GEO-HEAT CENTER

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September 30, 2006

The Geo-Heat Center conducted an evaluation of cascaded geothermal uses for the Myrtle Tree Geothermal Development Project in Canby, California. This work has been funded and completed under Midwest Research Institute, National Renewable Energy Laboratory (NREL) Task Order No. KLDJ-5-55052-03, "*Myrtle Tree Geothermal Development Project*".

Project Background

I'SOT, Inc. has been operating a geothermal district heating system in Canby, CA since 2004, which supplies space heating and domestic hot water to approximately 34 buildings, totaling about 53,000 ft^2. Geothermal water is supplied at 190^{o}F by a 2,100 ft deep well that is capable of yielding about 37 gpm. Geothermal effluent is currently treated by carbon filters, and then discharged to a river. A sketch of the existing district heating system is shown in Figure 1.

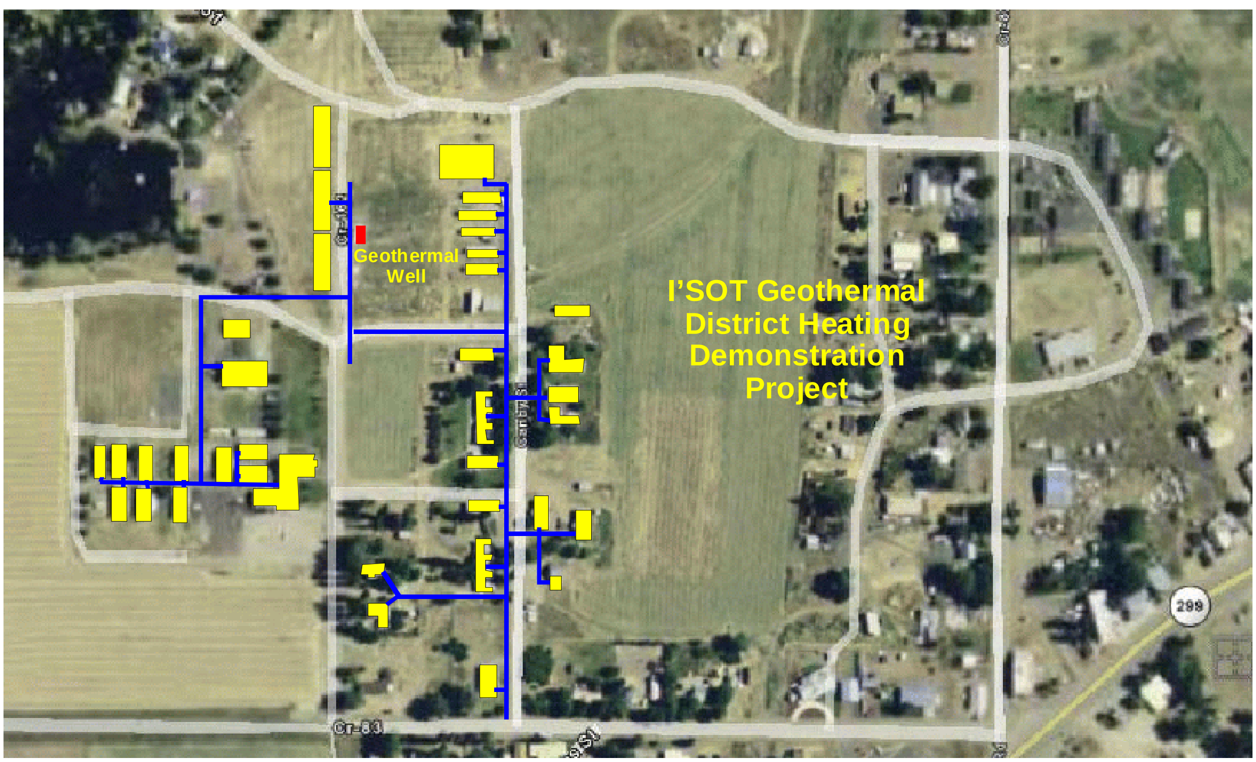

Figure 1. *Sketch of the existing geothermal district heating system at Canby, CA.*

Objectives and Scope

The long-term objective of this project is to fully exploit the geothermal resource at Canby, CA. When this Task Ordering Agreement was submitted, drilling of a new 5,500-ft deep geothermal production well was being planned, and the purpose of the TOA was to aid in the design of optimal uses of the geothermal resource cascaded from a geothermal power plant. Although funding for drilling operations was not realized in FY 06, project planning is still moving forward.

Given that the exact deep geothermal resource characteristics are unknown at this time, the Geo-Heat Center conducted the following tasks to remain on track with the project goals:

- Met with Dale Merrick, the project champion, both at the Geo-Heat Center and at the site in Canby to review possible cascaded geothermal uses that would be beneficial to the I'SOT community,
- Developed a spreadsheet design tool that can be used to optimize energy use and/or economics once the deep geothermal resource is characterized,
- Examined three scenarios of cascaded energy uses with varying geothermal fluid temperature and fixed flow rate, and
- Made recommendations to interface the new geothermal uses with the existing district geothermal heating system.

Proposed Cascaded Geothermal Uses

Once the deep geothermal resource at Canby is developed, the community will move toward becoming a net-zero energy community (meaning that they will generate as much or more energy than they consume on an annual basis). In addition, the community will become more sustainable and independent, and geothermal energy will significantly stimulate the local economy by creating jobs and generating income.

The highest temperature use of geothermal energy will be electrical power generation. If generating capacity exceeds I'SOT community uses (i.e. approximately 250 kW), excess electrical power will be sold to the grid. Cascaded geothermal uses most beneficial to the community at this time are: (1) continued and expanded space heating and domestic hot water generation, (2) greenhouse heating operations to create jobs and to gain capability of growing fresh produce for the community, (3), aquaculture tank heating, and (4) snow melting. Currently being planned are up to 10 acres of greenhouses and up to four 30-ft diameter aquaculture tanks. A new 5,000 ft^2 building is also being planned for food storage and laundry services, which will increase the space heating and domestic hot water demands.

Another benefit of the new proposed well is that the existing well can ideally be used as an injection well, allowing discontinued treatment and management of geothermal effluent and disposal into surface water. However, a limitation with this approach is that the existing well is capable of accepting only 225 gpm, based on flow testing.

Energy Calculations in the Proposed Cascaded System

As mentioned previously, since the geothermal resource characteristics are not known at this time, we developed a spreadsheet design tool for future use. The spreadsheet requires some simple input design data as shown in the following figures. The Excel Solver tool is used to calculate optimum flow rates and temperature drops at each point in the cascaded system, in addition to optimum power plant capacity, heated area of buildings, snow melt area, greenhouse area, and aquaculture tank area. Heat exchanger area is also calculated. A user can analyze a project in two ways: (1) maximize total geothermal energy used and/or (2) maximize annual worth of a 20-year life cycle.

Cascaded uses that are considered include electrical power generation, space heating with associated domestic hot water use, snow melting, greenhouse heating, and aquaculture. To demonstrate the use of the spreadsheet, screen captures of the optimized results for total geothermal energy use of three hypothetical scenarios are shown in Figures 2 *(a)* through *(c)*. As mentioned above, the spreadsheet tool is also capable of optimizing a project for annual worth, but a detailed economic analysis was deemed premature and not very meaningful at this time due to the number of unknown variables, and thus is not included in this report. The three geothermal scenarios that were examined consisted of varying geothermal fluid temperature and a fixed flow rate of 225 gpm. The geothermal fluid temperatures examined were 250^{o}F, 300^{o}F, and 350^{o}F, which are designated *(a), (b)*, and *(c)* in Figure 2, respectively. The flow rate of 225 gpm was chosen based on expected injection capacity of the current production well. If more geothermal fluid flow is desired, should it be available from the new deep well, a second re-injection well would be needed. Otherwise, the current NPDES permit would need modification for the different source water.

As shown in Figure 2, some of the main optimized parameters are power plant capacity and heated areas. The spreadsheet also optimizes flow rates, exiting temperatures, and heat exchanger areas. The user enters upper and lower limits to consider, and here, we considered 0 to 500 kW of electrical power generation. Heated floor space for the district heating system was set at 60,000 ft^2, to account for the existing heated floor space plus planned expansions. Domestic hot water loads were set at 20% of the peak heating load. Remaining lower and upper limits considered were 0 to 5000 ft^2 of snow melt area, 1 to 10 acres of greenhouses, and 1 to 4 x 30-ft diameter aquaculture tanks. Note that the peak greenhouse heat flux was set at 40 Btu/hr/ft^2 of floor space, which is about half of the actual peak load. This was done assuming a peaking system would be installed, and to effectively weight the resulting optimized greenhouse area. A baseload system designed for 50% of the peak heating load could handle about 90% of the annual load. The design snow melt heat flux was set at 100 Btu/hr/ft^2, based on ASHRAE snow melt design criteria for Reno, NV. This will keep areas snow-free about 95% of the time, and the remaining 5%, the snow-melt system will require more time to melt snow.

A review of Figure *2(a)* shows that most of the desired goals could be met with 250^{o}F fluid at 225 gpm. Optimum power plant capacity approaches 300 kW, and all other uses are maximized to their upper limits except snow melting and greenhouse heating. Snow melt area is maximized at 1,280 ft^2 and greenhouse heating is maximized at 60,700 ft^2 (or about 1.5 acres). However, if more greenhouse area is desired, snow melt heat flux could easily be decreased if a lower snow melting rate is still acceptable. Discharge fluid temperature in this scenario is 103^{o}F, which could still easily be used in a heat pump application if desired. The total heat extraction rate at peak conditions is 16.58 million Btu/hr.

A review of Figures *2(b)* and *2(c)* shows, as expected, progressively more possible electrical power generation capability, as well as increased possible snow melt area and greenhouse heating. Under the scenario of 300^{o}F geothermal water at 225 gpm (Figure *2(b)*), optimized electrical power generation capacity approaches 500 kW, optimum snow melt area increases to the maximum input value of 5,000 ft^2, and optimum greenhouse heating area increases to 82,773 ft^2 (or about 2 acres). The total heat extraction rate at peak conditions increases to 22.21 million Btu/hr. Under the scenario of 350^{o}F geothermal water at 225 gpm (Figure *2(c)*), optimized electrical power generation capacity reaches the maximum input value of 500 kW, and optimum greenhouse heating area increases to 253,000 ft^2 (or about 5.75 acres). The total heat extraction rate at peak conditions increases to 27.83 million Btu/hr. A summary of the cascaded use optimization results are shown in Table 1.

Table 1.
Summary of Possible Cascaded Geothermal Uses
Myrtle Tree Development Project, Canby, CA

Geothermal Temperature (^{o}F)	Binary Power Plant Capacity (kW)	Heated Floor Space + Domestic Hot Water (ft^2)	Snow Melt Area (ft^2)	Greenhouse Heating (ft^2)	Aquaculture Tank Heating (ft^2)
250	292	60,000	1,280	69,700	2,500
300	478	60,000	5,000	82,773	2,500
350	500	60,000	5,000	253,000	2,500

Note: Geothermal fluid flow rate is fixed at 225 gpm.

Project Layout and Retrofit Recommendations

Figure 3 is a Google Earth photo of the Canby area showing the proposed drilling location, pipeline route, and proposed new building locations. Buildings currently connected to the district heating system are shown in Figure 1. The drilling target is the intersection of two fault zones. The supply pipeline to the existing mechanical building (and current production well) is about ¾ miles, and would likely need to be constructed of pre-insulated ductile iron, but this decision would ultimately depend on the temperature and pressure of the geothermal water. The geothermal power plant would either be located near the production well or near the existing mechanical building.

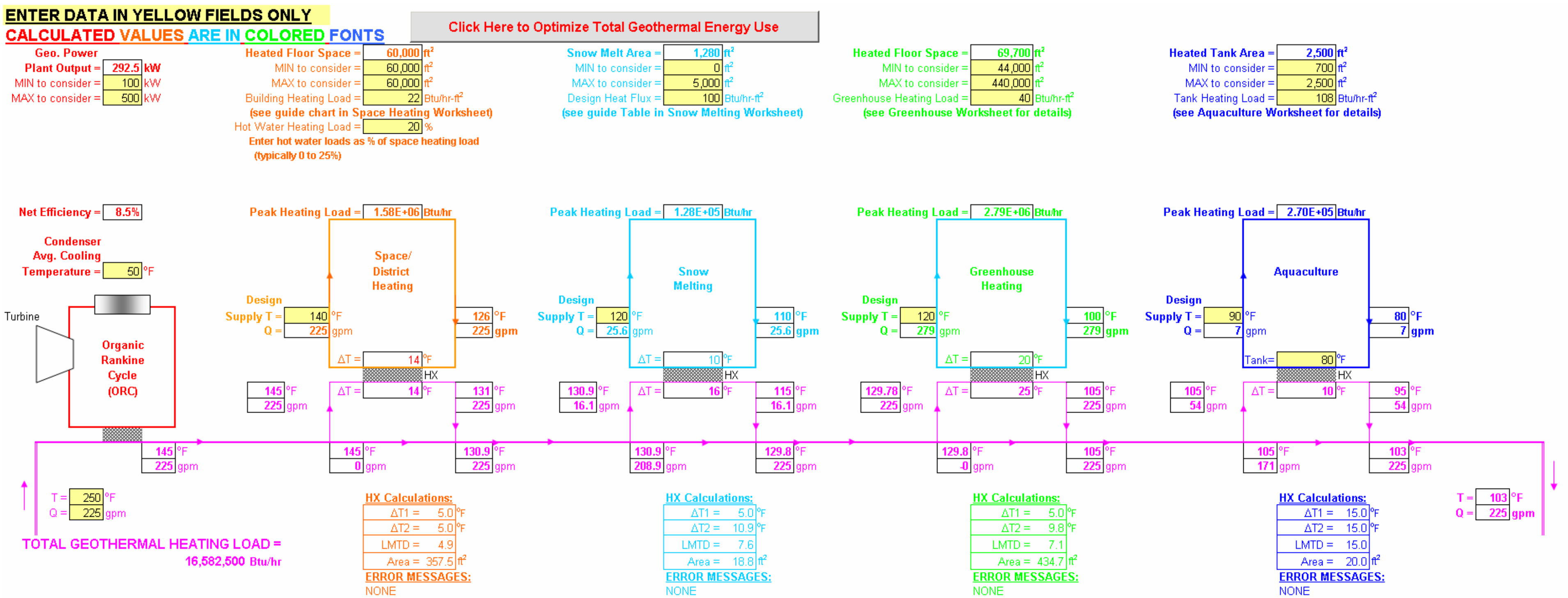

Figure 2 (a). *Design of a cascaded geothermal system optimized for maximum use of geothermal energy, assuming a geothermal fluid temperature of* ***250°F*** *and a flow rate of* ***225 gpm****.*

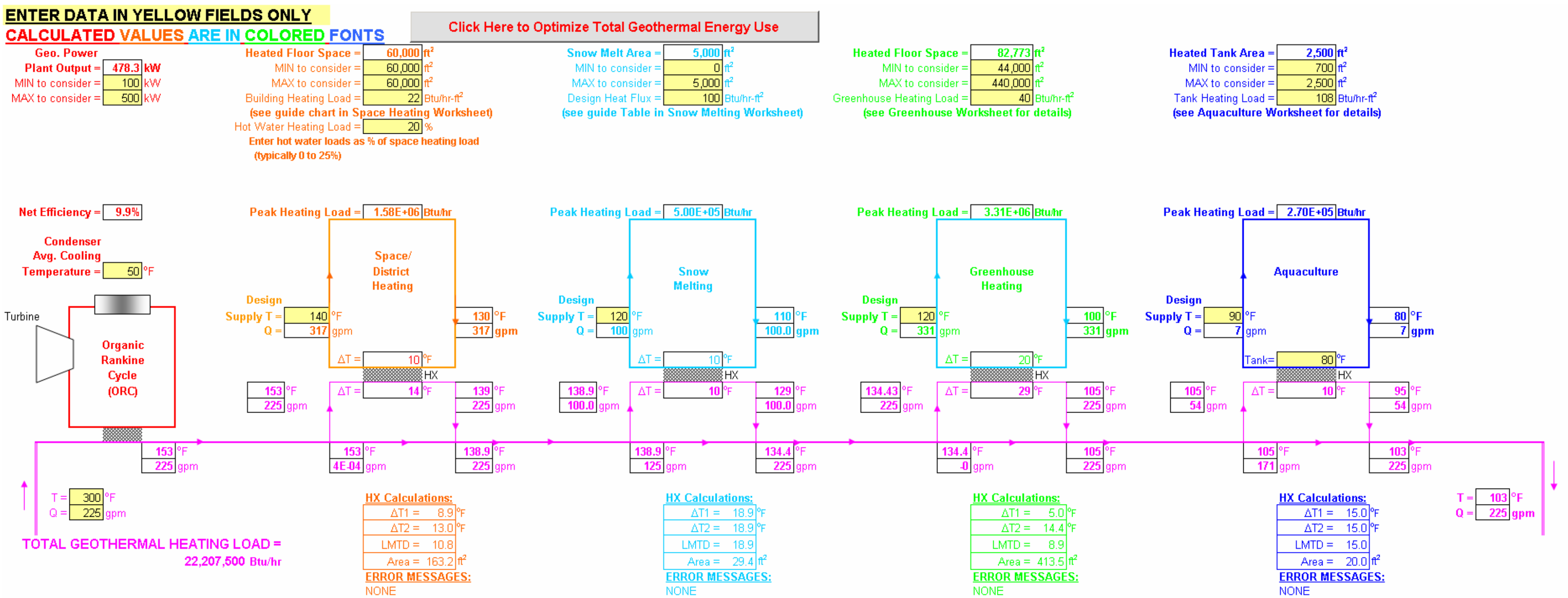

Figure 2 (b). *Design of a cascaded geothermal system optimized for maximum use of geothermal energy, assuming a geothermal fluid temperature of* ***300°F*** *and a flow rate of* ***225 gpm****.*

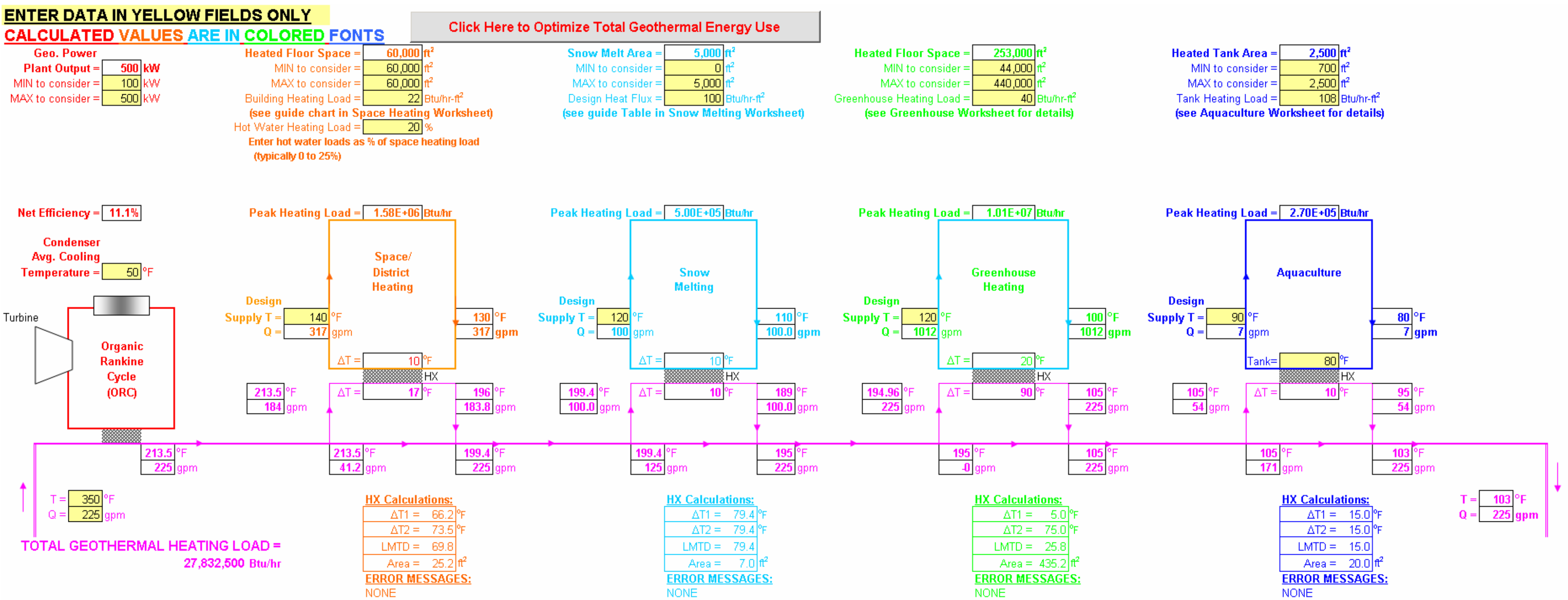

Figure 2 (c). *Design of a cascaded geothermal system optimized for maximum use of geothermal energy, assuming a geothermal fluid temperature of* ***350°F*** *and a flow rate of* ***225 gpm****.*

Figure 3. *Satellite photograph from Google Earth showing the proposed layout of the Myrtle Tree geothermal development at Canby, CA.*

As seen in Figure 3, the geothermal uses are somewhat spread out, and the existing district heating system sits between proposed greenhouse locations. Numerous possible retrofit designs are possible without the final details of the geothermal resource. Therefore, at this time, the simplest retrofit concept might be to combine the new geothermal uses with the existing by two additional sub-loops (greenhouse heating and aquaculture tank heating), which would be downstream of the existing district heating and hot water loop, off the power plant discharge water as shown in Figure 4. Snow melting could be done with small double-walled brazed plate-type heat exchangers (so as not to cross-contaminate potable water with glycol antifreeze in the snow melt loop) off the return water of the district heating system near the area to be melted. This type of design is consistent with the spreadsheet model, and effectively cascades one process to the next. Also, it allows each loop to be separated, such that maintenance or unexpected downtime of one loop won't adversely affect another loop.

Depending on the temperature, pressure, and chemical nature of the new geothermal water, new heat exchangers might be necessary for each loop. A welded plate-type block heat exchanger as shown in Figure 5 might be considered, given that these have no gaskets, therefore eliminating concerns of compatibility with the geothermal water. Maintenance and cleaning of the plates is accomplished by removing bolts and pressure washing as shown in Figure 5.

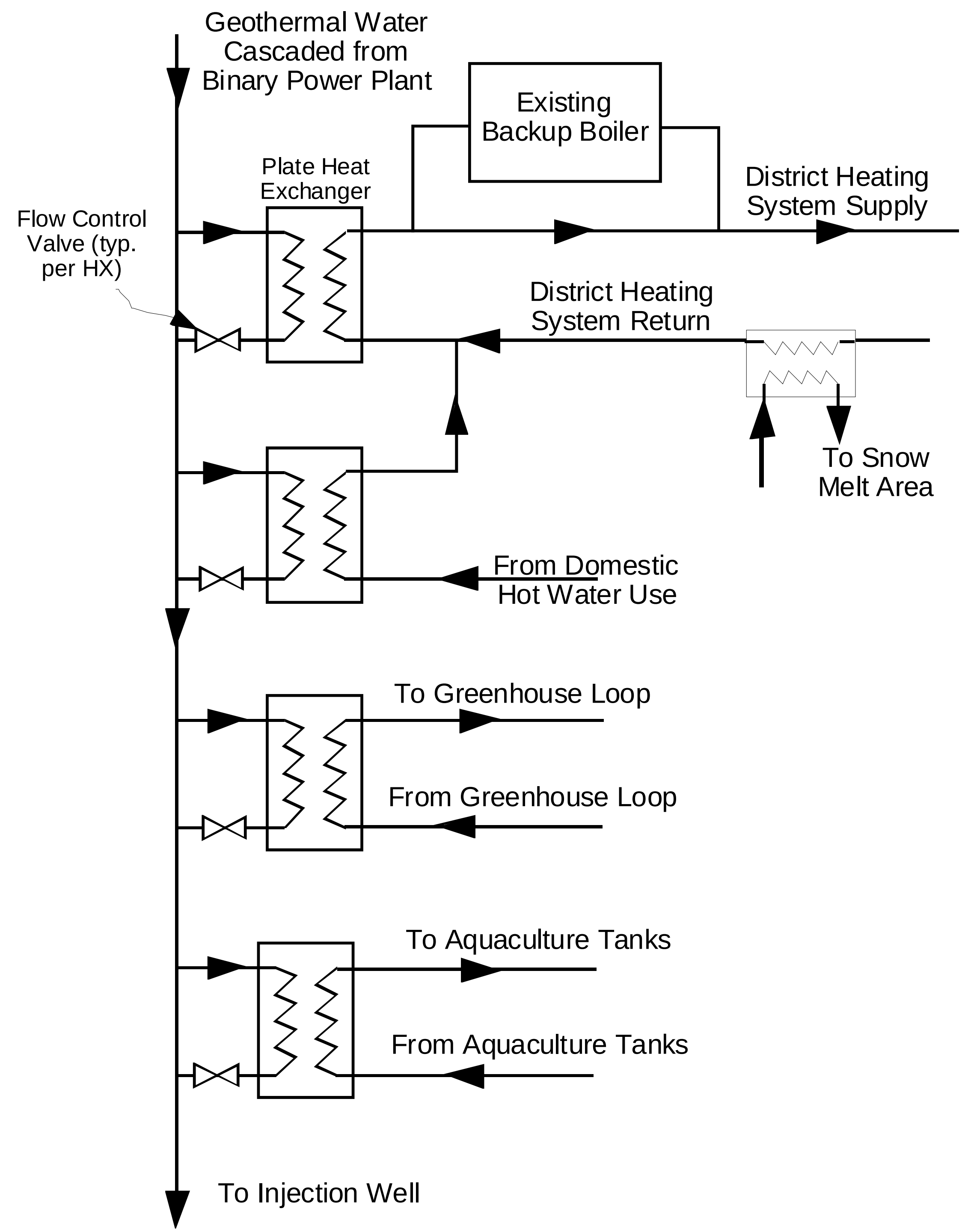

Figure 4. *Proposed retrofit of the new cascaded geothermal uses with the existing at the Myrtle Tree geothermal development at Canby, CA.*

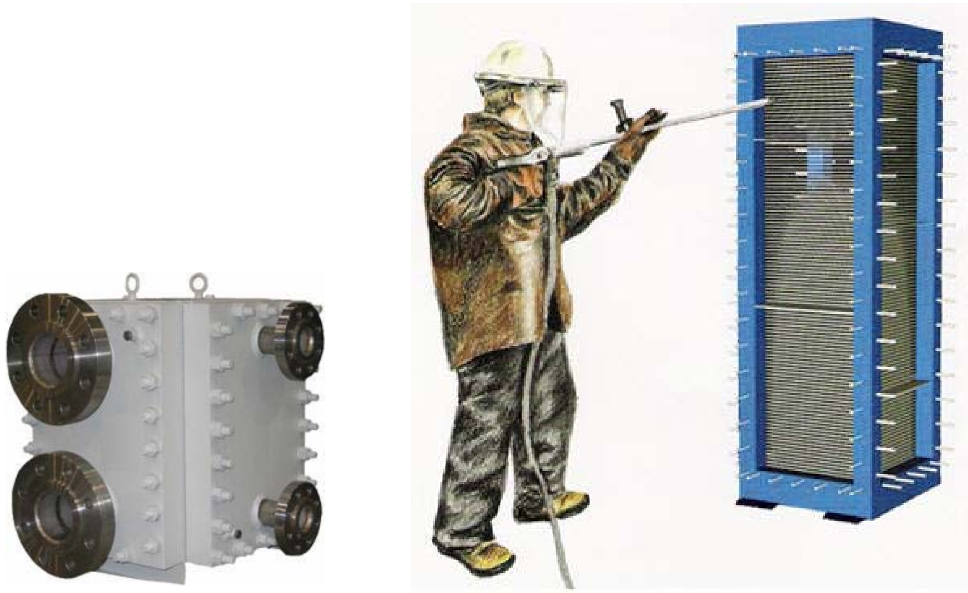

Figure 5. *Block welded plate-type heat exchanger (Source: WCR Inc. www.wcr-regasketing.com)*

Concluding Summary

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To stay on track with the project goals, we developed a spreadsheet design tool to optimize cascaded geothermal uses. The spreadsheet requires some simple input design data and can be used to calculate optimum flow rates and temperature drops at each point in a cascaded system, in addition to optimum power plant capacity, heated area of buildings, snow melt area, greenhouse area, and aquaculture tank area. Heat exchanger area is also calculated. A user can analyze a project in two ways: (1) maximize total geothermal energy used and/or (2) maximize annual worth of a 20-year life cycle.

Cascaded geothermal uses that are considered in this project include electrical power generation, space heating with associated domestic hot water use, snow melting, greenhouse heating, and aquaculture. Three hypothetical scenarios were examined which consisted of varying geothermal fluid temperature and a fixed flow rate of 225 gpm. The geothermal fluid temperatures examined were 250^{o}F, 300^{o}F, and 350^{o}F, and the flow rate of 225 gpm was chosen based on expected injection capacity of the current production well. If more geothermal fluid flow is desired should it be available from the new deep well, a second injection well would be needed. Otherwise, the current NPDES permit would need modification for the different source water.

Results of the possible cascaded optimization model are as follows:

- Most of the desired goals could be met with 250^{o}F fluid at 225 gpm. Optimum power plant capacity approaches 300 kW, and all other uses are maximized to their upper limits except snow melting and greenhouse heating. Snow melt area is maximized at 1,280 ft^2 and greenhouse heating is maximized at about 1.5 acres. However, if more greenhouse area is desired, snow melt heat flux could easily be decreased if a lower snow melting rate is still acceptable. The total heat extraction rate at peak conditions is 16.58 million Btu/hr.
- Under the scenario of 300^{o}F geothermal water at 225 gpm, optimized electrical power generation capacity approaches 500 kW, optimum snow melt area increases to the maximum input value of 5,000 ft^2, and optimum greenhouse heating area increases to about 2 acres. The total heat extraction rate at peak conditions increases to 22.21 million Btu/hr.
- Under the scenario of 350^{o}F geothermal water at 225 gpm, optimized electrical power generation capacity reaches the maximum input value of 500 kW, and optimum greenhouse heating area increases to about 5.75 acres. The total heat extraction rate at peak conditions increases to 27.83 million Btu/hr.

At this pre-design stage, the simplest retrofit concept might be to combine the new geothermal uses with the existing by two additional sub-loops (greenhouse heating and aquaculture tank heating), which would be downstream of the existing district heating and hot water loop, off the power plant discharge water. Snow melting could be done with small double-walled brazed plate-type heat exchangers off the return water of the district heating system near the area to be melted. Depending on the temperature, pressure, and chemical nature of the new geothermal water, new heat exchangers might be necessary for each loop. A welded plate-type block heat exchanger might be considered, given that these have no gaskets, therefore eliminating concerns of compatibility with the geothermal water.