SOLAR INDEX GENERATION AND DELIVERY

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This work was prepared under Contract No. DE-AC02-78ET-20090

for

Training Information and Education Branch
Conservation and Solar Energy
U. S. Department of Energy

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Abstract

The Solar Index, more completely defined as the Service Hot Water Solar Index, was conceptualized during the spring of 1978 with direction from a U.S. Government interoffice agency committee which was headed by the Department of Energy. *The purpose was to enhance public awareness of solar energy usability.* Basically, the Solar Index represents the percentage of energy that solar would provide in order to heat an 80-gallon service hot water load for a given location and day. The Index is computed by utilizing SOLCOST, a computer program, which in addition to solar service hot water systems, has the ability to estimate thermal performance of space heating, cooling, and heat pump systems. It also supplies economic analyses for these solar energy systems. The Index is generated daily for most large metropolitan locations in the country (see Fig. 1). This paper presents the definition of the Index, how the project came to be, what it is at the present time, and a plan for the future. Also presented are the models used for the generation of the Index, a discussion of the primary tool of implementation (the SOLCOST Program), and future efforts.

* This is a shortened version of a much larger paper with the same title.

Figure 1. Solar Index Locations (June, 1980)

Project Overview

The Solar Index is a number between 0 and 100 which represents the percentage of energy made available by a solar system that is used to heat an 80-gallon per day service hot water load for a given geographic location and given day. For example, if the Solar Index is 70 for a given day, it means that a solar service hot water system could provide approximately 70 percent of the heat needed to boost 80 gallons from ground water temperature to 120°F. The Solar Index is much like the pollen count, wind chill factor, and air quality index, in that it can provide more useful information than can be provided by observations such as ambient temperature or carbon monoxide concentrations.

The objective of the Solar Index[†] effort is to increase public awareness. Approximately two years ago it was decided within a U.S. interoffice committee that an index, general in nature, would increase public awareness of solar energy.

Several indices were investigated and it was decided that the Index should provide an indication of what the sun can do for the individual rather than to simply state how much solar radiation is available. That is why the current definition of the Service Hot Water Solar Index has been adopted--because it does give an indication of what the sun is capable of doing for the individual. The solar service hot water system was decided upon as a base because it appears to be one of the most commercially viable and is the most easily defined and most frequently installed solar system in the country at the present time. Also, the average hot water usage for a service hot water heating system is fairly constant throughout the country.

In order to obtain the Index, a set of simplified and representative systems must be defined for computer modeling purposes. These systems were

[†] Additional information, general in nature, can be obtained by writing to Solar Index, Conservation and Solar Energy, U.S. Department of Energy, Forrestal Building, Washington, D.C. 20585.

defined in the following manner. They are to be representative of service hot water systems which would be designed for the specific city of interest. In the south, drain-down systems, with water being the collection fluid, were modeled; while in the northern climates, heat exchanges were employed with an antifreeze agent in the collection loop. Furthermore, the systems were sized, with the storage being sized approximately $1\frac{1}{2}$ gallons per square foot of collector, since it has been determined that this is a cost effective storage size. The collector area is determined so that the system will be capable of providing approximately 70-75% of the annual service hot water heating load for an 80-gallon per day consumption rate. Consequently, there is a different system size for each city. In the south, the collector area may only be 40-50 square feet; while in the north, the area may very well exceed 90 square feet.

In the beginning of the project, initiation of the Solar Index for any given city required that the media in that city request the Solar Index. At the present time, cities which are prime market areas are being added to the list whether or not the media have shown interest. Media interest, however, will increase the motivation for inclusion. After deciding to possibly include a site in the effort, the SOLCOST Service Center⁺ selects the appropriate solar system type and determines the availability of weather information. Weather service information is essential.

⁺ Technical responsibility for the Solar Index is provided by the SOLCOST Service Center, 2524 E. Vine Drive, Fort Collins, Colorado 80524. Specific technical questions not addressed by this paper should be addressed to Loren J. Lantz at the above address.

Once it has been ascertained that all necessary information is available, the computer files required for generation of the daily Index are created. This is accomplished with SOLCOST, which is a computer program used to analyze prospective solar energy systems of various types on the basis of economics and thermal performance. It is basically a design tool which provides the user with the necessary information to facilitate decisions regarding a solar energy system. As pertaining to the Index, SOLCOST is used to size the system and then produce a data base of performance values based on historical weather data. The inputs to the program are: location, orientation, size of specific components, the load, and the location's weather history.

A simplified data base is created with the two inputs being average ambient temperature and percent sunshine with the output being the Solar Index. This may be accomplished either by tabular or graphical means (see Fig. 2). Both methods of analysis are easily implemented.

The Solar Index process is two-phased. The first phase is setting up and the second phase is execution. Involved in setting up is the decision to include a location. Then if weather service information is available, the necessary computer files are created for execution of the Index procedure on a daily basis. Execution of the Index on a daily basis requires utilization of computer files, which has already been defined in the setup phase.

As the Solar Index project currently stands, the Department of Energy, Conservation, and Solar Applications, provides direction for the overall project. There are two prime contractors who provide support to the Department of Energy. They are: 1) SOLCOST Service Center, 2524 E. Vine Drive, Fort Collins, Colorado 80524; and 2) National Solar Heating and Cooling Information Center, 20th and Race Streets, Philadelphia, Pennsylvania 19103.

SOLAR INDEX
Saint Louis, MO - January

If the PERCENT OF POSSIBLE SUNSHINE IS 70 and the AVERAGE TEMPERATURE is 30, the SOLAR INDEX is 65.

NOTE: Formulas: %SUNSHINE = percent of actual solar radiation received between clear and cloudy expected daily totals.

AVERAGE TEMPERATURE = sum of the maximum and minimum temperatures divided by 2

Figure 2. For a given location and month the Solar Index can be determined graphically as illustrated. This is usually the procedure used until the Index is automatically generated by computer.

The SOLCOST Service Center provides technical direction for the project. Its personnel are responsible for determining availability of weather information and setting up computer files for execution of the solar Index on a daily basis. They are also responsible for delivering the Solar Index in an automatic fashion to the news wire services, which is done at the present time by direct computer ties.

The National Solar Heating and Cooling Information Center in Philadelphia is responsible for delivering the Solar Index to interested parties who do not subscribe to the news wire services. They are delivered each evening by telephone. Individuals at the SOLCOST Service Center phone the Index number to the National Solar Heating and Cooling Information Center each evening for dissemination to those people who wish to receive the number by phone. They are also responsible for tabulating monthly summaries, keeping records, and dissemination of media information to interested parties.

There are two other agencies which are also very important. They are the United Press International, which at the current time is disseminating the Solar Index daily through its wire services, and a computer service agency located in Massachusetts, which collects the weather data each hour from the prime weather wires, including the wires generated by National Weather Service, National Oceanographic and Atmospheric Administration, and the Federal Aviation Administration. The latter is the one that is used primarily in the generation of the Index. More will be given later about how this weather data is transformed into a Solar Index for a given city.

At the present time, most large metropolitan areas (Fig. 1) are being serviced by the Solar Index effort. Figure 3 gives the Index for Washington, D.C., and Denver, Colorado for one month each. The Department of Energy is

constantly striving to inform the media of this new service, especially in the prime solar commercial market areas of the country.

Service Hot Water Model Description

A generic solar service hot water system model is chosen for each location and is selected to best represent what is commercially being installed in that particular locale. Service hot water systems are made up of many different basic designs. For purposes of the Index, two system types were decided upon: one for relatively non-freezing climates where the collector fluid was water and one for freezing climates where the collector fluid was antifreeze. These two systems are shown schematically in Figs. 4 and 5. Generically, the only difference between the two systems is a heat exchanger which is included to help prevent possible freezing of the collectors. In addition to the heat exchanger are associated pumps and plumbing which are shown between the collector and the storage system in Fig. 4.

Figure 3

Figure 4. Simplified Diagram for Freezing Climates

Figure 5. Simplified System Diagram for Non-Freezing Climates

The collectors were also chosen to represent the climate. In the model for nonfreezing climates, the collector is a flat plate design, with one glass cover, and a flat-black painted absorber. For freezing climates the collector is identical, with the exception of the number of cover plates, which is two. The storage tank for both systems was sized to be a ratio of the collector area. The multiplication factor is 1.5 gallons per square foot of collector. For example, if the collector area was 40 ft^2 , the storage tank would be sized at 60 gallons. A storage size of 97.5 gallons could result from using this method, a size which may not be available commercially. The Index numbers are not highly sensitive to the storage size. In reality, a storage size other than 97.5 gallons would probably be installed; however, this would depend on local availability. If storage sizes of 90 or 100 gallons were used in the model, the final Solar Indices would not be appreciably influenced. The hot water heater in both cases was assumed to be a standard 42 gallon electric hot water heater, and both systems are assumed to have a tempering valve set at 120°F where, if the hot water heater temperature goes above 120°F , cold water is mixed with the outlet water. It is also assumed that the hot water heater temperature control thermostat is set at 120°F . High temperature protection for the storage tanks in both models was set at 200°F . In other words, the storage tank temperature was never allowed to exceed 200°F .

Using the weather information for the city and a predetermined load of 80 gallons per day, and with the assumption that the ground water temperature is an average of 50°F throughout the year, the solar system was sized so that it gave an annual load fraction of 70 - 75%.

When the governing committee for the Solar Index project was originally formed, it was decided that the model used for generation of the individual

Solar Indices should be representative of what was being installed. It was also desirable to have some comparative base so that the Indices could be compared against each other across the country. As a result, it was decided that a solar fraction design point of 70 - 75% would be appropriate. In general, systems with this load fraction are cost effective compared to cost of electricity across the country, except possibly in the northwest where electricity is cheap. For certain situations, however, it might not be the most cost effective design or might not be what is actually being installed in a local area. For example, load fractions of 50% are commonly seen in the northeast part of the United States and in certain parts of the country; for example, in the southwest, load fractions may reach 90% or greater. Taking all of these local variations in mind, it was decided that a good all-around number for a sizing point was 70 - 75%. This particular decision may be reviewed later in the project and a new realization may take place. That is, the lowering of the load fraction for the northeast so that it is much more representative of what is actually being installed. In light of the new incentives, the generally expected design point in the industry may change substantially; also, if solar system sales increase greatly in the future, system costs may lower and again cause the representative system to appear much different than it is today.

Site Selection and Initialization

Several justifications can be used to add a particular site to the Solar Index effort. The two most important ones are: 1) that the media in a particular location show an interest in being serviced in this endeavor; or 2) that the city of interest is a prime market area. Expansion will continue until a total of approximately 200 - 250 sites are included in the effort. At that time, a reevaluation will take place to see if more sites can be included. The

SOLCOST Service Center will work with the Department of Energy in deciding priorities for adding these cities to the effort. It is expected that this project will last at least a total of three more years. See the future efforts section of this paper for more details.

Once it has been decided to add a city, several things need to be analyzed to determine whether or not such an effort can indeed be supported (see Fig. 6). Weather services need to be researched to find out what weather information is available for any particular site. The SOLCOST Service Center receives daily and hourly information for most cities in the country which have a National Weather Service, National Oceanographic and Atmospheric Administration, or Federal Aviation Administration observatory. At these particular sites, hourly cloud cover and surface observations data are collected and reported to computers, which in turn dispatch it over several high speed wire services. The wire of primary interest is the one maintained by the Federal Aviation Administration. A computer network in Concord, Massachusetts observes these wires, takes the information, and stores it in computer mass storage each hour. Software is then executed to reduce this data to numbers which are suitable for generation of the Solar Index on a daily basis. The data is reviewed to see, first of all, if data is recorded for the particular site of interest, and, second, whether there is enough data on an hourly basis to accomplish the transformation process and generate the Solar Index number on a daily basis with acceptable reliability (see Fig. 7). If no suitable information is available, then the search is stopped and the appropriate agencies informed. Otherwise, the next step would be to set up the necessary computer files for the daily procedure.

Coordination then takes place between all of the appropriate agencies. The media for the particular city are informed, and the daily procedure begins as soon as all coordination and computer hookup requirements are met.

Figure 6. Solar Index Setup Procedure

Accomplished Hourly
During Daylight
Hours to Acquire
Weather Information

Executed On A Daily
Basis Once Per Time
Zone

Figure 7.. Solar Index Daily Procedure

Daily Procedure

The next process is the Solar Index daily procedure. The wire services are reviewed each hour at the computer facilities in Concord, Massachusetts, and data is stored and filed for subsequent processing and reduction into the necessary information used for the generation of the Solar Index. Data is received for hundreds of cities. However, this data needs to be sorted, for it contains special reports, such as general information that is not of interest and information for sites which are not included in the effort. Reduced files are created at Concord, Massachusetts and then shipped via telephone lines to a mini-computer at the SOLCOST Service Center for subsequent processing and retransmittal. These particular files eventually end up in a high speed computer, utilized by the SOLCOST Service Center, which takes the cloud cover information, temperature, and pressure data, and transforms it into total horizontal radiation for the hour and for the cities of interest. This particular process goes on periodically throughout the day until local sunset occurs at the various sites of interest. For example, sunset does not occur in Washington, D.C. , exactly the same time as it does in Denver, Colorado.

Previously, as the sun sets in the various time zones, daily summaries were tabulated which included total horizontal radiation and the maximum and minimum temperatures for the day. The total horizontal radiation was transformed into percent of sunshine. These various data points are required for generation of the Solar Index by a table look up procedure. After the sun had set for a particular location, the individual Solar Indices were calculated. This particular procedure is still utilized, but the final Indices are not reported to the public. Approximate numbers are calculated in the mid-afternoon for each time zone by utilization of an incomplete data set. The information that is missing is the radiation values and temperature values

for the remainder of the day. It is assumed that these values are similar to what was experienced in the previous part of the day. This allows the Solar Indices to be delivered to United Press International in time for inclusion on the early evening news broadcast. The accuracy of this procedure has been calculated, and feedback filtering techniques are utilized in an effort to minimize the error. The error is typically 1 or 2 percent, plus or minus, and as far as the individual consumer is concerned, there should be no reason for concern. In the long run, the early delivery will increase the Index's primary objective considerably. This is, it will be viewed and heard by many more individuals than it could have been in the past. The number that is generated after sundown, as it has been in the past, is saved for record purposes. The final number that is calculated is not delivered to the media.

To deliver the Indices, the city names and numbers are reduced to a file which is transferred from the SOLOCOST Service Center, to the computer maintained by UPI. This is required, since the news services have special formatting requirements. The resultant news file is eventually shipped to the United Press International for subsequent routing and disposal through their wire services. For the media who do not subscribe to the news wire, phone calls are made by the National Solar Heating and Cooling Information Center to provide the Solar Index on a daily basis.

Future Efforts

The number of sites serviced by the effort will gradually increase to about 200 - 250 in calendar year, 1980. The first sites to be added will be in prime market areas. When this target has been achieved, the effort will be reevaluated to see if it is desirable to increase the effort further. Also

in this time frame, the Index will be delivered seven days per week for those locations where weather service data is available. If it is not available throughout the whole week, it will be delivered five days per week.

Several individuals have indicated the desire for possibly generating indices for alternative systems such as passive or space heating systems. Such indices can be defined but require some preliminary investigation to determine whether or not they are desirable and for which audience they would be applicable. Such an evaluation will take place during the next few months of operation, and afterwards, the Department of Energy will make the decision whether or not Solar Indices will be generated and delivered for alternate types of solar systems, both active and passive.