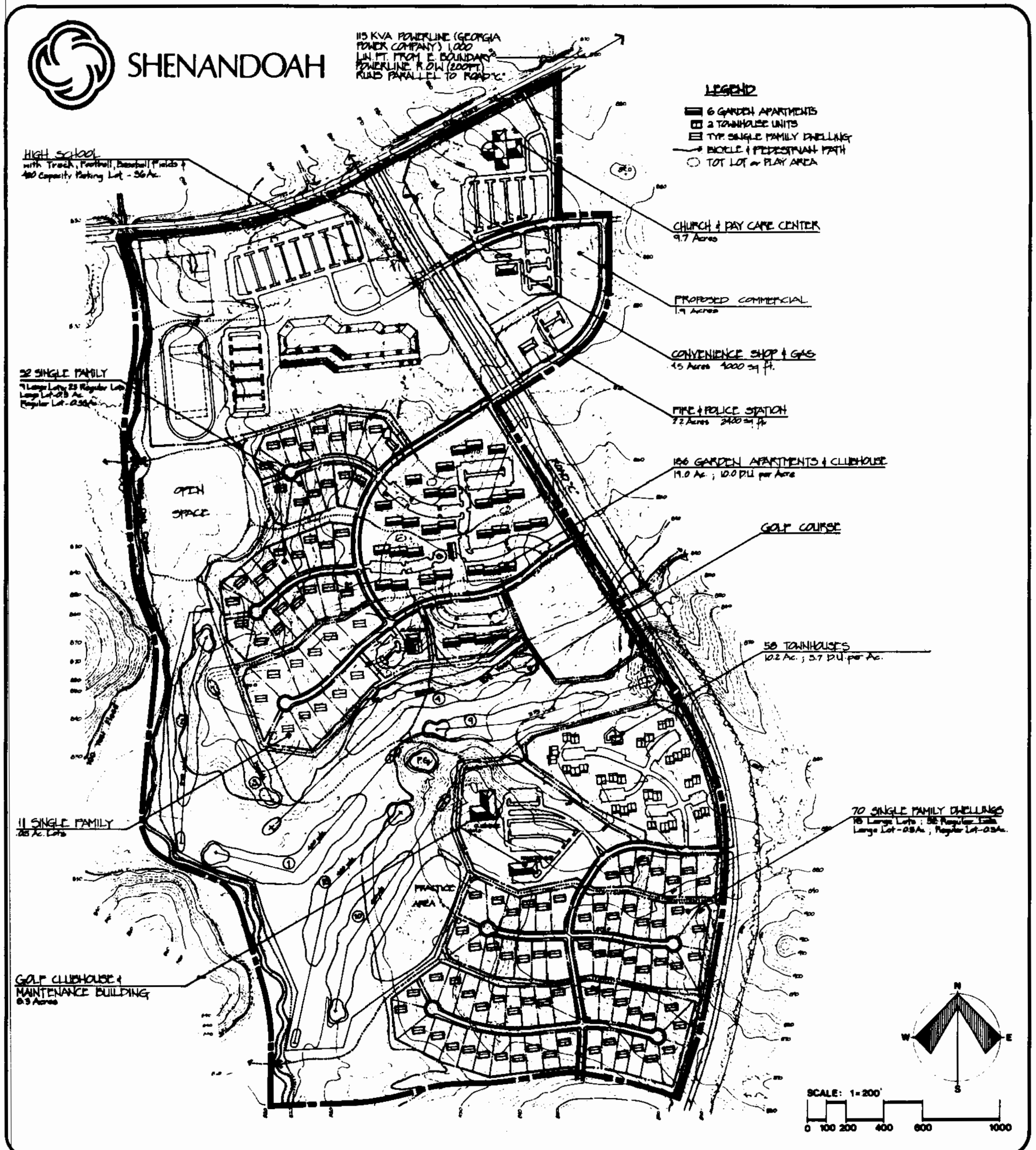


Figure S-11

CONSERVATION PLAN FOR CENTRAL UTILITY SYSTEM
Source: Shenandoah Report Map 1.5

from areas planned for higher intensive residential development and from public services and would be more suited for single-family homes. This area would be serviced by a loop road from Road "C" which would connect with future residential development to the south.

The golf course would occupy a major portion of the flood plain with the clubhouse and maintenance building on a north slope. The area that would be developed for the clubhouse is most suited for this facility because of its location in relation to the golf course.

Two groups of changes in the building construction would be necessary. First, in order to increase the overall thermal efficiency of the building and to reduce air infiltration certain changes would be needed. The revised construction calls for increasing the R-value of the walls and roofs of most of the building types. The R-values of the walls and roofs would be increased from R-11 and R-19 to R-19 and R-26. In addition, all windows would be replaced with double-glazing. Finally, a tighter building would be built by caulking around windows, doors, and any other part of the building where a structural break is made. These changes would reduce the overall U-value of each building and reduce air infiltration.

The second type of change necessary in the actual building design would be to accommodate the passive siting of each building. When the townhouses and apartments were designed in the clusters, rather than in the rectangular configuration shown in the conventional plan, the total perimeter of the buildings increased. This increase naturally would add to the cost of construction and was taken into account. Because of the southern exposure that would be enjoyed by nearly all of the buildings and the increased glass areas on the southern walls, care would have to be taken to minimize the direct solar gain through these windows in the summer months. To accomplish this, the plan calls for overhangs to be added to all buildings along the southern glass areas. The width of the overhangs would be approximately three-quarters of the height of the glazing.

The changes which would be necessary outside of the building include shading, berming, and shelterbelts. Shading would be provided by existing vegetation and additional planting. These changes would require that care be taken when grading and lot preparation is done to leave those trees which would enhance shading and act as shelterbelts. Planting of shade trees would be necessary on some single-family, apartment, and townhouse units in addition to the school, fire/police, and convenience store buildings. With proper shading placement, as much as 75 percent of direct solar radiation can be relieved.

Berming would be required on the townhouses and the school buildings. The townhouses would have their lower levels either partially or totally bermed depending on the particular slope on which they were placed. The school would have total protection on the north, east, and west walls.

By using the earth berms, existing vegetation, and additional planting, air infiltration could be reduced substantially. However, these shelterbelts would have to be located not more than 20 nor less than from 10 feet from the structures. Previous research has indicated that a properly placed shelterbelt can reduce air infiltration by 40 percent.

Level 2 (Dispersed Systems) Plan

The Level 2 plan is identical to the Level 1 site plan, except that a series of decentralized systems have been added to the residential units (Figure S-10). Four of the options presented earlier were considered economically and technically feasible and marketable; these were solar water heating, direct gain systems, attached greenhouse, and Trombe walls. Since it is unlikely that both a direct gain system and a Trombe wall would be used in conjunction with one another, the study team decided to use only the direct gain system in the Level 2 analysis.

Level 3 (Central Utility) Plan

In the central utility plan, the location of the central plant is on the eastern side of the site in a central location to the study site. The basic site plan is similar to the Level 1 plan, except that higher density dwellings have been moved to areas adjacent to central site. This move would reduce the distribution costs of these more dense, more energy-intensive land uses. Other than these changes, the same principles which were discussed in the Level 1 plan hold and were used for development of the Level 3 plan. The actual plant which is recommended for the site is the wood-fired cogeneration plant.

CONSERVATION PLANS SAVINGS

Level 1 (Passive) Plan

As indicated in Figure S-12, under this plan the total annual electrical savings is 496.25 MWH, and the total annual natural gas savings is 8,907.88 MMBtu. The electrical savings is 5.5 percent annually and the natural gas savings is 29.9 percent annually over the conventional plan.

The primary reason that the projected natural gas consumption was effected so greatly, while the electricity consumption was not, is that most of the features which the passive plan would incorporate enhance the heating of the buildings, rather than the cooling. The berms, shading, shelterbelts, southern glazing, overhangs, double glazing, and improved tighter construction would serve to allow more solar energy in and to reduce air infiltration. The main effects of these features are to reduce the heating load; in some cases these features can have detrimental effects on the cooling loads. Because of the theoretical nature of these designs and the computer simulation used to estimate energy loads, the reduced infiltration and increased southern glazing can actually increase the cooling load in some summer months in some buildings. The study team did, however, attempt to correct for these occurrences.

Figure S-12
ANNUAL ELECTRICITY AND NATURAL GAS
CONSUMPTION AND SAVINGS, PASSIVE PLAN

	Electricity		Natural Gas	
	Total Annual Consumption (MWH)	Total Annual Savings (MWH)	Total Annual Consumption (MMBtu)	Total Annual Savings (MMBtu)
Single Family (1,600)	1,137.45	148.19	5,802.52	2,451.34
(2,200)	560.16	73.06	2,287.90	1,207.44
Townhouse (1,200)	294.87	7.60	931.34	421.20
(1,500)	598.51	15.60	1,890.76	855.30
Apartment (950)	1,363.96	82.40	3,134.04	1,388.80
(1,300)	2,532.50	153.60	5,820.76	2,578.80
Senior High School	1,515.10	7.60	220.30	0.00
Fire/Police Station	66.70	0.00	31.10	0.00
Golf Clubhouse	283.10	4.00	152.20	3.90
Commercial Space	73.90	4.20	41.40	1.10
	8,436.25	496.25	20,882.32	8,907.88

Level 2 (Dispersed Systems) Plan

The total annual electrical "savings" projected for the dispersed systems plan is actually an additional 160.82 MWH over the passive plan. The annual natural gas savings, however, is 10,648 MMBtu when compared to the passive plan. Although the former represents a 1.9 percent increase in electricity over the passive plan, the dispersed systems plan would still use 335.43 MWH or 3.8 percent less electricity than the conventional plan. The Level 2 Plan would use 51 percent less natural gas than the Level 1 Plan does and 19,555.88 MMBtu or 65.6 percent less natural gas than the base conventional plan.

Figure S-13
ANNUAL ELECTRICITY AND NATURAL GAS
CONSUMPTION, DISPERSED SYSTEMS PLAN

		Total Annual Electricity Consumption (MWH)	Total Annual Natural Gas Consumption (MMBtu)
Single Family	(1,600)	1,176.87	2,809.52
	(2,200)	579.66	1,388.90
Townhouse	(1,200)	303.07	417.34
	(1,500)	613.81	930.76
Apartment	(950)	1,389.56	1,590.04
	(1,300)	2,585.30	2,652.76
Senior High School		1,525.10	200.30
Fire/Police Station		66.70	31.10
Golf Clubhouse		283.10	152.20
Commercial Space		73.90	41.40
		8,597.07	10,234.32

The additional electrical requirements are for the pumps necessary to run the active solar water heating systems. Naturally, the largest savings, and it is quite substantial, is in natural gas consumption. Because no decentralized cooling systems were economically feasible, the three alternatives chosen--direct gain, attached greenhouse, and solar water heating--all supplement natural gas for water heating and space heating.

Level 3 (Central Utility) Plan

Because of the chilled water cooling, a substantial amount of the electricity load is reduced. The central utility plan uses 29.6 percent or 2,499.4 MWH less electricity than the passive plan and 2,995.65 MWH or 33.5 percent less electrical energy than the conventional plan. Because of the hot water distribution, 100 percent of the natural gas used for space and water heating is replaced by the thermal energy generated at the central plant. Naturally, to offset these benefits, 33,779.52 MMBtu of thermal energy are required for the heating and cooling of buildings on the site.

Figure S-14
ANNUAL ELECTRICITY AND NATURAL GAS
CONSUMPTION AND THERMAL NEED, CENTRAL UTILITY PLAN

		Total Annual Electricity Consumption (MWH)	Total Annual Natural Gas Consumption (MMBtu)	Total Annual Thermal Need (MMBtu)
Single Family	(1,600)	841.07	0	6,551.02
	(2,200)	414.04	0	3,226.60
Townhouse	(1,200)	215.07	0	1,573.20
	(1,500)	397.81	0	2,921.70
Apartment	(950)	802.36	0	5,748.00
	(1,500)	1,643.30	0	11,670.00
Senior High School		1,262.40	0	1,508.00
Fire/Police Station		57.00	0	89.00
Golf Clubhouse		242.00	0	387.00
Commercial Space		61.80	0	105.00
		5,936.85	0	33,779.52

IMPLEMENTATION

The criteria for evaluating different energy-conserving options were technical feasibility, economic feasibility, and marketability. Although an option may meet the criteria, other factors could constrain its development. Impediments could include regulations and opposition from participants in the development process (utilities, bankers, zoning boards, builders, developers, etc.). This section discusses the most pertinent impediments to the development of energy-conserving communities.

The impediments for the Level 2 plan, which uses dispersed energy devices, are quite different from those for the Level 3 plan, which uses a central utility with thermal energy distribution. Impediments for the Level 1 passive plan would be similar to those for Level 2. The following categories of impediments may constrain implementation of energy-conserving designs in the community.

IMPEDIMENTS TO LEVELS 1 AND 2 PLANS

Utility Attitudes

In the Level 1 and Level 2 plans, the major utility requirement is for natural gas on either a primary or back-up thermal energy source and electricity as a power source for lights, cooling, and appliances. Georgia law requires that the utility companies provide energy in their service areas except in unusual circumstances that would probably not be applicable to the SAND study area. The Atlanta Gas Light Company has indicated that it would provide service to energy-conserving customers. The Coweta-Fayette Electric Membership Corporation (EMC) stated that it is currently providing "back-up" service to a few "solar customers" and, therefore, would be willing to provide some or all of the types of service required by these plans.

The Georgia Public Service Commission (PSC) has jurisdiction over Atlanta Gas Light Company policies and rates but not over Coweta-Fayette EMC. Atlanta Gas Light Company expressed a willingness to cooperate with energy-conserving developments to establish equitable rates; however, the rates would be subject to the load characteristics of the development, and Atlanta Gas Light Company has the approved right to add a surcharge to certain customers who have minimal energy requirements. A key provision for the SAND study area is that the annual load factor be less than 5 percent. The PSC will not allow the use of this surcharge in most cases when the load factor is greater than 5 percent. This is invariably true when gas is the sole source of thermal energy. The surcharge that may be added is $8 per therm per year. In all liklihood, the utilities would not constrain development of energy-conserving features in any way.

Utilities can also help promote installation of more energy-efficient options. For example, the Tennessee Valley Authority is hoping to bypass the construction of 2,000 megawatts of electric power plants through programs in energy conservation, solar energy, and wood energy. However, the capital investment for new capacity needed by gas utilities is substantially lower than that needed by electric utilities. Thus, it is unlikely that Atlanta Gas Light will be inspired to strongly support programs that decrease natural gas demand.

Regulatory and Legal Constraints

Regulatory measures can constrain or encourage implementation of energy-conserving designs. The most severe constraints occur in existing communities, where a variety of regulations govern additions to houses, and in communities having strict development plans that include no provision for energy conservation.

Land Use Regulations--The only land use regulation which is currently in effect for the SAND study development is the Coweta County Zoning Resolution. However, county approval of a proposed plan requires consideration by local county officials since the infrastructure will ultimately be dedicated to the county. Preliminary review indicates some potential impediments may be posed by maintenance considerations for open drainage channels. This review may require the elimination of some or all of the open drainage channels in order to implement the plan. There may be additional requirements imposed by subsequent reviews.

The SAND study development area is a part of a new community (NC) district described in Article 9-A of the zoning resolution. This type of district was established for innovative developments of large tracts of land in Coweta County and allows significant design and planning flexibility. Therefore, there are no zoning regulations in direct conflict with any of the proposed site plans. The major drawback to the resolution is that it provides no means for implementing any energy-conserving plan.

Building Codes--The Southern Standard Building Code is applicable, with minor modifications, to the SAND study development area. In January, 1978, the Southern Standard Building Code Association completed a contract with the National Bureau of Standards to determine if the code contains any conflicts which would deter the use of solar energy. Although none were found, it was recommended that the codes be modified to include some additional provisions which would require energy-efficient building design. These provisions are embodied in the Georgia State Energy Code for Buildings, effective July 16, 1978. In the absence of this or proven market experience, it is unlikely that builders could be induced to construct energy-efficient buildings. The code does not require the inclusion of solar energy systems, and many builders may be unwilling to consider solar as an option. All energy-conservation plans will require adequate enforcement of the Georgia State Energy Code for Buildings, in its entirety, by local officials to insure successful implementation of the building design features. The active systems integral to the Level 2 plan will require a favorable builders' attitude, appropriate cost-effective development guidelines, and, above all, market acceptance for their implementation.

Solar Access Provisions--One major problem with implementation of devices or designs dependent on solar radiation is how to guarantee that nearby objects will not block the path of the sun's rays. Georgia has adopted legislation, the Solar Easement Act of 1978, which validates the creation of voluntary solar easements. The easements must be privately negotiated, and it is likely that circumstances involved in some cases will make it difficult, if not impossible, for an agreement to be reached. However, it many instances solar easements should provide an effective means to insure continued solar access. Within the SAND study development area, a property owner could negotiate with his neighbor for solar easements. The negotiated easements would guarantee access to solar radiation even if either or both pieces of property were sold. Potential problems with this approach may be an adverse effect on marketability and the State of Georgia's legal limitation of 20 years duration on these easements. Based on a review of other possible alternatives, the most feasible solar access provisions appear to be those voluntary solar easements bills and the developer's use of covenants in the community, which will require amendment of the existing set (Section 9.02). Any covenants must be effective in guaranteeing solar access and, at the same time, acceptable to potential builders and homeowners.

Other Regulatory and Legal Considerations--Federal, state and local regulations provide design standards for water, sanitary sewer, and storm drainage systems and require site grading and construction practices which minimize soil erosion. There are no apparent conflicts in complying with these regulations and concurrently minimizing life-cycle energy use for the infrastructure; therefore, compliance should be routine for all the energy-conserving plans. No type of environmental impact statement is required for the Level 1 or Level 2 plans.

The National Energy Act (NEA) passed in October 1978 contains several incentives for energy-conserving design. The NEA promulgated rate design standards requiring their consideration by state regulatory agencies and nonregulated utilities. This regulation is intended to expedite the establishment of equitable rates for low or infrequent users of energy.

The NEA also contains numerous provisions for financing and tax incentives for energy conservation which should enhance marketability and expedite the implementation process. Tax credits for active solar equipment provide a 20 percent direct credit for purchases up to $2,000 and 15 percent for purchases from $2,000 to $10,000.

Environmental Concerns

Many of the features of the energy-conserving plans contain factors which are intrinsically related to the natural environment. Any incorporation of these features may inadvertently affect environmental factors in a manner that would promote the ultimate degradation of the natural environment. Coincidentally, many of the considerations for energy-efficient design correlate with environmental planning to minimize potential impact on the natural environment.

Incidence of costs and benefits

A major concern of the organizations that will have a role in the energy-conserving communities is who will pay the additional costs. Obviously, the costs will eventually be passed on to the owners of the community's buildings or will be supported by government agencies through tax incentives, direct grants, or loan guarantees.

Because the builder buys land from the developer and includes those costs in the final purchase price, the developer's costs should be passed on to the builder. Thus, the initial development costs will be paid by the developer. Upon sale of land, the builder assumes the development costs, which he includes as part of the total cost of the building to its eventual owner. Government incentives could be applied throughout this process.

For example, if the developer could not pay for shelter belts around the community, the government could provide a loan payable upon sale to the builder. If the builder was not willing to pay the extra costs of shelter belts, the government could extend the loan to him as well. If the homeowner did not consider reduced infiltration sufficient reason to pay $150 extra for a house, the government could offer a tax credit or other measures as an incentive. Without government incentive, both the developer and builder must assume the risk that the eventual buyer will be willing to pay extra for energy-conserving features.

Availability of Financing

The willingness of the investor (includes developer, builder, and buyer) to pay for energy-conserving features depends on the availablity of favorable financing for the additional costs. Banks in the Shenandoah area have given loans for solar homes so the Level 1 and Level 2 plans should not be constrained by the availability of financing.

Marketing

Marketing attempts to create a demand for a given product. In the Level 1 and Level 2 plans, marketable features for potential homeowners include reduced annual fuel costs, an aesthetically designed community, privacy provided by the large number of trees, accessibility to the nearby commercial/industrial area, modern building designs, and the novelty of living in a new town. Individuals would balance these features against the life cycle costs and future selling value as compared to conventional houses.

The Level 1 and Level 2 plans were selected because the life cycle costs were comparatively low. Nevertheless, the future selling prices of the homes are very uncertain. Individuals may perceive that rising fuel prices will ensure that the value of energy-conserving homes will increase. However, an appraiser may put a lower future price than the current buyer feels is warranted. The appraiser's view is critical as it determines the amount of financing available; the future buyer may be willing to pay the seller's price, but only if financing is available. The uncertainty of the future value may cloud the perceived attractiveness of the investment to the potential homeowner.

Builder's Attitudes

Builders, reflecting the attitudes of their homebuyers, typically try to minimize the costs of a house and virtually disregard annual energy costs required for heating and cooling. This tendency should change as fuel costs increase in the future. Nevertheless, builders remain extremely averse to designs that increase construction costs. The main reason for their conservative nature is an uncertainty whether a buyer will pay higher costs now in order to gain cost savings over the life of the house. Several approaches mentioned in the section on regulations can help overcome a builder's reluctance. Building codes can be instituted in special zones (solar energy utilization zones, for example) that require specific styles of construction. Shenandoah Development, Inc., could establish covenants that govern building designs or it could prescribe designs in the sales contract signed with the builder.

Developer's Attitudes

Shenandoah Development, Inc., has set a goal of establishing an energy-conserving community. However, it will not jeopardize its own existence by imposing too idealistic or impractical conditions on use of the lands. For Shenandoah to continue to exist, builders must buy land and construct houses, apartments, and townhouses. The developer will be very cautious about devising convenants or contractual agreements that may discourage builders. The developer, as well as the builder, is averse to additional development costs. The developer also welcomes cost savings for modifications that will not affect the eventual sale of property; thus, the Level 1 and Level 2 plans, which have lower site development costs than the conventional plan, should be attractive options.

IMPEDIMENTS TO THE LEVEL 3 PLAN

Utility Attitudes

The Coweta-Fayette Electric Membership Corporation (EMC) will supply electricity to the energy-conserving community. The EMC and its owner, Oglethorpe Power Corporation, agreed to consider ownership and operation of the central utility plant. The Georgia Power Company also expressed interest but felt that since an EMC would supply the community's electricity, Oglethorpe was the best candidate for ownership. Coweta-Fayette EMC's relationship with Oglethorpe would not allow it to own any sort of generating facility. Atlanta Gas stated that ownership was beyond the scope of its corporate purpose and policy, which is to sell natural gas. Shenandoah views its role as a land developer engaged in such activities as planning, land acquisition, and the installation of infrastructure to be deeded to the public. The company sees the ownership and operation of facilities, where necessary, is a transient activity for the developer and has no wish to own and/or operate a central utility plant. Nor does it have the technical expertise required to operate a utility plant. Coweta County has limited financial and labor resources (it took 6 years for Coweta County to accept infrastructure at Shenandoah and assumed ownership and maintenance responsibilities) to apply to such a project; therefore, it is doubtful that the county would pursue this undertaking. The only remaining alternative would be some form of private ownership of the plant and/or thermal distribution system.

Oglethorpe Power Corporation's decision to build rests primarily on several questions: Can the necessary capital be raised? Can Oglethorpe own a thermal plant and distribution system? Do they want to? Is the system indeed economical? Will the government support the system with incentives? Oglethorpe has made two commitments for proceeding with the central utility plan: (a) they will finance to some extent a feasibility study to investigate the above questions; and (b) they will go ahead with the project subsequent to favorable determinations in the feasibility study.

Environmental Impacts

The central utility plant is controlled by point source pollution regulations and is subject to numerous environmental regulations. The design of the plant meets all required pollution standards; no additional environmental problems are anticipated. Regulations of the Environmental Protection Agency require that an environmental impact statement be filed and approved for the proposed cogeneration facility prior to implementation of the plan. Although it is anticipated that the statement will be routine and will not significantly impede implementation, preparation, review, and approval are often subject to unexpected delays.

Incidence of Costs and Benefits

There are three major components of the central utility plan--the cogenerating facility, the thermal distribution system, and the individual buildings. The costs for the plant and distribution lines will be borne by the utility, presumably Oglethorpe Power Corporation. Revenues for steam and electricity sales will cover the utility's costs. The owners of the buildings will purchase the equipment used to transfer the heat in the thermal distribution lines to the rooms. The equipment will replace conventional gas furnaces, and the hot and chilled water will substitute for natural gas heating and electric cooling. However, the owners will also have to install electric heat pumps for back-up systems.

The time factor will influence the attractiveness of the central utility plan. The major costs fall before the system is even operational. The benefits accrue every year.

Financing

Oglethorpe Power Corporation raises capital through internal sources and external sources (bonds). The majority of OPC's long-term financing is guaranteed by the Rural Electrification Administration (REA). Banks in the Shenandoah area would probably provide financing for buildings up to the appraised value; however, appraisers may question the sense of investing in two heating systems. Thus, the appraised value of the thermal heating system with heat pump back-up may be less than its total cost. The economics of the system would have to be quite favorable for the system to be valued at true cost. Of course, salesmanship can help convince the appraiser of the virtues of the thermal heating system.

Marketing

The same marketing considerations exist for the Level 3 community as for Level 1 and Level 2.

Builder's Attitudes

The builders will consider the Level 3 plan much as Level 1 and Level 2.

Developer's Attitudes

The developer will consider the Level 3 plan much as Level 1 and Level 2. In order to insure that the thermal distribution system is used, Shenandoah could use covenants or provisions in sales agreements to encourage builders to install thermal heating/cooling systems. However, Shenandoah has said it will not force builders to put in one type of system. Therefore, builders must be willing to cooperate for the Level 3 plan to succeed.

SUMMARY AND CONCLUSIONS

The Shenandoah SAND case study looked at a 235-acre parcel that is part of the 7,400-acre Shenandoah new town development, 35 miles southwest of downtown Atlanta. Shenandoah new town is to be comprised of seven villages and a town center, with the villages containing schools and community facilities. The development is in the early stages of a 25-year plan, with an eventual projected population of 42,000. The area has 2,730 heating degree days, 1,539 cooling degree days, and an average maximum winter temperature of 56.8^{O}F.

The 235-acre study parcel is to contain 378 dwelling units, a senior high school, convenience shopping, and 7 holes of an 18 hole golf course. The Shenandoah SAND project developed and evaluated three alternative plans in conjunction with a conventional (base) plan. The Level 1 plan focused on passive site design. Level 2 added to the Level 1 plan active and passive decentralized heating systems to the residential structures. Level 3 examined the possibility of a central plant system for electricity and thermal needs.

ECONOMIC ANALYSIS OF PLANS

Level 1 Plan

The total present value of the passive plan is $35,202,443 over the 25-year life of the project study period. The savings/investment (S/I) ratio for the base passive plan is calculated by dividing the savings (in present value) of the energy costs realized by using the passive rather than the conventional plan by the change in investment required to implement the passive rather than the conventional plan and to bring about the energy savings. The energy savings in present value 1981 dollars is $1,231,516. The change in investment was calculated by adding the incremental interest, incremental construction, and incremental development costs. The resulting figure is $931,408. Since less money was invested than was returned in energy savings, the savings/investment ratio is greater than 1 and is equal to 1.32.

Figure S-15
INCREMENTAL CONSTRUCTION, DEVELOPMENT, AND ENERGY COSTS, PASSIVE PLAN*

Cost Center	Incremental Construction Cost	Incremental Development Cost	Incremental Energy Cost
Detached Dwelling Units	349,527	- 19,251	- 510,313
Cluster Dwelling Units	705,345	-169,303	- 704,871
Institutional Facilities	69,615	- 90,163	- 6,828
Community Facilities	28,396	- 611	- 9,514
Total	2,153,083	-279,329	-1,231,526
Interest	57,654	0	0

* All costs are present value dollars, January 1, 1981 and assumptions behind the analysis are the same as the Conventional Plan.

Total Net Present Value: $35,202,443

When making investment decisions, both the present value method and the S/I ratio method will give the same answer as to whether the investment should be made or not. However, the only true (and accepted) method to decide between two investments is the present value method. In this case the present value of costs of the passive plan ($35,202,443) is less than the present value of costs of the conventional plan ($35,502,561).

Level 2 Plan

The total present value of the dispersed systems plan is $35,344,603. The savings/investment ratio for the dispersed systems plan versus the conventional plan is 1.1. Since this is greater than 1 and since the present value of costs is less than that for the conventional plan, the dispersed systems plan is also the superior to the conventional plan.

Figure S-16
INCREMENTAL CONSTRUCTION, DEVELOPMENT, AND ENERGY COSTS, DISPERSED SYSTESMS PLAN*

Cost Center	Incremental Construction Cost	Incremental Development Cost	Incremental Energy Cost
Detached Dwelling Units	670,329	- 19,251	- 828,146
Cluster Dwelling Units	1,208,173	-169,303	-1,109,665
Institutional Facilities	69,790	- 90,163	- 6,828
Community Facilities	28,396	- 611	- 9,514
Total	1,976,689	-279,329	-1,954,152
Interest	98,834	0	0

* All costs are present value dollars, January 1, 1981, and assumptions behind the analysis are the same as the Conventional Plan.

Total Net Present Value: $35,344,603

Level 3 Plan

The total present value of the central utility plan is $36,422,816. The savings/investment analysis produces some interesting results. The present value of costs of the conventional plan is $35,502,561, while the present value for the central utility plan is $36,422,816. It may seem surprising that the central utility plan's present value is greater than that of the conventional plan. Upon examination, however, these results are understandable.

Figure S-17
INCREMENTAL CONSTRUCTION, DEVELOPMENT AND ENERGY COSTS, CENTRAL UTILITY PLAN*

Cost Center	Incremental Construction Cost	Incremental Development Cost	Incremental Energy Cost
Detached Dwelling Units	389,000	- 19,251	45,814
Cluster Dwelling Units	756,807	-169,303	214,338
Institutional Facilities	-266,683	- 90,163	-17,246
Community Facilities	38,842	- 611	- 7,186
Total	917,966	-279,329	235,719
Interest	45,898	0	0

* All costs are present value dollars, January 1, 1981, and assumptions behind the analysis are the same as the Conventional Plan.

Total Net Present Value: $36,422,816

This analysis priced the thermal energy at $10.59 per MMBtu, which should cover the construction of the central plant and all debt service. This price is relatively higher than the prices of electricity and natural gas. Therefore, the electricity which is displaced by the central utility plan, approximately 33 percent of the conventional plan's electricity consumption, and the natural gas which is totally displaced by the central utility plan are both cheaper than the thermal energy which replaces them. When examined from an overall conservation view, however, the central utility plan is extremely efficient in replacing scarce, nonrenewable energy sources with renewable, abundant sources. If this conservation goal is, indeed, considered to be in the public good, then there should be some additional "price" or benefit assigned to the conservation qualities of the central utility plan. The most obvious "price" to be assigned to this public benefit would be some form of subsidy or other monetary incentive which would defray the additional costs invoked by the plan. Therefore, with government assistance in the form of construction subsidies, tax incentives, or rate subsidization, the effective rate and effective present value of costs would be lowered. The converse of this system, of course, is to add an extra "cost" to the natural gas and electricity rates which would indicate the cost of additional use of these energy sources with respect to a national conservation policy. This would have the effect of raising the present value of costs of the other plans relative to the central utility plan. Without some form of government assistance (tax on normal energy sources or some subsidy technique for this cogeneration plan), the central utility plan would not qualify in terms of the present value analysis, given the assumptions within the model.

RECOMMENDATIONS

In light of the above conclusions, the study team recommended the following actions to encourage development of the passive plan and the dispersed systems plan:

- Investigate the use of energy-conserving and solar utilization zoning categories in the community.
- Urge the state to rigorously enforce the Georgia State Energy Code for Buildings in the Community.
- Encourage residents of the community to negotiate solar easements with their neighbors.
- Establish solar access covenants which restrict the obstruction of insolation on buildings in Shenandoah.
- Publicize the incentives passed in the National Energy Act and other federal programs for energy conservation
- Work to educate local builders, bankers, and appraisers about the economic savings of the energy-conserving plans.
- Perform market research studies to estimate the demand (and acceptable cost) for energy-conserving structures.
- Help market homes, apartments, and townhouses in the community.
- Consult with builders about the acceptability of different covenants and contractual agreements. Work out compromises that preserve the energy-conserving nature of the community.

Their specific recommendations for overcoming impediments to the central utility plan are as follows:

- Investigate in a detailed feasibility study the specific institutional arrangements for the plan.
- Provide loans for cogenerating facilities through federal, state, or private agencies.
- Make provisions for incorporating cogenerating systems with thermal distribution lines into the rate base.
- Provide tax credits for helping building owners purchase systems that use thermal energy from cogenerating power plants.

This case study, rather than serving as an application of a general theory of site planning and energy conservation, employs a potpourri of theories, some specific and some qualitative, to examine the effects of site planning and design and energy conservation. Although it is probable that the absolute values of energy consumption, energy costs, and construction costs will vary within limits around the calculated data, the relative costs and benefits should move together. The study team attempted to make its assumptions as realistic as possible, given today's life-styles and thoughts on energy conservation. Through intrastaff meetings and meetings with the advisory committees, the study team limited its degree of comprehensiveness to those options and plans which were felt would be accepted in the near term by the energy-option consumer, home buyer, and utility company. Perhaps with the energy use of the United States, the vulnerability to unreliable sources, and the shortages and recent price increases, the energy-conservation plans may seem to be too conservative. However, each of the three levels of conservation can be implemented and can show a reduction in energy consumption. In most cases this will require an increased level of investment, most of which will be passed on to the home buyer. When analyzed with respect to continued increases in the costs of all forms of energy and when analyzed over the life of the homes or other buildings, most of the options show a positive net present value.

SAND STUDY TEAM

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Architecture:
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Mechanical Engieering:
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SHENANDOAH
PROJECT DATA
(Conventional Plan)

Land Use Information

Site Area:	4,000 acres 1/ (1,620 hectares)
Total Dwelling Units:	6,000
Gross Density:	
Single-family	3.0 d.u./acre
Multifamily	9.0 d.u./acre
Net Density:	3.75 d.u./acre
Parking:	2/dwelling unit

Land Use Plan

	Acres	Percent
Residential	1,600	40.0
Commercial	200	5.0
Industrial	600	15.0
Open Space	1,000	25.0
Community Facilities	200	5.0
Roads and Utilities	400	10.0
Total	4,000 1/	100.0

Economic Information

Site Cost: $2,000/acre

Site Improvement Cost:
$4,500/single-family lot (average)

Construction Costs:
$20-24/sq. ft. (residential only)

Amenities Cost: $2,683,000[2]

Climate Information

General: Suptropical Humid

Average Temperature:
Winter . . . . . 45°F
Summer . . . . . 79°F

Average Rainfall: 53.5 inches/year

Average Annual Sunshine:
601 Langleys--May
226 Langleys--December

Unit Information

Type	Unit Size Complex	Lot Size (sq.ft.)	Sales (sq.ft.)	No.	Price	Bedrooms	Baths
Single-Family Detached	Laurel Woods	1,600	13,068	57	$44,000-$60,000	3-4	2-2½
	Buckthorne Grove	1,600	15,246	66	$44,000-$60,000	3-4	2-2½
	Windsong	1,150	15,682	49	$31,000-$45,000	3	1½
	Landsowne	2,400	37,897	12	$70,000-$90,000	4	2½
	Stonehaven	2,000	17,860	30	$60,000-$80,000	4	2½
	Deerwood	3,000	152,460	41	$80,000-$100,000	4-5	2½-3
Garden Apartment	Shenandoah Forest	800	-	48	$ 238	2	1
		860	-	22	$ 270	2	1½
		1,150	-	30	$ 307	3	1½

Notes:

1. Since the SAND final report was submitted, approximately 3,400 acres have been sold from the Shenandoah land holdings. In the body of this case study the 7,400-acre figure will be used.

2. Includes the $2,538,505 for a 58,000 square-foot solar-heated and -cooled recreation center. The solar system provides 95 percent of building's space heating, 64 percent of the cooling, 90 percent of the hot water, and 100 percent of the pool heating. DOE funded the design ($187,495) and construction of the solar system ($538,505). The recreation building was constructed under a $2 million grant from HUD.

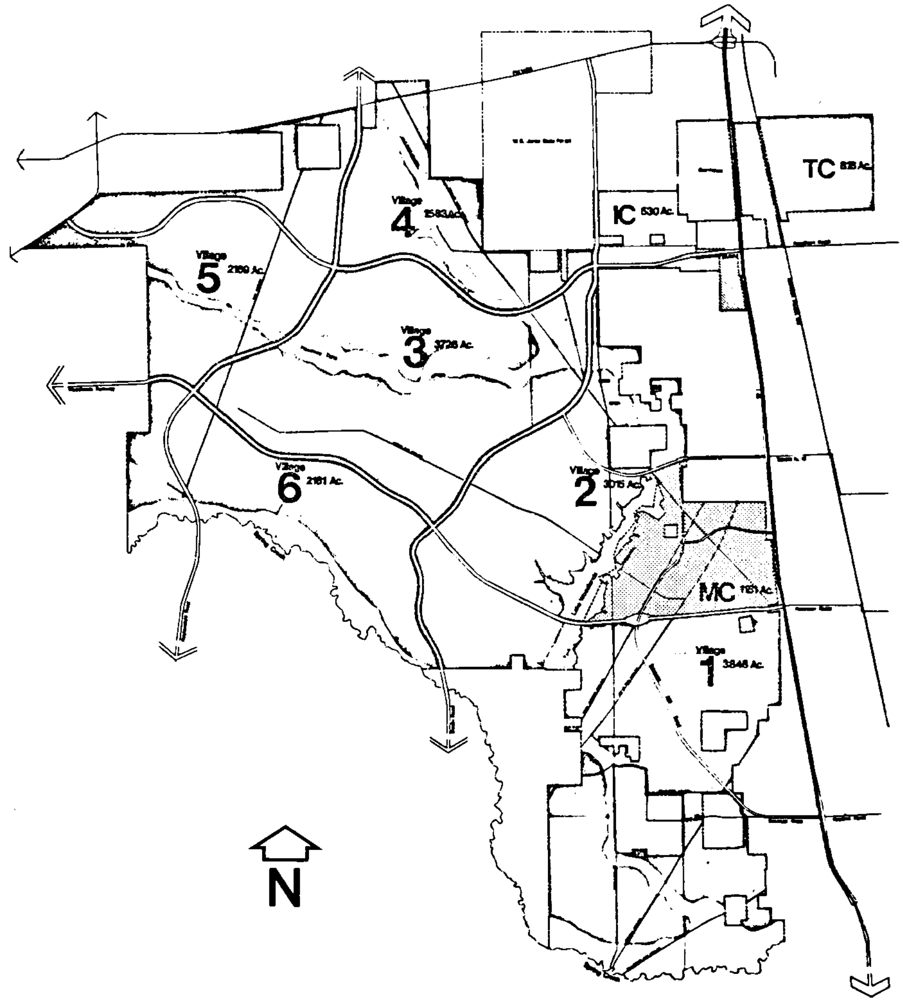


Figure W-1

THE WOODLANDS DEVELOPMENT SCHEMATIC PLAN
Source: The Woodlands Report Figure I-2

THE WOODLANDS

BACKGROUND

GENERAL DESCRIPTION

The Woodlands is a HUD Title VII new town, located 28 miles north of Houston in Montgomery County adjacent to Interstate Highway 45, which connects Houston with Dallas. The site for The Woodlands incorporates 22,000 acres and is made up of six residential villages of approximately 2,000 to 4,000 acres each, a town center called the Metro Center and several additional tracts, such as the Trade Center for large-scale industrial use. Individual villages are bounded by town-wide roads that form a major element of the transportation infrastructure. Each village is structured around one large and several supporting neighborhood centers. Included within the program for each village are schools and commercial activities, as well as employment opportunities. An open-space system provides pathway network linking the villages with the Metro Center. Residential densities in areas other than the Metro Center and its immediate environs are generally of middle and low density. Commercial development within each village is also of low to moderate intensity.

The Woodlands was planned to be developed over a 26-year period with an ultimate population of 150,000 by 1999. Development was begun during 1972, and the first phase was officially opened to the public in the fall of 1974. At the time of the SAND Study The Woodlands had a population in excess of 8,000 persons (1981 pop., 11,000), located primarily in the Village of Grogan's Mill and the Village of Panther Creek.

The Metro Center, the southern portion of which is the SAND study area, is planned as the future downtown for The Woodlands and will also serve as a major commercial area for the surrounding region. Located between Woodlands Parkway on the south, Tamina Road on the north, Lake Woodlands on the west and IH-45 on the east, the Metro Center incorporates approximately two square miles. Within the SAND study area, there are 562 saleable acres.

The land use program for the Metro Center study area calls for a high intensity, mixed-use development including offices, retail and other commercial space, high-rise and mid-rise residential development, recreational and cultural facilities, and some light industrial development. In addition, 176 acres of open space and 35,844 parking spaces are also contained in the plan.

A regional mall is planned close to IH-45 on the east, and the majority of cultural and recreational facilities are located adjacent to Lake Woodlands on the west. Most of the office development is located adjacent to major thoroughfares such as Woodlands Parkway. Residential development is concentrated within the interstices of the site, as well as adjacent to Lake Woodlands. The intensive mixed-use development (residential and commercial) generally occurs along a spine of open space transecting the site in an east-west direction. This open-space spine also forms a part of the "natural" stormwater drainage system.

PROJECT MARKET*

Phasing of development within the Metro Center study area has been scheduled in six increments with completion in 1999. The current general office and office space located in the Tech Research

* All of the methods discussed in the energy-conservation plan resulting from this SAND study, have been used by the developer for the two office buildings which were designed after this study. A computer analysis of these two buildings indicates an approximate 50 percent energy savings will be realized from the building and site design and in-building subsystem energy-conserving methods, roads, and drainage. In effect, The Woodlands is being constructed in an environment where few land-use controls are imposed by local governmental entities.

Park and Light Industrial Business Park will continue to develop through 1993, by which time retail facilities such as regional malls (1982-83) and an auto park (1982-83) will also be developed. This development program will continue to completion with the first high-rise and mid-rise residential units being developed by January 1989. The Metro Center study area at "build out" in 1999 will accommodate 8,030,721 square feet of nonresidential uses and 4,110,104 square feet of residential development, will provide employment for 24,054 persons, and will provide residences for a population of approximately 8,868 people. (Some dates and figures have been changed since the beginning of this study, but so as not to require recalculation for each change, the data on March 19, 1977 was used. The plan remains substantially the same in 1981 with the exception of a regional mall being projected for 1985-86.)

THE SITE

The Woodlands site falls within the extra-territorial jurisdiction (ETJ) of the City of Houston. Lands within Houston's ETJ are preserved for future annexation, effectively preventing incorporation of new municipalities in its suburban areas. Although its ETJ is preserved for future annexation, the City of Houston has few land-use control powers there. The major land-use requirement is that subdivision plats be submitted for approval by the city planning commission. The city has no power to require building code compliance. Further, Texas counties have little land-use control powers; they may only require building permits for flood elevation purposes and review subdivision plats.

The climate of the region is dominated by the Gulf of Mexico, which tends to mediate extremes of heat and cold, although the region's climate may generally be described as being hot and humid. Prevailing winds are southeast from February to December, while January winds tend to be northerly. Generally the area receives abundant rainfall, which is evenly distributed throughout the year. Reported annual extremes range from 17.66 inches in 1900 to 72.86 inches in 1917. Seventy-five percent of the reported years show annual rainfall amounts ranging from 30 to 60 inches. The average annual rainfall is approximately 48 inches. Fairly cool summer nights and mild winters are normal. On the average, freezing temperatures occur about seven days per year, with the average date of the first 32° F temperature (or lower) occuring on November 26, and the average date of the last 32° F temperature (or lower) occurring on March 1. The maximum number of clear days occurs in October, while the maximum number of cloudy days occurs from November to May. Daily maximum temperatures in and around The Woodlands average 63.2°F in winter and 93.5°F in summer. Mean annual relative humidity is 80 to 85 percent at 6:00 a.m. and 55 to 60 percent at noon (CST). The area receives about 65 percent of the total available sunshine annually.

RESPONSE

TEAM AND METHODOLOGY

Team Organization

The study team was organized into three components:

- the decision-making team
- the technical team
- the project advisory team

Management of the case study was centered in the decision-making team, which consisted of representatives of The Woodlands Development Corporation (WDC). The day-to-day administration of the grant occurred under the direction of the WDC Department of Community Planning and Development This staff also provided the study team with technical information on marketing, financing,

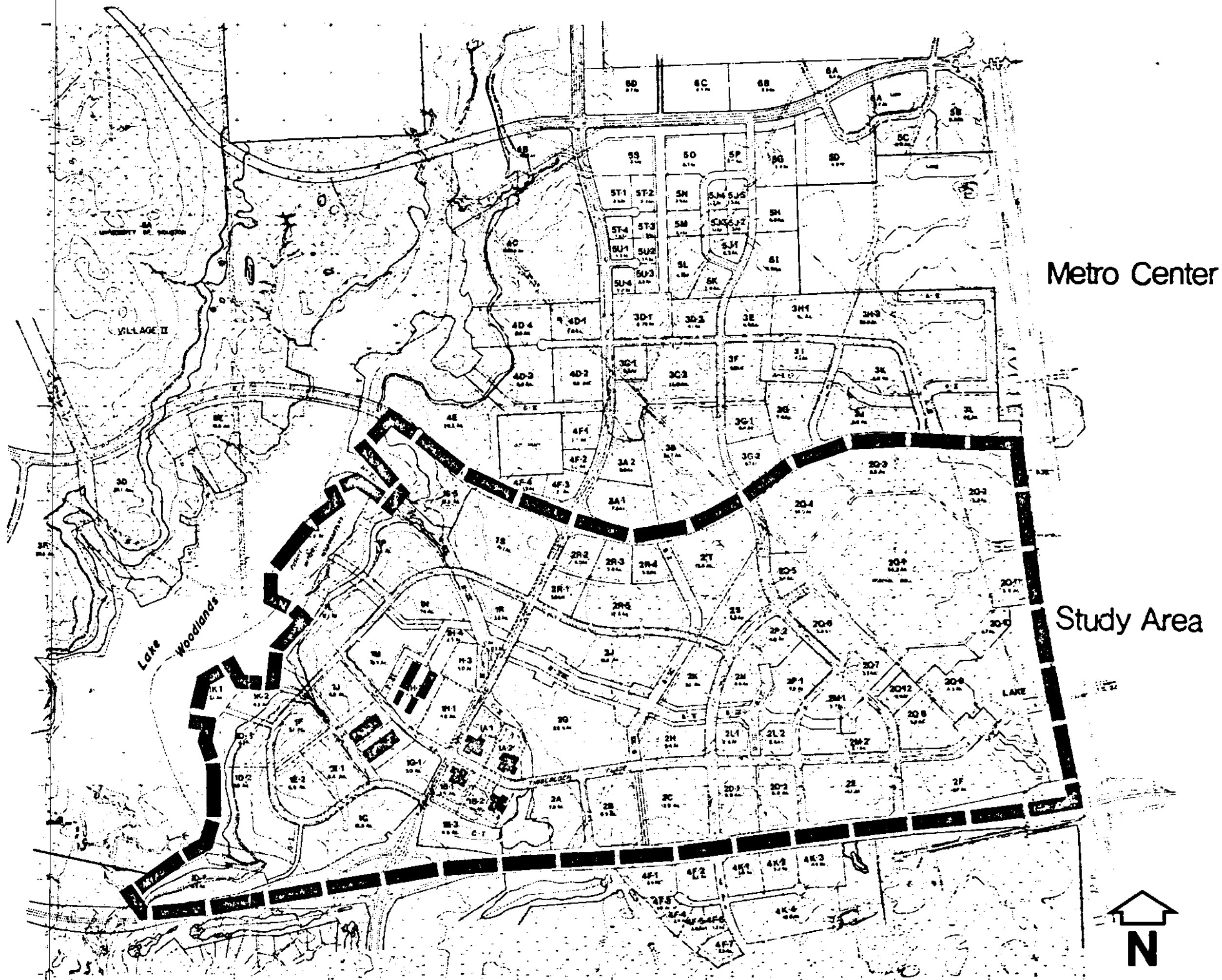


Figure W-2

THE WOODLANDS SAND STUDY AREA
Source: The Woodlands Report Figure II-4

development economics, regulatory control, and land use planning as they related to the land use practices in effect at The Woodlands.

The technical team consisted of representatives from six university-related research groups or professional firms. This group was primarily responsible for technical development and analysis of the conventional and energy-conserving plans for the Metro Center Study Area. The organizations and institutions represented and their functions were as follows:

- The firm of Phillips, Brandt, Reddick (PBR) from Newport Beach, California, was primarily responsible for the programming and land-use planning for both the conventional and energy-conserving plans.

- Technology, Engineering, Energy, Environment Management (TEEEM) of Seabrook, Texas, furnished the utility systems consultants responsible for the development of designs for the energy supply system incorporated within the energy-conserving plan. In conjunction with other members of the technical team, they also participated in the selection of energy-conserving methods beyond the immediate concerns of the supply system.

- The College of Architecture and Environmental Design of Texas A & M University, College Station, Texas, was primarily responsible for site and building design, in-building subsystems, and the analysis of energy consumption at the building scale. They also were responsible for providing economic data related to in-building subsystems and modifications to the building envelope.

- The firm of Barton-Aschman and Associates of Evanston, Illinois, was responsible for traffic and transportation planning, including estimation of energy consumption within the transportation sector.

- Frank O. Gehry & Associates, an architectural firm from Santa Monica, California, provided information on energy-efficient design of the regional mall.

- Finally, the Southwest Center for Urban Research (SCUR) of Houston, Texas, shared responsibility for project direction with WDC, especially in the more technical areas of investigation. In addition, this group provided estimates of embodied energy and environmental impact for both plans.

Membership of the Project Advisory Committee was comprised of representatives from other departments of The Woodlands Development Corporation, such as building construction, management and financing; Gulf States Utilities, responsible for providing electrical power to the region; ENTEX, responsible for the provision of natural gas to the region; the Houston-Galveston Area Council, the regional planning commission; the planning department of the City of Houston; the county engineer of Montgomery County; and the building industry. This committee acted as an advisory panel to both the decision-making and technical teams where their participation was essentially limited to review and comment. Gulf States Utilities, however, was also responsible for providing needed technical data to the technical team.

The primary forum for discussions among members of the technical team took the form of two- to three-day workshops held at The Woodlands. The Community Planning and Development Department of WDC assumed the functions of information gathering, coordination, and dissemination. While the relationship of the Project Advisory Committee to the decision-making team was direct, the relationship of this committee to the technical team occurred under the auspices of WDC.

Study Limitations

In any case study or demonstration approach, certain limitations are placed on the general applicability, breadth, and scope of the work. These limitations for this study were the following:

- The study area incorporated several limitations to land development in the form of easements and land parcels that were either already developed or in the process of development.

- The study was limited in scope to the land uses prescribed in the development program. For instance, major industrial development and low-density residential and commercial development were not included.

- The investigation was focused largely on the relatively restricted site of the Metro Center study area, essentially limiting the development of energy-conserving methods to aspects that were appropriate to the Metro Center and particular sites for development. However, in addressing the energy supply system and the transportation system, an effort was made to expand the scope of investigation beyond the limits of the study area. This allowed for the inclusion of system concepts and resource use (for example, solid waste) that are only appropriate when the Metro Center is seen as part of a larger land-development undertaking.

- Early in the study it became apparent that the application of energy-conserving methods, particularly related to transportation, (for example, reduced parking ratios, and shared parking), would result in a reduction of the actual land area consumed by the development program. The land-use requirements of the energy plan could be accommodated on a smaller site than those of the conventional plan. The problem of how to treat the residual land area while maintaining a basis for direct comparison between the two plans was resolved by postulating that the program of land development to the year 1999 would be the same for both plans and that any residual land area in the energy-conserving plan would be developed between the years 1999 and 2020.

- The project was initiated and supervised by a developer (WDC) and included some participation by relevant governmental agencies, the public utility industry, members of lending institutions, and representatives of the building industry.

METHODOLOGY

Preparation of the energy-conserving plan began with consolidation and description of the conventional plan (Figure W-3). This was necessary in order to bring prior plan descriptions to a level of specificity sufficient to allow a detailed analysis of energy consumption to be performed. The marketing program for the Metro Center study area was described in detail. This description included a more detailed specification of building prototypes, their site environs (parcels), and their expected occupancy characteristics. A parcel-by-parcel description resulted, showing individual buildings on their sites with adjacent car parks and transportation infrastructure. The phasing of each land parcel was also specified in accordance with the marketing program.

The second step in the preparation of the energy-conserving plan involved identification of planning criteria and other constraints not directly concerned with energy consumption that were to be used in the selection of energy-conserving methods. Essentially, these planning criteria and other constraints addressed issues that may inhibit or preclude implementation of elements of an energy-conserving plan. The types of criteria included gave consideration to the following areas:

- marketability--the ability to market some method, idea, or item to that portion of the public for which it was intended, with a reasonable degree of acceptance at the time it is proposed;

- functional planning--the ability for a plan to perform properly by minimizing undue time delays, congestion, and human stress;

- environmental considerations--preservation and, to a reasonable degree, maintenance of the natural environment and compliance with applicable regulatory control standards;

- socio-economic considerations--includes man-environment relations, effects on human behavior patterns, and human needs and psychological effects;

- legal and political considerations--compliance with current national and state laws and procedures and the probability of political acceptance;

- technical feasibility--the probability of technical feasibility at the time of proposed implementation;

- development economics--includes the economics of land development, building development, and utility infrastructure;

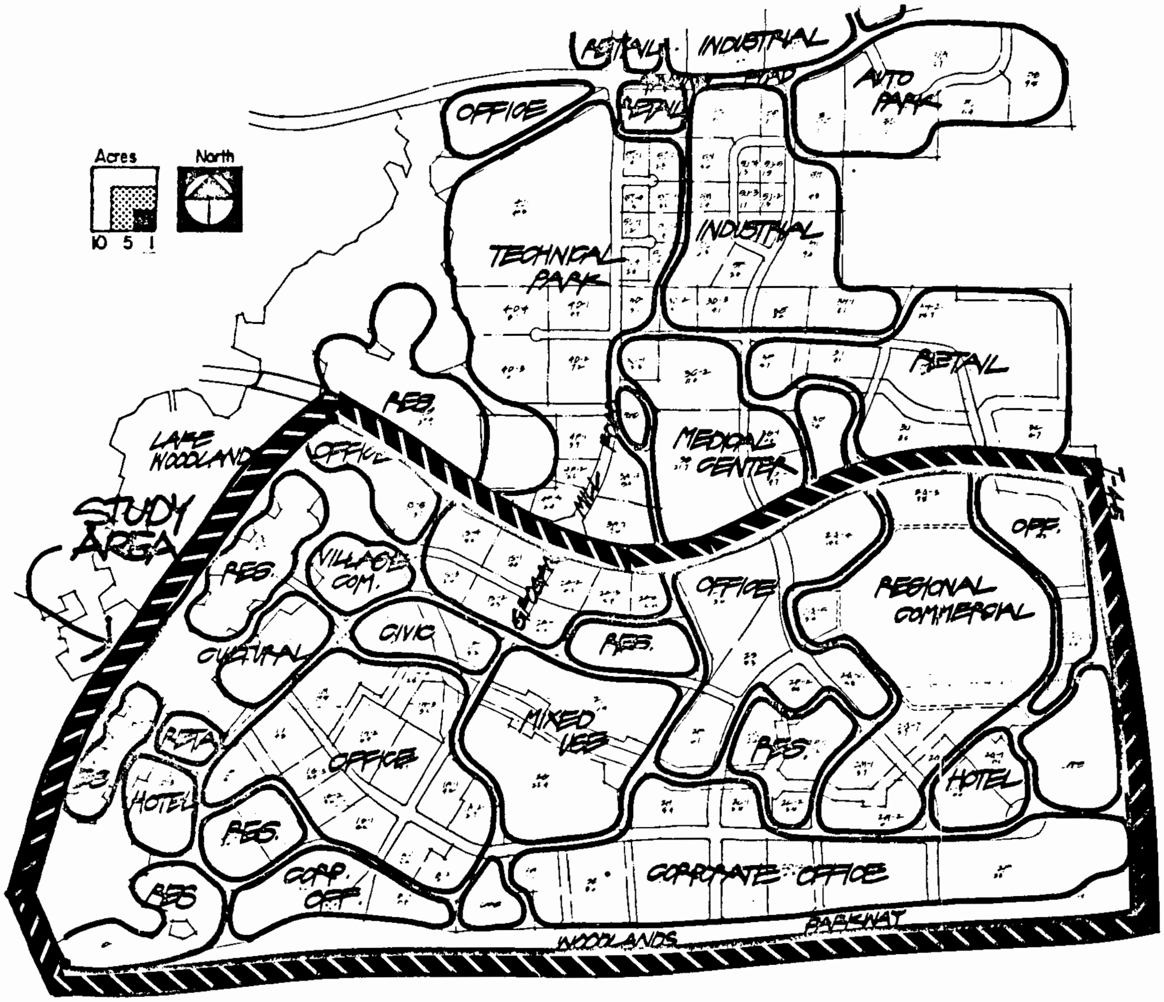


Figure W-3

CONCEPTUAL LAND USE PLAN FOR THE WOODLANDS SAND STUDY AREA
Source: The Woodlands Report Figure II-8

- financing--includes probability of financing through public and private sources or grants; and

- aesthetics--includes consideration of building size, location, materials, color facade treatment, landscaping, etc.

Before analysis and evaluation of the conventional plan was undertaken, an investigation was made in order to clearly identify the types of energy-related subsystems requiring consideration in a mixed-use development such as the Metro Center. This investigation took the form of a literature review of prior work on similar classes of problems and an exercise in which explicit diagrams were made describing energy and energy-related material flows within an urban area with the same general land-use program as the Metro Center. On the basis of this investigation three general areas of energy demand and consumption were identified for further consideration:

- energy consumption at the building level, including consumption by typical in-building subsystems;
- energy consumption associated with transportation; and
- energy consumption related to the embodied energy within the buidings themselves, and within the infrastructure.

This latter category was also extended to include energy expended during construction activity. In addition, the use of other resources related to energy consumption, such as solid waste generation and disposal, water consumption, and effluent disposal were also identified for further consideration in analyzing the conventional plan. General characteristics of the supply system, including the provision of space heating and cooling, hot water, and electrical power were also identified.

An analysis was then made of the likely levels of energy consumption for the conventional plan. Here, estimates of energy consumption were computed at the building level for each land parcel by applying a computer model that simulated the material composition, orientation, interior loads, and site parameters appropriate for each building. These estimates were then aggregated in conformance with the phasing schedule of the plan, resulting in average and peak profiles through time of energy consumption by source. Estimates of transportation-related energy consumption were made by first estimating the likely number of vehicle miles travelled with either an origin or a destination within the study area and then applying appropriate fuel consumption coefficients for the various modes and speeds of travel. Embodied energy expended during construction was estimated on the basis of data available from comparable developments or for comparable buildings. From similar sources, separate estimates were also made of embodied energy within elements of the transportation infrastructure, such as roadways and car parks.

In the analysis of the conventional plan, estimates regarding the use of selected (natural) resources and evaluation of their associated environmental impacts were also undertaken. While not directly related to energy conservation as such, the use of resources, such as water, solid waste, and sludge from effluent treatment plants, often forms an integral part of conventional utility systems and thus warrants consideration. In any event, the residual by-products of energy consumption, such as atmospheric emissions and other forms of effluent disposal, require evaluation. Within this study, consideration was given to water demand, waste water production and disposal, solid waste generation and disposal, stormwater management, and atmospheric emissions. The conventional energy-supply system was also described in detail for later comparison purposes. Here, estimates of prime fuel consumption (for example, oil and gas) and costs involved in the supply system were of considerable importance.

Identification of potential energy-conserving methods began with an enumeration of basic concepts and technical methods. This enumeration was subdivided into two major areas of consideration:

(a) reduction of energy demand, and (b) improved efficiency of energy supply. For the purposes of selecting among the alternative energy-conserving methods, the nine categories of nonenergy-related criteria described earlier, were redefined into a series of more explicit selection criteria. These criteria, in conjunction with technical considerations of feasibility and energy performace, were then used to develop the elements of the energy-conserving plan. The plan itself involved further refinement of these elements so that they could be most appropriately integrated.

The energy-conserving plan was then subjected to an evaluation similar to that applied to the conventional plan. Although the original research design for the case study called for a sensitivity analysis to be performed on the energy-conserving plan in order that system optimization could be achieved, the lack of adequate time and resources did not allow this analysis to be completed.

The final steps in the overall approach involved comparison between the two plans and identification of those factors potentially constraining or inhibiting implementation of the energy-conserving plan. The comparison between the two plans was made in terms of both energy conservation and cost. Most of the evaluation criteria concerned with nonenergy related aspects of the plans were addressed under the issues related to implementation, or in the environmental impact assessments.

In summary, all those methods that were found to be unfeasible were excluded from the energy-conserving plan. All those methods that were found to be reasonably feasible were included within the plan, but with the understanding that they could not become a part of the actual development strategy until their constraints to implementation were overcome. Those methods that could be directly implemented by the developer were, of course, incorporated directly into the energy-conserving plan.

CONVENTIONAL PLAN

Highlights of the analysis of energy consumption within the conventional plan are presented in Figure W-4. Here the total annual energy consumption at completion of the project in 1999 was estimated to be 10.94 X 10^{12} Btu. The bulk of this total (70 percent) was attributable to transportation energy consumption, although alternative development scenarios with more job opportunities closer to The Woodlands, and with few vehicle miles of travel, seemed likely to reduce the overall energy consumption to as low as 7.44 x 10^{12} Btu per year. A further 27.4 percent of total annual consumption was attributed to energy consumption at the building level, and a final 2.8 percent was due to maintenance activities including replacement. The intensity of energy consumption at the building level was estimated to be 235,109 Btu per square foot per year at the plant, or 80,800 Btu per square foot per year at the building line. Embodied energy, including investments in roadways and car parks was estimated to amount to 13.1 x 10^{12} Btu by 1999. Expressed in a relationship with operating energy consumption at the building level to a 4 to 1 ratio results. This is comparable with findings from other studies that have indicated ratios ranging from 2:1 to 6:1.

The predominate source of supply for the energy consumed was electrical power, with an annual demand in 1999 of 286 x 10^6 kWh and a peak demand of 133 MW. Natural gas consumption was quite low, with an estimated annual consumption of 61.8 x 10^9 Btu. This comparitively low use of natural gas was occasioned by an almost exclusive dependence, within the conventional plan, on electrical power. The only scheduled use of natural gas was for all hot water and space heating for the high-rise residential developments. The generation and distribution of electrical power was seen to be the responsibility of the Gulf States Utilties Corporation, which currently serves The

Figure W-4
ANALYSIS OF ENERGY CONSUMPTION FOR THE CONVENTIONAL PLAN
(in 10^{12} Btu)

Initial Embodied Energy:	Energy Consumption	Percent
Buildings, etc.	13.1	92.2
Transportation		
Roadways[1]	0.023	0.2
Parking[2]	1.08	7.6
Total	14.20	100.0
Annual:		
In-Building Energy Consumption[3]	3.0	27.4
Transportation System Energy Consumption[4]	7.66	70.0
Maintenance-Embodied Energy[5]	0.28	2.8
Total	10.94	100.0

NOTES: (All consumption expressed in terms of source energy; i.e., energy consumption traced back to basic producer.)

1. Based on 21.59 linear miles of internal roadway using factor of 1.06 x 10^9 Btu/linear mile. External roadways excluded as part of overall Woodlands roadway network.
2. Based on approx. 280.2 acres of at-grade car parking, assuming a factor of 7.3 x 10^8 Btu/acre and 45.8 acres of structured parking assuming a factor 1.9 x 10^{10} Btu/acre.
3. Summary and assumptions documented in the complete project report. See figure titled "Total Energy Use by Building Type" and Appendix I, Model Results, Conventional Plan.
4. Summary and assumptions documented in the complete project report. See figure titled "Annual Energy Consumption in the Transportation Sector for the Conventional Plan."
5. Embodied energy expended in maintenance activity assumed a 2 percent per year average level of maintenance and replacement. (All energy consumption dependant upon imported prime fuels; e.g., oil, gas, etc.)
6. Under alternative energy scenarios this could be reduced to 8.28 x 10^{12} Btu/year or 7.44 x 10^{12} Btu/year.

Woodlands. The cost of electricity, in 1978 constant dollars, was estimated to be 35 mills per kWh.

Water demand for the conventional plan was estimated to be about 1.5 x 10^6 gal. per day by 1999, producing a waste water loading of about 1.7 x 10^6 gal. per day. The peak flow for stormwater runoff in the developed condition, under 25-year storm conditions, was estimated to be 766 cfs (cubic feet per second). However, 9.5 acres within the open-space spine of the conventional plan are suitable for creation of ponds which would substantially mitigate any problems associated with stormwater runoff. The rate of solid-waste generation within the study area by 1999 was estimated to be about 29 x 10^3 tons per year, and later became an important consideration as a fuel stock in the development of an integrated utility system within the energy-conserving plan. In summary, the relatively high levels of environmental quality already maintained in The Woodlands seemed likely to continue with the addition of the Metro Center.

THE CONSERVATION OPTIONS

The first step in the development of the energy conserving plan involved selection of appropriate energy-conserving methods or techniques for application within the Metro Center. Identification of potential methods began with an enumeration of basic concepts and technical methods capable of enhancing energy conservation. This enumeration was subdivided into two major areas of consideration: reduction of energy demand and improved efficiency of energy supply. For the purposes of selecting among the alternative energy-conserving methods, a strategy was devised that allowed separation of the methods into one of three categories:

- methods that are unfeasible because of technological considerations, cost, or poor energy performance;
- methods that were reasonably feasible technically but which could not be implemented until existing institutional contraints could be overcome; and
- methods that could be directy implemented by the developer (WDC).

The feasibility of each energy-conserving method was appraised by members of the technical team, in conjunction with WDC, according to characteristics of energy performance, capital and operating costs, and compatibility with other favorable elements of the energy system and the plan in general. In the latter, consideration was given to the likely effect of a method on marketing, functional performance of the plan, environmental performance, and compliance with governmental programs and procedures.

In all, some 60 techniques or strategies were identified for further consideration. Upon analysis many of them proved to be technologically or economically unfeasible, at least for application to the Metro Center. Of the remainder, 13 were found to be feasible and could be implemented directly by the developer. A further 16 techniques were also found to be feasible but with constraints on their immediate implementation (Figure W-5). These constraints were found to be largely of an institutional nature, although some stemmed directly from the uncertainty associated with future economic conditions and relative energy costs.

Within the energy-conserving plan, all of the methods identified by the screening process were incorporated, at least for analytical purposes. Given the relatively long time allocated for the study and the uncertainty surrounding future market conditions and conditions of energy supply and demand, the objective in developing the energy-conserving plan became one of showing the magnitude of energy savings that could be reasonably achieved in the Metro Center rather than the production of a fixed plan of action. In other words, the energy-conserving plan took the form of modifications that could be made to the conventional plan rather than a completely new plan.

CONSERVATION PLAN

The energy-conserving plan responded to the same building program as the conventional plan. Hence, the land use totals are the same, and the building heights, amounts of structured parking, and other factors heavily influenced by the market remain substantially the same. The energy-conserving plan really took the form of a group of alternative strategies rather than a single course of action. Essentially it represented modifications that could be made to the conventional plan. Energy savings thus came about as a consequence of the manifest difference between the application of a strategy or group of strategies and similar circumstances in the conventional plan.

Land use locations were modified to better accommodate pedestrian use of the Metro Center area and to enhance utility sharing. Consideration was given to a land use compatibility matrix which illustrates relative degrees of compatibility between different use. For example, a restaurant retail use has a high degree of affinity for office uses. Location of these two uses together within walking distance reduces the need for lunch-time car travel. Land use groupings were also modified to achieve a finer "grain" and to place-related land uses adjacent to one another, so that shared parking, walking trips between uses, and off-peak utility loads could be more fully utilized (Figures W-6a and b and W-7).

The roadway network was modified in three ways (Figure W-8). The addition of a lake-front drive along Lake Woodlands and west of Grogan's Mill Road was made in order to reduce overloading

Figure W-5
FEASIBLE ENERGY-CONSERVING METHODS

Methods Capable of Direct Implementation by The Woodlands Group (Developer)

Transportation Considerations

1. Pathway System
2. Park and ride through a van pool system
3. Modification of roadway network, intersections, and access points

Building Envelope and Site Design Considerations

1. Use of insulation and thermally efficient building materials
2. Reduction in infiltration
3. Use of trees to achieve shading of exterior walls
4. Percent of glass
5. Building form
6. Building orientation
7. Surface reflection incident on building envelope

End-Use Building Subsystems Considerations

1. Lower wattage fluorescent lights
2. Computerized thermostat control
3. Variable volume fans and control

Methods That Are Feasible, But With Constraints

Transportation Considerations

1. Rearrangement of land uses in the form of clusters of different uses
2. Intra-Woodlands transit system
3. Intra-Metro Center transit system
4. Woodlands/regional transit system

Building Envelope and Site Design Considerations

1. Use of bodies of water for exterior micro-climate modification around the buildings

End-Use Building Subsystems Considerations*

1. Active solar for space heating, hot water, and absorption a/c
2. Desiccant dehumidification
3. Thermal storage
4. Heat pump
5. Gas heating
6. Flow reduction appliances
7. Ventilation enthalpy exchange wheels
8. Return air through light fixtures

Energy Supply Considerations

1. On site power generation--grid connected

Embodied Energy Considerations

1. Reduction in road pavement and parking lot area
2. Reduction in number of vehicles

* Only items 3 to 5 were analyzed in any detail within the energy conservation plan. The others were omitted primarily because of economic considerations.

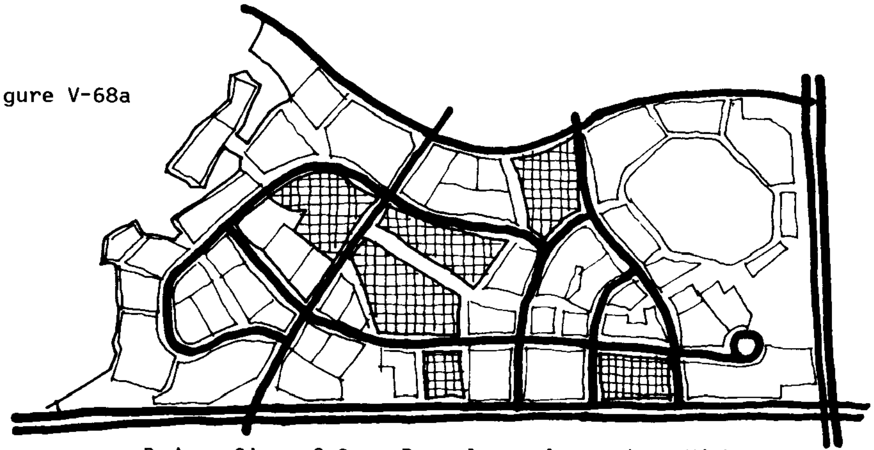
on Grogan's Mill Road and provide a secondary loop through the Metro Center. For similar reasons, a north-south link connecting to Lake Woodlands Drive was also added. In order to separate mall-related traffic from through-traffic trips and to reduce congestion, a major north-south road was moved from a location just west of the regional mall further west to Six Pines Drive. (These three roadway network modifications have since been incorporated in the Metro Center Roadway Master Plan.)

The Lake Woodlands shoreline was modified in order to create islands with primarily north-south views of the water instead of the dominant view to the west present in the conventional plan (Figure W-9).

Analysis presented in the previous section showed that increased transit travel, a reduction of parking ratios, and use of shared parking would reduce parking requirements and result in a "recapture" of 111 acres of land for use after the year 2000 (Figure W-10). Because of the

Figure W-6a

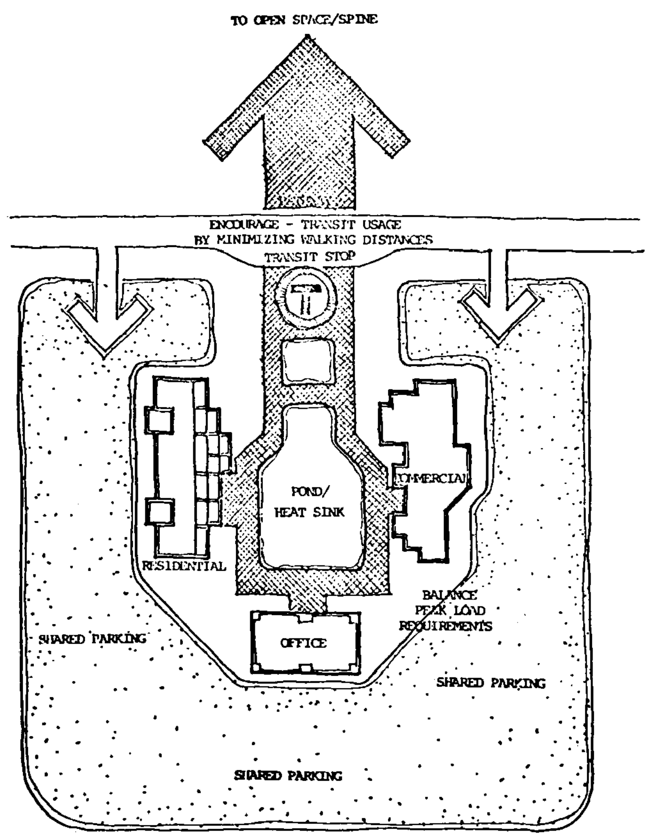
REDUCED PARCEL SIZES
Source: The Woodlands Report Figure V-68a



Reduce Size of Some Parcels to Accomodate Higher Densities and Parking Concept

Figure W-6b

PARKING PRIORITY LOCATIONS
Source: The Woodlands Report Figure V-68b



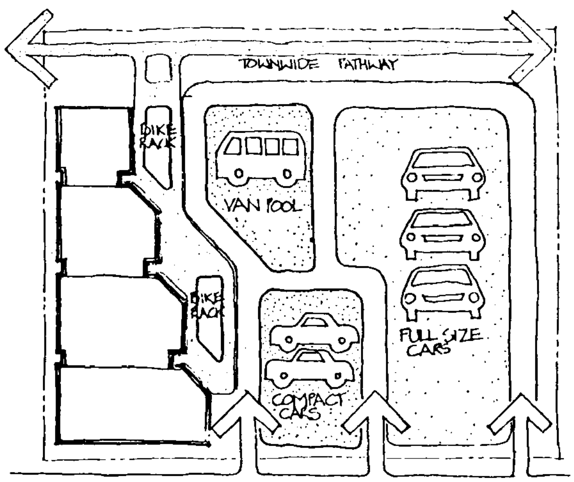
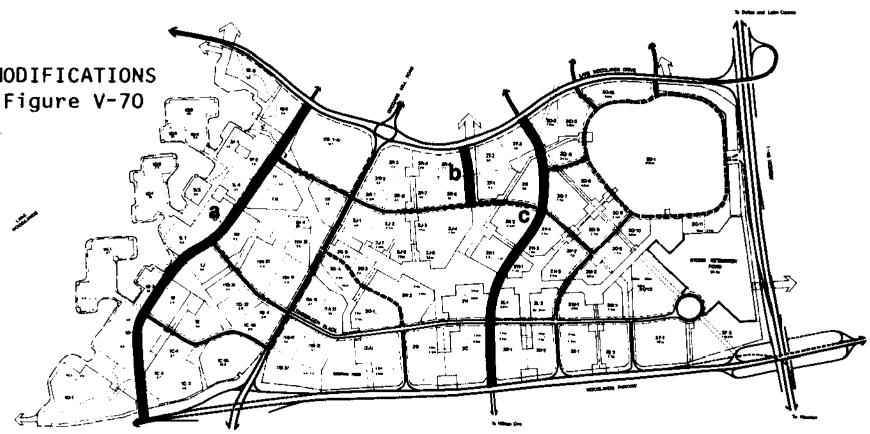


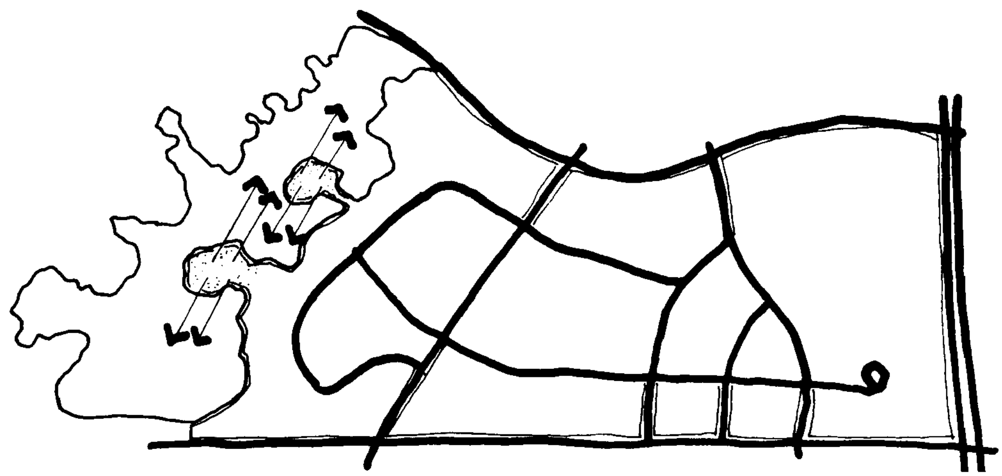
Figure W-7

THE WOODLANDS CONCEPT BUILDING CLUSTER
Source: The Woodlands Report Figure V-69

Figure W-8

THE WOODLANDS ROADWAY NETWORK MODIFICATIONS
Source: The Woodlands Report Figure V-70





Design Man Made Islands of Lake Woodlands To

Maximize North-South Views

Figure W-9

NORTH-SOUTH VIEWS ON LAKE WOODLANDS
Source: The Woodlands Report Figure V-71

Figure W-10

THE 111 ACRES RECAPTURED BY TRANSPORTATION INNOVATIONS
Source: The Woodlands Report Figure V-72

increased land values at that time, an increased overall intensity of use should occur, promoting transit and other energy-saving concepts which increase in feasibility with an increase in density. This increased building program is graphically portrayed in Figure W-10 but was not included in any comparison with the conventional plan because of the extension of the build-out time beyond the time frame of the study.

The transportation methods included in the energy-conserving plan which can be implemented directly by the developer are different from those presented in the conventional plan and include the following: (a) provision of a pathway system to encourage nonmotorized travel; (b) park and ride with a van pool system for Woodlands regional trips; and (c) modification of roadway network intersections, and access points to improve accessibility and efficiency as per the energy plan except for the elimination of a piece of roadway connecting parcel 2P to 2E.
In essence, these techniques support and represent a logical extension of the land-use concepts discussed previously.

Those transportation methods which could be implemented once certain constraints were overcome were also analyzed in conjunction with the energy conserving plan. They include the following:

(a) an expanded bus system linking the Metro Center to the rest of The Woodlands and providing transportation between residences outside the Metro Center and work destinations inside the Metro Center;

(b) formulation of an entity to organize a carpooling system from origins outside the Metro Center to work destinations inside the Metro Center; and

(c) a reduction in car-parking spaces through an examination of car-parking ratios, use of shared king between different land uses having different peak parking requirements, and implementation of the bus system.

Several assumptions which would directly affect the amount of usage of the private automobile in the energy-conserving plan should be stated. First, the energy plan assumes that 30 percent of those who live in The Woodlands will work in The Woodlands and that 20 percent of that group will commute to work via transit and would have the option of not purchasing a second car. An argument might be made that higher gasoline costs, lower availability of gas, and continued high residential land cost within the Loop around Houston will encourage firms relocating to Houston to choose suburban locations rather than urban locations. This move, while providing a more favorable range of housing prices for these firms' employees, may also result in reduced transportation costs. Here The Woodlands would appear to have a significant advantage over other suburban locations because of the wide range of residential, employment, and support uses planned and supported in a comprehensive manner. These factors could conceivably increase the estimated 30 percent of those residents who live and work in The Woodlands, as well as the proportion of those commuting to work within The Woodlands by means other than their cars.

Second, relocation of the high-density residential areas closer to the employment locations in The Woodlands would reduce the average bus transit trip from 5.5 miles used for estimation purposes in the energy plan and would increase the 6.5 dwelling units per acre along the transit route. Both factors would have a tendency to increase transit usage. Third, the development of the 111 acres "recaptured" in the Metro Center as a result of shared parking, parking ratios, and transit would increase the nonresidential land-use component to over 10 million square feet. When distributed within a one-square-mile area, this component would justify a higher level of transit service. A combination of the above factors could increase transit headways from 30 minutes to 15 or 20 minutes, thus making the service much more convenient and accessible.

The main design feature of the energy supply system for the energy-conserving plan is the incorporation of an integrated utility system. Although not economical for the Metro Center alone, this type of system can result in considerable energy savings with favorable economic returns when applied more broadly to The Woodland development and elsewhere. Two system configurations appear to be feasible. They are a gas engine system with heat recovery and a solid-waste-fired steam turbine system. Although the former is the more efficient and the least costly to put in place, the latter's high use of solid waste could reduce its dependence on other (nonrenewable) prime fuels by as much as 87 percent, while still maintaining a competitive delivery cost for electricity (35-40 mills/kWh).

Both the Woodlands Development Corporation and Gulf States Utilities, the local power company, have shown considerable interest in the concept. If and when details regarding ownership, operating control, integration within the existing power grid, etc. are resolved, the system should prove feasible.

CONSERVATION PLAN SAVINGS

With application of modifications to the building envelope, site design, and in-building subsystems, the annual energy consumption by 1999, at the building level, was estimated to be 0.51 x 10^{12} Btu at the building line, or 1.47 x 10^{12} Btu at the plant. This level of consumption converts to an average use intensity of 40,325 Btu per square foot per year at the building line, and represents about a 50 percent reduction from the conventional plan (Figures W-11 and W-12). Of this reduction, 18 percent could be attributed to site design modifications and changes in the building envelop. Modifications to in-building subsystems, such as lighting and thermostat settings, accounted for the remainder of the savings. Analysis also showed that these energy savings could be achieved using methods with economic payback periods of less than 5 to 6 years, and with most of the payback periods in the order of a year and a half. Expressed in terms of the present worth of all costs, the 50 percent energy savings could be achieved with an 18 percent reduction in all costs. The peak electrical load likely by 1999 was also reduced by 63 percent from 133 MW to 49 MW.

Reduction of energy consumption within the transportation sector was far less dramatic (Figure W-11). In fact the difference between the two plans was only 3.8 percent or 0.29 x 10^{12} Btu per year. The most significant savings (50 percent) were estimated for trips within the study area itself, where the coordination of relatively high intensities of development could be used to greatly enhance transit ridership. Economic savings attributable to the transportation methods seemed also to be quite slight, 3.5 percent.

One noteworthy effect of the modified transportation plan was a reduction in embodied energy attributable to buildings and their infrastructure. Shared parking and reduction in car-parking ratios facilitated an overall savings of 4.6 percent in overall embodied energy, with a 38 percent reduction in capital costs.

For the provision of electrical power, hot water, and environmental conditioning several integrated utility systems were investigated for application to the Metro Center. Generally they were found to be economical only with broader application beyond the study area. A gas-driven engine system with heat recovery and a system using a steam turbine fired by solid waste showed the most promise. The former showed possible energy savings in the use of enxternal prime fuels, such as oil and gas, of 15 to 17 percent. The latter showed higher savings, ranging from 48 percent to 87 percent. Here, the 48 percent savings could be achieved with the use of all the solid waste generated in The Woodlands, while the 87 percent savings could be achieved with use of additional sources of solid waste. Both estimates assumed a 60 percent plant factor necessary for economic considerations, and all systems were sized for an ultimate installed capacity of 56 MW by

Figure W-11
ANALYSIS OF ENERGY CONSUMPTION FOR THE CONSERVATION PLAN
(in 10^{12} Btu)

	Energy Conumption	Percent
Initial Embodied Energy:		
Buildings, etc.[1]	13.10	96.7
Transportation		
Roadways[2]	0.026	0.2
Parking[3]	0.42	3.1
Total	13.5	100.0
Annual:		
In-Building Energy Consumption[4]	1.47	16.1
Transportation System Energy[5]	7.37	80.9
Maintenance--Embodied Energy[6]	0.27	3.0
Total[7]	9.11	100.0
Energy Supply System Annual Use of Imported Prime Fuel[8]	0.19	

NOTES:

1. As per conventional plan.
2. Based on 24.16 lineal miles of internal roadway. External roadways excluded as part of overall Woodlands roadway network. Same energy factors used as for the conventional plan.
3. Based on a reduction of 26.9 acres of structured parking and 111 acres of at-grade parking from the conventional plan. Same energy factors were used as for the conventional plan.
4. Summary and assumptions documented in the complete project report and in Appendix I, Section 2b, "Energy Plan."
5. Summary and assumptions documented in the complete project report.
6. As per conventional plan, embodied energy expended in maintenance activity assumed a 2 percent per year average level of maintenance and replacement.
7. Under the alternative transportation scenarios this could be reduced to 6.54×10^{12} Btu/year or 5.74×10^{12} Btu/year.
8. Imported prime fuel means the fuel requirement not provided on-site or through some site-related resource activity, such as solid waste disposal. Prime fuels, here, refer to oil, gas, and coal. Estimate based on 87 percent projected savings with the steam turbine. Energy supply system, here, refers to supply or land-use (not transportation) activities.

1999. Without power distribution beyond the study area, only an 18 percent plant factor could be achieved with both systems, further underlining the importance of peak load reductions and more extended use of the system. With a 60 percent plant factor, both systems appeared capable of achieving delivery costs for power that would be competitive with Gulf States Utilities at 35 to 40 mills per kWh. For a first stage of application by 1983 the capital costs were calculated to be $5.5 million for the gas engine system and $12.3 million for the steam turbine. However, in order to meet the installed capacity required by 1999 it was estimated that the capital costs (1978 dollars) for the steam turbine system would be $41 million. With projected annual savings of $7.26 million, a payback period of seven to nine years resulted, making the investment appear attractive, particularly if the first costs could be borne in increments. Of course, an alternative approach would be to scale the installed capacity of the plan below the peak demand and draw power from the grid in order to satisfy the peak demand. Under either alternative, application of an integrated utility system seemed feasible, especially because the Metro Center is part of a more extensive area with additional and complementary power demands that are all under a single development entity.

In overall terms, application of the methods prescribed for the energy-conserving plan seemed likely to yield annual energy savings of about 17 percent. Under less pessimistic projections of

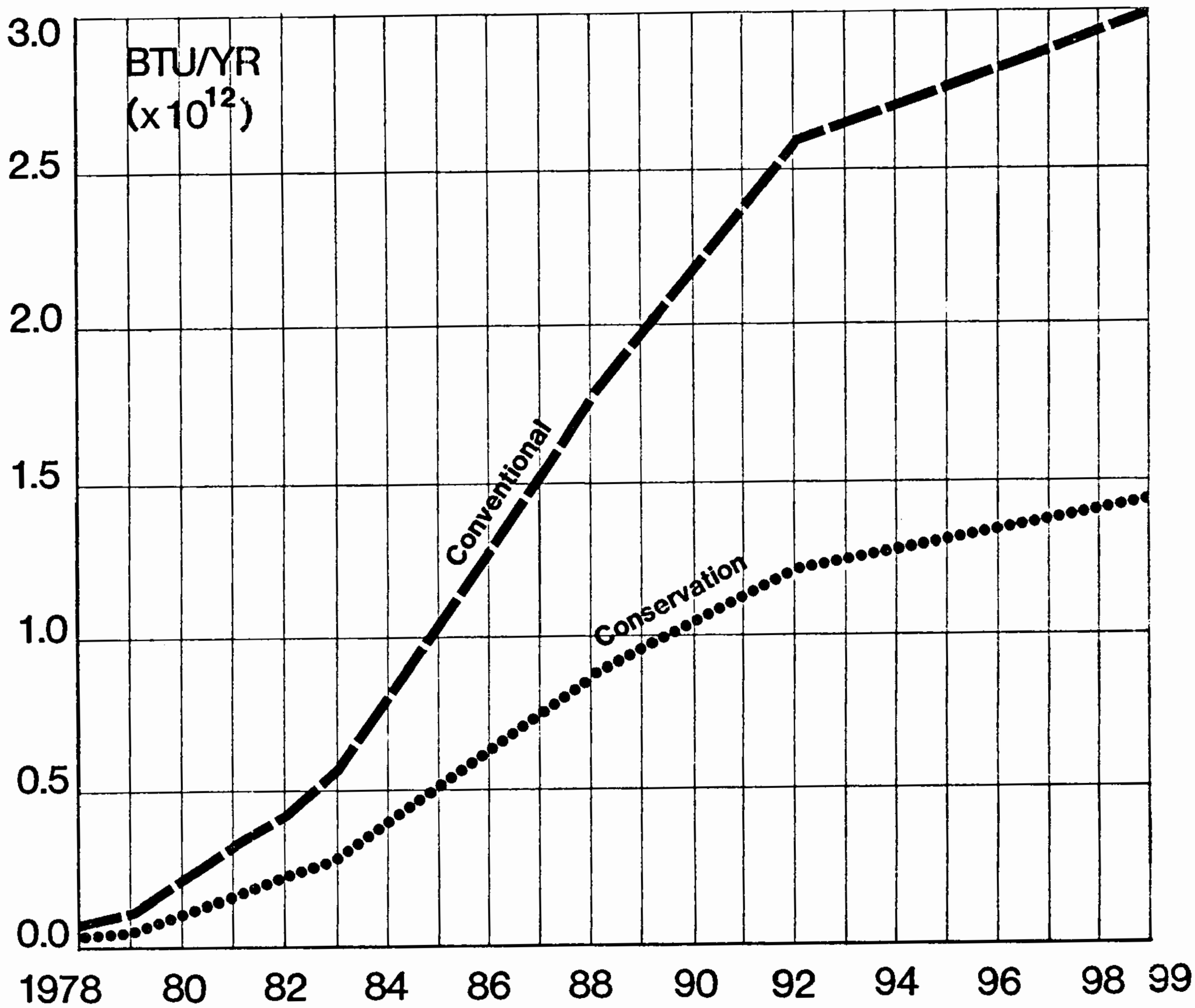


Figure W-12

TOTAL ANNUAL ENERGY CONSUMPTION (AT THE PLANT)
FOR THE CONSERVATION PLAN COMPARED WITH THE CONVENTIONAL PLAN
Source: The Woodlands Report Figure I-9

travel behavior, where the average length of external trips to and from the study area was reduced by 50 percent, a 23 percent reduction in annual energy consumption was estimated. Such reductions in vehicle miles of travel seem plausible as the Woodlands moves closer to becoming a place where people can live and work in the same environment and as more development occurs in the northern corridor leading out of Houston. Finally, with reduced demands for energy, and with the use of on-site power generation, a 30 percent reduction in the use of external sources of prime fuels could be achieved.

Nonenergy Benefits

Very few differences in the general environmental performance of the two plans are likely. A reduction in mobile sources of atmospheric emissions in the conservation plan becomes offset by the likelihood of additional stationary sources (that is, an on-site power generation facility). The rates and volumes of stormwater runoff in one plan will probably be indistinguishable from the other plan. Although the shared and reduced parking requirements of the conservation plan theoretically save on land area requirements, the real effect is more apt to be an overall increase in building intensity rather than a reduction in coverage. The functional performance of the two plans, in the user sense, is also likely to be highly similar. The energy-conserving plan exhibits a somewhat finer "grain" in the spatial distribution and mixture of land uses which, if anything, could improve functional performance while probably slightly impairing marketability.

IMPLEMENTATION

Methods which are technically feasible and are included in the conservation plan but for which constraints must be overcome for implementation to be achieved are discussed in this section. Methods which can be directly implemented by the developer have already been identified in the conservation plan. Perhaps the most meaningful way of discussing constraints to implementation is in terms of the interrelated functions or roles involved in The Woodlands development process. Six basic functions or roles can be identified. They are: (1) developer, (2) lender, (3) owner, (4) builder, (5) regulator, and (6) utility.

The process of development at The Woodlands, like many other processes of raw land conversion and building, involves a sequence of interactions or transactions among the roles just listed. Therefore, for a plan or any component of a plan to be fully realized, agreement must be reached among several participants. At a general level, the attitude and behavior of each entity are similarly directed towards protection and enhancement of their investment. In fact, the general guidelines which are applied by the developer, the lender, and the owner for instance, in determining their separate investment strategies are often very similar. This similarity occurs if for no other reason than anticipation by each entity of the investment posture of the other entities. Consequently, constraints to implementation for one may be equally viewed as constraints to implementation by others. Furthermore, the degree of constraint is usually determined by the most conservative of the actors involved in the process. For changes to occur, therefore, the most conservative actor must be "educated" or convinced by other actors in the same process.

DEVELOPER

Implementation of the energy-conserving plan would require the imposition of additional development constraints, particularly in the areas of transportation and to some extent in building envelope and site design. The imposition of additional development constraints not imposed by other competitive developers is likely to be a disadvantage to WDC marketing efforts. Further, implementation strategies that serve to differentiate Woodlands products from competing developments and result in higher costs to either the developers or eventual owners will be difficult to apply.

Several of the energy-conserving methods, such as the requirement for more highly disaggregated mixed-use development, provide the developer with less flexibility to adapt to changing market demands. Again, this may place the developer at a competitive disadvantage, particularly when it comes to responding to new unanticipated product lines later on in the Metro Center development scheme.

The imposition of additional constraints and necessary implementation strategies requiring the shared use of facilities, such as parking and elements of the energy-supply system, will probably increase the complexity of sales transactions with owners and lenders. In turn, this increased complexity may impair the marketing program and pace of development.

The implementation of energy-conserving methods requiring centralized forms of control and administration will probably devolve, at least in part, upon WDC. A possible organizational structure for intra- and inter-urban transit and a possible option for development and management of the energy supply system require participation by WDC in a central and ongoing organizational capacity. To carry on these managerial, and at times specialized, functions would necessarily require additional organizational structure within the development organization. While the additional services that are provided may eventually become profit centers, they will certainly involve investment risks.

Increases in capital investment and maintenance costs required by energy-conserving methods are likely to constrain their implementation. Here the severity of the economic constraint is likely to be far greater when the payback period of a particular method is beyond the investment horizon of the developer. While longer term life-cycle costing procedures may give an accurate estimate of the useful economic life of a method, they are often rendered irrelevant by the present structure of the local, state, and federal tax law. Within this perspective, substantial incremental increases in capital investments, regardless of payback period, tend to argue against the implementation of capital-intensive energy-conserving technologies. In essence, there is often a significant opportunity cost involved in implementing energy technologies that prevents investment of the same capital in other profit-making ventures with higher rates of return.

In principle, a final impediment to developer's participation in the application of energy supply options concerns prior agreements with utility companies. However, in case of The Woodlands and Gulf State Utilities, this type of constraint appears to be relatively insignificant.

LENDER

In addition to the constraints already noted, which involve transactions between developer and lender, several other aspects of the implementation strategies may also discourage participation in the project by lenders. Any factor that would prevent proposed land use from realizing the maximum return on the lender's investment would be of concern to most lending institutions.

Also of concern to a lender would be the situation in which the lender would not have complete control over the parcel for which funding is being provided. Several of the transportation methods that have been proposed involving facilities such as parking shared among owners would probably cause concern to lenders. Generally speaking, lending institutions are loathe to deviate from traditional lending patterns and from the development standards inherent in those patterns. In most if not all cases, this attitude seems to stem from a high reliance on past experience in protecting future investment opportunities.

OWNER

As in the case of the lender, any aspect of a land use implementation strategy that would potentially interfere with an owner's realizing the maximum return on his investment would discourage owner participation in the project. Similarly, factors which might impair resale of property, such as extreme permissible variation in adjacent uses and lack of uniformity in visual quality, would be of concern to an owner. Without careful planning and detailed design consideration, this possibility would argue against the use of highly disaggregated and variable forms of mixed-use development.

The uniform coordination of maintenance and related functions is required by owners sharing space, such as in the use of shared parking. The necessity for coordinating these functions may discourage owner participation in projects where this function is required.

It is probably likely that the owners will be reluctant to participate in the provision of the necessary economic incentives required to implement aspects of the proposed inter- and intra-urban transit system. Even without an objection in principle by the owners, the pricing structure for such economic incentives remains largely untested. Owners are also likely to exhibit concern for untested technologies, particularly with respect to their longterm reliability.

Response by owners to the development constraints required by many of the implementation strategies will probably require increased professional service costs. However, this will probably only apply to the earlier stages of development, as the technical capability necessary for dealing with energy-conserving methods becomes part and parcel of professional design services.

BUILDER

Implementation of many of the energy-conserving methods will necessitate the use of more advanced or nontraditional technologies. In some cases, especially with the supply system, building construction will require a more specialized labor force. In the short term at least, the unfamiliar nature of technologies and their special labor requirements may constrain the efficiency and ease with which the builder can comply with energy-related design specifications. Just as with professional service capabilities, builders may be expected to quickly adapt their buliding processes to the requirements of energy-conserving methods.

From a practical standpoint at least, one of the energy-conserving methods, fuel cell technology, will not be available until 1982. It is therefore unlikely that the general building contractor will be able to implement this technology until sometime thereafter.

REGULATOR

Several different aspects and types of energy-conserving methods will require special consideration by various regulatory control agencies that may in turn constrain the application of these methods. First, the fuel source used as part of the energy supply system and the in-building subsystem may be subject to more stringent regulation. This applies to nonrenewable fossil fuel sources such as oil, gas, and coal. For instance, in the immediate past, the use of natural gas in the region for boiler fuels was discouraged. While this policy has been altered, a strong argument can be made for an energy supply system configuration that is adaptable to a broad range of fuel sources. In effect, the on-site system recommended for use in the energy-conserving plan incorporates this basic principle, although it could be constrained at some future date by regulatory actions with respect to primary fuel sources.

Controversy in the short term over appropriate performance standards for various types of in-building equipment, ventilation rates and the like, may constrain certain technical applications. However, present attempts by federal, state, and local governments to publicly and rationally devise energy codes should attenuate the effect of this type of regulatory constraint.

Finally, on-site power generation, either in a grid-connected or free-standing form, will add additional stationary sources of air pollution to the area. However, with the rise of appropriate control devices, no major licensing problems are expected. Nonetheless, these sources would be subject to the jurisdiction of the Texas Air Control Board and would have to obtain both construction and operation permits. It might also be argued that these additional sources of air pollutants may only represent a redistribution of overall air pollution loadings because they are the residuals of the production of power that would be accomplished elsewhere in the region.

UTILITY

A major consideration in the use of thermal storage and on-site power generation is the nature of prior obligations established between the developer and the utility company. A related issue concerns the capitalization and operation of on-site plants and the willingness of the utility to become involved with a developer on some kind of partnership basis. This kind of venture, at present anyway, is a departure from standard procedures in which the utility acts in a largely autonomous fashion.

A recurrent theme throughout this section has been the presence of perceived constraints due to the requirement of applying nontraditional approaches for the implementation of energy-conserving methods. Overcoming what are essentially attitudinal constraints will require a concerted effort at education, as well as the provision of appropriate incentives for the various actors to experiment and become involved in the implementation of energy-conserving methods. According to the arguments presented, it seems unlikely that piecemeal attempts to induce experimentation will be successful unless they are tied closely with the strong prospect, if not realty, of sanctions for noncompliance with conservation practices.

SUMMARY AND CONCLUSIONS

The Woodlands is a 20,000-acre HUD Title VII new town that is 28 miles north of Houston. Development began in 1972. Its population at the time of the SAND study was 5,000; its projected population is 150,000, to be contained in six residential villages. Average daily maximum temperature in the winter is 63.2°F and in the summer is 93.5°F.

The Woodlands Site and Neighborhood Design case study focused on 0.9-square-mile portion of the Metro Center development plan, which was programmed to contain the following at build-out in 1999:

- 4 million square feet of residential uses (population: 17,736);
- 8 million square feet of nonresidential buildings (employment: 24,054);
- 126 acres of open space; and
- 280.7 acres of parking.

Analysis of the energy conserving modifications indicates the following magnitude of savings: (a) embodied, 49 percent; and (b) annual operation, 16.7 percent (50 percent in buildings). Application of the methods described for the energy-conserving plan, therefore, seems likely to yield annual energy savings of 17 percent. Under less pessimistic projections of travel behavior, where the average length of external trips to and from the study area was reduced by 50 percent, a 23 percent reduction in annual energy consumption is estimated. Such reductions in vehicle miles of travel seem plausible as The Woodlands moves closer to becoming a place where people can live and work in the same environment and as more development occurs in the northern corridor leading out of Houston. Finally, with reduced demands for energy and with the use of on-site power generation a 30 percent reduction in the use of external sources of prime fuels can be achieved.

On the basis of this case study, a number of general conclusions may be drawn regarding the applicability and performance of energy-conserving methods used in a relatively mixed-use setting, such as The Woodlands Metro Center. These conclusions may be summarized as follows:

- Any implementation strategy that serves to differentiate (Woodlands) products from competing developments and which costs more to the developer will be difficult to apply. Implicit here is the general assumption that consumers do not as yet place sufficient value on energy-conserving options to dictate choices. With the eventual erosion of this assumption, the use of energy-conserving methods may in fact be seen as a marketing advantage.

- As a related point, the reliance on a case study or voluntary case-by-case approach in order to achieve broad and timely use of energy-conserving methods is severely handicapped unless sufficient inducements are provided or unless energy standards are promulgated "across the board."

- Various measures of economic costs and benefits are more or less appropriate for deciding upon the application of energy-conserving technologies; their appropriateness depends on the financial structure within which the decision is being made. Here the time horizon of the investment decision is most critical; differences in time horizons among various actors may hinder application.

- Current attitudes toward "common property resources" (land and materials) hinder anything other than discrete applications of energy-conserving technologies. Traditional forms of land ownership and tenure, for instance, constrain applications requiring long-term sharing of land or other types of resource base, and constrain applications requiring a high degree of sharing and sustained cooperation among development entitities and other actors.

- The lack of reliable information about many aspects of energy-conserving technology has created entrepreneurial uncertainty about its application and, at times, market imperfections. This again will probably change over time.

- Many decisions regarding energy conservation are seemingly made in a milieu that disregards encroaching resource scarcity (that is, a confusion can develop between energy conservation and resource conservation as such). A strategy is usually pursued in which technical substitution is made in an apparently orderly fashion. This is appropriate only if the rate of substitution is greater than or equal to the rate of depletion of resources required to support the energy technologies.

- In this case study, the major components of energy consumption were found to apply to (a) the transportation system and (b) the end-use operating systems. By comparison, embodied energy, although still signigicant, was a small component over the life of the project.

- From the strategies that were applied, the major energy savings were seen to occur with modification of end-use subsystem, building envelope configurations and site design, and with more efficient energy-supply systems that were less dependent upon "outside" sources of fuel.

The Woodlands Development Corporation has already begun to incorporate suggestions from this study in their Metro Center Planning activity. Specifically, the energy-conserving methods categorized as being directly implementable by the developer are being incorporated in ongoing development.

RECOMMENDATIONS

Several areas pertinent to this study require further work, as refinements or extensions of the energy-conserving plan, as well as in the area of detailed development of appropriate implementation strategies. They may be summarized in the following manner:

BUILD-OUT STUDY

A detailed study needs to be undertaken that addresses the disposition and utilization of the land areas remaining vacant in the energy-conserving plan. First, an investigation needs to be made to more precisely estimate the area of land remaining. As a precursor to this investigation the pratical feasibility of reduced parking ratios and shared-parking concepts must be ascertained. Second, a new marketing plan will require development beyond the present "build-out" at 1999, clearly indicating the use to which undeveloped lands should be put. Part of this marketing plan should also reflect a mix of land uses that is conducive to on-site power generation. Third, the supply system will require reconfiguration based on new loads and material imputs. In short, a further refinement of the energy-conserving plan will be required.

BUILDING DESIGN STANDARDS

In order to reach the stage at which elements of the energy-conserving plan may be practically implemented, detailed development guidelines must be drafted. It is envisaged that these guidelines will become part of The Woodlands development standards and will provide sufficiently detailed information to allow individual participants in the Woodlands to adhere to energy-conserving principles.

ENERGY CONSERVATION APPLIED TO BUILDING DESIGN

The present study was made on the basis of hypothetical building prototypes, and the lack of specificity in the design precluded refined estimation of energy demand and the ways in which energy demand could be reduced. An in-depth study of several building types at a more detailed level could provide useful insights into the way in which energy performance may be improved and could also provide information with sufficient detail to facilitate the drafting of development guidelines.

POWER GENERATION (GRID CONNECT)

Further study of a power generation and energy supply option should also be undertaken. Although now linked with the build-out study, however, this option has such apparent energy-conserving potential it should be pursued regardless of the disposition of the build-out study. The institutional constraints and ownership and fuel source options also need to be further explored to create a firmer basis upon which to make detailed hardware specifications. The necessary economic analyses must also be made so that the concept can be mutually agreed upon by all interested parties.

SAND STUDY TEAM

Developer:
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(A subsidiary of Mitchell Energy)
2201 Timberloch Place
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(Contact Matt Swanson, Director of Architecture & Design)

Program & Land Planner:
Phillips, Brandt, Reddick
Newport Beach, California

Architecture:
Frank O. Gehry & Associates
Santa Monica, California

Architectural Analysis:
College of Architecture and Environmental Desgin
Texas A & M University
College Station, Texas

Traffic & Transportation
Barton-Aschmann and Associates
Evanston, Illinois

Utility Systems Analysis:
Technology, Engineering, Environment Management (TEEM)
Seabrook, Texas

Technical Analysis:
Southwest Center for Urban Research
Houston, Texas

Utilities:
Gulf State Utilities (electrical)
ENTEX (natural gas)

Governmental Jurisdiction:
Planning Department of the City of Houston
Engineer of Montgomery County

THE WOODLANDS
PROJECT DATA

(Conventional Plan)

Land Use Information

Site Area:
The Woodlands Total ...... 22,000 acres (8,910 hectares)

SAND Total (Metro Center) ... 554.5 acres

Total Dwelling Units:

High-Rise	959
Mid-Rise	3,475
	4,434

Gross Density:
High-Rise .... 45 dwelling units/acre

Mid-Rise .... 35 dwelling units/acre

Parking:

Residential	1.5 spaces/ dwelling unit
Office	4 spaces/1,000 sq. ft. GLA [2]
Retail	5 spaces/1,000 sq. ft. GLA [2]
Hotel	1.3 spaces/room
Light Industry	3.5 spaces/1,000 sq. ft. GBA [2]
Recreational	5 spaces/1,000 sq. ft. GBA [3]
Cultural	6 spaces/1,000 sq. ft. GLA [3]
Total	35,844 spaces

Land Use Plan

	Acres	Percent
Residential		
High-Rise	99.2	17.9
Mid-Rise	21.3	3.8
Office	214.6	38.7
Retail		
Regional Malls	88.5	16.0
Other	43.0	7.8
Hotel	5.0	1.0
Light Industry	44.4	8.0
Recreational	6.0[4]	1.1
Cultural	32.5	5.7
Total	554.5	100.0

Climate

General: hot and humid

Average Rainfall: 48 inches/year

Building Information

	GBA[3] Square Feet	Residents or Employees
Residential		
High-Rise	975,744	1,918
Low-Rise	3,134,360	6,950
Office	5,018,980	19,255
Retail		
Regnl. Malls	1,335,986	1,833
Other	469,142	723
Hotel	235,224	118
Light Industry	522,285	1,740
Recreational	65,340	60
Cultural	383,764	325
Total	12,140,825	32,922

NOTES

1. Unless otherwise specified, the project data relates only to the Metro Center area of The Woodlands new town.

2. GLA--gross leasable area.

3. GBA--gross building area.

4. In addition, 174.5 acres is open space related to the various land uses.

PART III

RESOURCES

ENERGY GLOSSARY

Active Solar System. A heating or cooling system that requires mechanical devices to move the collected solar energy.

ASHRAE. The American Society of Heating, Refrigeration and Air Conditioning Engineers, a source of basic data and design procedures on heating and air conditioning.

bbl. Barrel of oil. One bbl equals 42 U.S. gallons, and has a heat content of approximately 5.8 million Btu (U.S.).

Berm. A man-made mound of earth; important both as a freestanding, wind-sheltering technique and, when placed adjacent to buildings, as a means of increasing thermal resistance.

Biomass. Any organic matter which is available on a renewable basis, including agricultural crops and agricultural waste and residues, wood and wood waste residues, animal waste, municipal wastes, and aquatic plants; usually used in the context of the type of fuel for community central heating plant systems.

Btu. British thermal unit; the quantity of heat needed to raise the temperature of one pound of water one degree Fahrenheit at or near the water's maximum density (39.2° F). One Btu equals 252 calories; 1 kWh equals 3,413 Btu. A single lit kitchen match releases about one Btu.

Calorie (cal.). The quantity of heat needed to raise the temperature of one gram of water one degree Centigrade at a pressure of one atmosphere; 1,000 calories equals 3.968 Btu.

Capital-intensive. Refers to the relatively large percentage of the total costs of a system associated with the initial construction costs rather than operating costs.

Clerestory. A window above one's line of vision; provides natural light or air circulation within a building.

Cogeneration. The production of thermal energy and electricity in combination, whereby the waste energy from producing electricity, which is usually vented into the atmosphere or cooling water, is recovered and used. Frequent uses of the recovered heat include space heating and hot water heating which in turn can be used to produce air conditioning or to improve waste-water treatment efficiency. Cogeneration provides a higher overall cycle efficiency than generation of electricity and heat separately since the same energy source is used to provide more than one service.

Conductance (C). A property of a material that indicates the quantity of heat in Btu per hour that flows through one square foot of the material when a one-degree-Fahrenheit difference is maintained between the two sides. Conductance values are given for a specific thickness of material, not per inch of thickness (see conductivity).

Conduction. Transfer of heat through a mass from one part to another at a lower temperature with negligible movement of the particles of the mass.

Conductivity (k). The property of material that indicates the quantity of heat in Btu per hour that flows through one square foot of material, one inch thick, when a temperature difference of one degree Fahrenheit exists between two surfaces of the material (Btu/hour/sq. ft./inch thickness/°F). For homogeneous materials, such as concrete, multiplying the conductivity (k) of the material by its thickness gives the conductance (C).

Convection. The transfer of heat within a fluid medium (i.e., air or water) by movements within the fluid or the heat transfer between a moving fluid and a heated or cooled surface. Lighter, warmer fluids rise; heavier, cooler fluids sink.

Cooling Load. The amount of energy required to maintain a desired temperature in a room or building.

COP. Coefficient of Performance, the ratio of the useful energy output of a device to the energy input.

Degree Day. A measurement of the relative severity of an area's heating or cooling season; a degree day is equal to each one degree Fahrenheit deviation from the reference point of 65° F in the mean daily outdoor temperature. Thus a mean daily outdoor temperature of 55° F represents 10 heating degree days. Burke Centre in Fairfax County, Virginia (Washington, D.C., SMSA), has 5,010 heating and 940 cooling degree days annually.

Design Temperature. A temperature representing the lowest expected for a location and used in determining the design heating load (the total heat loss from a building during the most severe winter conditions likely to occur).

District Heating. A heating system that distributes a heated fluid, usually steam or hot water through pipes to individual buildings from a central plant. Some district heating systems contain cogeneration aspects of waste heat recovery from electricity production, incineration, and industrial processing. District heating is widely used in the Scandanavian countries. There are also district cooling systems.

Double-glazed. A sandwich of two separated layers of glass or plastic enclosing air to create an insulating barrier in windows, skylights, greenhouses, and solar collector coverings.

Easement. A right of one landowner to make lawful and beneficial use of another's land or air space above the land, created by an expressed or implied agreement; in terms of solar access this term is used to guarantee a landowner that at least part of his or her property will receive direct sunlight.

EER. Energy Efficient Ratio; the amount of useful heating or cooling a device provides (in Btu) per unit of electrical energy input (in kilowatt hours); an EER of 3.413 is equal to a COP of 1.0.

Embodied Energy. The amount of energy expended to manufacture and put building and infrastructure materials (and systems) in place.

Energy Budget. Usually expressed in Btu per square foot per year and describes the amount of purchased energy a building uses.

Fossil Fuels. Fuels derived from petroleum, coal, peat, or other organic materials produced over millions of years. Today's major commercial examples are oil, gasoline, and coal.

Grid. A network of service lines to utility customers.

Heat Pump. A space conditioning unit that cools like a conventional air conditioner or refrigerator by removing heat from the inside air and delivering it to outside air but that, in reverse, heats by removing heat from outside air and delivering it to the interior. Air-source heat pumps are most common but heat pumps can also exchange energy with a water body (see Greenbrier case study). Although gas-fired heat pumps are commercially available, heat pumps are usually powered by electricity. Electric heat pumps are an efficient use of electricity since it is possible to obtain 2 to 3 times the heat output (COP) for the same electric input as in conventional electrical resistance heating. Heat pumps also can be solar-assisted.

Heat Sink. A body, usually of high mass with high specific heat properties, such as brick, stone, and concrete, which accepts heat from ambient (surrounding) conditions. Due to its thermal storage capacity, many heat sinks are useful as heat (or cooling) sources because they will reconduct heat (or cool air) back to a room when a room's temperature falls below (or raises above) the temperature of the sink.

Horsepower. A unit of power to measure work; equal to 746 watts.

HVAC. Heating, ventilating, and air conditioning.

ICES. Integrated Community Energy System, a comprehensive approach to energy conservation at the community level involving partial or complete integration of a community's energy supply and demand system.

An ICES has four components--resource, central plant, distribution and storage, and end-use. The resource system supplies primary fuel, preferably the most abundant, least polluting fuel in the local area. The central plant provides the initial conversion of high quality energy such as electricity. The distribution and storage system takes the products and wastes of the central plant and delivers them to the appropriate end-use or storage system.

Community design is an important element of the ICES concept. By siting the central plant near residences and buildings, allowing growth along existing energy transportation lines, and considering energy usage in land use planning, a great deal of energy can be saved. Presently there is no public or private policy regarding ICES. Some forms of the ICES concept are the Total Energy System (TES); Modular Integrated Utility System (MIUS); Total Integrated Energy System (TIES); and Cogeneration. These forms of the ICES concept are defined elsewhere in this glossary.

Infiltration. The uncontrolled air leakage into or out of a building, usually expressed as the number of air changes per hour of an air volume equal to the interior space.

Insulation. A material or system that is used to retard heat loss or gain.

kW. Kilowatt or 1,000 watts of power or about 1.34 horsepower.

kWh. Kilowatt hour is one kilowatt of power being used for one hour; equivalent to 3,413 Btu.

Langley. A unit of solar radiation equivalent to one gram calorie per square centimeter of solar illuminated surface.

Life-Cycle Cost. A measure of total system cost over its expected lifespan to include initial production (or construction), maintenance and repair, and operating costs (such as energy consumption). The accumulation of costs over the system's life is usually presented in terms that reflect the relative value of money over time (discounting future costs to present value).

Load-Leveling or Load Management. A technique frequently used by utilities for shifting power usage from peak demand periods; utilities usually have done this by requiring constraints on peak power usage.

Market Penetration. The number or amount of a new product to be sold over a specified time; a measure of consumer acceptance.

MBD. Million barrels (of oil) per day.

MBDOE. Million barrels per day oil equivalent; fuels other than oil and natural gas liquids are converted to oil equivalents, using regional heating values for the fuels and the 5.55 million Btu per barrel of oil.

Mbh. A mechanical engineering abbreviation for thousands (M) of Btu (b) per hour (h).

MIUS. Modular Integrated Utility Systems are on-site combined package plants that provide communities of limited size (300 dwelling units minimum, upper limit flexible) with electricity, heating, air conditioning, water, and liquid and solid waste treatment and disposal. They are modular in that they are located near users and are designed to be in phase with the demands of the community. Resource requirements of one service are met by utilizing the waste of another where possible. Electric generation is placed near consumers in order to utilize waste heat more efficiently, minimizing transmission losses. Solid and liquid waste treatment systems are also integrated with the total energy system. Some technologies used to incorporate MIUS are internal combustion engines, gas turbines, solar energy, heat pumps, pyrolysis, and biological treatment of waste.

MMBTU. A mechanical engineering abbreviation for one million Btu; the predominant U.S. unit of measure for natural gas.

MW. Megawatt, one million watts or 1,000 kilowatts; a unit of large-scale electrical power.

Mwh. 1,000 kilowatt hours (kWh); a unit of large-scale electrical output.

Off-peak. Periods of low demand; for utilities, periods of low electricity demand are usually late evening and early morning.

OPEC. Organization of Petroleum Exporting Countries.

Passive Solar System. A heating or cooling system that requires no mechanical devices to capture, store, and utilize collected solar energy.

Payback. A measure of economic viability of a project or system; usually defined as the number of years required to accumulate savings which exactly equal the initial capital cost of the system. Payback does not give an accurate portrayal of the system's total life-cycle value.

Peak-Load Pricing. Charging more for a produce, service, or right during periods of heavy use; for electric utilities demand this can occur during summer weekday afternoons and winter weekday evening.

Percentage of Possible Sunshine. The daytime hours during which there is enough direct solar radiation to cast a shadow, divided by the total daytime hours possible for a location.

Photovoltaic. A solid-state electrical device capable of producing electric power when exposed to radiant energy (sunlight).

Quad. A quadrillion (10^{15}) Btu, a common measure of annual energy consumption; equivalent to 500,000 barrels of oil per day for 1 year (the annual energy required for the operation of eighteen 1,000-MW power plants or 50 million tons of coal). U.S. consumption in 1979 was about 78 Quads.

R. Resistance or R-value, the tendency of a material to retard the flow of heat; the higher the R-value, the better the insulating quality of that material. R is the reciprocal of a material's conductivity and the U value of a building component (i.e., floor, wall, ceiling, roof, etc).

Retrofit. The addition of a new technology to an existing building.

Specific Heat. The number of Btu required to raise one pound of a substance one degree Fahrenheit. The specific heat for water vapor 0.44; for air 0.24; and concrete 0.22. A high specific heat is usually indicative of a good thermal storage medium.

TES. Total Energy System. In TES electric power, heating media, and cooling media are produced by conventional means. The system is totally self-contained, and no energy conversion is required by the users within the system's boundaries. A total energy system is most efficient when waste heat byproducts of power generation coincide with heating and cooling demand of the users. Because this seldom occurs, auxiliary energy is used to meet the varied needs of the community. A self-contained energy system is attractive using thermal or electric storage. The system could be thermally controlled with excess electric power stored in batteries or as mechanical energy (flywheels, pumped storage, etc.). Auxiliary systems would still be required but would not be used often if equipment for the TES were sized to meet community demand.

TIES. Total Integrated Energy System. In a TIES, the electric power output of a local power generation plant goes into the utility company distribution grid (system) rather than to the user. The user is served with electric power from the utility grid and receives heating and cooling media from the local power plant's waste heat. The utility grid provides a large source-sink for electric energy. The TIES plant is controlled by thermal demand, without auxiliary energy requirements at individual buildings. Sizing of the plant is dependent on economics and waste heat demand.

Therm. 100,000 Btu; a measure used by natural gas utilities in billing.

Thermal mass. The potential heat storage capacity in a substance, system, or building; usually used in reference to common building materials (concrete floors, masonry floors and walls, adobe walls) and passive designs (drum walls, Trombe walls).

Ton. A unit of measuring air conditioning; the cooling effect obtained when one ton of 32° F ice melts to water at 32° F in 24 hours, which is equal to 12,000 Btu per hour. The capacity of an air conditioning unit in tons can be determined by dividing the unit's total Btu capacity by 12,000.

Trombe Wall. A passive solar collector, named after its French designer Felix Trombe, features glazing through which the sun's rays travel and strike a large dark thermal mass, usually a thick concrete or masonry wall or water-filled barrels painted black. In the colder months, air in the space between glazing and mass is heated during the day. As it warms, the air rises through the top vent and flows into the living quarters. Cooler air that is near the floor of the living quarters is pulled into the air space to be heated. Throughout the day, this convective process continues. At night, the mass, which has stored a significant amount of thermal energy, releases heat into the living quarters via radiation. In the warmer months, the Trombe-wall system can theoretically cool a building. Unfortunately, the wall itself tends to overheat and may add too much thermal energy to the structure, if unwanted heat is not vented to the outside. In such cases, shutters or shades may have to be placed over the Trombe-wall glazing in the summer.

U. Overall coefficient of heat transmission or U-value; the Btu per hour flowing through one square foot of roof, wall, or other building component when a one degree Fahrenheit difference in temperature exists between the outside and inside air. It is the reciprocal of the sum of all the resistances of each of the materials that comprise the building component, including air spaces and outside and inside air effects.

Watt. A unit of work or energy, equivalent to 1/746 horsepower, or the work done at the rate of one absolute joule (approximately 0.7375 foot-pounds or 10^7 ergs) per second; also the rate or work represented by a current of one ampere under a pressure of one volt (a U.S. standard).

ENERGY BIBLIOGRAPHY *

The following list of references on energy conservation in development is divided into four sections:

- Site Planning and Building Design
- Rehabilitation, Preservation, and Retrofitting
- Economics, Financing, Markets, Codes and Standards, and Legal Issues
- Community Planning for Energy Conservation

SITE PLANNING AND BUILDING DESIGN

Application of Solar Technology to Today's Energy Needs, by the Office of Technology Assessment. Washington, D.C.: Government Printing Office, 1978, 525 pp. (stock no. 052-003-00539-5) Includes an overview of existing technology, an assessment of the economics of solar systems, a review of the possible federal role, and a discussion of on-site solar as it relates to public utilities.

Architecture and Energy: Conserving Energy Through Rational Design, by Richard G. Stein. New York: Anchor Press, 1977, 322 pp. How building construction and buildings use energy.

A Bibliography for the Solar Home Builder, by Donald W. Aitkin. Sacramento, Calif.: Office of Appropriate Technology, State of California, 1979, 39 pp.

Building the Solar Home: Some Early Lessons Learned (Residential Solar Program Report no. 2), prepared by Dubin-Bloome Associates for U.S. Department of Housing and Urban Development. Washington, D.C.: Government Printing Office, 1978, 36 pp. (stock no. 023-000-00455-1) Analysis of HUD residential demonstration projects to identify problem areas and ways to avoid them.

Building to Save Energy, by Grant P. Thompson. Cambridge, Mass.: Ballinger, 1980, 259 pp. (Environmental Law Institute. State and local energy conservation project series.)

Building Underground for People: Eleven Selected Projects in the United States, by Michael B. Parker. Washington, D.C.: American Institute of Architects, 1978, 30 pp.

Buildings, Climate and Energy, by T.A. Markus and E.N. Morris. Marshfield, Mass.: Pitman, 1980, 540 pp.

Concepts in Thermal Comfort, by David M. Egan. Englewood, N.J.: Prentice-Hall, Inc.

Cost Effective Site Planning; Single Family Development, by National Association of Home Builders. Washington, D.C.: National Association of Home Builders, 1976, 143 pp. (Also available through ULI-the Urban Land Institute).

Design and Evaluation Criteria for Energy Conservation in New Buildings, by ASHRAE. New York: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., 1976.

Design With Climate: Bioclimatic Approach to Architectural Regionalism, by Victor Olgyay. Princeton N.J.: Princeton University Press, 1963, 190 pp. A classic work on how to minimize or maximize climatic elements through siting, form, design, and building materials.

Designing and Building a Solar House: Your Place in the Sun, by Donald Watson. Charlotte, Vt.: Garden Way, 1977, 282 pp.

"A Dollars and Cents Analysis of Energy Savings for Multifamily Housing," (Operating Techniques & Products Energy Bulletin no. 330), by Charles P. Cartee. In Journal of Property Management, July/August 1978, pp. 201-208. Site, building, and operational considerations.

The Double Shell Solar House, edited by Don Booth, Canterbury, N.H.: Community Builders, 1981, 120 pp.

* Updated and based on a bibliography originally compiled and revised by Libby Howland, ULI Resarch Analyst.

Earth Sheltered Housing: Code Zoning, and Financing Issues, by Ray Sterling, Roger Aiken, and John Carmady. Washington, D.C.: Government Printing Office, 1980, 141 pp. (Stock No. 023-000-00632-4).

Earth Sheltered Housing Design: Guidelines, Examples and References. Minneapolis: University of Minnesota, 1978, 310 pp.
Design considerations in general and descriptions of 17 houses.

"Earth-Sheltered Space." In Environmental Comment, December 1979, entire issue (several articles).

"Earth-Sheltered Housing from the Ground Up," by Carol Anderson. In Builder, August 1, 1980, pp. 44-59.

Encyclopedia of Energy-Efficient Building Design: 391 Practical Case Studies, by Kaiman Lee. Boston: Environmental Design and Research Center, 1977, 2 vols. (1023 pp.)

"Energy and Design." In AIA Journal, December 1977, entire issue Articles on federal and state energy policy, and examples of energy conscious design.

Energy & the Builder. Chicago: Cahners Publishing Co., 1977, 160 pp.
A compendium of articles from Professional Builder--news reports and special features published in the magazine since November 1973. Includes descriptions of how to build energy-conserving features into houses and how to sell energy conservation to home buyers.

Energy and Land Use, edited by Robert W. Burchell and David Listokin. Princeton, N.J.: Center for Urban Policy Research, 1980. 560 pp.

"Energy-Conscious Design." In Progressive Architecture, April 1979, entire issue. Articles on passive design and on HVAC and lighting techniques, on tax incentives, on building standards, on solar access; descriptions of energy conscious buildings; and annotated bibliography.

Energy Conservation Design Resource Handbook, by the Royal Architectural Institute of Canada. Ottawa, Ontario: Royal Architectural Institute of Canada, 500 pp., 1980.

Energy Conservation in Buildings: An Economic Guidebook for Investment Decisions (NBS Handbook 132). Washington, D.C.: Government Printing Office, 1980, 149 pp.

Energy Conservation in Residential Building, by American Institute of Architects Research Corporation. Washington, D.C.: U.S. Department of Energy, 1978, 2 vols.

Energy Conservation in Building Design, by AIA. Washington, D.C.: American Institute of Architects, 1974, 156 pp. Outlines areas of the building process where energy savings may be achieved--site planning, transportation, ventilation, heating, cooling, electric power, lighting, domestic hot water, and waste management. Describes trade-offs to be considered in choosing one measure over another.

Energy Conservation Standards for Building Design, Construction and Operation, by Fred S. Dubin and Chalmers A. Long, Jr. New York: McGraw-Hill Book Co., 1978, 413 pp.

Energy Conservation Through Building Design, edited by Donald Watson. New York: McGraw-Hill Book Co., 1979, 308 pp.
Includes chapters on how and why buildings use energy, climate based and solar design, windows, life-cycle costing, energy management, solar legal issues, and energy and land use patterns.

Energy Cost Reduction for Apartment Owners and Managers, by the Institute of Real Estate Management. Chicago: National Association of Realtors, 1977. 61 pp.

Energy Dictionary, by V. Daniel Hunt: New York: Van Nostrand Reinhold, 1979, 4,000 terms.

Energy Information Referral Directory, from DOE National Energy Information Center. Washington, D.C.: Government Printing Office (updated quarterly).

Energy Notebook, by AIA. Washington, D.C.: American Institue of Architects, updated quarterly. A looseleaf information service. Includes case studies, reference guides, bibliographies, codes and regulations information.

Energy Planning for Buildings, by Michael Sizemore, Henry O. Clark and William D. Ostrander. Washington, D.C.: American Institute of Architects, 1979, 156 pp.
Outlines an energy planning process for new and existing buildings.

Energy Requirements for Roadway Pavements, by Asphalt Institute. M.I.S.C.-73-3 April 1975.

The Energy-Wise Home Buyer: A Guide to Selecting an Energy Efficient Home. Washington, D.C.: Government Printing Office, 1979, 60 pp. (S/N 023-000-0518-2)

The First Passive Solar Home Awards, by U.S. Department of Housing and Urban Development, Office of Policy Development and Research, Division of Engineering, Building Technology and Standards. Washington, D.C.: Government Printing Office, 1979, 226 pp. (stock no. 023-000-00517-4)
Brief descriptions of 145 new homes designs and 17 residential retrofits which won HUD awards.

Focus on Energy Conservation, a Second Project List, by ULI-the Urban Land Institute, Washington, D.C.: ULI-the Urban Land Institute, 1980, 198 pp. (44 projects).

"Focus on Solar: Active and Passive." Update In Professional Builder, October 1979, pp. 61, 66-67, 80-81, 85, 91, 99.

Installation Guidelines for Solar DHW (Domestic Hot Water) Systems in One-and Two-Family Dwellings, by U.S. Department of Housing and Urban Development. Washington, D.C.: Government Printing Office, 1979, 111 pp. (S/N 023-000-00520-4)

Joint Development: Making the Real Estate-Transit Connection, by ULI-the Urban Land Institute with support of the Urban Mass Transportation Administration and with the assistance of Gladstone Associates. Washington, D.C.: ULI-the Urban Land Institute,, 1979, 216 pp.

Landscape Planning for Energy Conservation, edited by Gary O. Robinette. Reston Va.: Environmental Design Press, 1977, 224 pp.
Includes chapters on site analysis process and techniques, site selection, siting and orientation, site planning and design, retrofitting, and case studies.

Landscaping That Saves Energy Dollars, by Ruth S. Foster. New York: David McKay Company, Inc., 1978.

"The Location and Selection of Trees for Solar Neighborhoods," by James Zanetto. In Landscape Architecture, November 1978, pp. 514-519.

Metropolitan Physical Environment, by H.J. Plumbley. Washington, D.C.: U.S. Department of Agriculture, 1977.

Minimum Energy Dwelling (MED) Workbook, by U.S. Department of Energy. Springfield Va.: National Technical Information Service, 1978, 423 pp. (SAN/1198-1) Details energy saving techniques, materials and equipment tested in two southern California houses.

Mixed-Use Development: New Ways of Land Use, by Robert E. Witherspoon, Jon P. Abbett, and Robert M. Gladstone. Washington, D.C.: ULI-the Urban Land Institute, 1976, 193 pp.

Natural Solar Architecture: A Passive Primer, by David Wright. New York: Van Nostrand Reinhold Co., 1978, 245+ pp.

New Design Concepts for Energy Conserving Buildings, by AIA. Washington, D.C.: American Institute of Architects, 1977, 124 pp.
Results from an AIA Research Coporation sponsored student competition.

"New Homes Revive the Ancient Art of Living Underground," by David Martindale. In Smithsonian, February 1979, pp. 96-105.

"Notes on Residential Solar Heating," by A.J. Cote, Jr., John Hopkins Applied Physics Laboratory, Baltimore, September 24, 1975.

Options for Passive Energy Conservation in Site Design, prepared by the Center for Landscape Architectural Education and Research for the U.S. Department of Energy. Springfield Va.: National Technical Information Service, 1978, 320 pp.
Illustrates the applications of site planning principles for energy conservation in 4 climate regions.

Passive Design Ideas for the Energy Conscious Architect. Rockville Md.: National Solar Heating and Cooling Information Center, 1978, 54 pp.

"Passive Plans for Builders." In Professional Builder, February 1980, pp. 115-122.

Passive Solar Buildings: A Compilation of Data and Results, by R.P. Stromberg and S.O. Woodall. Springfield Va.: National Technical Information Service, 1977, 71 pp. (SAND 77-1204)
Documents measurements for 4 passive solar homes and 1 passively heated warehouse.

"Passive Solar Concepts." In AIA Journal, December 1979, pp. 48-59.

The Passive Solar Energy Book, by Edward Mazria. Emmaus, Pa.: Rodale Press, 1979, 460 pp.

Passive Solar Energy Design and Materials, edited by J.K. Paul. Park Ridge, N.J.: Noyes Data Corporation, 1979, 386 pp.

"Passive Solar Housing: The Other Way to Use the Sun," by Carol Anderson. In Builder, August 1, 1979, pp. 43-58
Describes passive solar desing concepts and shows several residential examples.

Passive Solar State of the Art, Proceeding of the 2nd National Passive Solar Conference, Philadelphia, 1978. 3 Vols. Edited by Don Powler. Philadelphia: U. of Pennsylvania, International Solar Energy Society, 1978.

Planning and Building The Minimum Energy Dwelling, edited by Kirk Williams, Solana Beach Calif.: Craftsman Book Co., 1977, 287 pp.
Ranges from community planning for energy conservation to design and construction techniques.

Plants/People/and Environmental Quality, by Gary O. Robinette. Washington, D.C.: Department of the Interior, National Park Service, 1972.

Principles of Solar Engineering, by Frank Kreith and Jan F. Kreider. New York: McGraw Hill Book Co., 1978, 778 pp.

"Recent Work in Passive Solar Design: The Use of Architecture Itself As the Primary Energy Device," by Vivian Loftness and Belinda Reeder. In AIA Journal, April 1978, pp. 52-63, 81

Regional Guidelines for Building Passive Energy Conserving Homes, prepared by American Institute of Architects Research Coporation for U.S. Department of Housing and Urban Development. Washington, D.C.: Government Printing Office, 1978, 312 pp. (stock no. 023-000-00481-0)

"Research and Redesign for Energy Conservation." In AIA Journal, September 1978, pp. 59-69.
Designers of 168 buildings were asked by the American Institute of Architects Research Corporation to rethink their original designs with energy conservation as the paramount consideration. Some of the results are discussed here.

Residential Energy Consumption. Multifamily Housing. Final Report, prepared by Hittman Associates, Inc., for U.S. Department of Housing and Urban Development. Washington, D.C.: Government Printing Office, 1974, var. pag. (stock no. 023-000-00282-5)
For townhouses, low rise apartments, and high rise apartments reports on thermal analyses and evaluates modifications whereby energy consumption could be reduced.

Residential Energy Consumption. Single Family Housing. Final Report, prepared by Hittman Associates, Inc., for U.S. Department of Housing and Urban Development. Washington, D.C.: Government Printing Office, 1975, 174 pp.
Reports on detailed thermal analyses on single family dwellings in the Baltimore/Washington area and evaluates technical modifications for minimizing energy consumption.

Saving Money with Energy Conservation: An Energy Audit Workbook for Retail Stores. Springfield, Va.: National Technical Information Service, 1979. (Order No. DOE/CS-0088) A similar workbook for restaurants is available from NTIS (Order No. DOE/CS-0097)

Site Planning for Solar Access: A Guidebook for Residential Developers and Site Planners, by the American Planning Association. Washington, D.C.: Government Printing Office, 1979. (Stock No. 023-000-00545-0).

Solar Dwelling Design Concepts, prepared by the American Institute of Architects Research Corporation for U.S. Department of Housing and Urban Development. Washington, D.C.: Government Printing Office, 1976, 146 pp. (stock no. 023-000-00334-1) (Also available from American Institute of Architects)

Solar Energy and Housing: An Introduction, by AIA. Washington, D.C.: American Institute of Architects Research Corporation, 1975, 32 pp.

Solar Energy and Housing--Design Concepts, by Giffels Associates, Inc. Washington, D.C.: American Institute of Architects, 1975, 145 pp.
Multifamily housing solar design, active and passive.

Solar Energy: Fundamentals in Building Design, by Bruce Anderson. New York: McGraw Hill Book Co., 1977, 374 pp.

Solar Heated Buildings of North America--120 Outstanding Examples, by William A. Shurcliff. Harrisville, N.H.: Brick House Publishing Co., 1978, 295 pp.

Solar Heating and Cooling Demonstration Program: A Descriptive Summary of HUD Solar Residential Demonstrations, Cycle 1, 1976. Washington, D.C.: Government Printing Office, 59 pp. (stock no. 023-000-00338-4).

Solar Heating and Cooling Demonstration: A Descriptive Summary HUD Solar Residential Demonstrations, Cycle 2, Fall 1976, prepared by American Institute of Architects Research Corporation. Washington, D.C.: Government Printing Office, 1977, 103 pp. (stock no. 023-000-00389-9)

Solar Heating and Cooling Demonstration Program: A Descriptive Summary of HUD Cycle 3 Solar Residential Projects, Summer 1977, prepared by American Institute of Architects Research Corporation. Washington, D.C.: Government Printing Office, 1977, 165 pp. (stock no. 023-000-00418-6)

Solar Heating and Cooling Demonstration Project Summaries, by U.S. Department of Energy. Washington, D.C.: Government Printing Office, 1978, 264 pp. (stock no. 061-000-00082-8)

Solar Installation Application Manual. Scarsdale, N.Y.: Solex Solar Energy Systems, Inc., 1980.

Sun/Earth: How to Use Solar and Climatic Energies Today, by Richard L. Crowther. New York: Charles Scribners Sons, 1977, 232 pp.

A Survey of Passive Solar Buildings, prepared by American Institute of Architects Research Corporation for U.S. Department of Housing and Urban Development. Washington, D.C.: Government Printing Office, 1978, 176 pp. (stock no. 023-000-00437-2)
Describes and illustrates 97 buildings.

Transporation Energy Conservation Data Book: Edition 2, by D.B. Shanka, A.S. Loebl, and P.D. Patterson. Oak Ridge, Tenn.: Oak Ridge (Tennessee) National Laboratory, 1977.

Trip Generation Intensity Factors, by Arizona Department of Transportation. Washington, D.C.: Federal Highway Administration, 1977 (reprint).

Toward a Solar Civilization, edited by Robert H. Williams. Cambridge Mass.: MIT Press, 1978, 251 pp. Papers covering a range of technologies from passive home heating to solar power plants, and discussing the potential for their application.

"Underground Architecture: Building Within the Earth Brings Some Significant Payoffs," by Andrea O. Dean. In AIA Journal, April 1978, pp. 34-51.

Underground Designs, by Malcolm Wells. Brewster Mass.: Malcolm Wells, 1977. 87 pp.

"The Underground Movement Widens: A Look At Six Subsurface Buildings Along With Some Ideas and Techniques," by Andrea O. Dean. In AIA Journal, November 1978, pp.34-42.

Village Homes' Solar House Designs, by David Bainbridge, Judy Corbett, and John Hoface. Emmaus, Pa.: Rodale Press, 1979.

REHABILITATION, PRESERVATION AND RETROFITTING

Assessing the Energy Conservation Benefits of Historic Preservation: Methods and Examples, prepared by Booz, Allen and Hamilton for the Advisory Council of Historic Preservation. Washington, D.C.: Government Printing Office, 1979, 91 pp. (stock no. 024-000-00856-8)

"Conserving Energy in Historic Buildings," by Baird M. Smith. In Preservation Briefs, no. 3, April 1978, 8 pp. (Technical Preservation Services Division, Office of Archeology and Historic Preservation, Heritage Conservation and Recreation Service, U.S. Department of the Interior)

Identifying Retrofit Projects for Buildings by the Federal Energy Management Program. Springfield, Va.: National Technical Information Service, 1980.

Saving Energy in the Home: Princeton's Experiments at Twin Rivers, edited by Robert H. Socolow. Cambridge Mass.: Ballinger Publishing Co., 1978, 330 pp.

Providing for Energy Efficiency in Homes and Small Buildings, by U.S. Department of Energy. Washington, D.C.: Government Printing Office, 1980. (DOE/IR/06065-1)

"A Two-Thirds Reduction in the Space Heat Requirement of a Twin Rivers Townhouse," by Frank W. Sinden. In Energy and Buildings, vol. 1 (1977/78), pp. 243-260.

"Ways to Save Energy and Stay Warm," by Douglas Peterson. In Historic Preservation, March/April 1979, pp. 41-48

ECONOMICS, FINANCING, MARKETING, CODES AND STANDARDS, AND LEGAL ISSUES

The Adoption of Energy Conservation Features in New Homes, by Edward J. Kaiser, Mary Ellen Marsden, and Raymond Burby. Chapel Hill, N.C.: Center for Urban and Regional Studies, University of North Carolina, 1979, 36 pp.

Application of Solar Technology to Today's Energy Needs, by Office of Technology Assessment. Washington, D.C.: Government Printing Office, 1978 (stock no. 052-003-00539-5) The market competitiveness of on-site solar energy systems, and federal actions that could promote them.

"Appraising the Sun: Experience to Date," by Arthur J. Reiger. In The Appraisal Journal, April 1980, pp. 224-229.

Basic Energy Conservation Code (Second Edition), by BOCA (Building Officials Code Administrators). Chicago, Ill.: BOCA International Inc. 1978.

Conservation Sourcebook: Summaries of State Legislative Enactments in 1977 Regarding Conservation. Denver: National Conference of State Legislatures, 1978, 75 pp.

Cost and Code Study of Underground Buildings, by the Underground Space Center. Minneapolis: University of Minnesota, 1978.

Early Use of Solar Energy in Buildings. A Study of Barriers and Incentives to the Widespread Use of Solar Heating and Cooling Systems, by American Institute of Architects Research Corporation. Springfield Va.: National Technical Information Service, 1976, 195 pp. (PB 267 832/4PTR)

Earth Sheltered Housing: Code, Zoning and Financing Issues, by the Underground Space Center, University of Minnesota. Washington, D.C.: U.S. Department of Housing and Urban Development, 141 pp.

An Economic Analysis of Solar Water and Space Heating, prepared by Mitre Corporation for Energy Research and Development Administration. Springfield Va.: National Technical Information Service, 1976, 71 pp. (DSE-2322-1/PTR)
Solar energy use compared to conventional fuel use in 13 U.S. cities.

"Economic Feasibility of Solar Water and Space Heating," by Roger H. Bezdek. In Science, March 1979, pp. 1214-1220.

An Economic Model for Passive Solar Designs in Commercial Environments, by Jeanne W. Powell. National Bureau of Standards, U.S. Department of Commerce. Washington, D.C.: Government Printing Office, 1980, 135 pp. (NBS Building Science Series No. 125).

Energy Conservation and Building Codes: The Legislative and Planning Processes, by Kaiman Lee and Stuart L. Rehr. Boston: Environmental Design and Research Center, 1977, 109 pp.

The Energy Conservation Design Resource Handbook, by the Royal Architectural Institute of Canada. Ottawa, Ontario, Canada, 1980, 500 pp. (Available through American Institute of Architects, Washington, D.C.)

Energy Conservation for the Homebuilder, 1978. Chicago: Cahners Publishing Co., 1978, 40 pp. Survey of homebuilders (750 responses) on current problems and advantages of energy conservation in home building. Note: The survey results are summarized in the June 1978 issue of Professional Builder. pp. 150-153.

Energy Conservation in Buildings: A Case Study of the State of California. 1978, 275 pp.; Colorado. 1979, 200 pp; Virginia. 1978, 140 pp; Massachusetts. 1977, 100 pp; Washington: National Institute of Building Sciences, 4 vols.
Case studies of experiences with state energy conservation standards for new buildings.

Energy Conservation in Buildings: An Economic Guidebook for Investment Decisions, by National Engineering Laboratory, National Bureau of Standards. Washington, D.C.: Government Printing Office, 1980, 149 pp. (NBS Handbook 132).

"Energy Costs and Home Values," by Errol Cowan. In The Appraisal Journal, July 1980, pp. 445-448.

Energy and Housing: Consumer and Builder Perspectives, edited by Raymond J. Burby and Mary Ellen Marsden. Chapel Hill, N.C.: Center for Urban and Regional Studies and the Institute for Research in Social Science, University of North Carolina, 1979, 396 pp.

Federal Home Loan Bank Board Journal, July 1980 (contains several articles on financing energy conservation in homes).

Financing the Solar Home: Understanding and Improving Mortgage-Market Receptivity to Energy Conservation and Housing Innovation, by David Barrett, Peter Epstein and Charles M. Haar. Lexington Mass.: Lexington Books, 1977, 201 pp.

"Implementation of Energy Conservation Codes," by James T. Quinn. In Construction Review, October 1978, pp. 4-8.

"Implications for Construction of Future Energy Availability," by J. F. Gustaferro. In Construction Review, February 1979, pp. 4-9

"The Influence of Solar Energy Systems on the Value of Dwellings: Theory vs. Practice," by James R. Webb. In The Real Estate Appraiser and Analyst, January-February, 1980, pp. 4-6.

"Institutional Barriers to Solar Energy: Early HUD Demonstration Experiences," by Gerald Mara and David Engel. Solar Law Reporter, vol. 1, no. 6, March/April 1980.

"Land-Use Regulation of Underground Housing," by Kenneth B. Labs. In PAS Memo, May 1979, 8 pp. (American Planning Association)

"Legal Obstacles to Decentralized Solar Energy Technologies," by Alan S. Miller. In Solar Law Reporter, September/October 1979, pp. 595-612, and November/December 1979, pp. 761-783.

Life-Cycle Costing: A Guide for Selecting Energy Conservation Projects for Public Buildings, by Rosalie T. Ruegg and others. Washington, D.C.: National Bureau of Standards, 1978 (Building Science Series No. 113)

Life-Cycle Costing Emphasizing Energy Conservation: Guidelines for Investment Analysis, revised edition. Washington, D.C.: Energy Research and Development Administration, 1977. (ERDA Manual 76/130)

"Light Years Ahead of Uncle Sam," by Valerie Dow. In Environmental Action, May 1979, pp. 19-20.
State solar energy programs.

"Market Acceptance of Solar Energy: Some Preliminary Findings," by Stephen Spigel. In Real Estate Report (Real Estate Research Corporation), Summer quarter 1979, pp. 7-8.

MIUS and You, The Developer Looks at a New Utility Concept: Seminar Guide and Manual of Information. Encino, Calif.: Group Management Associates, 1979, var. pag.

"The National Energy Act: Its Impact on Real Estate and Real Estate Financing," by Martin Klepper. In Real Estate Review, Spring 1979, pp. 40-49.

New Energy Technology for Buildings: Institutional Problems and Solutions, by Richard Schoen, Alan Hirshberg and Jerome Weingart. Cambridge Mass.: Ballinger Publishing Co., 1975, 217 pp. Identifies institutional barriers to the commercial application of new energy technologies within the construction industry.

"New Focus on Energy." In Housing, May 1979, pp. 78-83.
There is a new surge in buyer desire for energy efficient housing. Some efficiency will be mandated by law and some will come from market demand.

Notice of Proposed Rulemaking--Energy Performance Standards for New Buildings. Washington, D.C.: U.S. Department of Energy, Office of Conservation and Solar Energy, Office of Buildings and Community Systems, November, 1979 (DOE/CS/012).

Overcoming Legal Uncertainties About Use of Solar Energy Systems, by William A. Thomas, Alan S. Miller, and Richard L. Robbins. Chicago: American Bar Foundation, 1978, 80 pp.
Suggested statutes and commentary to establish a solar energy development commission, to authorize solar skyspace easements, to encourage the use of solar energy systems, and to provide tax incentives for the use of solar energy.

Preferential Tax Treatment for Alternative Energy Devices and Energy Conservation, by Robert C. Pitcher. Washington, D.C.: Federation of Tax Administrators, 1979, 36 pp. (Research report no. 82).

Protecting Solar Access for Residential Development: A Guidebook for Planning Officials, by Martin Jaffe and Duncan Erley. Prepared by the American Planning Association for the U.S. Department of Housing and Urban Development. Washington, D.C.: Government Printing Office, 1979, 154 pp. Stock No. 023-000-00523-9)
How to use conventional land use controls--police power or private agreements--to prevent shading of neighboring buildings.

The REALTOR'S[R] Guide to Residential Energy Efficiency: An Introduction in Using Energy to Sell Homes, Chicago: National Association of REALTORS[R], 1980, 48 pp.

Realtors and Appraisers Discuss Home Insulation and Other Energy-Related Issues. A Research Report, prepared by Opinion Research Corporation. Midland, Mich.: Dow Chemical Co., December 1978.

Renewable Energy Development: Local issues and Capabilities, by Office of Solar Policy. Washington, D.C.: U.S. Dpartment of Energy, 1980, 322 pp.

"Selling Solar Without Subsidies." In Housing, August 1978, pp. 63-71. Reports on 15 builders who are successfully marketing non-subsidized solar houses.

Selling the Solar Home '80, Market Findings for the Housing Industry, prepared by Real Estate Research Corporation for the U.S. Department of Housing and Urban Development. Washington, D.C.: Government Printing Office, 1980, 38 pp. (stock no. 023-000-00568-9).

"Solar and Utilities." In Solar Age, December 1978 (a number of articles).

Solar Access Law, by Gail Boyer Hayes. Cambridge, Mass.: Ballinger, 1979, 303 pp.

"Solar Energy: The Market Realities (Life-Cycle Costing Analyses Don't Persuade the Decision Makers)," by Arthur J. Rieger. In Real Estate Review, Winter 1979, pp. 49-52.

The Solar Greenhouse Book, edited by James C. McCullagh. Emmaus, Pa.: Rodale Press, 1978.

"Solar Heating and Cooling: State and Municipal Legal Impediments and Incentives," by Mary Shiflett and John V. Zuckerman. In Natural Resources Journal, April 1978, pp. 313-336. Access to sunlight, marketing and financing, design and construction, operating problems, institutional attitudes.

Solar Law: Present and Future, With Proposed Forms, by Sandy F, Kraemer. Colorado Springs, Colo.: Shepard's, Inc., 1978, 364 pp.
An analysis of the legal issues that have or will arise with increased use of solar power--solar access, land use, building codes, public utility rates, certification programs, tax incentives, financing, liability, warranties, insurance.

Solar Law Reporter, (bi-monthly periodical). Editorial Offices: Solar Energy Research Institute, Golden, Colo. Subscriptions: Government Printing Office, Washington, D.C.

The Solar Market. Washington, D.C.: Government Printing Office, 1978 (stock no. 018-000-00216-7)
30 papers from a Federal Trade Comission symposium on consumer and competition issues facing the development of the solar industry.

"Solar Standards Emerge Slowly: Their Arrival Will Unlock Market Doors," by Ryc Loope. In Solar Age, May 1979, pp. 26-30.

"Some Comments on Drafting Solar Access Regulations," by Martin Jaffe. In Land Use Law & Zoning Digest, 1978, no. 8, pp. 4-7.

States' Energy Conservation Standards for New Housing and Buildings:
Status of Regulatory Activities. 1978, 29 pp.;
Development, Administration and Enforcement Processes. 1978, 38 pp.;
State Legislative Analysis. 1978, 48 pp. Washington, D.C.: National Institute of Building Sciences, 3 vols.

"The Sun--Who Owns It?" by Earl A. Talbot and Dawn Walter. In The Appraisal Journal, October 1979, pp. 601-605.

"Valuing the Solar Home," by Edgar H. Hemmer. In Real Estate Today, October 1978., pp. 16-20.

COMMUNITY PLANNING FOR ENERGY CONSERVATION

Capacity-Building: Local Government Approaches to Energy Conservation, by HUD Office of Policy Development and Research. Washington, D.C.: Government Printing Office, 1980.

"Community Energy Planning: Bridging the Information Gap," by Yale Schiffman and Abbie Page. In Practicing Planner, June 1979, pp. 17-21.

Compact Cities: A Neglected Way of Conserving Energy. Joint Hearings Before the Subcommittee on the City of the Committee on Banking, Finance and Urban Affairs and the Subcommittee on Oversight and Investigations of the Committee on Interstate and Foreign Commerce, House of Representatives, U.S. Congress, December 11 and 12, 1979. Washington, D.C.: Government Printing Office, 1980, 471 pp.

Compact Cities: Energy Saving Strategies for the Eighties, a report of the Committee on Banking, Finance and Urban Affairs (Subcommittee on the City). Washington, D.C.: U.S. House of Representatives, 1980, 86 pp.

Compact City, A Plan for a Liveable Urban Environment, by George B. Dantzig and Thomas L. Saaty. San Francisco; W. H. Freemen & Co., 1973.

Comprehensive Community Energy Planning. Final Report:
Vol. 1: Workbook. var. pag.
Vol. 2: Appendices. var. pag.
Vol. 3: Worksheets. 106 pp.
Prepared by Hittman Associates, Inc., Washington, D.C.: U.S. Department of Energy, 1978.

Davis Energy Conservation Report: Practical Use of the Sun, by Living Systems. Davis Calif: Community Development Department, 1977, 128 pp. Also available from National Technical Information Service, Springfield, Va. (PB 276 616/OWU)

"Distinct Heating: An Old Story With A New Ending." In Environmental Comment, December 1980, entire issue (several articles).

Energy and Form: An Ecological Approach to Urban Growth, by Ralph L. Knowles. Cambridge, Mass.: MIT Press, 1974, 198 pp.

Energy and the City. Hearings before Committee on Banking, Finance and Urban Affairs, House of Representative, U.S. Congress. Washington, D.C.: Government Printing Office, 1977, 461 pp.

Energy and the Community, edited by Raymond J. Burby III and A. Fleming Bell. Cambridge Mass.: Ballinger Publishing Co., 1978, 140 pp.

"Energy Conservation and Land Development." In Environmental Comment, July 1977, entire issue.

Energy Conservation and Community Development, December 13, 1979 hearing by U.S. Senate Committee on Banking, Housing, and Urban Affairs (Subcommittee on Housing and Urban Affairs). Washington, D.C.: U.S. Senate, 1979, 163 pp.

Energy Conservation Choices for the City of Portland, Oregon

Vol. 1: *Preliminary Energy Data and Analysis*. 343 pp.
Vol. 2: *Energy Information Retrieval System*. 171 pp.
Vol. 3: *Summary of Conservation Choices*. 97 pp.
Vol.3A: *Residential Conservation Choices*. 110 pp.
Vol.3B: *Transportation and Land Use Conservation Choices*. 95 pp.
Vol.3C: *Commercial Conservation Choices*. 79 pp.
Vol.3D: *Industrial Conservation Choices*. 85 pp.
Vol.3E: *Government Conservation Choices*. 86 pp.
Vol. 4: *Model Local Code Revisions for Energy Conservation*. 158 pp.
Vol. 5: *Capital Budgeting and Energy Use*. 66 pp.
Vol. 6: *Project Overview*. 84 pp.

Prepared by Policy Analysis Section, Bureau of Planning, City of Portland, Oregon for the Office of Policy Development and Research, U.S. Department of Housing and Urban Development. Springfield Va.: National Technical Information Service, 1978 (PB 276 778/AS).

Energy Conservation Training Institute, prepared by the Conservation Foundation for the U.S. Federal Energy Administration. Washington, D.C.: Conservation Foundation, 1977, var. pag. 20 papers on energy use in society, public policies affecting energy conservation strategies, specific energy conservation strategies, and the citizens' role in energy conservation.

Energy-Conserving Development Regulations, by the American Planning Association for the U.S. Department of Energy. Chicago: American Planning Association, 1980.

Energy-Efficient Community Planning, by James Ridgeway. Emmaus, Pa.: The JG Press, 1979, 224 pp.

Energy-Efficient Land Use, by Duncan Erley and others. Chicago: American Planning Association, 1979, 25 pp. (Planning Advisory Service Report no. 341).

"Energy Saving Landscapes: Urban Development Versus Landscape Resources," by Marta Braiterman, Julius Gy. Fabos, and John H. Foster. In *Environment*, July/August 1978, pp. 30-37.

Energy Taxation: An Analysis of Selected Taxes (Energy Policy Study Volume), by the U.S. Department of Energy. Washington, D.C.: Government Printing Office, 1980, 112 pp. (Stock No. 061-003-00136-0).

The Energy Vista: Policy Perspectives on Energy Conservation Through Land Use Management, prepared by Technology and Economics, Inc. for the U.S. Federal Energy Administration. Springfield Va.: National Technical Information Service, 1976, 407 pp.
Discusses the energy use implications of federal tax laws, federal agency programs, and regional and state programs. Explores the land use implications of emerging energy technologies.

Factors That Influence the Acceptance of Integrated Community Energy Systems, by A.S. Kennedy and others, Argonne National Laboratory. Springfield Va.: National Technical Information Service, 1977, 241 pp. (ANL-77-XX-72).

Financial Overview of Integrated Community Energy Systems, by K. G. Croke and others, Sandia Labs. Springfield Va.: National Technical Information Service, 1977, 125 pp. (ANL-77-XX-71).
Commercialization potential of community scale energy systems.

"In Denmark, Builders Take a Crash Course in Saving Energy," by David Garfinkel. In *Builder*, August 1 1979, pp. 59-65
Energy conservation programs affecting housing in Denmark.

Land Use and Energy Utilization: Final Report, by T. Owen Carroll, Robert Nathans, and Philip F. Palmedo. Prepared by Brookhaven National Laboratory. Washington, D.C.: U.S. Federal Energy Administration. 1977, 44 pp.

Local Government Energy Activities:
Vol. 1: *Summary Analysis of Twelve Cities and Counties*.
Vol. 2: *Detailed Analyses of Twelve Cities and Counties*.
Vol. 3: *Case Studies of Twelve Cities and Counties*.
By U.S. Department of Energy. Springfield, Va.: National Technical Information Service, 1979.

Methodology for Energy Management Plans for Samll Communities, prepared by Sizemore and Associates. Washington, D.C.: U.S. Department of Energy, 1978, 165 pp.

"Modifying Subdivision Regulations for Solar Access," by Duncan Erley. In PAS Memo, October 1978, 4 pp. (American Planning Association)

"The Planner's Energy Workbook. A User's Manual for Exploring Land Use and Energy Utilization Relationships," by T. Owen Carroll, Robert Nathans, Philip F. Palmedo and R. Stern. Prepared by Brookhaven National Laboratory for U.S. Federal Energy Administration. 1976, (unpublished). Presents a set of procedures and worksheets for planners to use in evaluating alternative land use and design programs for energy conservation.

Planning Solar Neighborhoods, by Jonathan Hammond, James Zanetto, and Ianto Evans. Prepared by the American Planning Association. Washington, D.C.: U.S. Department of Housing and Urban Development, 1979.

Renewable Energy and the City. Joint hearings before U.S. House Committee on Banking, Finance, and Urban Affairs (Subcommittee on the City) and the Committee on Interstate and Foreign Commerce (Subcommittee on Oversight and Investigations). Washington, D.C. U.S. House of Representatives, October, 1979, 361 pp.

Residential Energy Conservation (Vol. 1), by Office of Technology Assessment, U.S. Congress. Washington, D.C.: U.S. Congress, 1979.

Residential Solar Design Review: A Manual on Community Architectural Controls and Solar Energy Use, by Martin Jaffee and Duncan Erley. Chicago: American Planning Association, 1980.

"Solar Access and Urban Form," by Ralph Knowles. In AIA Journal, February 1980, pp. 42-49, 70.

A Strategy for Energy Conservation, by Energy Conservation Ordinance Project. Davis, Calif.: City of Davis, 1974.

Solar Assessment Study in the Support of the International Ekistics Program, Phase I Report, prepared by Arthur D. Little, Inc., for the U.S. Energy Research and Development Administration. Springfield Va.: National Technical Information Service, 1977, 258 pp. (ANL/ICES-TM-12) Program for designing community energy systems, emphasizing renewable energy sources, for a new town being planned for Crete, Greece.

Urban Form and Energy Consumption, by Gene Desfor and Michael Miloff. Toronto, Canada: Middleton Associates, 1979, 99 pp.

Using Land to Save Energy, by Corbin Crew Harwood. Cambridge, Mass.: Ballinger Publishing Co., 1977, 335 pp.
The role of public regulatory policies in energy conservation--land use planning, zoning, energy standards, capital facilities programming, land acquisition, energy impact statements.

PRIVATE SECTOR SOURCES

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1925 K Street, N.W.
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(202) 857-0666

American Institute of Architects
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1735 New York Avenue, N.W.
Washington, D.C. 20006
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American Planning Association
Energy Planning Division
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(703) 827-6244

American Planning Association
1313 East 60th Street
Chicago, IL 60637
(312) 947-2560
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1776 Massachusetts Avenue, N.W.
Washington, D.C. 20036
(202) 872-0611

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
345 East 47th Street
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(212) 644-7500

Center for Renewable Resources
1001 Connecticut Avenue, N.W., Suite 510
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(202) 466-6350

Citizens Energy Project
1110 6th Street, N.W.
Suite 300
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(202) 387-8998

Citizen/Labor Energy Coalition
606 West Fullerton Street
Chicago, Illinois 60614
(312) 929-9125

Conference on Alternative State and Local Policies
2000 Florida Avenue, N.W.
Washington, D.C. 20009
(202) 387-6030

Consumer Action Now
355 Lexington Avenue
New York, New York 10017
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Cooperative League of the U.S.A.
1828 L Street, N.W.
Suite 1100
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Energy Research and Information Foundation
3500 Kingman Boulevard
Des Moines, Iowa 50311
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9208 Christopher Street
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Institute for Local Self-Reliance
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National Association of Home Builders
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National Association of Realtors
430 N. Michigan Avenue
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National Center for Appropriate Technology
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National Rural Electric Cooperative Association
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3734 Atlanta Highway
Montgomery, Alabama 36130
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(800) 572-7226 (State Solar Hotline)

Alaska Division of Energy and Power Development
338 Denali
Anchorage, Alaska 99501
(907) 276-0512

Arizona Energy Office
1700 West Washington, Room 504
Phoenix, Arizona 85007
(602) 255-3303
(800) 352-5499 (State Energy Hotline)

Arkansas State Energy Office
Commerce Department
3000 Kavanaugh
Little Rock, Arkansas 72205
(501) 371-1370
(800) 482-1122 (State Energy Hotline)

California Energy Commission
111 Howe Avenue
Sacramento, California 95825
(916) 920-6430
(800) 952-5670 (State Solar Hotline)

Colorado Department of Energy
1525 Sherman, 4th Floor
Denver, Colorado 80203
(303) 839-2507
(800) 234-2105 (State Energy Hotline)

Connecticut Office of Policy and Management
Energy Division
80 Washington Street
Hartford, Connecticut 06115
(203) 566-7038
(800) 342-1648 (State Energy Hotline)

Delaware Energy Office
56 The Green
Dover, Deleware 19901
(302) 736-5644
(800) 282-8616 (State Energy Hotline)

District of Columbia Office of Planning and Development
409 District Building
1350 E Street, N.W.
Washington, D.C. 20004
(202) 727-6365

Florida Governor's Energy Office
301 Bryant Building
Tallahassee, Florida 32301
(904) 488-2476
(800) 432-0575 (State Solar Hotline)

Georgia Office of Energy Resources
270 Washington Street, S.W.
Suite 615
Atlanta, Georgia 30334
(404) 656-5176

Hawaii State of Energy Office
Department of Planning and Economic Development
1164 Bishop Street, Suite 1515
Honolulu, Hawaii 96813
(808) 548-4150

Idaho Office of Energy
State Capitol Building
Boise, Idaho 83720
(203) 334-3800
(800) 632-5954 (State Energy Hotline)

Illinois Institute of Natural Resources
Divisions of Solar Energy and Conservation
325 West Adams Street, Room
Springfield, Illinois 62706
(217) 785-2800

Indiana Energy Office
Indiana Department of Commerce
440 North Meridian Street
Indianapolis, Indiana 46204
(317) 232-8940

Iowa Energy Policy Council
Lucas Building, 6th Floor
Capitol Complex
Des Moines, Iowa 50319
(515) 281-4420
(800) 523-1114 (State Energy Hotline)

Kansas Energy Office
214 West 6th Street
Topeka, Kansas 66603
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(800) 432-3537 (State Energy Hotline)

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Capitol Plaza Tower
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Louisiana Department of Natural Resources
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150 East Kellogg Boulevard
St. Paul, Minnesota 55101
(612) 296-5120
(800) 652-9747 (State Energy Hotline)

Mississippi Department of Energy
510 George Street
Jackson, Mississippi 39201
(601) 961-4733

Missouri Division of Energy
P.O. Box 1309
Jefferson City, Missouri 65102
(314) 751-4000
(800) 392-0717 (State Energy Hotline)

Montana Department of Natural Resources
and Conservation
Energy Division
32 South Ewing Street
Helena, Montana 59601
(406) 449-3940

Nebraska Energy Office
301 Centennial Mall, Box 59085
Lincoln, Nebraska 68509
(402) 417-2869

Nevada Department of Energy
400 W. King Street, #106
Carson City, Nevada 89701
(702) 885-5157

New Hampshire Governor's Council on
Energy
2½ Beacon Street
Concord, New Hampshire 03301
(603) 271-2711
(800) 852-3466 (State Energy Hotline)

New Jersey Department of Energy
Office of Conservation
101 Commerce Street
Newark, New Jersey 07102
(201) 648-3902
(800) 492-4242 (State Energy Hotline)

New Mexico Energy and Minerals Department
P.O. Box 2770
Santa Fe, New Mexico 87503
(505) 827-2472
(800) 432-6782 (State Energy Hotline)

New York State Energy Office
2 Rockefeller Plaza
Albany, New York 12223
(518) 474-2161
(800) 342-3722 (State Energy Hotline)

North Carolina Department of Commerce
Energy Division
P.O. Box 25249
Raleigh, North Carolina 27611
(919) 733-5078
(800) 662-7131 (State Energy Hotline)

North Dakota Energy Office
State Capitol Building
Bismarck, North Cakota 58505
(701) 224-2250

Ohio Department of Energy
30 East Broad Street, 34th Floor
Columbus, Ohio 43215
(614) 466-6797
(800) 282-9234 (State Energy Hotline)

Oklahoma Department of Energy
4400 North Lincoln Boulevard
Suite 251
Oklahoma City, Oklahoma 73105
(405) 521-3441

Oregon Department of Energy
Labor and Industries Building
Salem, Oregon 97310
(503) 378-4040
(800) 452-7813 ("Access 800" State
Government Hotline)

Pennsylvania Governor's Energy Council
1625 North Front Street
Harrisburgh, Pennsylvania 17102
(717) 783-3610
(800) 882-8400 (State Energy
Conservation Hotine)

Puerto Rico Office of Energy
Minillas Governmental Center
North Building Office, Postal Stop 22
P.O. Box 41089, Minillas Station
Santurce, Puerto Rico 00940
(809) 726-3636

Rhode Island Governor's Energy Office
80 Dean Street
Providence, Rhode Island 02903
(401) 277-3773 (will accept collect calls from state residents)

South Carolina Office of Energy Resources
1122 Lady Street, #1130
Columbia, South Carolina 29201
(803) 753-7502

South Dakota Office of Energy Policy
Capitol Lake Plaza
Pierre, South Dakota 57501
(605) 773-3604
(800) 592-1895 ("Tie Line" State Government Hotline)

Tennessee Energy Authority
226 Capitol Boulevard, Suite 707
Nashville, Tennessee 37219
(615) 741-6671
(800) 342-1340 (State Energy Hotline)

Texas Energy and Natural Resources Advisory Council
200 East 18th Street
Austin, Texas 78701
(512) 475-0974

Utah Energy Office
Empire Building
231 East 400 South
Salt Lake City, Utah 84111
(801) 533-5424
(800) 662-3633 (State Energy Hotline)

Vermont Energy Office
State Office Building
Montpelier, Vermont 05602
(802) 828-2393
(800) 642-3281 (State Energy Hotline)

Virginia State Office of Emergency and Energy Services
Energy Division
310 Turner Road
Richmond, Virginia 23225
(804) 745-3245
(800) 552-3831 (State Energy Hotline)

Virgin Islands Energy Office
P.O. Box 90
St. Thomas, Virgin Islands 00801
(809) 774-0750

Washington State Energy Office
400 East Union, 1st Floor
Olympia, Washington 98504
(206) 754-0728

West Virginia Fuel and Energy Office
1951 Washington Street, E.
Charleston, West Virginia 25311
(304) 348-8860
(800) 642-9012

Wisconsin Division of State Energy
101 S. Webster
Madison, Wisconsin 53702
(608) 266-9861

Wyoming Energy Conservation Office
320 West 25th Street
Cheyenne, Wyoming 82002
(307) 777-7131
(800) 442-8334 (State Solar Referral Hotline)
(800) 442-2744 (State Government Hotline)

FEDERAL INFORMATION SOURCES

*Emergency Conservation Service
Office of Emergency Programs
U.S. DOE
Rm. GE 004A (2S39)
Forrestal Building
Washington, D.C. 20585
(800) 424-9122
In Alaska, Hawaii, Puerto Rico, Virgin Islands
(800) 424-9088
In Washington, D.C. (202) 252-4950

Federal Tax Information
Internal Revenue Service
(800) 527-3880

National Energy Information Center
1726 M Street, N.W.
Suite 850
Washington, D.C. 20461
(202) 634-5610

*National Ridesharing Information Center
U.S. Department of Transportation
Room 4432
400 7th Street, S.W.
Washington, D.C. 20590
(800) 424-9184
In Washington, D.C.: (202) 426-2943

*National Solar Heating and Cooling Information Center
P.O. Box 1607
Rockville, MD 20850
(800) 523-2929
In Alaska and Hawaii: (800) 523-4700
In Pennsylvania: (800) 462-4983

National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161
(703) 557-4650

*President's Clearinghouse for Community Information
400 N. Capitol Street, N.W.
Washington, D.C. 20001
(800) 424-9040
In Alaska and Hawaii: (800) 424-9081
In Washington, D.C.: (202) 252-2855

*Solar Energy Research Institute
1536 Cole Boulevard
Golden, CO 80401
(800) 525-5000
In Colorado: (800) 332-8339

Superintendent of Documents
U.S. Government Printing Office
Washington, D.C. 20402
(202) 783-3238

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* At the time of this report, an information hotline that may be consolidated or eliminated.

* U.S. Department of Energy Regional Solar Energy Centers

Northeast Solar Energy Center
70 Memorial Drive
Cambridge, MA 02142
(617) 661-3500

Southern Solar Energy Center
Exchange Place
Suite 1250
2300 Peachtree Road
Atlanta, GA 30338
(404) 458-8765

Mid-American Solar Energy Center
8140 26th Avenue, South
Bloomington, MN 55420
(612) 853-0400

Western Sun
Pioneer Park Building, Suite 800
715 S.W. Morrison Street
Portland, OR 97205
(503) 221-2437

U.S. Department of Energy
Conservation and Renewable Energy
Community Systems Division
Forrestal Building
1000 Independence Avenue, S.W.
Washington, D.C. 20585
(202) 252-9393

U.S. DOE Regional Offices:

DOE Region 1 Office
150 Causeway Street
Boston, MA 02114
(617) 223-3701

DOE Region 2 Office
26 Federal Plaza
New York, NY 10007
(212) 264-1021

DOE Region 3 Office
1421 Cherry Street
Philadelphia, PA 19102
(215) 597-3890

DOE Region 4 Office
1655 Peachtree Street, N.
Atlanta, GA 30309
(404) 881-2837

DOE Region 5 Office
175 W. Jackson Blvd.
Chicago, IL 60604
(312) 353-0540

DOE Region 6 Office
P. O. Box 35228
Dallas, TX 75235
214/767-7741

DOE Region 7 Office
324 E. 11th Street
Kansas City, MO 64106
(816) 374-2061

DOE Region 8 Office
P. O. Box 26247, Belmar Branch
Lakewood, CO 80226
(303) 234-2420

DOE Region 9 Office
333 Market Street
San Francisco, CA 94105
(415) 764-7014

DOE Region 10 Office
915 Second Avenue
Seattle, WA 98174
(206) 442-7280

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