GEOTHERMAL GREENHOUSES AT KAWERAU

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INTRODUCTION

Geothermal Greenhouses Ltd was established in 1982 by a small group of Tasman Pulp and Paper Company employees who saw an opportunity to utilise geothermal steam available in the Kawerau geothermal field. The operation produces capsicum (bell pepper) for local and export markets and is located entirely within the production steamfield at Kawerau. Heating for the greenhouses is provided by a small flow of geothermal steam taken from a two-phase pipeline, fed by several deep geothermal wells.

The greenhouse operation is small, with a permanent staff of five, including a share holding manager. Marketing and packing of the crop is handled by a separate company. Total greenhouse area is 5250 m^2, consisting of 3600 m^2 in an early timber frame fan ventilated single plastic covered design built in 1982, and an area of 1650 m^2 in a modern fan ventilated twin skin steel and aluminium framed greenhouse built in 1994. Heating requirements are relatively high compared to other greenhouses in New Zealand, due to the high minimum night and day temperatures needed for the crop grown, and the cool Kawerau climate.

The primary utilisation of geothermal steam at Kawerau is as a heat source for the Tasman Pulp and Paper Company mill, which uses approximately 300 tonnes/hour of steam, mainly to generate clean steam for paper drying. High temperature lumber drying kilns are also supplied with geothermal steam at the same site. Steam supplied to the greenhouse is a very small part of total steam production. Although the greenhouse is independently owned and operated it would not exist without the paper mill, since steam production would not be viable for the greenhouse operation alone. Without geothermal heating the climate at Kawerau would preclude heated greenhouse operation, as freezing night time temperatures occur during winter. Geothermal heating has allowed the high sunshine levels found in the Bay of Plenty area to be used to advantage without the problem of frost being a major factor.

Carbon dioxide, which is a very effective growth stimulant for plants, is used in the greenhouses. Studies have shown that as CO_2 concentration is increased from a normal level of 300 ppm (mmol/kmol) to levels of approximately 1000 ppm crop yields may increase by up to 30% (Ullmann, 1989). Bottled carbon dioxide is utilised at a rate of about 50 kg per day, to provide CO_2 levels of 800 mg/kg when the greenhouse is closed and 300 to 350 mg/kg whilst venting. In England and the Netherlands CO_2 levels of 1000 mg/kg are often used (Ullmann, 1989) and similar concentrations are desired at Kawerau, but current costs of 0.60 NZ$/kg for bottled CO_2 are too high.

Geothermal greenhouse heating offers an opportunity for utilisation of the carbon dioxide present in the geothermal fluid. The main difficulty is that plants react adversely to hydrogen sulphide which is mixed with the CO_2 in the steam. Even very low H_2S concentrations of 0.03 mg/kg can have negative effects on the growth of plants (National Research Council, 1979). Therefore, purification of the available CO_2 would be required before it could be used in the greenhouses. Some work on this subject was presented by Dunstall and Graeber (1997).

GREENHOUSE CONSTRUCTION

Two fan ventilated greenhouses are currently in use in Kawerau. The older greenhouse, built in 1982, covers 3600m^2 and is timber framed with a single plastic cover. This greenhouse provides a relatively large night time heat load, as capsicum has a relatively high temperature requirement (Table 1).

Figure 1. **Older greenhouse with Capsicum (green peppers) plants and heating pipes (bottom one is condensate return)**

The second greenhouse covers an area of 1650 m^2, and is a modern design fan ventilated twin skin stainless steel and aluminum framed greenhouse built in 1994. The twin skin dramatically lowers heat load requirements in this greenhouse, compared to the older design.

Table 1. Minimum growing temperatures for several greenhouse crops

Crop Type	Minimum Night Temperature (ºC)	Minimum Day Temperature (ºC)
Tomato	15	18
Capsicum	18	20
Aubergine	20	25
Roses	16	18
Carnation	10	18

* Higher temperatures may be required with high CO_2, humidity and light levels.

Figure 2. New greenhouse with manager, Brian Foster.

CROP AND GROWING SYSTEM

Geothermal Greenhouses grows its capsicum crop in a specially graded pumice, fertilised and watered using a hydroponics method. The irrigation system is controlled by solar sensors, dispensing nutrients at a rate dependent on the uptake rate in the plants. Mature plants grow to a height of approximately 3.5m, at which point they are discarded and the growing process is restarted from new seedlings.

A high quality crop is grown, with a crop yield of over 20kg/m^2 annually for red and yellow capsicums, and 30kg/m^2 annually for green capsicums. This compares very well with a target figure of 25kg/m^2 annually, given in 1994 by the New Zealand Ministry of Agriculture and Fisheries.

The greenhouse climate is controlled using a MAXSYS greenhouse computer control system, with humidity control and a CO_2 enrichment system. The MAXSYS system is a commercial crop management system designed for New Zealand climate, and gives crop production rates which are about twice that of traditional type greenhouses.

HEATING SYSTEM AND CONTROLS

Steam for the greenhouse is supplied from the a two phase line fed by several wells in the north eastern part of the bore field. The primary separator for this two phase fluid is some 500m distant, so a small separator mounted to one side of the two phase line is used. Flows to the greenhouse are quite low, so steam can be tapped from this small separator and the remaining water returned to the two-phase line. The steam supply is at 270ºC and a pressure of 15 bar in the two phase line, but a pressure control valve reduces this to 5 bar in the 50mm greenhouse steam supply line, which is buried in a shallow trench. Estimated annual energy usage is about 700,000 kWh, with an energy cost of about NZ$4900. The unit energy cost is therefore NZ$0.007/kWh, or about NZ$5.50 per tonne of steam. The steam flow is not metered; instead a flat rate is charged each year, based on historical condensate flow data.

Figure 3. Separator on two-phase line with pressure control valve.

Fast growing crops in heated greenhouses are very vulnerable to a loss of heating, so a backup supply is required. At Kawerau, several wells supply the two-phase line so a shut down of any individual well for maintenance does not affect the greenhouse. The most vulnerable part of the system is probably the short buried steam supply line from the pressure control valve to the greenhouse. To date, this has not caused any problems.

The pressure control valve maintains a constant 5 bar inlet pressure to the system. Motorised valves connected to temperature controllers in the greenhouse then determine the flow of steam admitted to distribution headers, which in turn supply a network of 25mm diameter heating pipes. Condensate and residual steam from the heating pipes flow to atmosphere. The black steel heating pipes are installed above the crop, supplying heat to the air and radiant energy to the plants. Wet and dry bulb sensors (PT100) are used for humidity and temperature control as part of the MAXSYS system.

Data is not available for the original costs of the heating system, but based on data collected during the 1994 upgrade of the 1650m^2 unit, installed costs are estimated at NZ$8.30 per m^2, including pressure control valves, temperature control valves, pipework and installation costs. Total costs for the heating system are therefore around NZ$44,000 capital cost + NZ$4,900 annual running cost. Assuming a 20 year equipment life the discounted cost (12% discount rate) is NZ$0.036/kWh ($0.029 equipment + $0.007 energy). Some comparison with other fuels is then possible.

Heating a similar greenhouse with electricity in the Franklin district (an intensive crop growing area) would cost about 11c/kWh (7c energy + 4c installation), based on a heating requirement in Franklin of 110 kWh/m^2 annually. compared to 133 kWh/m^2 annually in Kawerau. This is a $38,000 yearly saving to the geothermal greenhouse, but at least part of this saving is offset by transportation costs, as Kawerau is much further from major domestic markets and ports of export.

Most heat is lost from greenhouses by air leakage and wind effects due to poor construction. Modern plastic covered greenhouses may use as little as 30% of the heat needed for an older glass covered greenhouse. Typical heat loss rates at Kawerau are 3.5W/m^2K in plastic greenhouses compared to 12W/m^2K in glass covered greenhouses. The new twin-skin plastic greenhouse achieves these low heat losses without loss of solar light transmission required for plant growth. Heat loss rates impact heavily on greenhouse profitability.

OPTIMUM GROWING CONDITIONS

Plants grow and develop most efficiently when the environment is controlled with specific day and night temperatures. Generally, higher crop yields are obtained at higher temperatures and the cost of supplying additional energy for heating must be balanced against the increase in yield expected. Low marginal cost forms of energy, such as geothermal, give higher optimum temperature conditions than high marginal cost system such as electricity.

Most crops respond to 24 hour mean temperatures, provided the variation in temperature over that time is not too extreme. This means that electrically heated greenhouses can tolerate lower temperatures during times of high tariff, and operate at higher temperatures during low tariff times to compensate. The Kawerau greenhouse is not constrained in this manner, but could be operated in this way if the steam supply shared with another operation was critical at certain times of the day.

Humidity control has a very significant beneficial effect and often it is humidity control, rather than dry bulb temperature, which controls greenhouse conditions. Fungus disease control is highly dependent on the humidity level. Continuous air movement through the leaves of the plants is also important to control fungus, by eliminating moisture from the leaf surface. The reduction in cost and risk associated with chemical sprays substantially offset the additional expense involved in a more sophisticated control system. Improving fruit quality and yield result in increased profitability.

Air leakage rates have a severe impact on economics when CO_2 enrichment and humidity control are used, since these factors are much more expensive to control and provide than dry bulb temperature. At Kawerau the annual cost of providing bottled CO_2 is higher than the geothermal energy cost. Best growth rates are achieved when humidity, CO_2 enrichment, and temperature are all controlled in a low loss greenhouse. High temperature only translates to high growth rates if the level of CO_2. is also high. Without additional CO_2 higher temperatures will stress the plants.

It is interesting to note that the steam supplied to the greenhouse each year for heating purposes contains almost exactly the quantity of bottled CO_2 used each year (Geothermal & Nuclear Sciences, 1992). With appropriate treatment, the geothermal steam might ultimately be as valuable for its CO_2 contribution as for its heating value.

OTHER FACTORS AND FUTURE TRENDS

A number of proposals for geothermal heating of New Zealand greenhouses have been studied over the past 15 years or so. In most cases the relatively mild New Zealand climate has greatly reduced the advantage obtained from geothermal heating. High capital costs are difficult to recover when energy costs are quite low. In addition, the geothermal areas are further from markets than traditional greenhouse areas and transport costs have been high.

However, the size of new greenhouse developments has increased dramatically in recent times, from a typical size of 2000m^2 to 10 to 50 times larger. The heating demand has consequently risen by a similar factor, as these new export oriented units are developed. With falling transport costs, and with more intensive heating and crop production rates, geothermal greenhouse heating is becoming more attractive.

The use of geothermal carbon dioxide for growth stimulation of plants might be possible if a purification process is used to reduce the initial hydrogen sulfide content. This would greatly increase the attractiveness of geothermal energy in greenhouses where a steam source is available. The CO_2 could be worth as much as the energy in the Kawerau operation. However, a cheap purification process is needed.

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