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ABSTRACT

The design of any solar heating system is influenced heavily by climate; in this bulletin, information on climate as related to solar heating is as related to solar heating is provided. Topics discussed include: (1) solar radiation; (2) degree days; (3) climate and calculations which make use of solar radiation and degree days; and (4) microclimate. Also included are two methods for calculating solar energy, sources of climatic information, and other sources of information. (JN)

DOE/CE-0104

INFORMATION

U.S. DEPARTMENT OF ENERGY

CONSERVATION AND RENEWABLE ENERGY INQUIRY AND REFERRAL SERVICE

Climate Fundamentals for Solar Heating

The design of any solar heating system is influenced heavily by climate. How much sunshine do you get in January? How cold are the winters in your area? These are some of the first questions that must be asked when considering solar heating for your home or community.

In this fact sheet, sunlight will be referred to as solar radiation (it also goes by the names solar irradiance and insolation). The cold of winter is expressed as a number of degree days (see Degree Days).

A third climatic factor, microclimate, also has an important affect on a solar heating system. Microclimate refers to the weather patterns (e.g., winds, fog, frost) that are unique to the building site.

Solar Radiation

The amount of solar radiation that reaches the earth's surface in approximately three days equals roughly the total energy content of all known supplies of fossil fuels. The average solar radiation that strikes the outer surface of the earth's atmosphere directly facing the sun is 429 Btu per square foot per hour (Btu)/ft²/hour). This number is known as the solar constant. Because of reflection into space and absorption by the atmosphere, about 30 percent of this amount never reaches the earth's surface (Figure 1).

Solar radiation reaching the earth falls into two categories, direct and diffuse. Direct radiation strikes the earth's surface unimpeded, while diffuse radiation is reflected by atmospheric particles. On a clear day most of the rays are direct; on a cloudy day most or all are diffuse.

Since the earth revolves around the sun and rotates on a tilted axis, the solar energy reaching the earth's surface varies widely from hour-to-hour and month-to-month (Figure 2). In the winter, the sun follows a low path through the sky. As a result, the sun's rays are at a sharp angle to the earth's surface, traveling a greater distance through the atmosphere than the rays in the summer. The same principle applies to the hourly variations of solar radiation. In early morning and late afternoon, the sun is low in the sky, and its rays must pass through a greater thickness of atmosphere than at noon when the sun is at its highest point. Therefore, the greatest amount of solar energy reaches the earth's surface at noon.

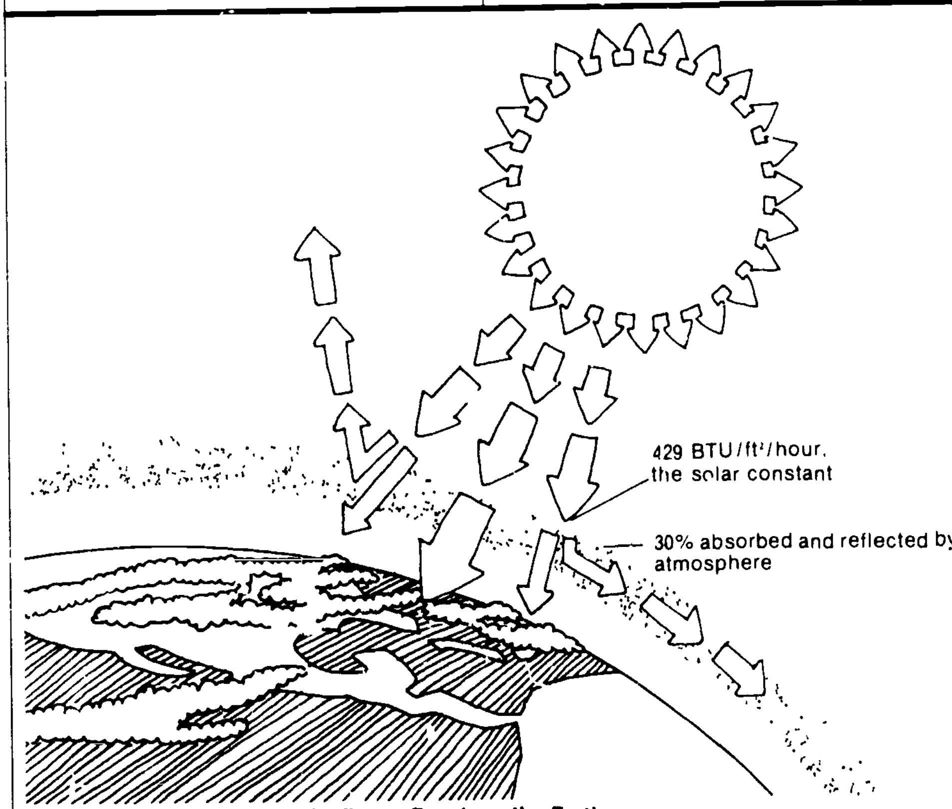

Figure 1. Amount of Solar Radiation Reaching the Earth

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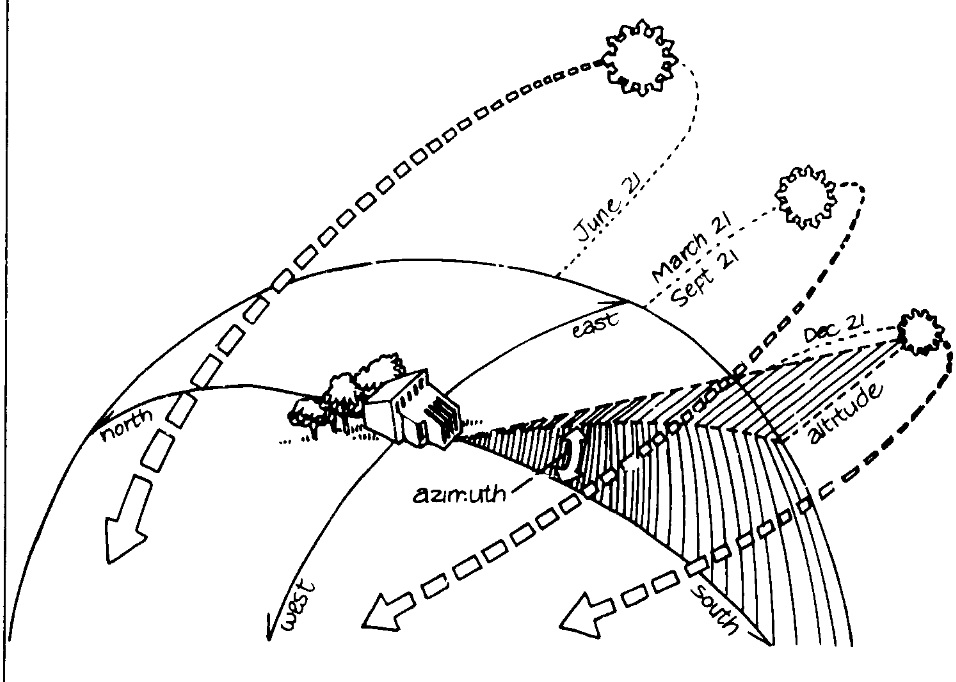

Figure 2. The sun's position relative to a surface location changes seasonally, daily, and hourly

The amount of solar radiation reaching any specific location in the United States is determined by that location's latitude and cloud cover. Southern locations generally receive more solar radiation than northern locations. However, two cities having the same latitude can have wide variations in the actual amount of solar radiation they receive; one city might be clear while the other might be cloudy. Two methods for finding the average daily solar radiation for a given location are described in the box, Solar Radiation–Two Methods of Calculation

Degree Days

Outdoor (or ambient) temperature determines how much heat is lost from a solar collector. The lower the outdoor temperature, the faster heat will be lost from the collector, thereby reducing its efficiency and effectiveness. Low outdoor temperatures also increase the amount of heat lost from a building.

Over the course of a heating season, daily average outside temperatures are accounted for as degree days. For instance, if the high temperature for a day is 45°F and the low is 35°F, then the average is 40°F. Forty degrees subtracted from 65°F (the temperature below which heat is presumed to be needed) equals 25°F or 25 degree days for the particular day.

The number of degree days that accumulate over a heating season is a measure of its severity. In Philadelphia, for example, the degree days in January are about 1000, and for the entire heating season about 5000. The greater the number of degree days, the more heat required to heat a house. The average annual degree days for various locations in the United States are shown in Figure 3.

Climate and Calculations

The calculations that make use of solar radiation values and degree days are beyond the scope of this fact sheet. But a good example of a solar energy system sizing method is the FCHART computer program. FCHART makes use of solar radiation data (adjusted for percentage of actual sunshine) and degree days. The program contains this data for 248 cities in the United States. When this information is interfaced with the project location and the specifications for both the solar system and the building to which the systems are being applied, an estimate of the fraction of the heating load supplied by solar will result.

Microclimate

The microclimate (Figure 4) of any building site can make or break a solar project. If, for instance, a particular valley has a morning fog that lasts until 10 a.m., then the solar system will not benefit from a southeast facing orientation that seeks to collect early morning sunlight. By facing the collector to the west of south, it can take greater advantage of the clear afternoon sky, thereby compensating for the morning hours lost to the fog.

Shadows cast by nearby hills, trees, or other buildings may also dictate a change in orientation. Wind, as redirected by those same objects could also affect how a building or system is designed. A familiarity with a site's microclimate variations could pay dividends in the improved performance of a solar system.

Source of Climatic Information

National Climatic Center

The National Climatic Center (NCC), part of the National Oceanic and Atmospheric Administration (NOAA), is the central archive for all U.S. weather data. They publish a wide variety of material and the following are some of their most useful documents.

Climates of the States ($1.00 each) — contains a general description of the state's climate, including: temperature and precipitation data from many local weather stations; percentage of possible sunshine; number of clear, partly cloudy and cloudy days; and heating degree days.

Climatic Atlas of the U.S. ($15.00) — contains national maps of various climatic variables, including temperature, wind, percentage of possible sunshine and heating degree days. Single maps for specific months or specific variables are also available for $1.00 each.

Solar Radiation — Two Methods of Calculation

The following are two ways to calculate the total solar radiation striking a tilted surface, where the tilt equals the latitude of the location. (Both methods use the radiation available in Philadelphia in January as an example.)

Method A — Use Input Data for Solar Systems and HUD Intermediate Minimum Property Standards Supplement (IMPS) (see sources).

Step 1 — From Input Data for Solar Systems (p. 142) use "mean daily solar radiation" (I_h) for Philadelphia in January, which is 555.3 Btu/day/ft^2.

Step 2 — From HUD IMPS, use Table A-4 (p. 103) to find the clearness factor (the fraction of the radiation transmitted through atmosphere given as K_t) for Pennsylvania State College, which is .381.

Step 3 — From HUD IMPS use the ratio of the monthly average daily radiation on a tilted surface to that on a horizontal surface (given as R in Table A-6). Use the table to find the R value for the K_t value closest to the K_t value of the location of the collector. For example, since the K_t value for Pennsylvania State College is .381, we would use the R table for K_t = .40. On that table, the R value for 40° latitude in January where the tilt equals the latitude (or latitude - tilt = .0) is 1.64.

Step 4 — Calculate the average solar radiation on a tilted surface, I_t, by multiplying I_h by R ($I_t = I_h \times R$). For our example, the average solar radiation of a tilted surface in January in Philadelphia equals 555.3 x 1.64 or 910 Btu/day/ft^2.

Method B — Use ASHRAE clear-day tables and Comparative Climatic Data (NOAA) (see sources).

Step 1 — From ASHRAE clear-day tables, use the Solar Position and Insolation Values for the latitude of the collector location for the month. In our example, the latitude of Philadelphia and the solar position (tilt) are both 40°, and the month is January.

Step 2 — Under the column for the tilt angle, find the surface daily total (which we will call It). The I_t for January for a 40° tilt in Philadelphia equals 1810 Btu/day/ft^2.

Step 3 — From Comparative Climatic Data, use the table of the "Mean Percentage of Possible Sunshine for Selected Locations" and determine the percentage of sunshine for the collector location in the given month. For Philadelphia in January, the percentage of sunshine is 51.

Step 4 — To find the average daily solar radiation on a tilted surface (I_t) multiply the surface daily total for the given tilt (I_t) by the percentage of sunshine. For Philadelphia, I_t = 1809 and the percentage of sunshine = 51, so I_t = 1809 x .51 or 923 Btu/day/ft^2.

Comparative Climatic Data for the United States; Annual ($4.00) — contains summaries of observed climatic data, including average percent of possible sunshine.

Local Climatological Data (Monthly - $1.00; Annual - $8.45) — contains climatic data for various specific weather stations around the country.

Monthly Normals of Temperatures, Precipitation, and Heating and Cooling Degree Days (1951-1980) ($1.50 each) — contains 30-year averages for temperatures, precipitation, and heating and cooling degree days for many weather stations.

Selected Climatological Publications (Free) — describes NOAA publications containing climatological data.

The National Climatic Center also has hourly and daily solar radiation data collected at 37 different locations, available on unedited paper tapes. Printouts are available for each, with an annual printout costing $5.00 per station.

A more complete list of publications is available from:

National Climatic Center
Federal Building
Asheville, NC 28801
(704) 259-0682

Other Sources

HUD Intermediate Minimum Property Standards Supplement: Solar Heating and Domestic Hot Water Systems. Order No. 4930-2, GPO, 1977 (free). Contains factors for converting radiation on a horizontal surface to equivalent value for tilted surface. Available from Department of Housing and Urban Development, Washington Office, Region 3, 1875 Connecticut Avenue, NW, Room 1201, Washington, DC 20009

Tables of clear day insolation are available in ASHRAE 93-77, ***Methods of Testing to Determine Thermal Performance of Solar Collectors*** from:

The American Society of Heating Refrigeration, and Air-Conditioning Engineers, Inc.
1791 Tullie Circle, NE
Atlanta, GA 30329
(404) 636-8400

Insolation Data Manual — Solar Energy Research Institute, U S. Department of Energy, 1980, 280 pp. Available from NTIS (see Source list) for $23.50. Stock Number SERI/SP-755-789. Presents monthly averaged data which describes the availability of solar radiation at 248 National Weather Service stations, principally in the U.S.

Microcomputer Methods for Solar Design and Analysis — Solar Energy Research Institute, U.S. Department of Energy, 1981, 24 pp. Available from NTIS (see Source list) for $7 00. Stock Number SERI/SP-722-1127. Serves as a

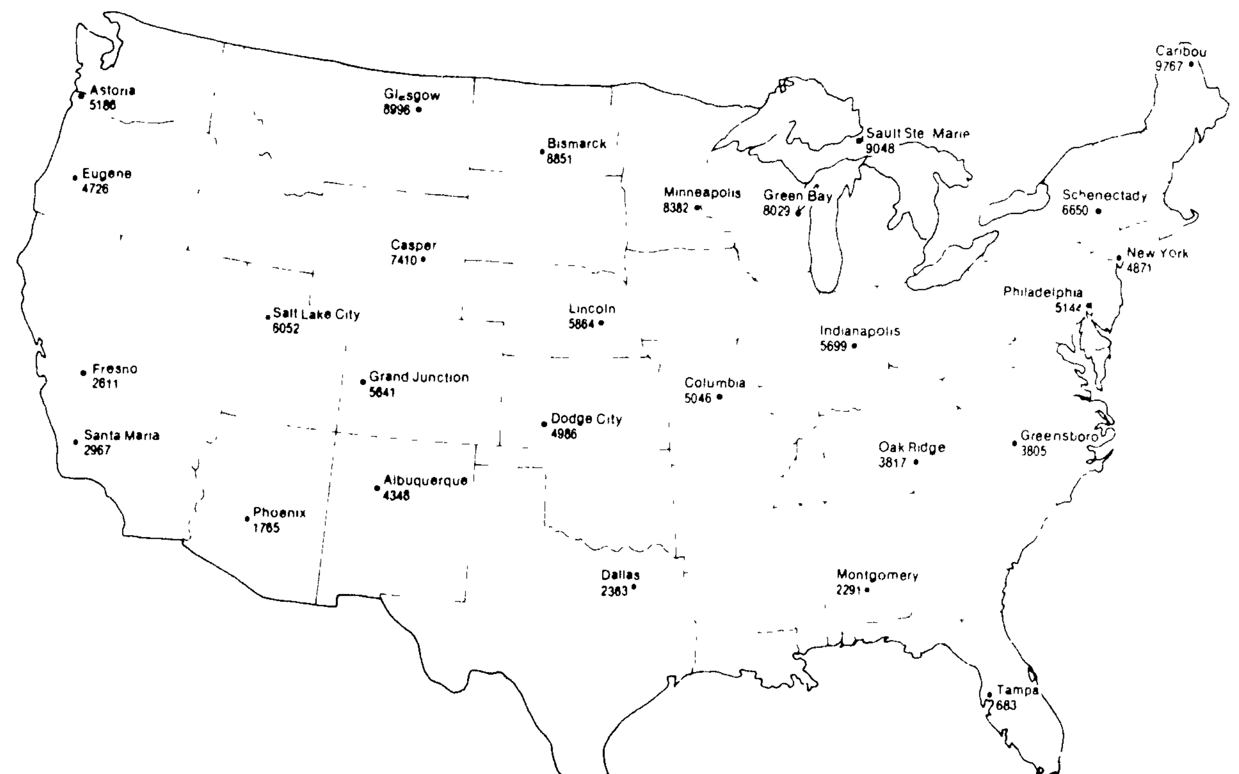

Figure 3. Annual heating degree days for various cities in the United States

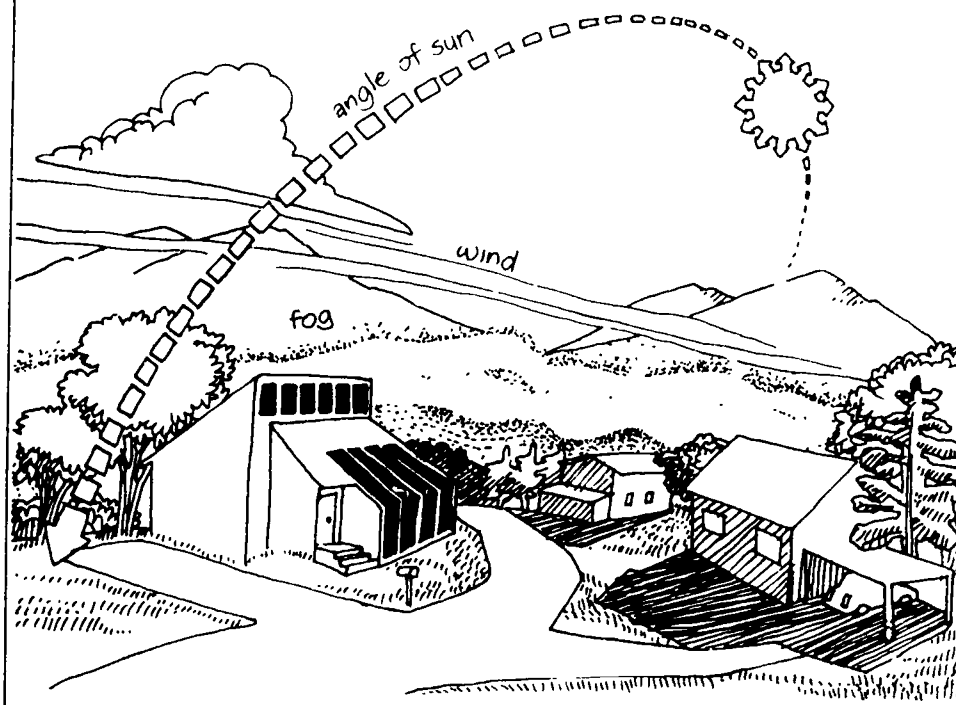

Figure 4.
Microclimate is a combination of factors interacting at any particular site. These may include a tendency for haze or fog, wind patterns and breezes, and water table level.

a source guide for available solar design and analysis software programs to be used on a variety of microcomputers.

Source List

NTIS
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161