NORTH CAROLINA
SOLAR CENTER

SOLAR CENTER INFORMATION

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Siting of Active Solar Collectors and Photovoltaic Modules

To install a solar energy system properly, it is important to understand the siting and tilt requirements for solar collectors. This is true for all types of solar collectors, whether they are flat plate collectors for heating water, or photovoltaic modules for generating electricity. The flat plate collectors or photovoltaic modules must be oriented and tilted to obtain maximum solar radiation and to avoid unwanted shading. Evaluating these factors at the outset is essential to determine if your proposed site is suitable for collecting solar energy and to ensure that your system operates efficiently.

Orientation of the Collectors or Modules

A solar collector or photovoltaic (PV) module gathers the most sunlight when it is perpendicular to the sun. Ideally, it should be tilted to follow the sun's change in elevation during the course of the year, and turn to follow the sun's apparent path from east to west during the day. Daily east-west tracking is possible for a photovoltaic system with an active or passive tracking system, and can produce 20 to 40 percent more electricity, depending on the time of year.

The hardware, machinery, and controls needed to track the sun, however, are usually not cost-effective when used with solar thermal flat plate collectors. For a fixed, non-tracking system, solar collectors or photovoltaic modules are usually installed facing true south. This is the one fixed orientation by which they almost always intercept the greatest amount of solar radiation during the year. An exception to this rule may occur due to unusual local weather patterns or locations near large bodies of water. For example, if the site tends to have cloudy weather in the morning and sunny weather in the afternoon, a shift in collector or module orientation to the west might increase the total solar energy collected.

Variations

To accommodate local weather conditions, the orientation of an existing building, or other factors relating to the building site, such as shading, you can modify the orientation of a solar collector or module from true south. Deviating active solar or PV solar systems from true south by as much as 20° to 30° east or west will not significantly reduce the total solar radiation received. Passive solar systems, on the other hand, are much more sensitive to deviations from true south because of the increased potential for unwanted summer heat gains. Major glass areas on passive solar structures should face within 15° east or west of true south. (See "Selecting a Site for Your Passive Solar Home," "Passive Solar Options for North Carolina Home," "Passive Solar Home Design Checklist" and "Energy Saving Landscaping for Your Passive Solar Home," free factsheets distributed by the North Carolina Solar Center.)

Magnetic Declination

True south is not the same as magnetic south at most locations. Because of the earth's magnetic field, a compass reading of south varies as much as 22° from true south in some parts of the country. This variance is called magnetic declination and is usually represented as the number of degrees that compass (magnetic) north varies from true north.

An imaginary line of zero degrees runs through Madison, Wisconsin and Birmingham, Alabama. Along this line, true north and south are the same as compass north and south. The amount of declination increases as you move away from this line. For example, if solar energy systems in Raleigh are oriented south according to a compass without accounting for the declination, they would actually face about 7° east of true south. Therefore, they should be installed to face 7° west of compass south in order to face true south.

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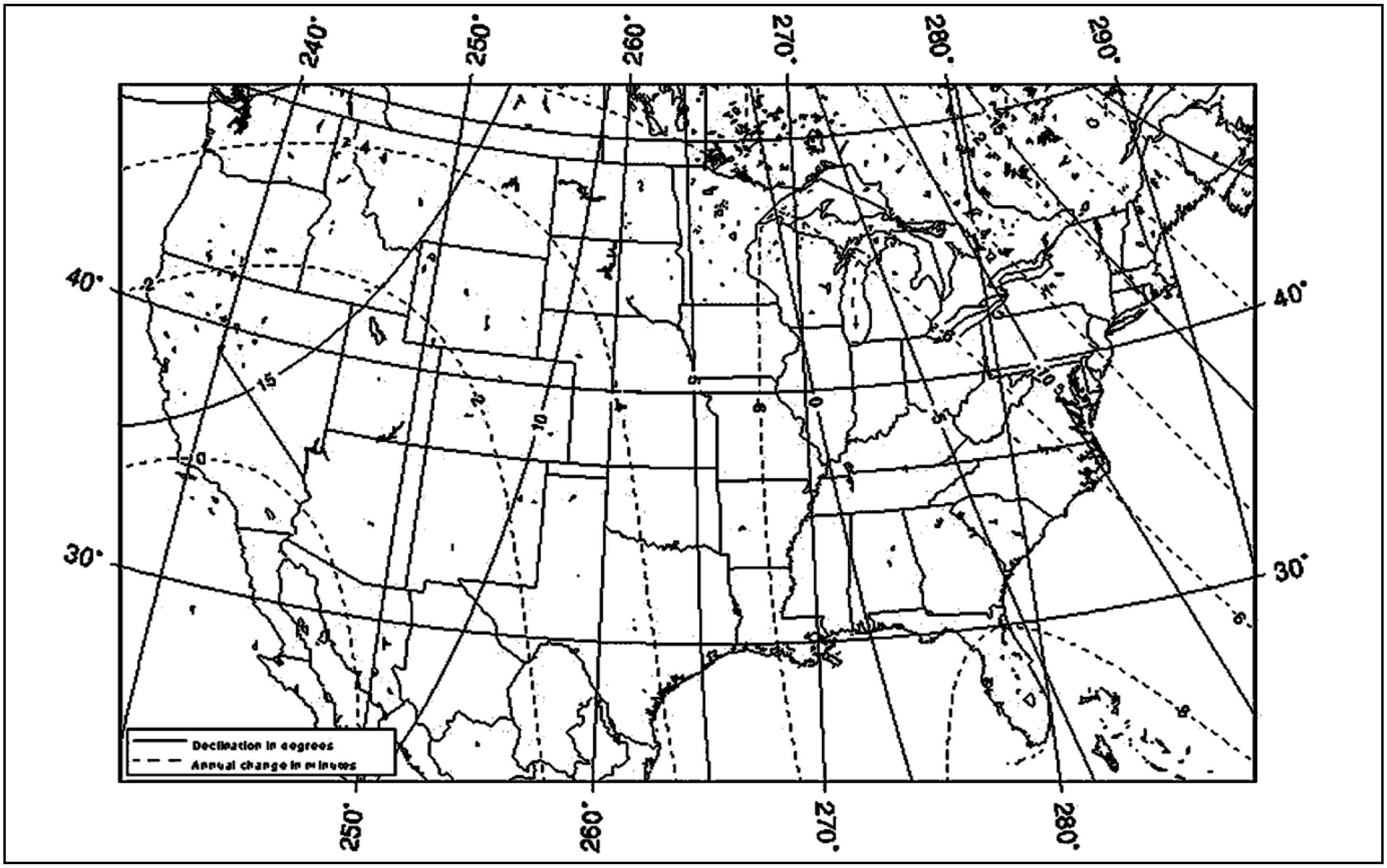


Figure 1. Magnetic Declination in the United States - 1995 US Geological Survey

Magnetic declination changes slowly over time, so beware of using the declination maps published in many older texts and publications; most use a map from 1965. The US Geological Survey publishes new isogonic maps every five years. The most recent one is shown in Figure 1.

The declination found in Figure 1 is sufficiently accurate to site your system. If you would like to find a more exact current magnetic declination figure for a particular location, ask a local surveyor, or look at either a recent topographic map of the area or a plot map from a local tax office. If you have access to a computer with a modem, you may obtain this information directly from the National Geomagnetic Information Center of the US Geological Survey at http://geomag.usgs.gov/ngic.html.

You may also obtain this information from the National Oceanic and Atmospheric Administration (NOAA). The first request is free; a small fee may be charged for multiple requests. Contact NOAA at:

NOAA/NESDIS/National Geophysical Data Center
Code E/GC1
325 Broadway
Boulder, CO 80303
(303) 497-6826 Fax: (303) 497-6513
E-mail: info@ngdc.noaa.gov
Web: http://ngdc.noaa.gov/ngdc.html

A Do-It-Yourself Method to Determine True South

There is an easy method for determining true south if you are able to visit the site at solar noon on a sunny day. Solar noon, by definition, is the time of day when the sun shines from true south, so the shadow cast by any object at solar noon will run from true south to true north.

The exact time of solar noon is different from the time of noon on your clock, and changes slightly throughout the year. It can easily be determined by consulting a local newspaper, however. Most newspapers publish the time of sunrise and sunset for the day in the weather section. Solar noon is the time of day which is exactly midway between the times of sunrise and sunset.

Although this technique for determining solar noon is very easy to apply, be sure to avoid making one of two very simple mistakes. First, be sure that you use the times of sunrise and sunset on the day on which you plan to visit the site (i.e., don't determine the time of solar noon from a newspaper in April and then decide to use it when you visit the site in July). Second, make sure that the times you use for sunrise and sunset are from a local source (i.e., if you live in Asheville but wish to find true south for your beach house in Wilmington, use the Wilmington times to determine that solar noon). The time change due to daylight savings should also be taken into account.

If you want to check to make sure you're marking the shadow direction at the right time, also measure shadow length for a few minutes before and a few minutes after the time you chose to mark the shadow direction. In addition to running from true south to true north, shadows cast at solar noon have the additional distinction of being the shortest shadows of the day.

Avoid Shading on the Collectors or Modules

Once true south is identified, the installation site must be carefully analyzed to determine if obstructions to the south will prevent access to the sun during some or all of the year. While solar collectors and modules do not require guaranteed access to sunlight from sunrise to sunset, they should be shaded as little as possible between 9 AM and 3 PM solar time, when nearly 85 percent of the sun's energy reaches the earth. Shading affects the performance of photovoltaic modules more critically than it affects solar thermal collectors. In any solar energy system design, however, shading should be avoided, and solar access maximized. By determining the sun's position throughout the year, you can accurately predict potential shading problems.

Altitude, Azimuth, and Suncharts

The sun's position in the sky is defined by two angles: altitude and azimuth. (See Figure 2.) Altitude measures the sun's height above the horizon. At sunrise or sunset, the sun's altitude is zero degrees above the horizon; at an altitude angle of 90°, the sun would be directly overhead. (That extreme an angle is never reached in North Carolina.)

Azimuth describes the sun's position from east to west; it is the angle between true south and the point on the horizon directly below the sun. The azimuth, measured with a compass, has a negative value to the east of south, and a positive value to the west.

The path that the sun travels changes throughout the year. It follows its lowest path on the winter solstice (December 21) and, every day following that, it traces a progressively higher path in the sky until it reaches its highest path on the summer solstice (June 21). Following the summer solstice, the sun's path becomes lower every day until it again reaches its lowest path on December 21.

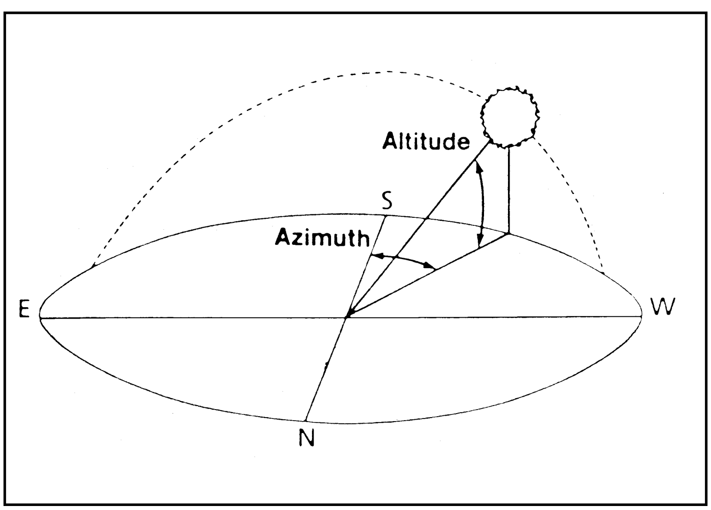


Figure 2. Altitude and Azimuth Angles

The path that the sun travels also varies with latitude. Because of the earth's tilt, the further north a location is, the lower in the sky the sun's path will be.

Suncharts are used to represent the sun's path at a given latitude at different times of the year. Figure 3 contains a sunchart for 36° north latitude, which is appropriate for use for Boone, Winston-Salem, Greensboro, Raleigh/Durham, Washington, and Nags Head, and other cities at their approximate latitude. Figure 4 contains a sunchart for 34° north latitude, which is the latitude for the lower coastal area of the state, including Whiteville and Wilmington. Cities at approximately 35° north latitude, including Murphy, Charlotte, Fayetteville, Clinton, and New Bern, should use an average of the readings from Figures 3 and 4.

Note that the sun path curves are symmetrical about true south and solar noon. For example, the sun's position at 9 AM solar time (three hours before solar noon) on June 21 is -85° azimuth (85 degrees east of south), 50° altitude; at 3 PM it is 85° azimuth, 50° altitude.

The Solar Window

Solar collectors or photovoltaic modules must have a clear view of the sky defined by the sun's apparent daily crossings. This area is referred to as the solar window or skyspace. This solar window should be kept free of shading from 9 AM to 3 PM solar time, when the maximum solar radiation occurs. (See Figure 5.)

The altitudes of the sun on December 21 and June 21 (the winter and summer solstices) determine the upper and lower boundaries of the solar window. In most cases, it is the lowest altitude of the sun, reached on December 21, that is most important for protecting solar access. If the longer winter shadows do not shade the solar collector or photovoltaic module, it is usually safe to assume that shorter summer shadows will not shade the collector either.

The differing effects of foliage with the change of the seasons is another factor that determines the amount of sunlight that will reach the solar collector or photovoltaic module. It should be noted, however, that even the shading provided by the bare branches of a deciduous tree can cause significant shading on a solar collector, and particularly on a photovoltaic module. Shading of only one cell within a PV module can reduce the module's power output as much as 75%.

At low solar altitudes, the atmosphere, clouds, smog, and air pollutants can absorb or deflect considerable amounts of solar radiation. So much solar radiation is lost that solar altitudes below 12° are essentially useless for collecting solar energy.

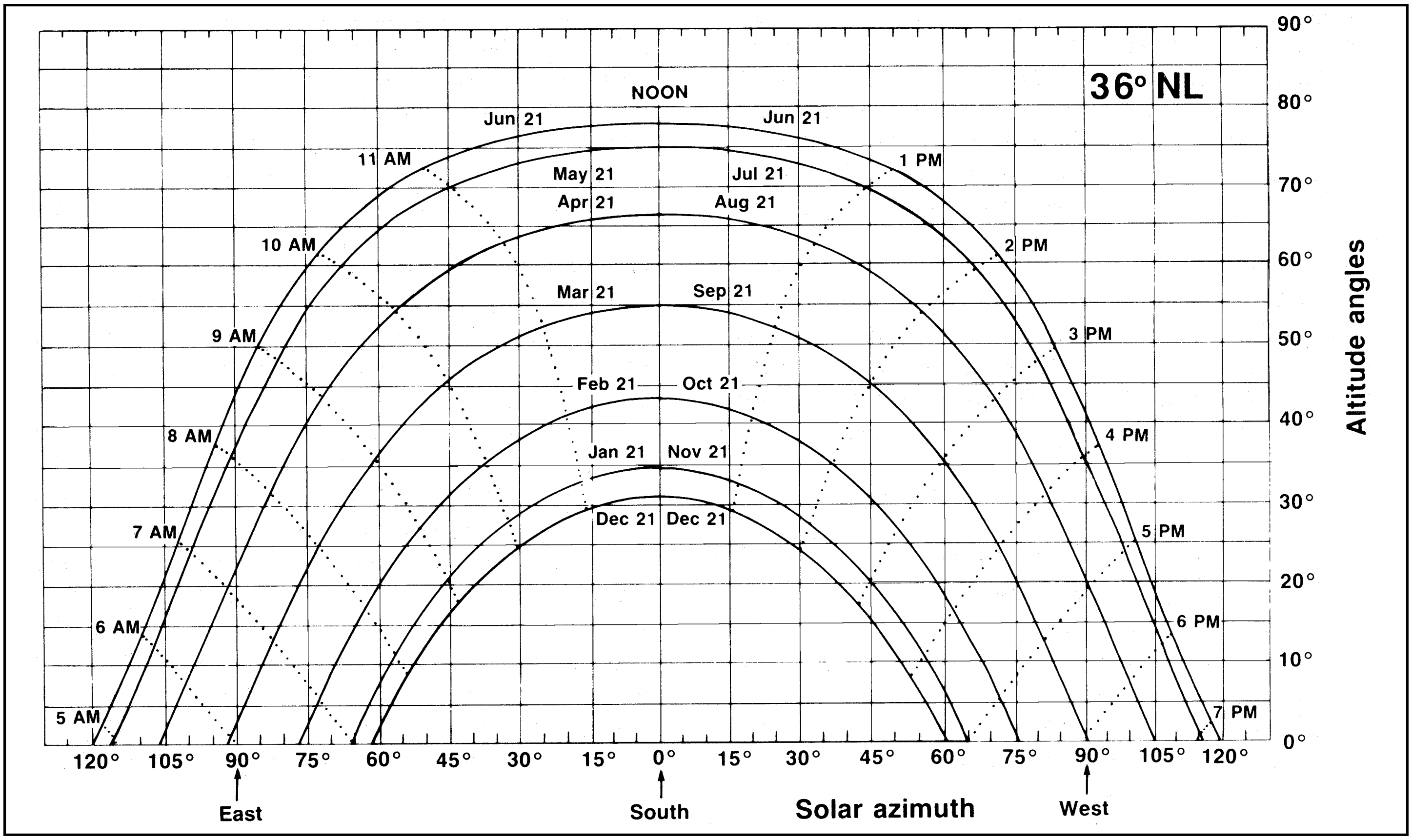


Figure 3. Sunchart for 36° North Latitude (Boone, Greensboro, Nags Head, Raleigh, Washington, Winston-Salem)

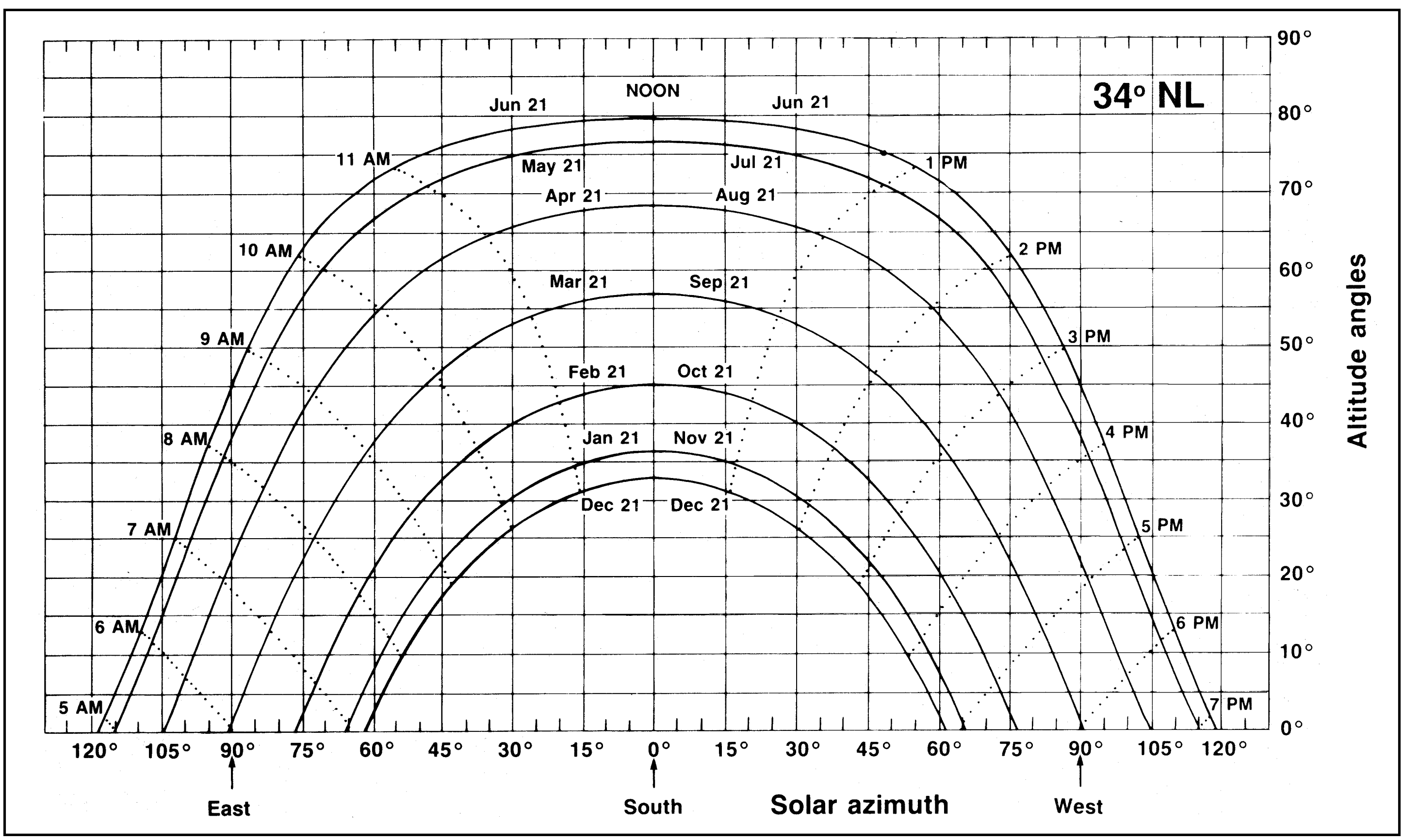


Figure 4. Sunchart for 34° North Latitude (Whiteville, Wilmington)

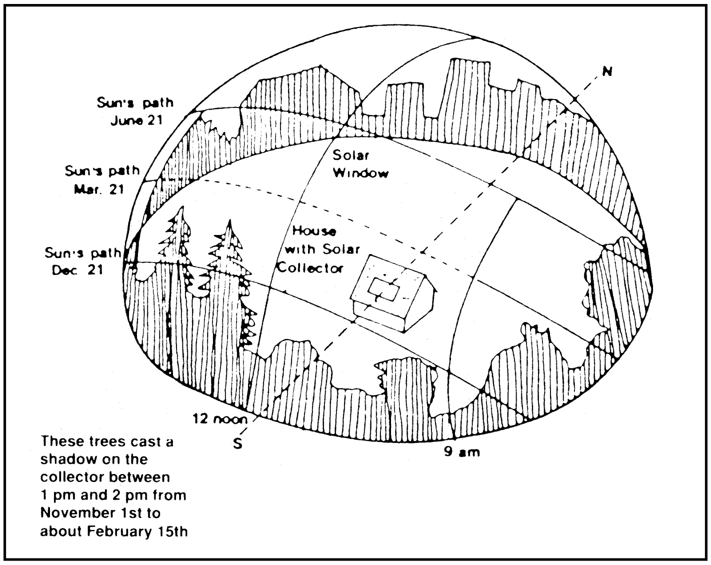


Figure 5. The Solar Window

The Popular Science Sun Locator

A method for determining the solar window was created for Popular Science Magazine. Make a copy of the sun locator (included in this factsheet) and glue it to a cardboard backing. Trim along the line of the latitude nearest you. Place the locator in a level position at the area where the collectors are to be mounted. Align a compass along the correct magnetic declination line for true north and south. View from the corner over the top of the latitude line from 9 AM to 3 PM solar time. This is the path the sun will take in midwinter. If more than five percent of the path is blocked, the site may need closer evaluation. Even tree branches without leaves can block a considerable amount of winter sunlight. Consider trimming them if necessary.

Tilt Angle

A solar collector or photovoltaic module collects the maximum solar radiation when the sun's rays strike it at right angles. As the solar collector or module is tilted away from perpendicular alignment to the sun, less solar energy is received. However, small deviations away from the ideal tilt will not affect energy output much, and may be preferable from an appearance or stability standpoint.

The optimal tilt angle for a solar energy system depends on both the site latitude and the application for which it is to be used. Fixed collectors and modules that need to produce heat and electricity on a year-round basis are usually tilted at an angle equal to the latitiude of the site. This angle points the collectors and modules directly toward the sun in the spring and the fall when the sun is at its midpoint position in the sky. Energy from the low winter sun and the high summer sun is not collected as efficiently, but the average yearly collection of energy is maximized. For example, in Raleigh, the collector or module is positioned so that a 36° angle is made between the collector or module and the horizontal. In Charlotte, the optimal angle would be 35°; in Wilmington, it would be 34°.

Figure 6 contains a graph of the amount of solar radiation that would be received by south-facing surfaces placed at various tilt angles in Charlotte. The 0° curve corresponds to a flat, horizontal surface; the 90° curve corresponds to a vertical surface, such as a wall. The curves for 35°, 25°, and 45° represent surfaces tilted at latitude, latitude minus 10°, and latitude plus 10°, respectively.

Following are rules of thumb for determining tilt angles for various kinds of solar systems:

Tilt Angles for Solar Heating Systems

- **Domestic Water Heating:** Tilt collectors to an angle equal to the latitude.

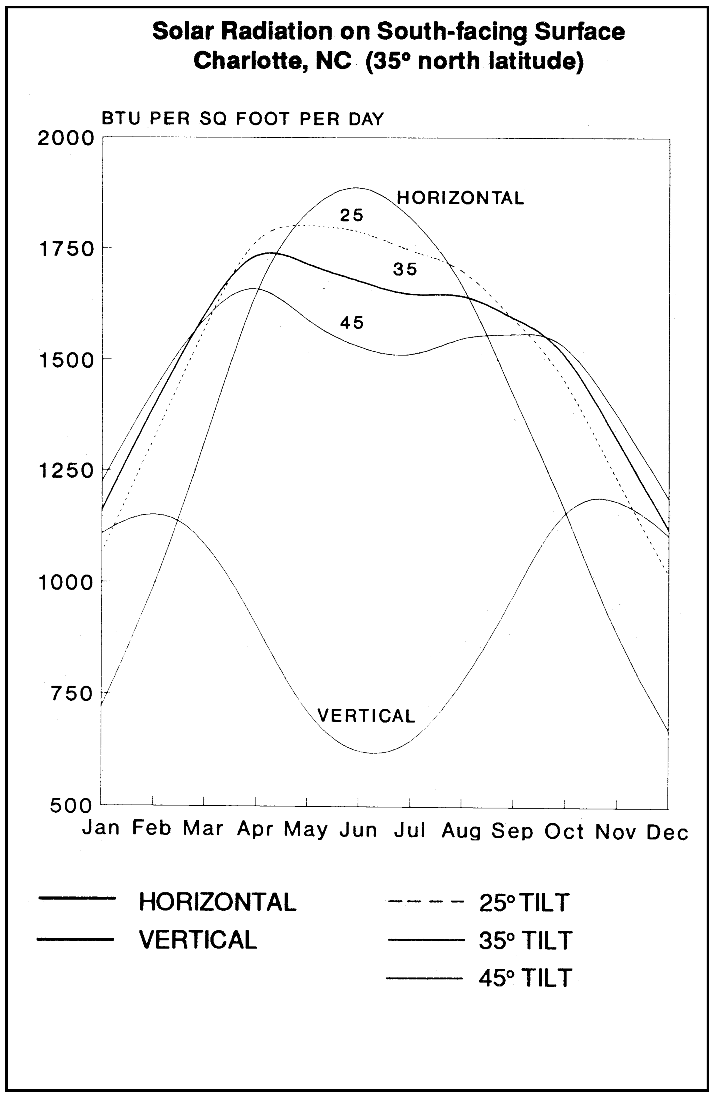


Figure 6. Solar Radiation at Various Tilt Angles

- **Space Heating Only:** Tilt collectors to latitude plus 15°. At this steeper angle, the solar collector directly faces the low winter sun, when heating is needed most.

- **Space and Water Heating:** Tilt collectors to latitude plus 15° to directly face the low winter sun, when heating is needed most.

- **Swimming Pool Heating:** For year-round pool heating, tilt collectors at an angle equal to the latitude. For summer heating only, tilt collectors to latitude minus 15°. For winter heating only, tilt collectors to latitude plus 15°.

Tilt Angles for Photovoltaic Systems

- **To maximize annual electricity output**, tilt modules at an angle equal to that of the latitude.

- **To maximize winter electricity production**, use a tilt angle equal to the latitude plus 15°. This would be desirable when winter electricity demand exceeds summer demands: for example, where lighting is a major system load, since lighting use is greater in winter. Another reason to use this tilt angle would be to better balance year-round output, since solar radiation levels in winter are normally less than in summer.

- **For small, fixed photovoltaic systems with adjustable framing mounts**, making four adjustments per year will keep the photovoltaic module within about 10° of perpendicular to the sun's rays year round, yielding more electricity. (However, the value of this electricity should be compared with the effort needed to make the adjustments.) Tilt the module at an angle equal to the site latitude on March 21; to latitude minus 10° on May 7; back to latitude on September 21; and to latitude plus 10° on November 7.

Tracking

Solar collectors or photovoltaic modules can be mounted on a tracking mechanism to receive more solar energy. A single-axis tracker follows the sun's apparent east-to-west movement across the sky. A double-axis tracker, in addition to east-west tracking, tilts the solar collector or module to follow the sun's changing altitude angle, slightly increasing energy collection. The use of tracking is only cost-effective if the value of the additional energy by the tracking system exceeds the cost of purchasing, installing, operating, and maintaining the tracker.

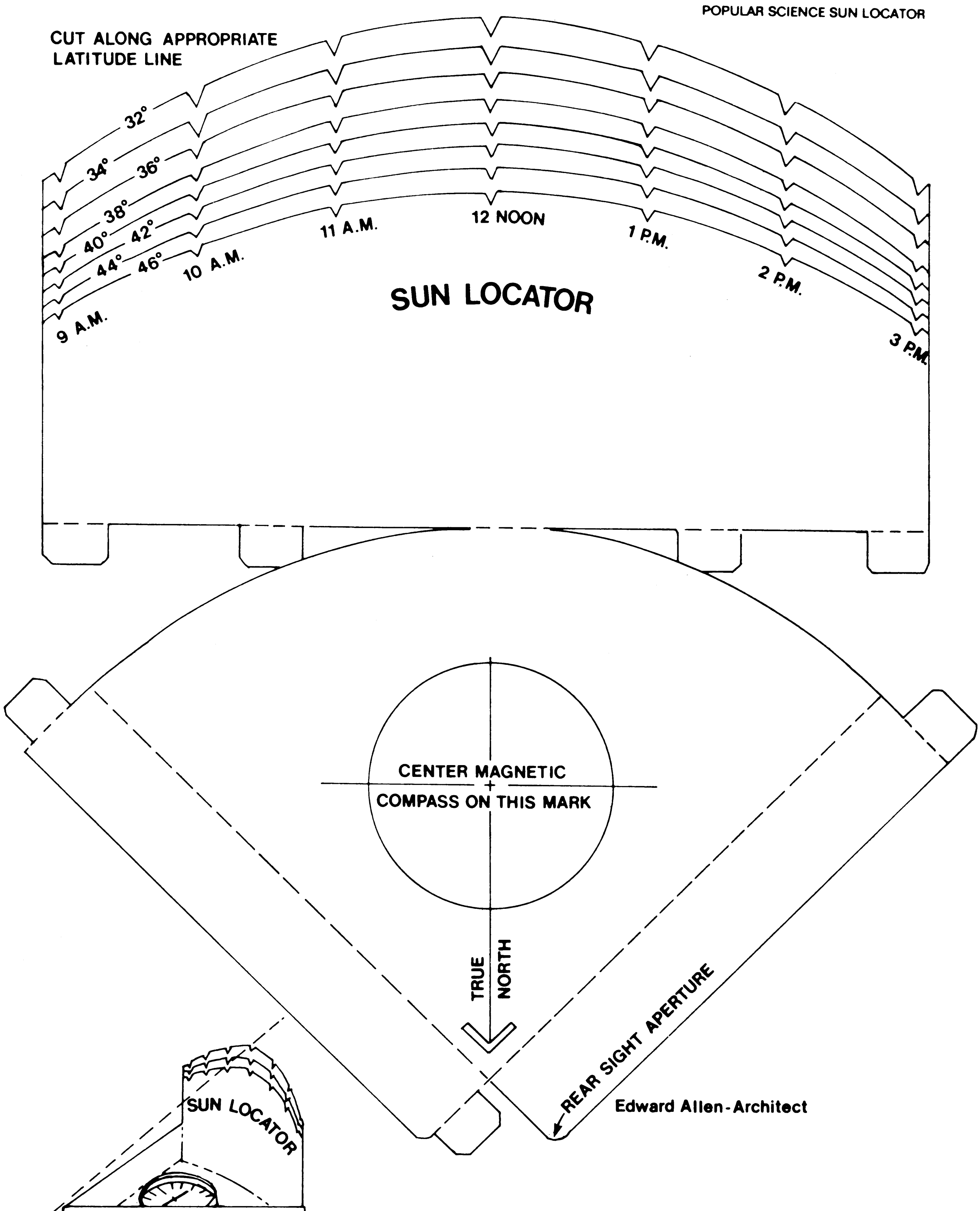
Proper orientation is even more crucial for solar concentrating collectors, both solar thermal and photovoltaic. Solar concentrators must track the sun. They cannot tolerate the small deviations in tilt and orientation that are acceptable to non-concentrating collectors.

Summary

These guidelines give general advice for the orientation and tilt of flat plate collectors and photovoltaic modules. Many factors may affect the optimal positioning of a solar collector or photovoltaic module. Therefore, it is not recommended that you design or orient a solar heating or photovoltaic system without professional help or a solid background in the field.

References

For references, see the reference fact sheet.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CUT ALONG APPROPRIATE LATITUDE LINE
32°
34°
36°
38°
40°
42°
44°
46°
9 A.M.
10 A.M.
11 A.M.
12 NOON
1 P.M.
2 P.M.
3 P.M.
SUN LOCATOR
CENTER MAGNETIC COMPASS ON THIS MARK
TRUE NORTH
REAR SIGHT APERTURE
Edward Allen-Architect
SUN LOCATOR

Take advantage of the state tax credit for renewable energy!

North Carolina offers a personal tax credit of 35 percent of the construction, equipment and/or installation costs for renewable energy systems. The maximum credit per year and per system is $10,500 for residential photovoltaic, micro-hydro, biomass, biogas and wind systems; $3,500 for residential passive and active space heating; and $1,400 for solar water heating systems.

For commercial and industrial installations of solar equipment for production of heat or electricity, the corporate tax credit per year and per system is 35 percent, with a maximum credit of $250,000 for all solar, wind, hydro and biomass applications. For solar systems, additional tax incentives also are available from the federal government (10 percent tax credit and 5-year accelerated depreciation). For wind and biomass, there is also a kWh production tax credit. There is also a corporate tax credit for North Carolina of 25 percent for the costs of constructing a renewable energy equipment manufacturing facility, with no maximum credit, which can be carried over to the next year for up to ten years.

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