

Landscaping To Reduce the Energy Used In Cooling Buildings

John H. Parker

ABSTRACT—Although much less energy is expended in the United States for space cooling than for space heating, this end use is significant in many areas of the country and is often the major factor in utility peak electrical demands during the warmer months. Vegetative landscaping can reduce the energy required to cool residences by providing shade and wind control and through microclimate cooling via evapotranspiration. "Precision landscaping" design concepts can optimize the energy savings, particularly during utility peak demand periods. Energy analyses of an insulated mobile home show that landscaping can reduce cooling energy by more than 50 percent during warm summer days. Deciduous trees are particularly useful because they allow solar radiation to reach a building during the heating season.

In recent years, interest in urban forestry has increased significantly. A major justification for planting and preserving vegetation in urban environments is climate amelioration. This article will discuss the ways in which vegetative landscaping can reduce the energy consumed in air-conditioning a residence. Major design concepts that will be analyzed include precision landscaping, peak load landscaping, landscaping for natural ventilation, shading and microclimate cooling near the air conditioner, and indirect energy maintenance inputs.

Precision Landscaping For Energy Conservation

A number of recent studies (DeWalle 1978, Parker 1979, Parker 1981) have analyzed the potential of vegetative landscaping for reducing the energy used in cooling a residence. Most have focused on landscape designs that maximize shading but minimize obstructions to summer breezes. To optimize effectiveness, the concept of "precision landscaping" has been developed (Parker 1979). It involves an analysis of the climatic data of a specific locale as well as the thermal and energy utilization patterns of the residence under study. Landscaping reduces cooling requirements by:

- Blocking solar radiation from the building, the adjacent ground, and the foundation,
- Creating cool microclimates near the residence by evapotranspiration, and
- Either channeling or blocking air flows through and around the residence.

In what follows, a precision approach will be illustrated by designs and concepts applicable to residences in hot, humid areas of the United States. Specific climatic characteristics of Miami, Florida, will be utilized since they are representative of hot, humid environments and have already been analyzed in several previous studies (Robinette 1977, U.S. Department of Energy 1978). Nevertheless, the concepts are generally appropriate for any geographical area with significant cooling requirements. It will be assumed that the residence has a well-insulated ceiling so most of the heat

gain will be via the walls and windows.

A primary characteristic of precision landscaping is the placement of trees and shrubs reasonably close to the residence. This proximity planting provides optimal shading patterns and also uses solar energy for evapotranspiration, thereby creating cool microclimates directly adjacent to the walls and windows. The resultant reduction in ambient air temperatures and in incoming solar radiation reduces the rate of heat transfer through the walls and windows. A design that maximizes this effect is a multi-layer tree canopy with dense shrubs located underneath and immediately adjacent to the walls and windows.

Peak Load Landscaping

The relation between various energy conservation activities and electrical utility power demand patterns (Shlachtman and Parker 1981) is important but relatively unresearched. A major problem of most electrical utilities is supplying power during peak demand periods, when the most expensive equipment or fuels are often employed. Furthermore, consumer utility bills significantly increase when new and much more expensive power plants are built to meet future peaks. In response to these load-management problems, many government agencies and utilities throughout the United States are considering the imposition of "peak load pricing" where higher rates are charged for electrical consumption during peak load periods.

In much of the United States and particularly in the so-called sunbelt, the energy used for air conditioning makes up a large fraction of the peak electrical utility loads during the warmest periods of the summer. Consequently, a landscape design that specifically reduces cooling requirements during peak load periods is particularly effective. If peak load pricing is implemented, the dollar savings also will be large. In fact, the widespread adoption of "peak load landscaping" could significantly delay the building of new power plants, thus saving consumers even more money.

The center of the seasonal peak demand period for southern Florida occurs on August 6. For other areas in the South and probably elsewhere in the United States, a date nearer August 1 would be appropriate. Typically, the daily peak demand in the summer occurs during late afternoon, when ambient temperatures reach a maximum and when people coming home from work turn on their air conditioners. Consequently, the angles between the sun and the windows on the west, southwest, and south (unless there is a significant overhang) sides of a building during the mid- to late afternoon on August 6 designate primary positions for the placement of trees and shrubs for a residence in Miami.

In contrast to some other energy-conserving techniques, the cooling effects of vegetative landscaping are maximized during periods of maximum temperature and solar radiation. This statement has been corroborated by recent quantitative comparisons (Parker 1981) of the temperatures of walls of residences, with and without vegetative shading, during daytime hours. These studies have shown that planting large-canopied trees on the west side in combination with a hedge planted immediately adjacent to the west wall can reduce west-wall temperatures by 28 degrees Fahrenheit (from 113°F to 85°) during very hot, humid afternoons in south Florida. *Figure 1* shows a representative experiment includ-

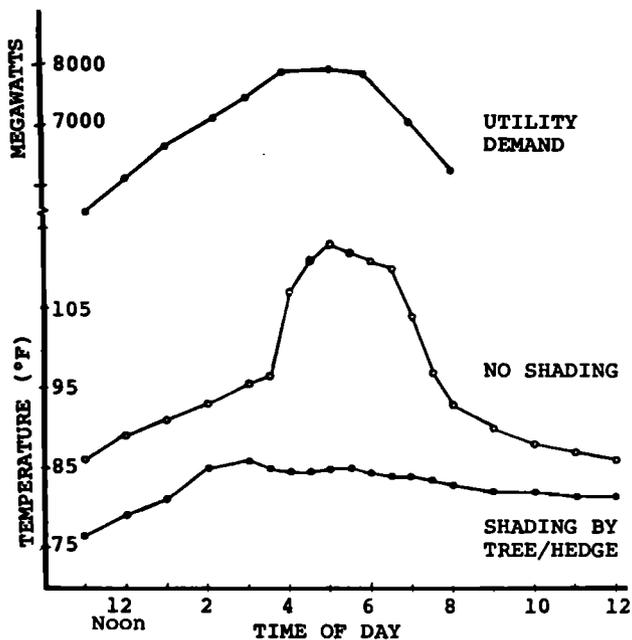


Figure 1. Surface temperature of the west wall of a residence with and without vegetative shading: electric utility demand on a warm summer day.

ing a typical electrical utility load curve for a peak load day. Clearly, trees precisely positioned to shade west-facing windows during the late afternoon on August 6 (or August 1 in other areas), combined with closely planted shrubs, can dramatically reduce electrical consumption by air conditioners during this peak period. Trees and shrubs planted on the south side are also important because of the considerable solar radiation on the lower sections of the south wall and the immediately adjacent ground during August and September afternoons when sun angles have become lower.

Shading and Microclimate Modification Near the Air Conditioner

Of high priority for landscaping is the area immediately surrounding the air-conditioning unit or units. One or two trees should be planted fairly close to the unit so that after five years of growth their canopies will completely shade the air conditioner and the adjacent ground and walls during mornings and afternoons of the entire cooling season. Care should be taken to ensure that the exhaust air flow of the air conditioner is not obstructed by the vegetation.

Preliminary temperature measurements indicate that the blocking of direct solar radiation, coupled with the evaporative cooling by the vegetation, can reduce the ambient operating temperature of the unit by 6 or 7 degrees Fahrenheit. Thus, this strategic planting of only one or two trees can increase the operating efficiency of the air conditioner by as much as 10 percent during the warmest periods.

Landscaping for Wind Control

Trees and shrubs can be positioned to influence the movement of air through and around a residence (White 1954, Parker 1981). It should be noted that wind patterns at a specific residential site are often much different and more variable than those recorded at a local weather station (particularly if other buildings and structures are in the immediate area). Consequently, landscaping for wind control generally should be based on

data gathered at the specific site. If wind directions are not consistent on a daily or seasonal basis, the appropriate positions for specific plants will not be well defined, and potential energy savings will be less.

If air conditioning will be used only minimally, low branches should be pruned to allow the passage of prevailing summer breezes through the house. Trees and shrubs should be positioned so as to funnel the breezes into the windows.

A major conflict arises with a residence cooled sometimes by natural ventilation and sometimes by air conditioning. Earlier studies of energy-saving landscaping have focused on heat loss via air infiltration during the heating season (Mattingly et al. 1976) but have generally ignored heat gain via air infiltration during the cooling season. Winds can significantly increase the heat gain of an air-conditioned residence by increasing the infiltration of warm water-laden air through cracks around the windows and doors as well as wall joints. Consequently, designs that channel winds toward an air-conditioned residence can actually increase the energy consumed in cooling.

One study (Steen et al. 1976) of the summer cooling load of a typical air-conditioned house in Florida estimated that the total heat gain via infiltration exceeded the heat gain by radiation and conduction through the windows and walls. This design conflict can be alleviated by a careful placement of shrubs and trees so that winds are channelled into the dwelling when the windows are open, but away from it when the windows are closed. For example, in southern Florida the prevailing summer winds are from the southeast. Consequently, air infiltration can be reduced by locating tall shrubs immediately adjacent and north of east-facing windows or west of south-facing windows. When the windows are opened, these same shrubs will facilitate natural ventilation. Figure 2 illustrates this shrub placement concept.

If a house will be air-conditioned during most of the cooling season, shrubs and low-canopied trees should be used to block prevailing winds. For example, if summer winds are from the southeast, tall shrubs should be positioned on the south sides of east windows and the east sides of south windows. Recent anemometer measurements (Parker 1981) have documented that this type of vegetative arrangement can significantly reduce velocities of air impinging on the windows, and thus can

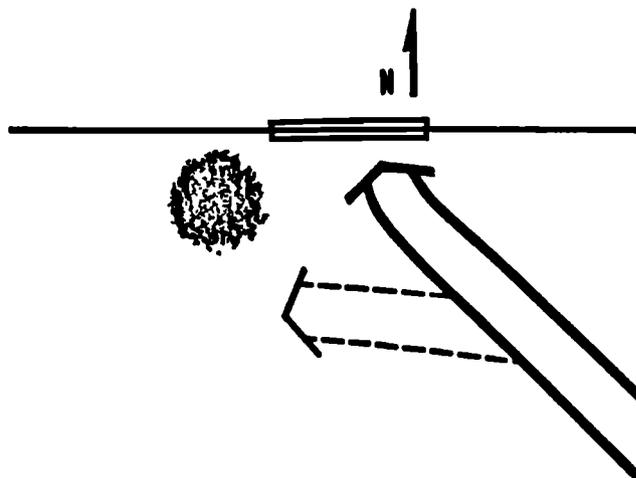


Figure 2. Shrub valve system: shrub placement facilitates breezes when window is open, reduces infiltration when window is closed.

lessen warm air infiltration. The same shrubs can also shade the adjacent walls and windows.

Plant Species

It is important to use plant species which do not require large amounts of water, fertilizer, or pesticides. *Table 1* shows the result of a recent analysis (Parker 1982) of the annual indirect energy costs for lawns, shrubs, and trees in a Florida landscape. The energy contained in each of these maintenance materials was significantly larger than that in the gasoline used in mowing the lawn. Native trees and shrubs resistant to drought and disease and appropriate to the site (especially soil) can sharply reduce these indirect energy inputs.

Although both evergreen and deciduous trees are effective in reducing cooling needs, deciduous species should be planted on the south side so that passive solar heating (via radiation through south-facing windows) can occur during the winter. In southern Florida this is not a major consideration, since the heating season is extremely brief. Shrubs near south and east walls could be deciduous to allow for some passive solar heating and to facilitate breezes during mild weather.

Energy Conservation Landscaping Of A Mobile Home

In order to establish the validity of these energy-conserving landscape design concepts, a detailed study was made on a mobile home that is a daycare center on the campus of Florida International University in Miami (Parker and Parker 1979, Parker 1981). The double-width mobile home has insulation values of about 7 for the ceiling, floor, and walls—thermal characteristics

Table 1. Annual indirect energy costs per square meter for lawns, shrubs, and trees in a Florida landscape.¹

Material	Lawn	Shrub	Tree (5 years old)
----- BTUs per square meter -----			
Fertilizer	3,500	5,800	22,600
Water	18,400	18,400	18,400
Pesticide	6,700	84,600	42,000
Gasoline	1,300		
Total	29,900	108,800	83,000

¹ For details, see Parker (1982).

Table 2. Rate of electrical energy consumption for air conditioning the daycare center during a number of warm summer days.

Time period and landscape condition	Average ambient temperature	Average rate of energy consumption	Reduction in air conditioning
	°F	Kilowatt-hours per hour	Percent
Morning (9 A.M.—NOON)			
No landscaping	90.0	5.56	
Landscaping	91.0	2.28	58.9
Afternoon (NOON—6 P.M.)			
No landscaping	93.8	8.65	
Landscaping	93.9	3.67	57.6

that are comparable to those of many concrete-block single-family detached residences in Florida. Both patterns and levels of air-conditioning consumption by the totally unlandscaped child-care center were monitored during very warm summer days. Then an energy conservation landscape plan was designed and installed during the summer of 1978.

Table 2 shows a brief summary of the data obtained (Continued on page 105)

Forest Home Sites Influence Heating And Cooling Energy

David R. DeWalle, Gordon M. Heisler, and Robert E. Jacobs

ABSTRACT — Experiments with small mobile homes in Pennsylvania indicated that shade of trees can significantly reduce solar heating and that by lowering wind speeds forests can lessen infiltration of outside air. In one deciduous stand in summer, cooling energy needs were 75 percent less than in the open. In winter shading is counterproductive, offsetting savings from reduced infiltration of cold air. In the deciduous stand, savings in winter heating energy were only 8 percent, and with greater shading in a dense pine forest heating energy needs rose 12 percent. Forests and windbreaks are especially effective with poorly sealed houses and in windy weather. On forested sites in most of the United States, energy use can probably be lessened by manipulating forest growth to allow the sun to strike the house in winter. On open sites windbreaks and carefully located shade trees would lessen year-round energy use.

Rising energy costs have caused homeowners to seek ways of reducing energy needs for space conditioning. Management of trees and other landscape vegetation offers one approach. By modifying the microclimate,

the vegetation affects exchange of heat between a house and its environment.

Home heat exchange occurs through three basic processes: air infiltration, heat conduction through walls, roofs, and floors, and transmission of solar radiation through glass. Air infiltration is the passage of air into a structure through joints, pores, cracks, and other openings. Such flows result from pressure differences between inside and outside air. Pressure differences in turn may be caused by the force of the wind and by differences in temperature between inside and outside air. Wind velocity reductions by vegetation can reduce air infiltration significantly.

Shade from trees can lessen heat conduction and radiation transmission into a home primarily by reducing solar radiation reaching exterior surfaces. Wind velocity reductions by vegetation also reduce heat conduction, by lessening heat convected to and from exterior surfaces of buildings.

Information on the use and management of trees and forests to reduce energy requirements for home space conditioning has been developing in a number of studies dating back to about 1940 (see reviews by DeWalle 1980 and Heisler 1977). This article summarizes several experiments to determine effects of forest sites on energy use for summer cooling and winter heating of mobile homes. Forest sites are of particular interest because houses are often located in forests for esthetic reasons. The information from these experiments also indicates some effects of windbreaks and shade trees on energy use.

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before and two years after the vegetative landscaping. The results are the averages of large numbers of experimental data points gathered during periods of similar climatic conditions. Overall, the energy used in air conditioning during warm summer days was reduced by about 58 percent. Other data (Parker 1981) indicate that comparable savings would be achieved during the entire cooling season.

Clearly, vegetative landscaping can be an extremely effective energy-conservation technique. The magnitude of the savings suggests that trees and shrubs reduce cooling requirements not only by shading but also by reducing warm air infiltration and creating cool microclimates immediately adjacent to the building. Future attempts to improve energy efficiency should not focus on the building alone, but should include landscaping as an integral component. ■

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THE AUTHOR—John H. Parker is an associate professor in the Physical Science Department, Florida International University, Miami 33199. The research reported here was sponsored by the Service Through Applied Research Program of the Florida State University System and by the Florida Governor's Energy Office.

Managers' Perceptions of Experiences Sought by Ski-Tourers (from page 90)

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THE AUTHORS—Donald H. Rosenthal is research geographer, and B. L. Driver is research forester, USDA Forest Service Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado 80526.

Designated-Dispersed Tentsites (from page 91)

and 1981 the sites were not marked but the patrols found that some of these sites were used almost every night. Yet, all the sites are completely out of view from the main trail and are so small, relative to each area, that the ecological impact has been insignificant. Even the most heavily used sites were, for all practical purposes, completely recovered by August 1981.

It would appear that designated-dispersed tentsites deserve a place in the continuum of backcountry camping opportunities. We hope this simple technique provides backcountry managers the incentive to encourage campers to disperse. ■

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THE AUTHORS—Herbert E. Echelberger is a social scientist with the USDA Forest Service's Northeastern Forest Experiment Station, Burlington, Vermont 05402. Raymond E. Leonard is project leader with the station; he is located in Durham, New Hampshire. Steven P. Adler is vice-president of D. C. I. Associates, Bradenton, Florida.