
Multi-physics dynamic modelling with Modelica: the study case of an experimental tomato greenhouse over a whole production season

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Mass and energy exchanges are highly coupled in greenhouse cultivation because of the plants interactions: radiative and convective heat transfers implying the canopy; latent heat and water mass transfers through the transpiration process; light absorption, carbon dioxide and dioxygen transfers through the photosynthesis and respiration processes. Indoor climate is also highly dependent on external weather due to the greenhouse structure itself: air and sky apparent temperatures, humidity, wind and solar gains. Thus greenhouse systems modelling is an intensive research topic since several decades because of this cultivation method advantages such as: crop protection against pests and meteorological hazards, better yields, easier production planning on extended periods, reduced water and treatment usage. However, heated vegetable greenhouses in Western France comes with environmental impacts due to a strong dependency on fossil-fuel energies as well as with an intrinsic vulnerability to energy costs, which question their viability. In the framework of a project aiming at the design of a new sustainable greenhouse concept adapted to the local climate (SERRES+), a system approach will be used to evaluate the performance of combined technologies including materials, energy production and storage systems, ventilation and air conditioning.

At first, a dynamic physical model of an existing experimental tomato greenhouse located in Nantes (France) has been set up using the Modelica language and open-source components libraries such as *Greenhouses* (Liege University, Belgium). In addition to existing and modified components from shared libraries, several models have also been specifically implemented: horizontal screens system, direct and diffuse irradiances management, air volumes, etc. Yearly simulations provide indicators that can be compared with experimental data recorded during an entire production period describing the indoor climate (temperature, humidity, CO₂ concentration), as well as the crop evolution (harvested fruits mass, leaf surface and temperature) thanks to the embedded tomato yield model. In order to illustrate the difficulty to evaluate *a priori* the required level of details when modelling physics, the impact of more or less simplified hypotheses related with solar radiation management is shown as an example, since the latter is a predominant factor for both plant development (photosynthesis) and indoor climate (heat gains).