Windbreaks and shade trees

save energy, money, and the environment
Prepared by

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Planting trees around homes is an ancient concept used to conserve home energy use. Windbreaks, which consist of rows of trees placed perpendicular to prevailing winds, were greatly used in the Midwest to protect exposed houses, livestock, and crops from severe winds. The use of shade trees was especially emphasized during the 1970s to combat the energy crisis caused by Arab oil embargoes. The recent concern over global warming has made tree planting and energy conservation important issues again.

The global warming problem is thought to be caused by industrial and automotive emissions of greenhouse gases, such as carbon dioxide, to the atmosphere as well as from clearing of tropical forests for agriculture. Many scientists believe that a historical buildup of greenhouse gases in the atmosphere is trapping more of the sun’s energy once it reaches the earth. The result has been a slow rise in the earth’s temperature by about 0.5°C (1°F) over the past century. Many computer models now predict a 0.3°C (0.5°F) temperature rise over the next decade.

The results of such changes in the earth’s temperature could be severe. Scientists believe that changes in rainfall patterns, increases in global sea level, and a general shift in climates may be imminent.

The use of planted windbreaks and shade trees can combat this problem on two fronts. First, trees consume carbon dioxide and produce oxygen, thus reducing the amount of carbon dioxide in the atmosphere. Second, strategic location of trees can reduce home energy use and, therefore, reduce the amount of greenhouse gases produced by energy utility companies. Since residential heating and cooling represents about 11 percent of total U.S. energy use, windbreaks and shade trees may offer significant energy savings. If windbreaks and shade trees could reduce heating and cooling energy needs by 10 percent at the residential level, total U.S. energy demand would be reduced by about 1 percent. Such savings seem minor, but when multiplied by millions of households, the overall reduction in utility emissions of greenhouse gases could be important.

The incentive to homeowners to plant windbreaks and shade trees is based on their potential to save money from subsequent energy reductions. Winter heating bills may be reduced by 15 percent while summer cooling needs may be reduced by 75 percent in certain types of homes.

This publication is meant as a guide for homeowners interested in utilizing windbreaks and shade trees for energy savings. The material includes sections on how energy savings are accomplished, how to properly build and locate windbreaks, and how much windbreaks will cost and save the typical household.

Windbreaks and shade trees save energy, money, and the environment

Home heat exchange

To take full advantage of the effects of trees, 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 sunlight transmission through windows.

Air infiltration is the passage of outside air through cracks around doors and windows or other home openings. Outside air is forced or drawn through these openings by wind on the outside of the home or by temperature differences between inside and outside air. Wind on the outside of the home will replace indoor air with an equal amount of outdoor air.
Depending on the outside temperature, this process may cause undesirable temperature changes in the house.

Temperature differences between inside and outside can also create a natural circulation of air in the home. Warm interior air will rise and escape the house through openings near the roof while cool air is drawn into the home through lower house openings. This process is known as the “chimney effect” (Figure 1).

Air infiltration due to the chimney effect and from wind exposure often occur simultaneously. But the chimney effect often is most important in winter due to the large temperature differences between inside and outside air. The combined effect of wind and temperature differences may cause air within a home to be completely changed several times per hour.

Properly placed trees can reduce air infiltration by reducing wind velocity in the vicinity of the home. However, a large, dense forest near the home may also reduce exterior air temperatures and tend to increase air infiltration by the chimney effect in winter.

**Heat conduction** is the transmission or loss of heat through home construction materials. Different construction materials conduct heat differently depending on their thermal conductivity, thickness, and surface area.

Most walls and ceilings are composite layers of materials and are effective in reducing heat conduction by trapping air within or between the layers. Windows are less effective at stopping heat conduction unless a double-pane-style window is used with an air layer sandwiched between two panes of glass.

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 method of conserving energy in winter is 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 the outside air temperature, wind velocity, and solar radiation, as well as by the amount of heat being conducted through the material.

Trees 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 rapidly being conducted 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 from trees would interfere with this beneficial heating.

**Sunlight transmission** through windows can also transmit heat into homes. If sunlight is received perpendicular to a single-pane glass surface, up to 90 percent will be transmitted into the home. Although sunlight can pass through glass, heat produced inside the home cannot escape. Thus, the net effect of sunlight transmission is heating of the inside of the house.

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 sunlight in home heat exchange. Many homes are being designed to capture greater amounts of radiant energy from the sun. In these homes, radiant energy is absorbed and used to heat water or air. Trees around a home can be used to influence sunlight transmission by blocking sunlight from windows during midday, which is desirable in summer.

**Energy savings**

The potential role of trees in home energy conservation in Pennsylvania varies between summer and winter seasons due to shifts in the importance of heat exchange processes.

In winter, air infiltration becomes the major heat exchange process and the use of trees to reduce wind velocity is most important. Shading in winter reduces the already small amount of beneficial solar heating at this time of year.

In summer, air infiltration accounts for small heat gains in the home due to the relatively small temperature differences between inside and outside air. Heat conduction and transmission of sunlight predominate in summer and the use of trees to shade the exterior surfaces and windows is most important.

Shading by trees in the summer reduces the amount of sunlight absorbed by the home. One observer in New Jersey noted that the exterior surface temperature of a shaded, wood-sided home was 9°C (16°F).
cooler than similar unshaded surfaces in June. Such reductions in exterior surface temperatures can lower the exterior-interior temperature differences substantially and thereby reduce the rate of heat conduction into the home.

Without air conditioning, differences in heat conduction will cause differences in interior air temperatures. In a mobile home shaded by trees, interior temperatures were up to 11°C (20°F) less than in an unshaded trailer during mid-day. Maximum temperatures in the shaded trailer occurred up to 3.5 hours later than at an open site. Cooling of interior air to tolerable levels also occurred sooner at the shaded site.

When a home is air conditioned, trees can save energy. In Alabama, where the need for air conditioning is greater than in Pennsylvania, results of one study indicated that shaded mobile homes had annual electricity bills ranging from $45 to $100 less than unshaded mobile homes. Differences in electric bills prevailed even when homes averaged only 20 percent of their roof shaded per day. In a Pennsylvania study, the energy required for air conditioning a mobile home was estimated to be 75 percent less in a dense red pine plantation in Pennsylvania, which reduced solar radiation by 75 percent in winter, heating energy needs for a small trailer were estimated to be 12 percent greater than at an unshaded site. Here any benefit from reduced wind velocity was completely offset by reduced solar heating of the trailer.

Energy consumption for trailer heating in a deciduous grove was up to 8 percent less than for a similar trailer in an open site. Even though the deciduous grove reduced wind velocities by 40 percent in winter, solar radiation was also reduced by 37 percent by the leafless tree canopy. Thus it appears that trees around a home can reduce wind velocity, but heat energy savings will not occur if the dwelling is heavily shaded at the same time. Vegetation arrangements that reduce wind velocities around homes but do not shade homes will produce the greatest energy savings in winter. Windbreaks located considerable distances from a building can reduce wind velocities without shading it.

Research in Pennsylvania indicated that up to 15 percent of heat energy savings are possible using windbreaks. Most of these savings resulted from reduced wind velocity and, therefore, reduced air infiltration in homes downwind from the windbreak. Effects of windbreaks are greater at higher wind velocities. Savings will increase with the amount of reduction in wind velocity affected 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.

Hints for homeowners

An optimum arrangement of trees for year-round energy savings seems to include windbreaks for reducing wind velocity in winter accompanied by several large trees that shade the home in summer. The difficulty of achieving this optimum arrangement depends on vegetation already present on the property and ownership of sufficient land. Homes built

Figure 2. A windbreak properly located upwind of the house will greatly reduce both wind velocity and snow accumulation at the house.
**Figure 3. Recommended windbreak species.**

<table>
<thead>
<tr>
<th>Planting area</th>
<th>Medium-size evergreens for outside rows</th>
<th>Tall evergreens for inside rows</th>
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</thead>
<tbody>
<tr>
<td><strong>South of Blue Mountains, and east of Susquehanna River</strong></td>
<td><img src="image1" alt="Colorado blue spruce" /> <img src="image2" alt="Douglas fir" /></td>
<td><img src="image3" alt="Hemlock" /> <img src="image4" alt="White pine" /></td>
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<td></td>
<td><img src="image5" alt="Colorado blue spruce" /> <img src="image6" alt="Douglas fir" /></td>
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<td><img src="image9" alt="Serbian spruce" /> <img src="image10" alt="White spruce" /></td>
<td><img src="image11" alt="Austrian pine" /> <img src="image12" alt="Norway spruce" /></td>
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<tr>
<td></td>
<td><img src="image13" alt="White fir" /></td>
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</tr>
<tr>
<td><strong>North of Blue Mountains, and west of Susquehanna River</strong></td>
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<td><img src="image16" alt="White pine" /></td>
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<tr>
<td></td>
<td><img src="image17" alt="Red pine" /> <img src="image18" alt="Hemlock" /></td>
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<td></td>
<td><img src="image19" alt="Serbian spruce" /> <img src="image20" alt="White spruce" /></td>
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<tr>
<td></td>
<td><img src="image21" alt="White fir" /></td>
<td></td>
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<tr>
<td><strong>Entire state</strong></td>
<td><img src="image22" alt="Hybrid poplar" /></td>
<td><img src="image23" alt="Lombardy poplar" /> <img src="image24" alt="Japanese larch" /></td>
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<td></td>
<td>These deciduous trees will grow more rapidly than most pines, spruces, or firs. Planted in one or two rows, they will form a temporary windbreak in a shorter time.</td>
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</tbody>
</table>
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, nearly all of the necessary trees and shrubs must be planted.

**Windbreak considerations**

Windbreaks should be located upwind from the home in the direction of the prevailing wind. In Pennsylvania, the winter wind is primarily from the west and northwest. The rows of trees should be oriented perpendicular to this direction. Local topography and structures can channel the winds so that prevailing direction in the vicinity of the home can vary considerably. Observation of drifting snow can be used to determine the prevailing direction around the home (Figure 2).

**Location** of the windbreak should be upwind from the home a distance of 50 to 200 feet, with the optimum distance being 100 to 150 feet. To minimize problems presented by drifting snow, plant trees at least 50 feet away from the home or driveway. Where possible, the rows of trees should extend 50 feet beyond the ends of the area to be protected. Limited lot size often necessitates reducing both the distance from the home and the length of the windbreak. There is no need for planting additional windbreak trees if large areas of dense forest already occur upwind at the required distances.

**Design and composition** of the windbreak depend on the space available on the property and on the species and size of planting stock that can be obtained. Local ordinances may restrict species and location. Where space is limited, a single row of spruce trees is sufficient. However, five rows of several evergreen species are much more effective. The outside rows—both upwind and downwind—should be trees with dense, low growth such as white, Colorado blue, or Serbian spruce, Douglas fir, or white fir. The inside rows should be faster, taller-growing trees such as red, white, and Austrian pine, hemlock, or Norway spruce.

White pine is recommended for planting only south of the Blue Mountains and east of the Susquehanna River because the white pine weevil is present north and west of this area. Colorado blue spruce and Douglas fir are only recommended for use in the southeast. Any of the spruces and any of the firs may be used to the north and west. Most spruces other than Colorado blue spruce are not adapted to the climate in the southeast portion of the state (Figure 3).

**Spacing** in one-, two-, and three-row windbreaks should be 6 feet between trees. With four or more rows, the spacing 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 a quicker, partial protection is desired, then one or two rows of faster growing trees may be planted at least 15 feet upwind of the permanent windbreak.

Hybrid poplar, Lombardy poplar, or Japanese larch should be spaced 4 feet apart in single rows or 6 feet in staggered arrangements if two rows are planted. These will grow to 10 or 15 feet in height in 5 years and should be regarded only as a temporary planting. They should be removed within 10 years so they do not retard the growth of the permanent planting. Lombardy poplar should be regarded as a short-lived tree due to fungal disease problems.

**Sizes and choices of planting materials** include seedlings, transplants, container-grown trees, or trees that are dug with a ball of soil and wrapped in burlap (B&B). Seedlings are lowest in price but slowest to become established; container plants and B&B trees are higher in price and become established and grow more rapidly. Transplants are moderate in price, establishment, and rate of growth. Windbreak tree species may be purchased from most commercial nurseries.

Property owners should determine if local ordinances restrict planting near boundary lines or restrict planting of certain species. Early spring generally is the most successful.

<table>
<thead>
<tr>
<th>Table 1. Approximate costs of planting stock.</th>
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<tbody>
<tr>
<td><strong>Number of rows</strong></td>
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<tr>
<td><strong>Spacing (feet)</strong></td>
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<tr>
<td><strong>Number of trees</strong></td>
</tr>
<tr>
<td><strong>2-year seedlings</strong></td>
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<td>(50¢–$2 each)</td>
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<tr>
<td><strong>3-year seedlings</strong></td>
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<tr>
<td>(75¢–$3 each)</td>
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<tr>
<td><strong>5-year transplants</strong></td>
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<td>($4–$7 each)</td>
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Larger 4- to 7-foot B&B trees cost $50–$100 each.
planting time. However, B&B trees may be set in fall if given proper winter care. Container plants can be set any time the soil is not frozen.

**Preparation and maintenance of planting site** are recommended to ensure optimum growth. Competing vegetation such as grass, weeds, or woody plants must be eliminated by cutting, cultivation, or herbicidal treatment or a combination of these. A soil test will reveal whether soil acidity and nutrient levels should be adjusted for proper establishment and growth. Recommendations for lime and fertilizer use will accompany the soil test results.

Assistance in planning and establishing a windbreak may be obtained from your local extension office and the conservation district office. Lists of commercial nurseries selling tree planting stock and soil testing kits are available at county extension offices. Most commercial nurseries offer advice on selection, planting, and care of trees.

Approximate cost for planting stock by tree size and windbreak size is based on a 150-foot-long windbreak. This windbreak length would protect a home or building 50 feet long, and extend 50 feet beyond either end of the structure (Table 1).

**Protection and care** are needed. After the windbreak trees are planted, they must be protected and kept in a healthy and vigorous growing condition. It is especially important to protect the lower branches from injury or stunted growth. Exclusion of pets, livestock, and children may be necessary while trees are getting started. Competing vegetation such as grasses, weeds, and woody brush must be kept away from the growing trees. While mowing is partially effective, mowed plants still rob the trees of soil moisture and nutrients. Recommended chemical herbicides, when correctly used, are safe and effective on most annual weeds and grasses without harming the trees.

**Corrective pruning** may be required as the trees grow. Multiple tops should be cut so that only a single terminal leader is growing from the top of the tree. Multiple tops allow trees to be easily damaged during ice and snow storms. Trees that die or become badly damaged should be replaced the following year so that openings do not develop in the screen.

**Fertilizing** may be needed if the trees do not show normal to vigorous growth. One year after planting, fertilizer should be applied to the trees in March or early April. This process
should be repeated at two-year inter-
vals thereafter. Unless a soil test has
been taken and specific recommen-
dations received, these general rules
may be followed:
■ Apply 5-10-10 granular fertilizer.
■ Spread in an 8-inch circular band
at least 8 inches away from the tree
stem for trees less than 2 feet high.
Apply 0.25 pound to each tree.
■ Treat trees more than 2 feet high
with a circular band 12 inches wide
under the ends of the lower branches.
Apply 0.5 pound to trees that are
4 feet high, 2 pounds to trees 6 feet
high, and 4 pounds to trees 8 feet
high. Larger trees should receive
2 pounds per inch of trunk diameter.

Disease and insect outbreaks are
usually first noticed when portions of
the tree foliage turn brown, reddish,
or yellowish. Closer observation will
reveal insect and disease outbreaks
before they become too serious. If the
disease or insect causing the problem
cannot be determined by the home-
owner, foliage and twig specimens
should be taken to the county exten-
sion office for identification.

Thinning is often required when
the trees grow together and threaten
to become overcrowded. Weakened,
injured, or badly crowded trees
should be cut first. This stage may
occur 12 or 15 years after planting.

Additional windbreak benefits.
Most windbreaks serve several other
purposes besides energy conservation.
Studies have demonstrated that trees
are effective as noise barriers where
busy highways or noisy industrial
plants are nearby. Visual screening is
also provided when trees become 5 to
6 feet in height. A well-planned and
properly maintained windbreak is also
aesthetically pleasing (Figure 4).

The properly placed windbreak is
an effective snow barrier. Multiple-
row windbreaks trap some snow
within the trees while much larger
amounts are dropped on the pro-
tected lee side. Tree height and wind
speed determine how close to the lee
side the snow accumulates, but it is
generally within twice the height of
the trees.

Wildlife is a most important
benefit from a living windbreak. Birds
and mammals are attracted to trees
for protection and food. Songbirds
may use a windbreak throughout
the year or when they are migrating.
Ringneck pheasants, rabbits, squir-
rels, and other animals may use the
windbreak when the trees are large
enough to provide cover.

Composition of the windbreak
may be altered if the owner is highly
interested in encouraging wildlife.
The incorporation of some decidu-
ous shrubs and trees would increase
the attractiveness to wild birds and
mammals but would reduce the wind
barrier effect. Deciduous shrubs with
proven wildlife food value could be
planted in the outside rows and coni-
fers in the core section (Figure 5).

Summer shade considerations
Summer shade is best provided by
several large deciduous trees strate-
gically located along the southerly
ele edge of the home. Location of these
trees is determined by the mature
height of the tree and the angle at
which summer sunlight is received.
In Pennsylvania, the position of the
sun in the sky in summer ranges
from about 45 to 75 degrees above
the horizon during mid-day. Trees
should extend along the southeast to
southwest edge of the home and be of
sufficient height to protect the home
at these angles. In winter the leafless
deciduous trees should not shade the
roof of the home. Typically, the sun
in winter during mid-day 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.
Trees too far away from the home to
provide summer shade may provide
unwanted shade in winter.

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 on main-
taining a desirable view from win-
dows, aesthetic 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 the trees are to be planted, fast-growing poplars can be intermixed among slower-growing, more desirable shade trees. Poplar trees can be removed later and the larger B&B trees planted for permanent shade at the southern edge of the home.

**Final effect and costs**

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. Although up to 75 percent reduction in cooling energy needs can be achieved by providing summer shade, air conditioning is normally not needed in many portions of Pennsylvania. However, summer shade would make the interior living spaces more comfortable. In winter, at wind velocities typical of Pennsylvania, windbreaks may save 10 to 15 percent of the heating bill, with the greatest savings occurring in loosely constructed dwellings.

The final costs of developing summer shade and windbreaks must be compared to the values of energy savings plus other wildlife benefits and environmental advantages. Where planting is required, the investment is necessarily long term. However, since most homeowners invest in some landscaping for their home, a little more time devoted to planning the best planting arrangement and species can pay off.
Penn State College of Agricultural Sciences research and extension programs are funded in part by Pennsylvania counties, the Commonwealth of Pennsylvania, and the U.S. Department of Agriculture.

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Code# UH172 R7C3/11mpc1929