Sustainable use of geothermal energy in Icelandic horticulture

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Abstract

The greenhouse industry in Iceland is based on abundant geothermal energy in form of steam or hot water. The annual use of geothermal energy in greenhouses is approx. 216 GWh/yr that accounts for 80% of the geothermal and hydroelectric energy used in horticulture. Other uses of geothermal energy are soil disinfection, 6 GWh/yr and soil heating in the cultivation of field vegetables, 15 GWh/yr. Artificial light has become an integral part of production in greenhouses to increase yield during the dark winter months. Cut flowers are now produced year-round with artificial light and this application is expected to increase substantially in vegetable production in the next decade. High-pressure sodium lamps, which are used for lighting, produce a lot of energy as heat that will partly substitute geothermal energy as a source for heating of the greenhouse, i.e. if no new lamp types will become available. Better cultivation techniques will also give more yield pr. m^2 resulting in a decreased greenhouse area. The estimated use of geothermal energy for heating greenhouses will therefore only be 114 GWh/yr in year 2011 that is approximately 60% of total geothermal and hydroelectric use in horticulture. No major changes in usage of geothermal energy for soil disinfection or soil heating in field vegetables are expected in this period. Soil heating in sports fields might increase in the next decade resulting in an annual use of 20 GWh/yr.

Keywords: *geothermal energy, greenhouse, horticulture, heating, disinfection, soil heating.*

1 Introduction

The first known experiments in Iceland with use of geothermal energy in horticulture date back to 1850 when potatoes were grown in naturally warm soil. In 1886 there are reports that open concrete ducts where used as a mean for soil warming in vegetable production to enhance growth (Hansson 1982). Soil heating has been used ever since to some extent, but it was not until in the 1970´s with the appearance of plastic materials that the systems for soil heating became economic and applicable for modern cultivation. Soil heating in field vegetable production is now applied on 12 ha and has not increased much for the past 10 years.

The greenhouse industry in Iceland, which dates back to 1924, has from the beginning been based on the utilisation of geothermal energy, mainly for heating greenhouses, but also to some extent for soil disinfection. Today the total greenhouse area is 18.5 ha (Table 1). More than 50 % of the area is used for vegetable production, 28% for cut flowers, 6% pot plants and 10 % for nursery stock and bedding plants.

Because of Iceland’s northerly altitude, global radiation in winter is way below minimum for plant growth. Even in summer extra light is needed to maintain high yields in vegetables. For the above reasons the use of artificial light is now an integral part of greenhouse production. Almost all growers of cut flowers use assimilation light in their production and in vegetable production there has been an increase is the use of artificial light. About 35% of the production area for vegetables is now installed with lights.

Table 1: The greenhouse area in Iceland 2003.

Cultures	Area, m^2	Area with artificial light, m^2	% artificial lights
Vegetables	97,093	34,161	35%
Cut flowers	52,788	50,754	96%
Pot plants	11,945	3,000	25%
Nursery stock, bedding plants	18,001		
Other uses	5,770		
Sum total	185,596	87,915	

Amenity horticulture is growing in Iceland and there are now 52 golf clubs with an estimate of 29 ha putting greens and over 50 full-size soccer fields for matches at an approximate size of 25 ha in total. Soil heating has been proposed to extend the playing season on these courses and it can be estimated that up to 6 ha of soccer fields and 10 ha of golf greens might be installed with soil heating apparatus in the next decade.

2 The utilisation of geothermal energy in Icelandic horticulture

Thin walled, welded steel pipes are used to emit heat into a greenhouse. Direct use of steam or hot water into the pipe system of the house is predominant although in some locations a heat exchanger has to be applied because of the corrosive nature of the steam/hot water. In order to maintain optimum temperatures the flow is controlled by a valve, which is normally situated at the end of the pipe system, equipped with a thermostat.

In recent years a change in cultivation technique has caused the energy use from geothermal sources to decrease. This is mainly due to the fact that year-round production with artificial light is now predominant in the flower sector and increasing in the cultivation of greenhouse vegetables. The lamps used to give the assimilation light emit a lot of heat, which substitutes the geothermal energy for heating. Higher productivity has also caused a decrease in greenhouse area thus demanding less energy for heating.

For soil disinfection three main methods are used. Where steam is available it is led under a tight plastic sheet, which is put over the beds and left running for 24 hrs, which is sufficient for adequate disinfection. Where only hot water is available an improved Hoddeston method (Johnson and Aas, 1960) is used where nozzles are put on a steel pipe to distribute the hot water over the soil. A simpler way for soil disinfection is to soak the soil thoroughly with 80-90°C hot water. The geothermal energy used for soil sterilisation has decreased in the past years due to increased use of inert growing media, which demand less hot water for sterilisation or even no sterilisation at all.

The main purpose of soil heating is to extend the growing season in order to be able to increase yield and to grow vegetable cultures and cultivars which otherwise would not be possible in the cool summer climate of Iceland. Soil temperatures in Iceland in summer rarely exceed 11°C but it is possible to maintain over 20°C with soil heating. In winter the soil normally freezes, forming a core of ice extending some 10-30 cm down into the soil profile. The ice-core prevents drainage of the soil in spring because it takes time for it to melt away and the soil gets waterlogged and cold. When soil heating is applied ice formation is prevented and soil preparations, planting or sowing can already take place in end of April. Losses from frost damage after planting or sowing in spring can also be diminished with soil heating, especially if applied together with fleece coverings. Soil heating of vegetable fields is predominantly applied for cultivation of carrots and cabbages, but also for leek, which is dependent on soil heating for normal growth.

A great increase in soil heating of vegetable fields was realised in the 1970's when improved techniques to install the heating systems was started, i.e. ploughing down PEL-pipes with a tractor. The heating grid is normally placed at a depth of 65-85 cm with 1-2 m spacing (Johannesdottir et al., 1986). The flow in controlled as to keep a temperature of 20-23°C in the soil. In some cases the heating is supplied by means of wastewater from greenhouses but a separate supply is more usual.

In recent years soil heating of soccer fields has been tried in 3 locations in Iceland with similar technique as for field vegetables. It can be expected that this application will increase in the coming years although it is not easy to predict how widespread this usage will be. Field experiments are now being run to investigate how the soil heating affects the design and maintenance of such fields.

3 The energy use in Icelandic horticulture

The three main uses of geothermal energy in horticultural production are greenhouse heating, soil disinfection and soil heating of vegetable and sports fields.

The major part of energy used in horticulture is to heat greenhouses, amounting to 88% of the total. Agustsson (1991) calculated the total energy use for heating of greenhouses to be 204 GWh/yr, on the basis of estimation from Orkusparnefnd (1987) that yearly energy use for greenhouses in Iceland is 1,200 kWh/m^2 (Table 2). In the next decade there was a 6% increase in the use of geothermal energy following an expansion of greenhouse area resulting in a total use of 216 GWh/yr in 2001.

Table 2: The energy use (GWh/yr) in horticulture 1991 and 2001. Estimation for 2011.

Use	GWh/yr		
	1991	2001	2011
Heating of greenhouses	204	216	114
Soil heating in field vegetables	14	15	16
Soil disinfection	8	6	4
Amenity horticulture (soccer, golf)		2	20
Total geothermal energy	226	239	154
Artificial lighting	6	26	57
Other electricity use	2	3	3
Total energy use	234	268	214

Agustsson (1991), Gunnlaugsson and Agustsson (2001)

Until the year 2011 it is expected that the use of geothermal energy for greenhouse heating will decrease by almost 50% (Table 2). There are two reasons for this. Given that similar lamp technique will be used, increased use of artificial light in the production will make the contribution of geothermal energy used for heating less important because the lamps emit a lot of energy. This energy, which is in the form of heat, contributes directly to heating of the greenhouse and substitutes energy from geothermal sources. Secondly, higher productivity, especially as a consequence of increased use of artificial light, but better cultivation techniques in general will also lead to a decrease in greenhouse area and thus less energy use from geothermal sources.

Energy used for soil disinfection is only a minor part of the total energy used in horticulture and it will decrease in the coming years if the trend to use inert growing media continues.

Agustsson (1991) calculated the use of geothermal energy for soil heating in vegetable fields again based on estimation from Orkusparnefnd (1987). His calculations show the energy use to reach a soil temperature of 20-23°C is 130 kWh/m^2/yr. For 10.5 ha of heated vegetable fields in 1991 this gives a total of 14 GWh/yr or 6% of the total energy use in horticulture. The increase of this usage is approximately 6% in a 10-year period giving an estimate of total 16 GWh/yr in 2011.

To predict the need for geothermal energy to heat sports fields the same prerequisite is used as above for vegetable fields, i.e. 130 kWh/m^2/yr to maintain optimum soil temperatures. Thus it is estimated that the use of geothermal energy in amenity horticulture will amount to 20 GWh/yr in year 2011 provided that in total 16 ha of sports fields will be heated.

4 Conclusions

The market for Icelandic horticultural products is limited to the domestic supply and has little opportunity to expand beyond that. A model to predict the energy use of horticulture in the future based on this fact therefore gives a distinct reduction of the use of geothermal energy in horticulture in the years to come. Only in amenity horticulture an increase is expected.

The competitiveness of Icelandic horticulture is poor and threatened by import of inexpensive horticultural products, mainly from S-Europe. If it is to survive in the future the productivity must increase and cost must go down. Electricity is one of the most important cost factors because of the extensive use for artificial light.

Alternative methods to produce electricity from geothermal sources by means of a thermoelectric generator may prove to be a tool to increase the competitiveness of Icelandic produced vegetable and ornamentals in future. It gives the possibility for decentralised production of electricity in the nurseries. The hot water could then firstly be used to generate electricity and secondly the effluent still contains enough energy for heating the greenhouse. If this method proves to be efficient geothermal energy may again gain its role as the most important source of energy in Icelandic horticulture.

5 References

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