GrewFarm: Optimal Management of Connected Solar Greenhouse for Energy and Crop Production

M. Gobert[1], M. Gazdallah[2], P. Lybaert[2], Z. De Grève[1]

1. Electrical Engineering Department, University of Mons, Belgique
2. Thermal Engineering Department, University of Mons, Belgique

UMONS University of Mons — POLYTECH MONS — wagralim APPETITE FOR INNOVATION

GrewFarm Project

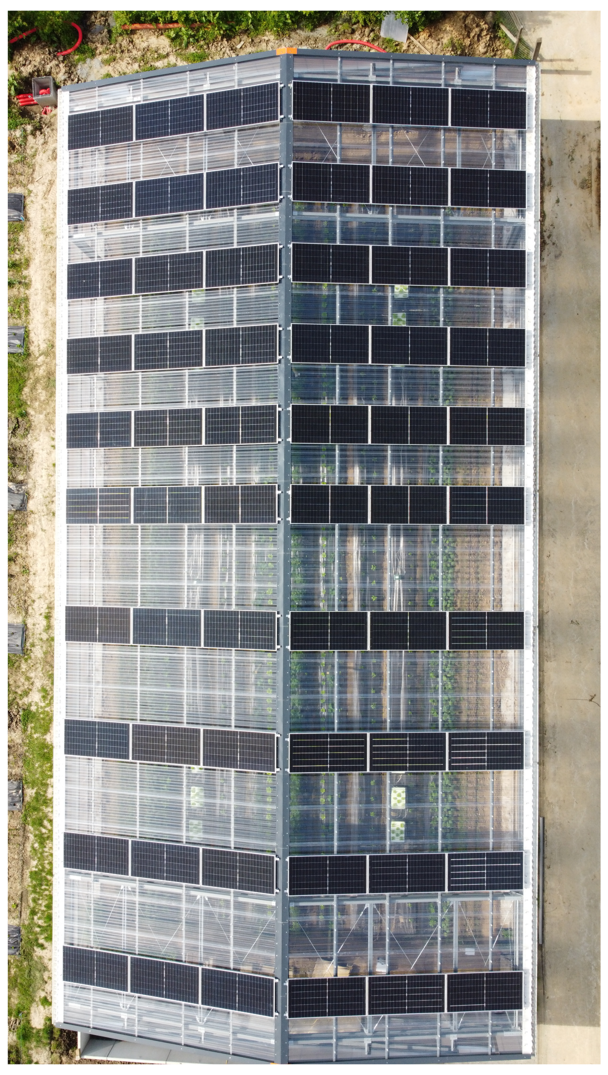
The GrewFarm project aims to develop an innovative solution for solar greenhouses. It investigates **connected greenhouses that adapt to the grower's needs and increase his sustainability**, notably in regard to climatic conditions. The objectives are:

- **study** the impact of roof covering on the development of the crops,
- **design** effective greenhouses according to the needs (do we need heating, lighting, etc.),
- **optimize** the operation of the auxiliary equipment to maximize the crop production and minimize the energy consumption, in an individual and Energy Community context.

The first motivation is to **reconnect agricultural and renewable energy productions** which both require large surface areas.

Greenhouse and auxiliary equipment

The GrewFarm project **experiments at both theoretical and practical levels**. Three sites are chosen to experiment with greenhouses equipped with different auxiliaries.



They serve as references to compare the crop growth and also to collect important data, used for the validation of the numerical model. The rooftops are covered with photovoltaic cells representing 50% or 30% coverage. The impact of the coverage on the crops is monitored on different growing beds.
Several control means are considered to preserve a suitable climate for crop growth.

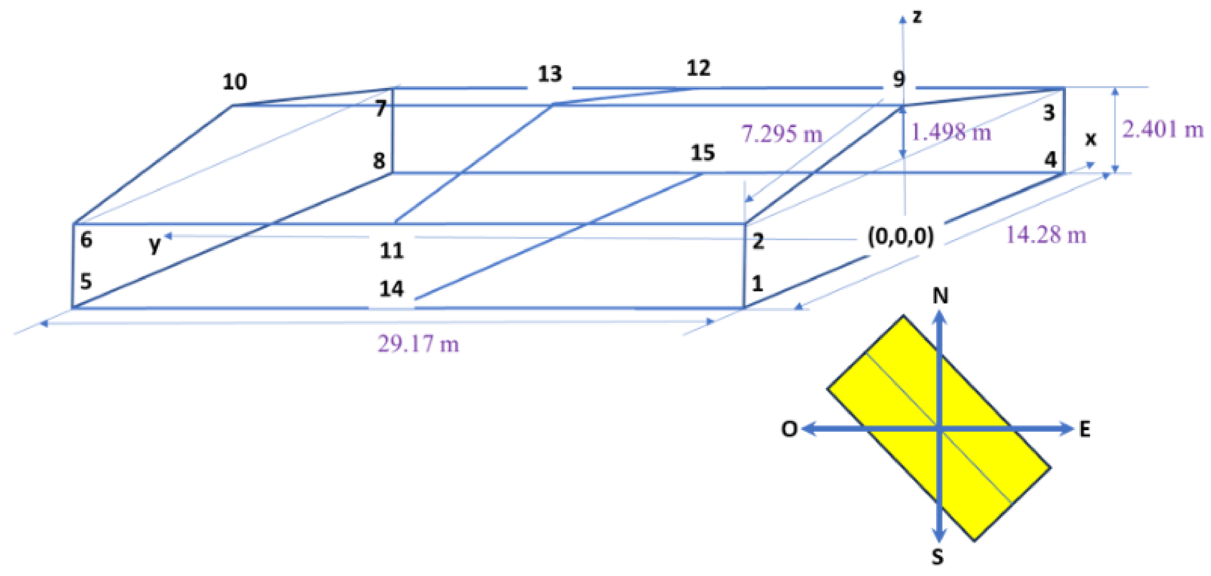
Our investigation concerns:
- mechanical ventilation,
- LED panels,
- heat pumps,
- irrigation system,
- energy storage.

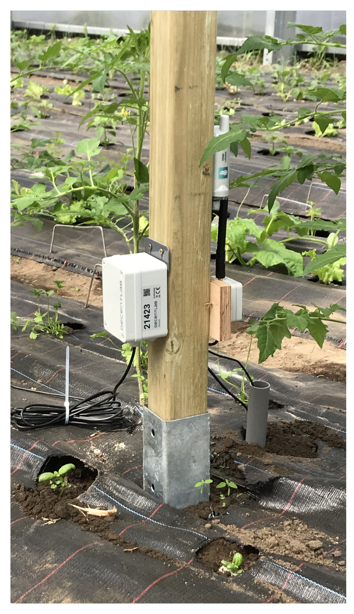
Those decision variables are denoted $\boldsymbol{u}$.

In conjunction with the experimentation on real greenhouses, **a numerical model must be designed to assess the influence of the auxiliary equipment** on the internal climate and determine their pertinence.

Simulator

The Thermal Engineering department is developing a simulator that **describes the internal climate** of the greenhouse according to meteorological data from sensors and technical data from the design of the greenhouse.





The evolution of the state of the greenhouse writes: $\dot{\boldsymbol{x}} = f(t, \boldsymbol{x}, \boldsymbol{u}, \boldsymbol{d})$, where t is the time, $\boldsymbol{x}$ is the current state (temperature, relative humidity, received light, etc.), $\boldsymbol{u}$ represents the decisions to activate the auxiliaries that are taken at the current time, and $\boldsymbol{d}$ includes the external data, such as weather data.

Model Predictive Control

Given the auxiliary equipment, a set of actions is defined to **maintain an optimal climate inside the greenhouse, while limiting the energy bill**. The optimal management is written under the form of a **Model Predictive Control** (MPC) problem.
It takes into account the energy exchanges between the local production and the retailer and focuses on the minimization of the energy bill. We define a control horizon of 24 hours, separated into n_{steps} decision intervals. The objective function is computed over the control horizon and defined as the sum of the energy costs for each of the n_{steps} time steps. The objective function writes:

$$\min_{\boldsymbol{u} \in \Omega} \sum_{k=1}^{n_{steps}} \alpha_k \phi_k(\boldsymbol{u_k}),$$

where Ω is the search space, α_k is a discount factor that decreases with k and ϕ_k are the partial costs of each time step.
The computation of future greenhouse states requires the prediction several variables such as weather data, resulting in a complex **high-dimensional and stochastic optimization problem**.

Ongoing work

The simulator must be validated to confirm its reliability in comparison with the real observed data. The optimization might require important computation resources so that special care is taken regarding the implementation of the MPC.
Financing the structure can be a significant obstacle for growers, consequently **the project provides for third-party investor** and the profitability from both the grower's and investor's point of view will be investigated, **especially in the context of renewable energy communities**.

ACKNOWLEDGEMENT AND PARTNERS

wagralim — PÔLE MECATECH — GREEN WIN — UMONS — LIÈGE université Gembloux Agro-Bio Tech — Province de Hainaut — HAUTE ÉCOLE CONDORCET — GREEN ENERGY 4 seasons — DHK GROUP

MORE INFORMATION

Main Author
Maxime GOBERT
UMONS – GELE Department
PSMR group
maxime.gobert@umons.ac.be
https://www.epeu-umons.be/research

Obourg site