Landscaping to Reduce Year-Round Energy Bills

By D. R. DeWalle and G. M. Heisler

Homeowners are becoming increasingly aware of the energy savings possible with landscaping. Through proper use of trees and shrubs, the natural terrain, and manmade structures, the climate around a home can be modified to reduce heat gains in summer and heat losses in winter. Reductions in energy use commonly are brought about by either protecting the house from the wind or shading the house from direct sunlight.

Although homeowners have intuitively used landscaping to save energy for many years, we are only beginning to realize the magnitude of the savings possible. Winter heating bills may be reduced as much as 15 percent, while summer cooling energy needs may be cut 50 percent or more.

Reductions in energy use for home heating and cooling translate into good economics for both the homeowner and the Nation. On the average in the United States, 63 percent of the total energy used in the home goes for space heating and 3 percent for air-conditioning.

Given rapidly rising energy costs, even a 10 percent energy savings can be significant to the homeowner. Such savings would be even more substantial in colder regions where a greater fraction of total energy use will be devoted to heating, and in hotter climates in centrally-cooled homes where more energy will be used for air-conditioning.

Energy use for home heating and cooling also represents about 8.5 percent of total national energy use. Thus reductions in home energy use will reduce total U.S. consumption and perhaps assist in cutting importation of foreign oil.

Purpose of this chapter is to discuss how landscaping can be used to achieve home energy conservation. The role of landscape vegetation will be emphasized, but advantage can also be taken of

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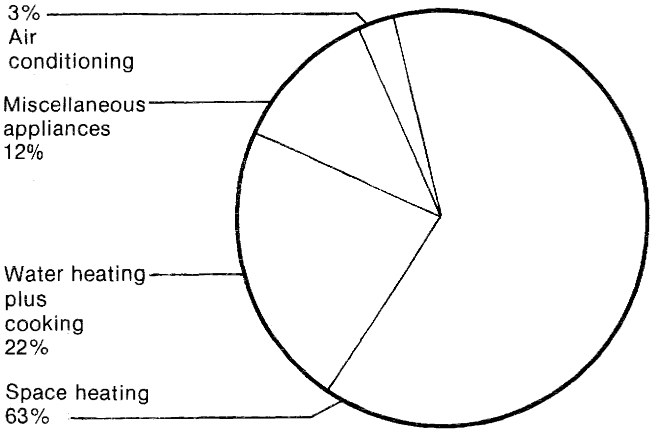


natural terrain and artificial structures around a home to modify climate and conserve energy.

Home Heat Exchange

To take full advantage of the effects of landscape vegetation, the ways in which homes gain or lose heat must be understood. Heat exchange in a home occurs through three major processes: air infiltration, heat conduction, and radiation transmission through windows.

The first mechanism, air infiltration, is the passage of outside air through cracks around doors and windows, porous materials, open doors and windows, and other openings. Outside air is forced or drawn through these openings into the home by pressure differences. These pressure differences are caused either by the force of the wind on the outside of the home or by temperature differences between inside and outside air.

Surfaces of the home facing the wind will experience increased air pressures as wind velocity increases, and air will enter the home through openings in these surfaces. Passage of air into the home will force an equal amount of interior air out of the home through openings in surfaces facing away from the wind.

Because warm air rises, temperature differences between inside and outside air will also create a natural circulation of air in the home. Warm interior air will rise and flow out of the home through openings near or at the top of the home, while at the same time outside air is drawn into the home through lower openings. This type of circulation has been referred to as the "chimney effect."

Air infiltration due to temperature differences and infiltration due to the wind frequently occur simultaneously. But the chimney effect often is most important in winter due to the large temperature differences between inside and outside air. When winds are high in winter, the combined effect of wind and temperature differences may result in very high air infiltration rates.

This combined effect of wind and temperature differences may cause air within a home to be completely changed as often as several times an hour. In winter, heat losses due to air infiltration may represent up to half the total losses by all methods on the windiest, coldest days.

For average home and weather conditions, from 20 to 33 percent of the heat loss in winter is by air infiltration. In summer, air infiltration is a minor component of heat exchange in cooler northern climates because of rather small differences between inside and outside temperatures. Conversely, in hot arid climates air exchanges in summer may be quite effective in increasing the heat load on a home.

Properly placed landscape vegetation can reduce air infiltration by reducing wind velocity in the vicinity of the home. The effect of landscape vegetation on air infiltration will depend on the extent to which wind pressure forces, rather than temperature difference forces, are causing air exchange.

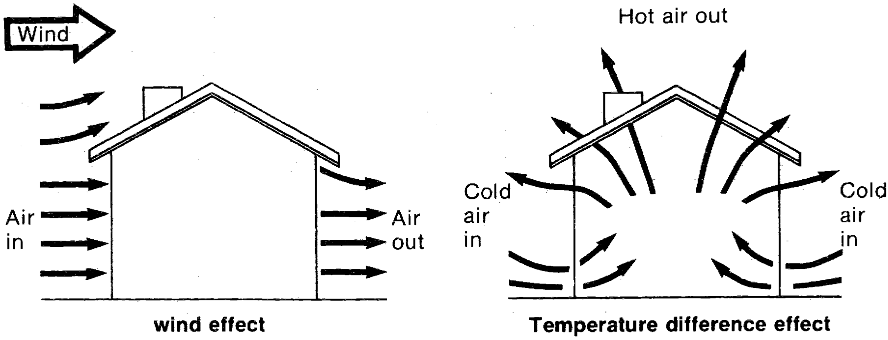
Heat Transfer by Conduction

A second major way a home gains or loses heat is by conduction through materials from which the home is constructed. Heat conduction through solids is controlled by thermal conductivity of the building materials, thickness of the material, and surface area available for heat flow (for example, area of walls, floor, glass, or ceiling) and the temperature difference between the inner and outer surfaces of the material.

Thermal conductivity is a way of comparing the rate at which heat can be transferred through materials — from the hotter to the cooler surface for a standard thickness, surface area, and temperature difference.

A layer of still air has the lowest rate of conductivity of materials commonly encountered in the home. Insulating materials are effective in reducing the rate of heat conduction because they entrap air within their pores.

Most walls and ceilings are composites of materials and are effective in reducing heat conduction by trapping air within or between the layers, even when the basic materials, such as metals, have a high thermal conductivity. Heat conduction through glass windows is rapid unless



the double-pane type or storm window is used (with an air layer sandwiched between the panes).

Control of the temperature difference between inner and outer surfaces of walls, ceilings, and floors offers the best opportunity for reducing heat conduction.

The inner surface temperature is largely controlled by the interior air temperature. One way of conserving energy in winter is obviously to lower the interior temperature, reducing the difference in temperature between inside and outside surfaces.

The outer surface temperature of a home is controlled by outside air temperature, wind velocity, and solar radiation, as well as by the amount of heat being conducted through the material. Full sunlight can raise exterior surface temperatures to levels considerably above outside air temperatures, but this difference will be reduced somewhat at higher wind velocities.

Landscape vegetation can reduce the amount of sunlight reaching the outer surfaces of a home and thereby reduce the temperature difference between inner and outer building surfaces in summer, when heat is being conducted rapidly into the home. However, in winter, solar heating of the building's exterior surfaces can be beneficial in reducing rates of heat loss. Winter shade would interfere.

Heat conduction generally represents from 33 to 50 percent or more of the total heat exchange between a home and the surrounding environment.

A third and highly variable mechanism for heat transfer into homes is transmission of solar radiation through windows or other glazed surfaces. If sunlight is received perpendicular to a single-pane glass surface, up to 90 percent will be transmitted into the interior living space. However, sunlight will be increasingly reflected by the glass as the sunlight departs from the perpendicular.

One-Way Radiation

Radiation transmission through glass is essentially a one-way process. Radiation from the interior of the home has long wavelengths which are not easily transmitted by glass. Thus, short-wave radiant energy from the sun can pass in through the windows but long-wave radiation cannot be transmitted back out very well.

Obviously the size, position, and type of windows in a home relative to the position of the sun in summer and winter greatly influence the role of transmission in home heat exchange. Vegetation around a home also can influence radiation transmission by blocking sunlight from windows during midday, which is desirable in summer.

Since transmission and conduction of heat loss through windows are generally treated in combination, estimates of the role of transmission alone in heat transfer are not available.

Role Varies by Region

The role of landscape vegetation in conserving energy varies from region to region. In cooler, northern regions where most energy is consumed in winter heating, control of cold air infiltration is paramount.

Hotter, southern locations place more emphasis on use of shade to control heat conduction and summer air-conditioning. In southern zones where outside air temperatures regularly exceed interior temperature by 20° to 30° F or more (for example, with 90° to 100° outside air temperature), control of infiltrating hot air may also be important.

Regions of moderate climate calling for some winter heating and some summer cooling require landscaping which conserves energy year-round.

Before offering some specific hints for homeowners, let's review what is and isn't known about the effects of landscape vegetation.

When a home is air-conditioned, trees can save energy. In Alabama, results of one study in 1973 indicated that mobile homes receiving summer shade by trees had annual electric bills ranging from $45 to $100 less than bills for unshaded mobile homes. Differences in electric bills prevailed even when homes averaged only 20 percent of roof shade per day.

In Pennsylvania, energy required for air-conditioning a mobile home was estimated to be 75 percent less in a grove of tall deciduous trees than for an open, unshaded site. Sunlight received on the roof in the deciduous grove was only about one-tenth of that received in the open.

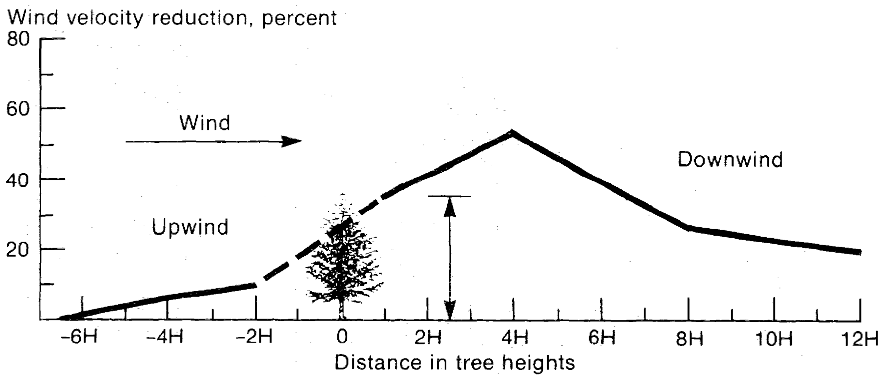
Vegetation arrangements which provide shade in summer may be detrimental in winter if solar heating of the home is interrupted. In a dense red pine forest in Pennsylvania, heating energy needs for a mobile home were 12 percent greater than at an unshaded site. Here reduced solar heating of the home offsets any benefit from reduced wind velocity caused by the trees. A home should not be located in a dense coniferous forest where winter heating needs are important.

Even a deciduous forest can provide considerable shade in winter. Leafless deciduous trees in winter may reduce the amount of sunlight reaching the roof of a home by more than a third. Consequently, energy consumption for heating a mobile home in one study was only reduced 8 percent even though the deciduous trees reduced wind velocities by 40 percent.

Windbreaks that are sufficiently far away from a building can reduce wind velocities without shading it. A windbreak is a single row or several rows of trees oriented perpendicular to the prevailing winds which will reduce impact of the wind. The windbreak is located upwind from the home at a distance which depends on maximum tree height. Windbreaks properly located on one side of a home can be expected to reduce average wind velocities by about 40 percent.

Air infiltration rates can be cut by reducing wind velocities with windbreaks. For example, the single row of white pine trees depicted in the sketch produced up to 50 percent reductions in air infiltration rates in a small mobile home.

Since air infiltration accounts for about one-third of total heat loss in winter in this mobile home, maximum energy savings for heating were about 1/3 x 1/2 or 17 percent. But considering that the winds blew from the preferred direction in winter only 65 percent of the time for this Pennsylvania site,



average heating energy savings in winter would be about 11 percent. A windbreak on several sides of this home would have helped immensely.

Another study of windbreaks in New Jersey showed that air infiltration rates in a townhouse could be reduced as much as 42 percent. Accounting for the fraction of heat loss due to air infiltration and the frequency of occurence of optimum wind directions produced an estimated average heating energy savings of 3 percent for this site.

Virtually nothing is known of the effects of windbreaks on air infiltration in summer and energy savings for summer cooling. Reduced wind velocity in summer should cut infiltration of hot outside air and reduce the energy required for cooling. However, reduced wind velocities in summer would carry away less heat from unshaded surfaces of the home and possibly permit greater rates of heat conduction into the home.

Research in the Great Plains indicated that up to 25 percent heating energy savings are possible using windbreaks. These results may not apply directly to Eastern States, where average wind velocities are considerably lower. In the East, average reductions are estimated to range from 3 to 15 percent.

Savings will depend upon the amount of reduction in wind velocity effected by the windbreak. Savings also will be greater for loosely constructed homes. It should be remembered, though, that windbreaks have almost no effect on air infiltration during calm days or when the wind blows from the wrong direction.

An optimum arrangement of trees for year-round energy conservation seems to be: windbreaks for reducing wind velocity in winter, accompanied by vegetation which shades the home in summer. Achieving this optimum arrangement depends on vegetation being already present on the property, and ownership of sufficient land.

Homes built on land formerly in forest very often have enough trees on the property to achieve the desired arrangement relatively quickly. However, when homes are built on cleared agricultural land, all or nearly all the necessary trees and shrubs must be planted.

Windbreaks — Windbreaks should be located upwind from the home in the direction of the prevailing wind.

In the East, the winter wind is primarily from a westerly direction. However, local topography and structures can channel the winds so that prevailing direction in the vicinity of the home can vary considerably. Observation of snowdrifts can be used to determine the prevailing direction around the home.

In hot, arid climates the direction of summer winds would also be important so the windbreak could be used to reduce infiltration of hot air.

Whatever wind direction prevails, the windbreak must be oriented perpendicular to this direction. The windbreak may have to extend along several edges of a property where wind direction is highly variable.

The windbreak should be located upwind from the home a distance depending upon tree height. The optimum distance for reducing air infiltration is about one to three times tree height. Remember, windbreaks can cause drifting of snow which can be a nuisance if a driveway is located between the trees and the home. Where possible, the rows of trees should extend 50 feet beyond the ends of the area being protected.

Limited lot size often necessitates reducing both the distance from the home and the length of the windbreak.

Where large areas of dense forest already occur upwind at the required distances, there is no need for planting additional windbreak trees. The effect of other upwind homes acting to slow the wind reduces, but does not eliminate, the need for a windbreak.

Windbreak trees grow to an effective height (say 15 feet for a single-story home) long before reaching their maximum height. If the windbreak is planted at 3H, where H is considered to be an effective height (for example, 15 feet), then the windbreak would still be within the recommended 1H to 3H zone when the trees grow to greater heights. Therefore, a rough rule of thumb is to plant windbreaks 40 to 50 feet upwind of a single-story home where possible.

Design and composition of the windbreak depend upon the space available on the property and upon the species and size of planting stock which can be obtained.

Where space is limited, a single row of conifers such as spruce trees is quite effective. However, up to five rows consisting of several evergreen species is much more effective. The outside rows — both upwind and downwind — should be trees with dense, low growth. The inside (core) rows should be faster, taller growing trees such as pine.

Assistance in planning and establishing your windbreak may be obtained from the County Extension Office and the local Conservation District Office. Lists of commercial nurseries selling tree planting stock and soil testing kits are available at County Extension Offices. Most commercial nurserymen offer advice on selection, planting, and care of trees.

Spacing in one, two, and three-row windbreaks should be 6 feet between trees. With four or more rows the spacing between trees should be 8 feet. Rows should be 10 to 12 feet apart, with trees planted in a staggered arrangement.

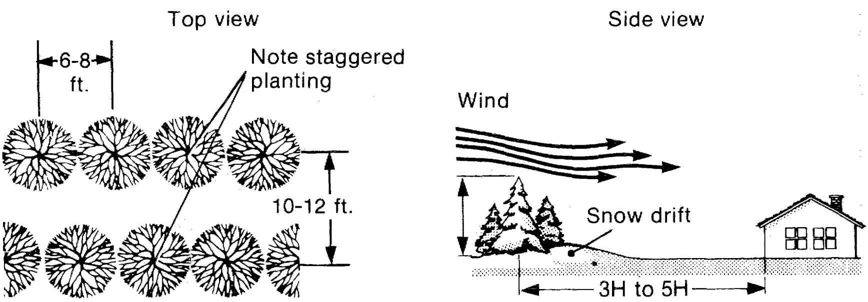
If there is enough space and quicker, partial, protection is desired, one or two rows of faster growing trees may be planted at least 15 feet upwind of the permanent windbreak. Fast-growing deciduous trees such as one of the poplars could be used for this purpose. These trees would be only a temporary planting and should be removed before they retard growth of the permanent planting.

Most windbreaks serve several other purposes. Visual screening is provided when trees become 5 to 6 feet in height. A well-planned and properly maintained windbreak is esthetically pleasing to most people. A most important benefit from a living windbreak is wildlife. Birds and mammals are attracted to trees for protection and food.

Summer Shade — Summer shade is best provided by strategically located vegetation along the sunny borders of the home. The location of shading vegetation varies with the direction that the surface of the home faces.

Walls facing generally to the east or west should be protected since these surfaces receive considerable direct sunlight in the morning and afternoon when the summer sun is low in the sky. Shade should also be provided for south-facing roof surfaces which receive the most direct sunlight during midday when the sun is higher in the sky.

House walls facing either in an easterly or westerly direction can be shaded with clumps of vegetation. Deciduous or evergreen vegetation which



reaches a height great enough to shade the wall may be used.

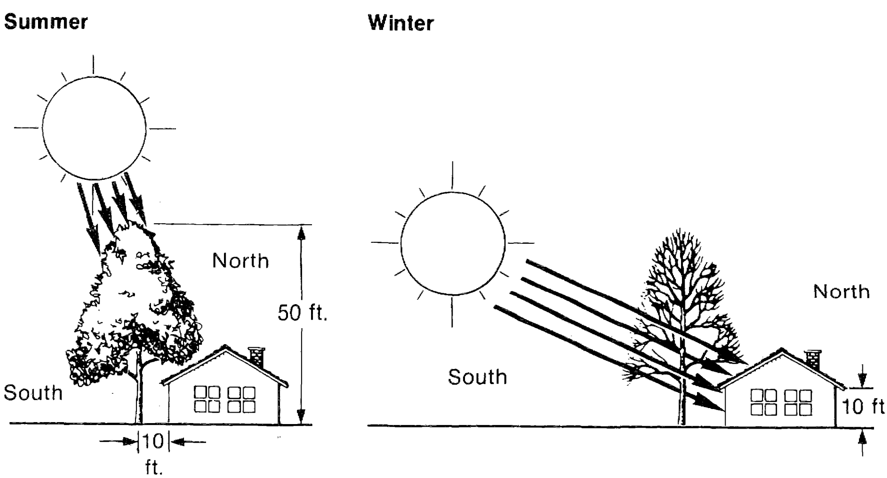
Conifers which hold the foliage year-round may be preferred if winter winds also come from an easterly or westerly direction. This vegetation could provide summer shade for the walls and winter protection from the force of the wind. Although the planting may not fully substitute for a windbreak, such conifers planted near the home may also trap a warm layer of air against the home and help insulate the wall in winter.

Shrubs and small trees planted very near the home, or perhaps ivy, could be used to shade the walls, but shade for the roof requires taller vegetation.

South-facing roof surfaces would be shaded in summer by several deciduous trees. Location of shade trees depends upon the height and shape of the tree crown, elevation of the sun in the sky above the horizon, and height of the roof.

Securing shade for south-facing roof surfaces in summer generally depends upon having overhanging tree crowns. Trees which do not overhang the roof will not cast much shade on the roof during midday in summer due to the high position of the sun in the sky. Thus shade trees should be planted as close to the home as practical based upon other considerations. If tall shade trees which form a closed canopy over the roof can be preserved on a wooded lot during construction, this would be ideal.

In winter, leafless deciduous trees should not significantly shade the roof of the home. Typically the sun in winter during midday is less than 45



degrees above the horizon and what shading of the home does occur will be largely by the tree trunks.

For this reason only trees necessary for summer shade should be maintained along the southerly edge of the home, and the lower trunk should be pruned to allow maximum solar heating of walls in winter. Trees too far away from the home to provide summer shade may provide significant unwanted shade in winter.

Leaves in gutters in summer are undesirable consequences of large deciduous trees near a home, but most people can cope with this nuisance. Prompt removal of diseased or damaged trees is also necessary to avoid future damage to the home from falling debris. Exact placement of the trees may also depend upon maintaining a desirable view from windows, esthetic appeal in landscaping a home, and avoiding overhead wires and underground pipes.

Trees for summer shade may be present on forested home sites, provided the developer can save them during construction. If trees are to be planted, fast-growing poplars can be intermixed among the slower-growing, more desirable shade trees. As few as two or three large deciduous trees with well developed crowns may suffice, but numerous smaller shade trees with narrower crowns may be required to provide complete summer shade for the roof.

The final effect of vegetation arrangements on total energy needs for heating and cooling will vary with location, weather, and the characteristics of the home.

Up to 75 percent reduction in cooling energy needs can be achieved by providing summer shade, at least in mobile homes. Even where air-conditioning normally is not needed, summer shade would make the interior living space more comfortable.

In winter, windbreaks may save 10 or 15 percent of the heating bill, with the greatest savings occurring in loosely constructed dwellings.

Costs of developing windbreaks and summer shade must be compared to the value of the energy savings plus other advantages. Where planting is required, the investment is necessarily long-term. However, since most homeowners invest in some landscaping for their home, a little time devoted to planning the best planting arrangment and species can pay of handsomely.