

Greenhouses: A Modelica Library for the Simulation of Greenhouse Climate and Energy Systems

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Abstract

This paper presents Greenhouses, an open Modelica library for the simulation of greenhouse climate and energy systems. In the literature, a small number of models are available for greenhouse climate simulation and crop growth. However, an open-source simulation platform is still lacking. The Greenhouses Modelica library aims at providing a robust open-source framework to simulate greenhouse climate and its integration with energy systems (e.g. generation and storage units). The goal is to provide an integrated and fully open-source solution ranging from the computation of energy flows in a greenhouse, to the simulation of complex systems with their control strategy. To that end, the library proposes models covering the following aspects:

- Greenhouse climate, to compute the energy consumption of a greenhouse given its specific design, outdoor conditions and a specific control.
- Thermal systems, with models ranging from heat distribution systems in greenhouses to generation and thermal storage units.
- Crop yield, to account for crop requirements as well as crop behavior (e.g. transpiration and photosynthesis), which influence the indoor climate and thus, the greenhouse energy consumption.

Climate control systems (heating, ventilation, CO₂ enrichment and supplementary lighting) are also included in the library. Furthermore, several numerical methods are developed and implemented in order to enhance the robustness and the simulation speed of the models during initialization and integration.

The proposed modeling framework can be used for multiple purposes, such as the optimal control of the greenhouse actuators, the optimal sizing of the heating appliances, or the optimal integration of the units in the power system. The Greenhouses library also comprises multiple example models, making it readily usable for both research and industrial applications.

The full compatibility (connector-wise) of the library allows the connection with other libraries more specialized in modeling thermal systems (e.g. Buildings, ThermoPower, ThermoCycle), thus increasing the simulation

possibilities of the Greenhouses library.

The presented library is released as open-source (using the permissive Modelica License 2) and can be downloaded from <https://github.com/queraltab/GreenhouseLibrary>. The library is simple to implement and intuitive to use. The required information for a new user to get started is provided in this paper. Moreover, an additional documentation including a user guide with the required steps to run the models and extended documentation of the library content is available online (<https://greenhouses-library.readthedocs.io>). Ongoing and future works will mainly focus on the integration of new components and on the validation of the proposed models.

Keywords: Greenhouse climate, CHP, Crop yield, Thermal systems, Climate Control, Dynamic modeling