Effects of electric power supply for artificial illumination of greenhouse crops at volatile current supply

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Objective

In Germany, the increasing generation of electricity based on renewable energy is accompanied by a high volatility in the availability. Greenhouses could be such flexible users of volatile current supply. They can use it for heating the greenhouse and/or illuminating the crops. The present model study evaluates the potential benefit effect of illuminating a tomato crop. The photosynthesis and the potential yield are simulated in the course of a year. In addition, the savings in heat energy consumption due to the heat by the lamps released into the greenhouse is estimated.

Method

The photosynthesis of a tomato crop is estimated by a model (Kläring et al., Agric. For. Meteorol. 143: 208-216) from data of a reference year of Grossbeeren, Germany (52 °N, 13 °E) using the following parameters:

- Leaf Area Index: 3 $m^2 m^{-2}$
- CO_2 concentration: 400 ppm
- Transmission of PAR radiation: 75 %

Simulated scenarios are compared under:

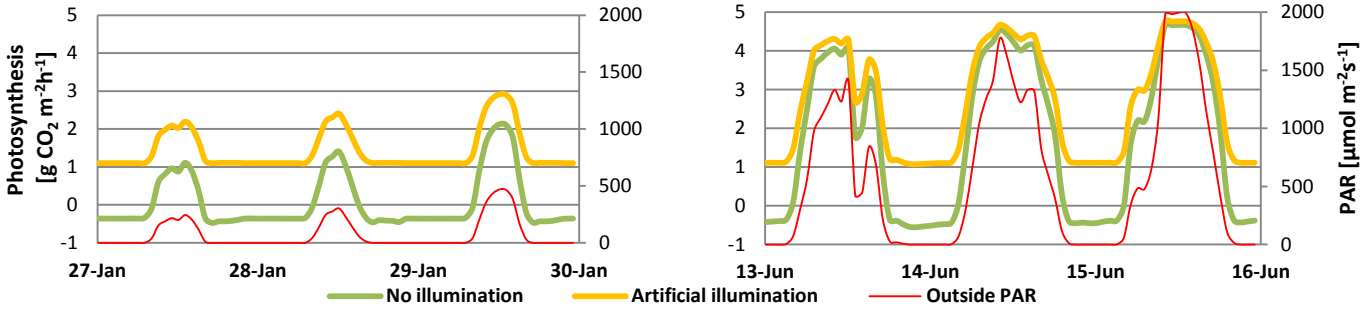
- Artificial illumination: 200 µmol $m^{-2} s^{-1}$
- No illumination (only solar light)

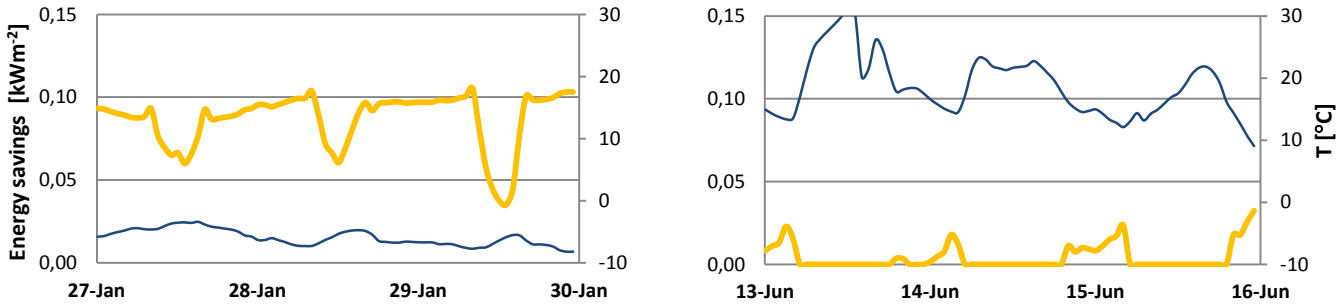
Heat energy savings (Schuch, PhD Thesis HU-Berlin, 2014: pp. 22-25) are estimated considering:

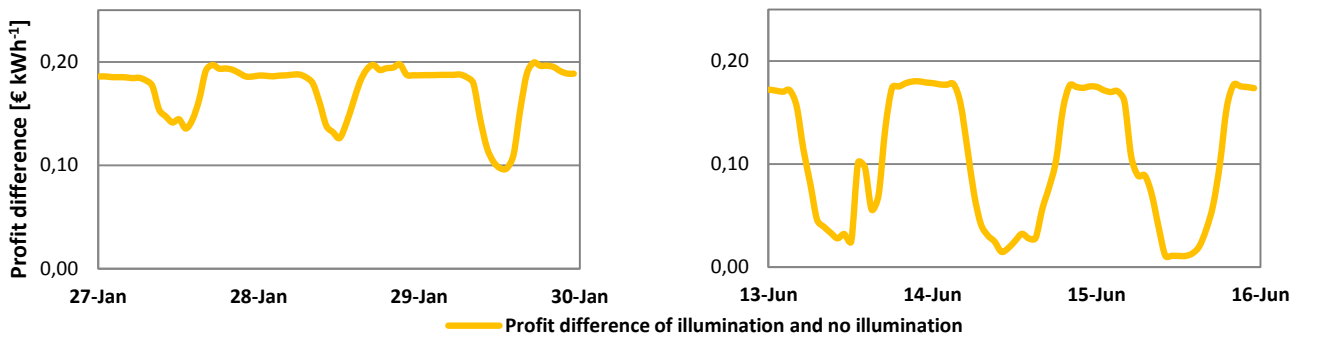
- Heating set points: 19°C/17°C day/night
- Power of HPS lamps: 160 W m^{-2} (75% heat efficiency)
- Price of heat produced from oil: 0.04 € kWh^{-1}
- Average tomato price: 2 € kg^{-1}

Results

Artificial illumination has a high positive impact on photosynthesis during nights and winter time. As complement, the energy savings due to the heat released from the lamps are higher in winter than in summer. The benefit from using artificial illumination is more affected by the surplus in photosynthesis and yield than by the heat energy savings (data not shown).







Discussion

During the winter, using electricity for illuminating plants would be profitable if prices are in the range below 0.15 € kWh^{-1}. In summer, illumination may be profitable only during the night hours. However, the estimated effect must be proven in experiments, because a feedback inhibition of assimilates on photosynthesis could be possible due to a very high source/sink ratio. During summer other options could be much more profitable such as using the electricity for cooling the greenhouse in the (semi) closed operation mode.

This study considers only the operation phase, thus investment costs are not included. It also does not take into account the possible effect of a 24-h light phase which however, will rarely happen in the investigated conditions of volatile current supply.

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