Optimal management of energy resources in greenhouse crop production systems

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1. Background

In the interest of reducing energy consumption and CO_2 emission while maintaining productivity, greenhouse growers have installed a wide range of auxiliary equipment, such as heat exchangers, short and long term heat buffers, co-generation units and heat pumps. An overview of the equipment in this project is shown in Figure 1. The task of the grower to manage this equipment in the most economical way has become very complicated, not only because of the complex physics of the greenhouse dynamics, but also because of uncertainty in the weather, and, in addition, the strongly fluctuating market prices of energy. The main challenge of this project is to formulate and solve this optimization problem and to develop optimal scheduling or management procedures.

2. Goal

The goal of this research is to formulate and solve the optimization problem associated with scheduling of the available energy resources under uncertainty to increase the energy efficiency compared to the current situation. To solve this problem, the problem is split into two parts.

- Minimize the total energy input (heating and cooling) to the greenhouse while maintaining a desired climate.
- Optimize the utilization of energy resources, given the required energy input.

The final product will be the core of a control decision support system to help growers making operational decisions.

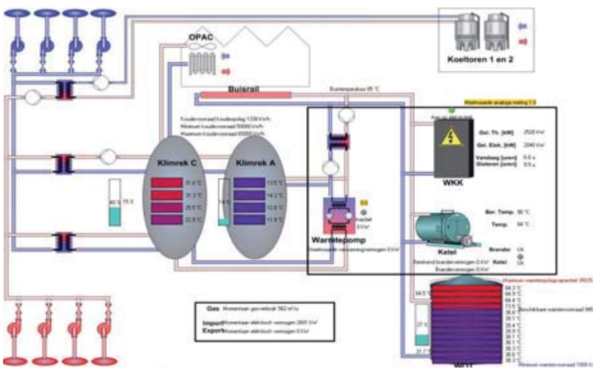

Figure 1. Symbolic overview of energy (re-)sources in the greenhouse

Figure 2. 4 ha commercial greenhouse production facility.

3. First results

For minimization of the energy input to the greenhouse we only take into account, in first instance, temperature and humidity. This will be extended later with CO_2, because these are the three main variables of interest. Data was collected to test the model and results showed a good model performance. Results of minimizing the energy input show that relaxing temperature boundaries reduces the energy input to the greenhouse and constraining relative humidity increases energy input (Figure 3).

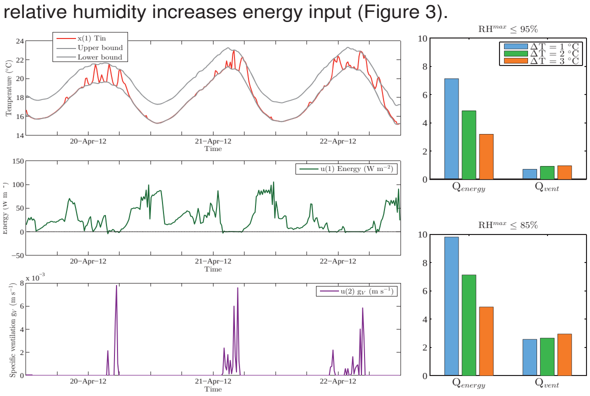

Figure 3. Optimal temperature T_{in}, energy input and specific ventilation for 3 days in April (left). Energy input and energy flux due to ventilation for 3 different temperature boundary regimes and 2 different constraints on relative humidity for the same 3 days in April (right).

4. Acknowledgements

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