Software for Calculating the Effect of Energy Saving Investments on Greenhouses

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Abstract

This paper describes the development of software (EOM) to provide a tool for commercial growers in order to determine the site-specific effects of energy saving investments. Results consist of energy use, crop production and an extensive economic overview. The core of the software is a scientific model (KASPRO) which simulates the greenhouse climate accurately and computes the resulting energy consumption. Instead of simply adding general (manufacturer) data about the energy potentials of investments, mutual influences of a combination of investments are taken into account automatically. With the software it is easy to determine both the energetic and economical effect of e.g. a changed illumination level, a double layered greenhouse cover or the use of bio fuel. Currently the software is available for tomato, freesia, kalanchoe and chrysanthemum growers.

INTRODUCTION

Greenhouse climate simulation models quantitatively describe the relations and the interactions between greenhouse crop processes (photosynthesis and transpiration) and climate, accounting for the effects of greenhouse structure, physical properties of cover materials, outside weather conditions, and action of controllers on greenhouse microclimate. Therefore, such a model can serve for the optimization of greenhouse design, climate and crop management (Weihong, 2005).

Based on greenhouse energy and mass balances, De Zwart (1996) proposed a whole greenhouse-system simulation model for the Venlo-type greenhouse (KASPRO). This model simulates the greenhouse climate on base of greenhouse data and climate set points and calculates the energy consumption as a result. KASPRO includes a climate controller with a behavior very similar to what happens in commercial greenhouses climate control. This makes it easy to take account of the typical ways in which growers use their greenhouse and climate control equipment.

In the past, KASPRO is used for many research projects in which greenhouse climate or energy consumption was analyzed. Because of the complexity of KASPRO this could only be done by skilled researchers. In order to make KASPRO available for commercial growers a software tool EOM (in Dutch: “Energiebesparing Op Maat”) was developed. With this tool commercial growers are able to calculate the effects of energy saving investments on energy consumption. EOM calculates the use of natural gas and electricity effects on crop production and gives an extensive economical overview. Growers are able to use their site-specific greenhouse data, select one or more energy saving investments and calculate the effects. In Fig. 1a schematic overview of EOM is given.

MATERIALS AND METHODS

Model Description

The greenhouse climate model KASPRO is constructed from modules describing the physics of mass and energy transport in the greenhouse enclosure, and a large number of modules that simulate the customary greenhouse climate controllers (Weihong, 2005). Thus, the model takes full account of mutual dependencies between greenhouse characteristics and climate control. The state variables and boundary conditions in the KASPRO model are shown in Fig. 2. Full details of the model can be found in De Zwart (1996).

The simulation of the greenhouse physical processes comprises separate computation of convective and radiative heat exchange and also includes latent heat fluxes associated with evaporation. The radiative heat exchange processes are computed from the Stefan-Boltzman equation, taking into account the aspect factors and the emission and transmission coefficients of the radiating surfaces: the greenhouse cover; the inside thermal or shade screen; the upper heating pipes; the canopy; the lower heating pipes; and the greenhouse floor. The convective heat exchange between all the surfaces is calculated using standard heat exchange theory.

The climate controller of KASPRO enables climate management by means of heating, ventilation, de-humidification, moistening, shading, artificial illumination and carbon dioxide supply. The model also describes the behavior of the boiler, short-term and seasonal heat storage facilities, co-generation of heat and electricity and heat pumps.

All controllers are proportional. The control of heating is performed through day- and night-time set points of temperature, below which the heating system is switched on. The temperature in the house is allowed to exceed that, until the set point of ventilation is reached. In addition, both heating and ventilation set points are raised whenever sun radiation exceeds a given value. Windows are open (disregarding temperature set points) whenever humidity inside the greenhouse exceeds a set point.

The radiative heat exchange processes are computed from the Stefan Boltzman equation, taking into account the view factors and the (wavelength dependent) emission and transmission coefficients of the radiating surfaces.

The crop biomass simulation module in KASPRO is based on the model described by Goudriaan and Van Laar (1994). Actual biomass of indefinite growth fruit vegetable crops does not accumulate in the same way as with one-harvest field crops, but oscillates throughout the harvest season due to multiple harvests. In the KASPRO model, the crop growth module simulates potential biomass production, that is the production determined by solar radiation and temperature without water and nutrient stress and pests infection.

Working of EOM

Using KASPRO the way it is used normally requires knowledge about the model to a high degree and can only be done by skilled researchers. In fact, EOM is not much more than a graphical user interface for KASPRO which also collects, interprets and displays the simulation results.

KASPRO requires a large amount of input parameters while EOM shows only a selection to users. The other parameters are hidden and set to their defaults. Users are able to fill in the most important greenhouse characteristics like cultivated area, covering material, type of crop and climate set points. In case a parameter is unknown to the user, a default value, which is common for most Dutch growers, is used. Having done this, users are able to select one ore more energy saving investments and modify their accompanying parameters. The costs of these investments will be calculated by EOM automatically and sets these as defaults. Users are free to replace these with their own data. The economical benefits of energy saving investments strongly depend on market prices for natural gas and electricity. These can be changed easily in economical module of EOM. Pressing the 'start' button EOM first simulates the current situation as the reference situation. Subsequently, a second simulation will be done, while using the selected energy saving investments. By comparing the results of both simulations the net effects of these investments can be determined.

By selecting more than one investment, users are able to calculate the effect of a combination of investments. Instead of simply adding general (manufacturer) data about energy savings potentials, EOM simulates the greenhouse climate accurately and computes the resulting energy consumption. As a result, mutual influences are taken into account automatically. With EOM it is easy to calculate the effects of e.g. the bandwidth for temperature integration or the effect of a changed capacity of CHP.

Results consist of the natural gas use, electricity use, crop production and an extensive economical overview. Crop production, in terms of photosynthesis, is affected by changed illumination, net solar radiation, temperature, humidity and CO_2-dosing. With given product price, changes in crop production are taken into account.

In the end, EOM calculates the consumption of primary energy as a result of using alternative energy conversion systems like CHP a heat pump or bio oil.

RESULTS AND DISCUSSION

KASPRO has been validated in several research projects. The most recent validation was done during a study by Weihong (2005). The objective of this study was exploring alternatives to the existing Venlo-type greenhouse climate control policy under Chinese subtropical climate conditions, through simulation analysis using the KASPRO model. Experiments were carried out in a Dutch Venlo-type glasshouse on a farm in Shanghai (31.3oN, 121.4oE), to collect climate and crop data to validate the model. The results show that using outside hourly weather data as inputs, the KASPRO model generally gives satisfactory predictions of greenhouse air temperature and humidity, and of canopy transpiration rate under both summer and winter climate conditions for subtropical China.

During the developing of EOM the software has been tested extensively. As a result a large number of scenario studies have been made. Although the results were satisfying, the aim of the project did not include these studies and no reports were made. The main objective of the project was introducing the software to commercial growers and consultants. For this reason, about 100 cd's with the software including an evaluation form were spread on several occasions like grower meetings and the international Hortifair. Articles about the tool were also publicized in horticultural magazines, including an internet link from which EOM can be downloaded.

The results of the evaluation made clear that growers in general are hesitating to install the software and use it for their purposes. According to some of them, the software is too much a black box. However, a majority is planning to use EOM whenever they consider an energy saving investment. Even some of them were really eager.

CONCLUSIONS

The EOM software is a unique tool which allows commercial growers to calculate the benefits of investments in an accurate and objective way. Using it, it is easy to determine both the energetic and economical effect of e.g., a changed illumination level, a double layered greenhouse cover or the use of bio fuel. Until recently growers in general were hesitating to use EOM. One explanation for this is the fact that the benefits of common investments like an energy screen are well known among growers. Other investments (e.g. a double layered covering material) are not profitable beforehand. However, considering the rapid increase of the price of energy, the potentials of EOM are growing.

Currently EOM is available for commercial growers of tomato, freesia, kalanchoe and chrysanthemum and is downloadable from http://www.greenhousetechnology.nl. In the future the software might be suitable for other crops and other outside environmental conditions.

ACKNOWLEDGEMENTS

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Figures

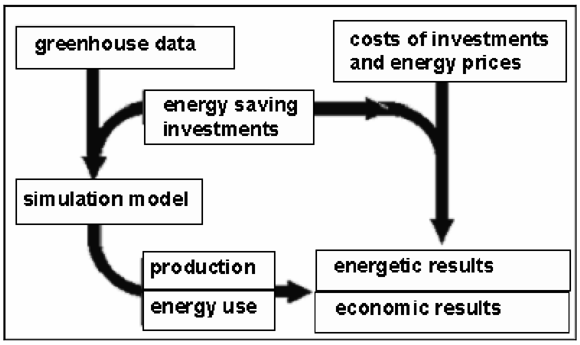

Fig. 1. Schematic overview of EOM. First, users are able to enter their greenhouse data, energy prices and costs for investments. Then they must select one or more energy saving investments. Subsequently the climate model KASPRO will simulate the effect of these investments. Finally the energetic and economic results will be presented.

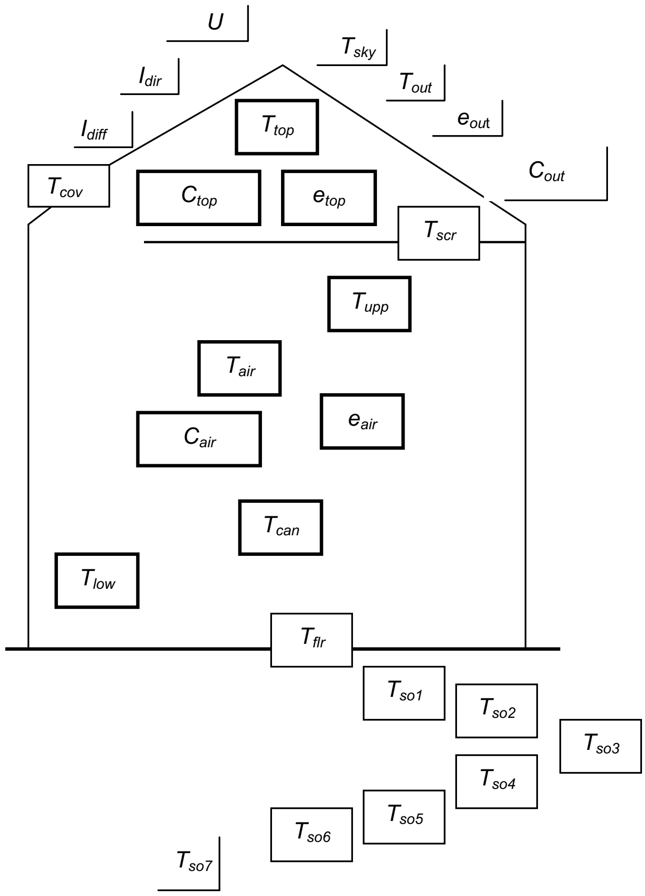

Fig. 2. State variables and boundary conditions in the KASPRO model; U, wind speed; I_{dir} and I_{diff}, direct and diffuse solar radiation; C_{air}, C_{top} and C_{out}, CO_2 concentration of greenhouse air below and above the thermal or shade screen and of air outside of greenhouse; e_{air}, e_{top} and e_{out}, water vapour pressure of greenhouse air below and above the thermal or shade screen and of air outside of greenhouse; T_{air}, T_{top}, T_{out}, T_{cov}, T_{sky}, T_{scr}, T_{upp}, T_{low}, T_{can}, T_{flr}, and T_{so1} – T_{so7}, temperature of greenhouse air below and above the thermal or shade screen and of air outside of greenhouse, of greenhouse cover, of sky out of greenhouse, of thermal or shade screen, of upper and lower pipe, of canopy, of greenhouse floor, and of soil layer 1 to 7.