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Federal Renewable Energy Screening Assistant (FREScA)

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FEDERAL RENEWABLE ENERGY SCREENING ASSISTANT

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ABSTRACT

The Federal Renewable Energy Screening Assistant is a software tool to be used by energy auditors to prioritize future studies of potentially cost-effective renewable energy applications at federal facilities. This paper describes the structure and function of the tool, gives an inventory of renewable energy technologies represented in the tool, and briefly describes the algorithms used to rank opportunities by the savings-to-investment ratio.

INTRODUCTION

The National Energy Policy Act of 1992 directed the Federal Energy Management Program to conduct energy conservation audits at a large number of federal facilities. Executive Order 12902 further directed federal agencies to "significantly increase the use of solar and renewable energy." Given limited resources for each facility audit, a tool was needed to assist auditors in efficiently screening renewable energy applications so that detailed evaluations could focus on applications most likely to be cost effective. A computer-based data entry and processing tool useful for facilitating the screening process has been developed and is called "Federal Renewable Energy Screening Assistant (FREScA)." FREScA provides a consistent methodology and reporting format for audits conducted in various locations by auditors with various backgrounds.

First, we provide a short overview of the capability and operation of the program. Second, we summarize the technical scope of the calculations and analyses which are completed by the software.

PROGRAM OPERATION

FREScA is written as an application of a commercial relational data base program. The program is a DOS application operating on IBM-compatible hardware using a 286 or better coprocessor.

Data entry windows help in accumulating the site, building, and energy load data necessary to complete a valid screening. Solar and wind resource data and energy economics data are stored within the FREScA data base and are called up when the facility location (zip code or longitude/latitude) is entered. The auditor collects summary data on facility and building energy use, supply, and operational characteristics; local energy-cost data; building construction; and use patterns that might influence energy use. Assistance in collecting and entering data is offered by options within the software and context-sensitive help messages incorporated throughout the program.

Relatively sophisticated analyses of technology performance and cost are completed within the program, consistent with the desire to keep data requirements to a minimum. The calculations include projecting the system energy savings or displacement, cost of installing the system, and life-cycle cost (LCC) and net present value (NPV) analyses following the procedures of *42 USC 8254* and *10CFR436*.

The results of the audit and analyses are processed and presented in detail or as summary formats which can be output directly to a printer or in digital format. Some measures, such as biomass electricity, are assessed on a facility-wide basis; others, such as active solar space heating, are assessed on a building-by-building basis.

TECHNOLOGY ALGORITHMS

The FREScA program includes the following list of technology options:

- Active solar heating
- Active solar cooling
- Solar hot water
- Daylighting (sidelighting)
- Photovoltaics
- Solar thermal electricity
  - Parabolic dish
  - Parabolic trough
- Wind electricity
- Small hydro

- ▸ Electricity from biomass
- ▸ Electricity from wood
- ▸ Building space conditioning load avoidance
  - Multiple glazings
  - Window shading

Where performance or cost are not strongly dependent on climate, they are described by published catalog and technical literature information. Examples of this approach are small hydro, electricity from refuse, and electricity from wood. Each of these technologies is mature and well documented. If the auditor can describe the water source, or the nature and cost of wood or other biomass, the remaining calculation is a simple matter of determining efficiency and capacity factor to adequately describe the option.

In cases where performance is strongly coupled to climatic data and time variability of these data, the calculations are more extensive. The zip-code-sorted data within the program include:

- ▸ Maximum and minimum direct and total solar radiation from the *DOE Solar Radiation Data Manual* (NREL/TP-463-5607).
- ▸ Wind data from the *DOE Wind Energy Resource Atlas* (DOE/CH10094-4).
- ▸ Weather data, including design and average temperatures, wet-bulb temperatures, heating degree-days, cooling degree-hours, and seasonal air enthalpies for each area taken from the DOD Facility Design and Planning Engineering Weather Data (NAVFAC P-89).

Based on these data, we can calculate the monthly variation of each parameter and complete an analysis for one day representative of each month. Monthly values are summed for the annual result.

The following examples illustrate the level of the calculation that is completed within FREScA.

Active Solar Heating

The design building load is calculated based on the definition of the building entered by the auditor and the design weather accessed from the zip-coded file. This load accounts for wall, roof, and window losses (and gains), infiltration, and occupancy load. Annual loads as a function of heating degree-days, solar radiation, loss coefficients, solar exposure, glazings, solar absorption coefficient, and occupancy are calculated from nomographs as described in the next section.

The performance of the solar collector is modeled based on the methods and data in *Engineering Principles and Concepts for Active Solar Systems* (SERI, 1987). The size of a solar collector adequate to meet the building design load for January insolation and temperatures is calculated. This is compared to the available space for collectors identified by the auditor, and the smaller of the two is established as the maximum size for the system. Three subsequent calculations are completed for systems 75%, 50%, and 25% of the maximum size. Part-load operation is assessed using data from NAVFAC P-89.

Figure 1 is a set of curves generated from the frequency of temperature occurrence data in NAVFAC P-89. The abscissa of Figure 1—percent of maximum load—is the indoor-outdoor temperature difference as a percentage of maximum (design) temperature difference. The ordinate—frequency of occurrence—is the number of degree days occurring at that temperature difference as a fraction of total degree days for the location. Locations as diverse as Washington, D.C.; Fairbanks, AK; Detroit, MI; and Knoxville, TN, plot as similar curves.

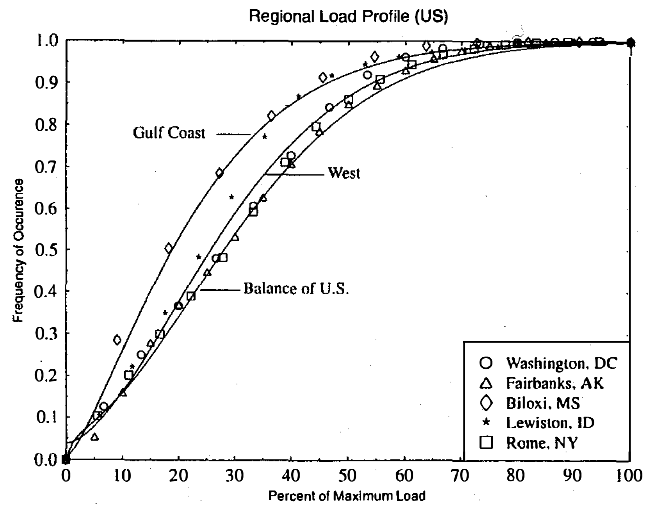

FIGURE 1. SET OF CURVES GENERATED FROM FREQUENCY OF TEMPERATURE OCCURRENCE DATA IN NAVFAC P-89

On examining about 40 locations around the country, we determined that the nation could be characterized in three sections (and corresponding degree-day relationships). These locations are (1) the Gulf Coast (extending about 100 miles inland) and Florida, (2) the semiarid West, not including coastal Oregon and Washington, and (3) the rest of the country. Each of these sections is identified in the zip code file, so that for each area it is then possible to calculate the fraction of the total degree days (and load) that occur at each value of temperature difference. System performance month by month for each collector size is then calculated.

The ratio of the winter-season solar system capacity-to-load that occurs at temperature differences below those associated with the collector sizing gives an estimate of the safety factor associated with the system size. For example, a system sized to meet half the maximum load will always have more capacity than the load that occurs for all temperatures below that half-load value.

The final step of the analysis is calculating the NPV of the energy cost savings and LCC of the system. The ratio of the two is the savings-to-investment ratio (SIR). An SIR greater than 1.5 is the criterion for justifying a more-detailed feasibility study. The program searches for the maximum system size that results in an SIR greater than 1.5, or the largest value of SIR if no system can achieve an SIR equal to 1.50. The value is displayed in the result window. All other results are printed in a detailed report output of the program.

Active Solar Cooling and Hot Water

The same type of analysis as just described is completed for cooling and hot water systems. The percent of maximum cooling load versus fraction of maximum temperature difference is not as well correlated for cooling as for heating. However, when the impact of wet-bulb temperature is added to the dry-bulb result, the result adequately captures the annual load for a location. Solar cooling systems always supply heat in the winter season, and economic analyses include that contribution.

Because the hot water load is fairly well defined on a seasonal and daily basis, it is possible to compare daily capacity and daily load and take credit only for the minimum of the two. The analysis sizes the system based on both summer conditions (so that there is inadequate capacity for winter load) and winter conditions (so that capacity is dumped in summer) and presents both results.

Daylighting

The daylighting option addresses controlling artificial lighting to take advantage of light entering existing windows. Daylighting calculations implement the methods of the *IES Lighting Handbook* (IES, 1993). A room-cavity ratio is calculated based on room dimensions and glazing area. Based on the required illumination in the room (for general lighting), illumination at the existing windows is calculated. It is then possible, based on IES correlations of illumination with solar elevation and azimuth angles and using solar trigonometry and the methods of Liu and Jordan (1977), to calculate the time of day when the illumination will be adequate to meet the indoor general lighting requirement and thus turn off artificial lighting with a photocell unit.

The rooms are divided into three sections (using IES methods), and the calculations are repeated for near-window, far-wall, and mid-room locations. The calculations are done for each month of the year, and the results are summed for the year. The conservation is the artificial lighting energy that can be avoided with the daylighting.

Photovoltaics

Photovoltaics and solar thermal production of electricity use additional data from the *DOE Solar Radiation Data Manual* and are included, as a function of zip code, in FREScA. These data are

- Annual average total radiation on a horizontal surface.
- Annual average direct radiation on a one-axis tracker.
- Annual average direct radiation on a two-axis tracker.

Using these three data and the methods of Liu and Jordan (1977), the hourly variation of power produced for each month of the year is calculated. Because maximum solar output is generally coincident with demand in summer peaking utilities, a peak-clipping module is included with the solar electric options. This module asks for a description of the load shape. Based on this information and a description of battery storage, the program searches for the optimum battery size that, because of utility demand charges, makes electricity supply during peak periods more valuable. The details of specific utility rate structures (e.g., ratchets, stand-by charges) are not modeled. The calculation defines the solar generation and battery combination that yields the best economic payback over the equipment life.

A second module in the solar electric options describes remote locations where the cost of an avoided grid extension could significantly increase the value of the solar electric installation. The auditor can evaluate the impact of this factor in the site analysis. In all of the electric options, comparisons can be made of purchased (utility) or on-site (generator) production of electricity.

Solar Thermal Electricity

Electricity generated by a steam turbine fed by parabolic trough collectors or a central boiler with heliostats, as well as electricity generated by a parabolic dish with Stirling engine, is represented by efficiency-based models. Efficiency of the collector as a function of solar resource and temperature is multiplied by turbine efficiency as a function of temperature to calculate system efficiency. Annual capacity factor and design power output for the system are calculated without energy storage.

Electricity from Wind Energy

The wind energy option allows the assessment of wind turbine farms as a facility electrical power source. Average annual wind speed for the nearest data base site and power curves for three types of wind turbines available today are provided by the program. The auditor chooses parameters describing surrounding terrain, and the program calculates a Weibull distribution of wind speeds, interacts this wind regime with the power curve for the wind-turbine type, and calculates an annual capacity factor and design power output for the farm. Costs are modeled against each of the input parameters, and an analysis of cost effectiveness is completed.

Small Hydro and Biomass

The remaining technology options describe the conversion options, which are fairly mature, and their description is straightforward. In the case of hydro, the auditor must provide capacity factor input; however, for biomass and refuse direct firing, modules are provided that account for refuse disposal cost savings and the cost of obtaining biomass fuels. The biomass option provides selection of hardwoods, softwoods, peat, bagasse, and sawmill waste. The cost to process and bring the fuel to the site is included in the analysis.

Load Avoidance

The FREScA analysis tool includes two building load avoidance options which can be considered with the renewable supply alternatives. These options are window shading and insulated glazing.

These options incorporate a set of design nomographs included in the *Architects and Engineers Guide to Energy Conservation in*

Existing Buildings (DOE/CS-0132). These nomographs reflect detailed modeling of building performance using sol-air temperature, building mass, building construction parameters, infiltration and ventilation, internal gain, and weather variations for 12 geographic regions of the United States . The auditor can explore the potential for building load avoidance associated with windows for any climate data included in the zip code data base.

CONCLUSIONS

Implementation of the facility audits mandated by the National Energy Policy Act of 1992 and Executive Order 12902 represents a large undertaking that will extend into the next century. FREScA provides a method to facilitate a comprehensive assessment with a minimum of cost to the government. In light of the number and diversity of auditors involved in the effort, FREScA will provide uniform input and analysis methods that can normalize the analysis output and help prioritize the recommendations arising from the process. As the software's data base and the analysis methods are enhanced, the methodology will be useful for more-sophisticated requirements and to less-technically sophisticated users.

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