GREENHOUSE BASE LOAD/PEAK LOAD ANALYSIS

INTRODUCTION

Most existing geothermal greenhouse operations use the geothermal energy to meet 100% of the heating needs of the facility. As these operations expand, some may encounter limits in therms of the amount of fluid that can be produced from the geothermal aquifer and/or wells. In these cases (where the effluent from one house may be used to heat a second house) or in the case of a facility with a very low resource temperature, it may be worth considering a design in which the geothermal source serves as the base load for heating purposes and a second fossil fuel system provides additional capacity in the coldest weather. This is a strategy that has been used effectively in large district heating systems in Europe for many years. In the context of a greenhouse, this strategy allows the geothermal system to capture the majority of the annual heating needs of the facility without the capital cost associated with equipment designed to meet the peak load.

Due to climate related temperature occurrences, it is possible to design a geothermal system for only 50 to 60% of the peak heat loss of a greenhouse and still meet over 90% of the annual heat energy needs of the structure. This is the result of the fact that the coldest outside temperatures (for which heating systems are normally designed) occur only a very few hours per year. The bulk of the hours in a typical heating season occur at roughly half way between the minimum outside air temperature and the temperature maintained inside the greenhouse. As a result, a down sized geothermal system is able to satisfy most of the annual heating energy requirements.

This spreadsheet is designed to evaluate the relative contributions of a geothermal base load system coupled with fossil fuel fired peaking system in terms of annual energy supplied. Two types of peaking systems are considered by the spreadsheet: individual unit heaters and a boiler connected into the hot water system served by the geothermal system. The unit heater approach typically results in a higher capital cost but a lower fuel cost for a given base load/peak load ratio. The boiler approach tends toward lower capital cost and higher energy cost.

For additional detail the user may wish to order the publication entitled "Fossil Fuel Fired Peak Heating for Geothermal Greenhouses" from the Geo-Heat Center at http://geoheat.oit.edu or 541-885-1750.

<u>Input</u> (blue shaded area)

<u>Night Temp</u>. Enter the night air temperature to be maintained in the greenhouse in ^{o}F.

<u>Day Temp</u>. Enter the daytime air temperature to be maintained in the greenhouse in ^{o}F.

<u>Efficiency</u>. Enter the overall heating efficiency of the heating equipment to be used for the peaking system. Older standard efficiency equipment is typically in the range of 65 - 78%, newer moderate efficiency units 78 - 83% and high efficiency condensing type units >90%.

UA. Enter the unit heat loss of the structure in Btu/hr °F. This is the peak heat loss in Btu/hr divided by the design temperature difference. For example, a 1 acre facility with a peak loss of 3,700,000 Btu/hr with a design inside temperature of 65 °F at an outside design temperature of 4°F would have a UA value of 3,700,000 / (65 - 4) = 60698 Btu/hr °F.

% Day Load. Enter the percentage of the gross day heating load to be carried by the heating system. This value is used to simulate the solar heating impact on the energy required from the heating system. Entering a value of 100% means that the spreadsheet assumes that there is zero contribution from the sun in terms of heating of the greenhouse during the daytime hours. Entering a zero would cause the spreadsheet to assume that the sun supplies all of the heating needs of the facility between the hours of 0900 and 1600. Anecdotal evidence suggests that the solar contribution to daytime heating requirements for greenhouses in clear, high desert type climates is on the order of 55 to 85% (45 to 15% as input for % Day Load).

% Design. Enter the percentage of the peak load that the geothermal portion of the system is designed for. In general most applications will be in the range of 40 to 65% of the peak load.

Out Des T. Enter the outside design temperature for the site where the greenhouse is located. This is typically the ASHRAE 99% value for greenhouses. It is defined as a temperature below which only 1% of the hours in a typical winter occur.

Fuel Energy. Enter the unit energy content of the fuel to be used for the peaking system. Natural gas - 100,000 Btu/therm, propane 90,000 Btu/gal, #2 fuel oil 138,000 Btu/gal

Bin Data. Enter the number of bin hours for the location for the temperature intervals indicated under the 1st column (Bin). Enter values for the day period only (2nd column - 9-16) and the total hours (3rd column - Total) separately. Temperatures appearing in column 1 are the mid points of the 5°F temperature bins found in most references.

Summary Output

Geo Cap. This is the calculated capacity of the geothermal (base load) portion of the system. It is determined by UA x (Day temp - Out Des T) x % design

UH Fuel. This is the total calculated annual peaking fuel required for a unit heater type peaking system based on the inputs provided. The quantity of fuel units is based on the fuel energy per unit entered at Fuel Energy. The quantity of fuel required for peaking with unit heaters is always less than that for a boiler approach since the unit heaters, operating in parallel with the geothermal equipment do not compromise it's capacity.

UH Geo. This is the percentage of the total annual heating energy required by the greenhouse that is supplied by the geothermal system when it is coupled with a unit heater type peaking system.

Blr Fuel. This is the total calculated annual peaking fuel required for a boiler type peaking system based on the inputs provided. The quantity of fuel units is based on the fuel energy per unit entered at Fuel Energy. The quantity of fuel required for peaking with boiler is always greater than that for a unit heater approach since the unit heaters, operating in parallel with the geothermal equipment do not compromise the geothermal heat exchanger's capacity as is the case with the boiler.

Blr Geo. This is the percentage of the total annual heating energy required by the greenhouse that is supplied by the geothermal system when it is coupled with a boiler type peaking system.

Load Factor. This is the load factor for the greenhouse based on the total annual heating energy required (minus solar heat gain) divided by the peak load multiplied by 8760 hrs per year.

Output Table

Night Load Btu/yr. This column calculates the total heating energy required by the greenhouse at the temperature bin indicated in column 1 based on the number of hours (col 3 - col 2) and the peak load appearing in column 6.

Day Load Btu/yr. This column calculates the total heating energy required by the greenhouse at the temperature bin indicated in column 1 minus any contribution from the sun as specified in the "% Day Load" input. Based on the number of hours in column 2 and the peak load shown in col 7.

Night Load Btu/hr. This is the calculated load (Btu/hr), at night, for the temperature bin indicated in col 1. It is based on UA x (Night Temp - Bin).

Day Load Btu/hr. This is the calculated load (Btu/hr), during the day, for the temperature bin indicated in col 1. It is based on UA x (Day Temp - Bin).

UH Night Fuel. This is the calculated annual fuel requirement (in units as specified in Fuel Energy) for the night hours (col 3 - col 2) of temperature bin indicated in col1 for a unit heater type peaking system. The calculation assumes that the geothermal system will be used to meet the load first. If the capacity of the system (Geo Cap in summary output)is less than the load appearing in col 6, the peaking system will be operated to the extent necessary to make up the difference between the geothermal capacity and the load. The geothermal system continues to operate at it's full capacity at any time the peaking system is in operation. Thus the peaking system meets only the unsatisfied load (actual load minus geothermal contribution) of the structure.

UH Day Fuel. This is the calculated annual fuel requirement in (units as specified in Fuel Energy) for the daytime hours (Col 2)temperature bin indicated in col1 for a unit heater type peaking system. The calculation assumes that the geothermal system will be used to meet the load first. If the capacity of the system (Geo Cap in summary output)is less than the load appearing in col 7, the peaking system will be operated to the extent necessary to make up the difference between the geothermal capacity and the load. The geothermal system continues to operate at it's full capacity at any time the peaking system is in operation. Thus the peaking system meets only the unsatisfied load (actual load minus geothermal contribution) of the structure.

Boiler Day Multiplier. This is a calculation that accounts for the fact that the capacity of the geothermal heat exchanger is degraded by the operation of the peaking boiler. The user is referred to the Geo-Heat Center publication referenced in the introduction to these instructions for a detailed explanation of this issue. In short, the gradual application of heat input to the loop from a peaking boiler (as outside temperature decreases)with a supply water temperature indexed to outside temperature results in a gradually rising return temperature to the geothermal heat exchanger. The effect of this is to gradually reduce the ability of the geothermal heat exchanger to supply heat to the loop. The multiplier calculated in this column is used in the energy calculations to account of this impact during the daytime hours of operation. The actual design of a system and the temperature reset schedule for the peaking boiler, system delta T among other issues will influence the extent to which the geothermal heat exchanger capacity decreases.

Boiler Night Multiplier. This is a calculation that accounts for the fact that the capacity of the geothermal heat exchanger is degraded by the operation of the peaking boiler. The user is referred to the Geo-Heat Center publication referenced in the introduction to these instructions for a detailed explanation of this issue. In short, the gradual application of heat input to the loop from a peaking boiler (as outside temperature decreases)with a supply water temperature indexed to outside temperature results in a gradually rising return temperature to the geothermal heat exchanger. The effect of this is to gradually reduce the ability of the geothermal heat exchanger to supply heat to the loop. The multiplier calculated in this column is used in the energy calculations to account of this impact during the night hours of operation.

Boiler Day Fuel. This is the calculated annual fuel requirement in (units as specified in Fuel Energy) for the day hours of the temperature bin indicated in col1 for a boiler type peaking system. The calculation assumes that the geothermal system will be used to meet the load first. If the capacity of the system (Geo Cap in summary output)is less than the load appearing in col 7, the peaking system will be operated to the extent necessary to make up the difference between the geothermal capacity and the load. The geothermal system continues to operate at a capacity adjusted by the multiplier in col 10 at any time the peaking system is in operation.

Boiler Night Fuel. This is the calculated annual fuel requirement in (units as specified in Fuel Energy) for the night hours (col 3 minus col 2) of temperature bin indicated in col1 for a unit boiler type peaking system. The calculation assumes that the geothermal system will be used to meet the load first. If the capacity of the system (Geo Cap in summary output)is less than the load appearing in col 6, the peaking system will be operated to the extent necessary to make up the difference between the geothermal capacity and the load. The geothermal system continues to operate at it's the capacity adjusted by the multiplier in col 11 at any time the peaking system is in operation.

Bal Pt Temp. This calculation, located in a box below the output table calculates the balance point temperature for the geothermal portion of the system. This is the minimum outside air temperature at which the geothermal system is capable of supplying 100% of the heating needs of the structure. Below this temperature the peaking system must be operated in conjunction with the geothermal system. Two temperatures are calculated one for night and one for day operation since in many greenhouses different temperature set points are used.