LCA of Phase Change Materials application to heat hydroponic crops' root zone in substitution of a conventional root zone heating system

Fertilecity

CILCA 2015

Pere Llorach-Massana[1,2,3,*], Javier Peña[3], Juan Ignacio Montero[4], Joan Rieradevall[1,2]

[1] Sostenipra Research Group (SGR 01412). Z Building, Universitat Autònoma de Barcelona (UAB), Campus UAB, 08193 Bellaterra, Barcelona, Spain.

[2]Institute of Environmental Science and Technology (ICTA). Z Building, Universitat Autònoma de Barcelona (UAB), Campus UAB, 08193 Bellaterra, Barcelona, Spain.

[3]ELISAVA Barcelona School of Design and Engineering. La Rambla 30-32. 08002 Barcelona (Spain)

[4]Institute of Food and Agricultural Research (IRTA), Carretera de Cabrils, km 2, 08348 Barcelona, Spain

Corresponding author: **pere.llorach@uab.cat** Tel.: (+34) 935 86 86 45

1 Introduction

Due to the increase of **fossil fuel prices** and the public concern about **CO_2 emissions** the development of more efficient and sustainable greenhouse heating systems is needed. One of the proposed solutions are **root zone heating systems,** in substitution of environmental air heating, which still have significant environmental impacts associated due to its dependence on non-renewable resources such as oil.

Phase change materials (PCM) have a great potential to replace conventional root zone heating systems. PCM **could store the excess of heat** from a greenhouse during the day and release it over the night, when temperatures drop, to **heat the root zone** of the crop without using additional energy and heating systems.

2 Goal and Scope

The purpose of the study is to assess the **environmental feasibility of using PCM** for a solar energy storage system applied in the root zone of tomato crops (scenario A) **in substitution of conventional hot water root zone heating systems** (scenario B) which are oil dependent (figure 1). The selected functional unit is 1 kg of tomato.

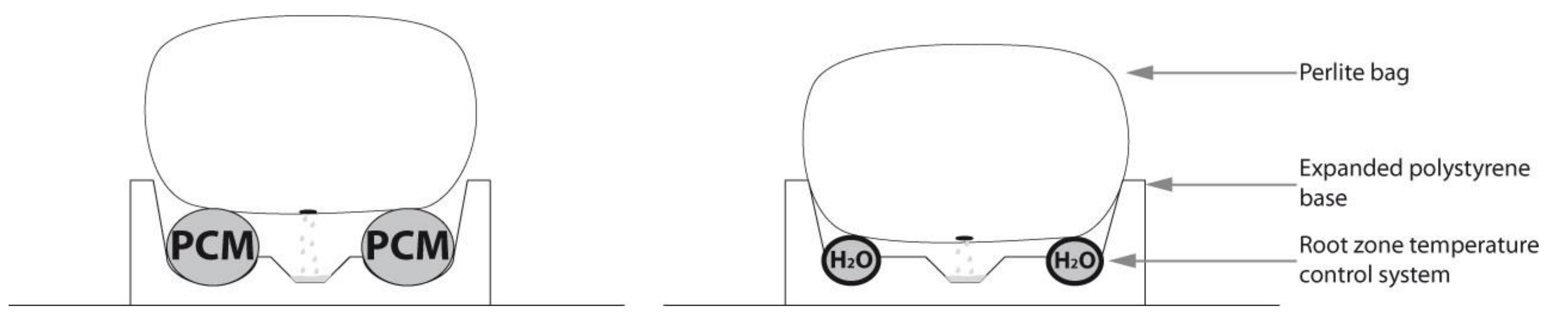

Figure 1. Left: Scenario A PCM application for root zone temperature control. Right: Scenario B oil dependent conventional root zone heating system with hot water scenario.

3 Methodology

Life Cycle Assessment (LCA) methodology was used for the environmental assessment, according to ISO 14040. LCA is a recognized and standardized method for quantifying environmental impact supported and used by the UNEP and the European Commission.

The hypothetic scenarios were designed and sized taking into account its possible application for a tomato crop, in a multitunel greenhouse situated in southern Spain. Such greenhouse was analyzed in the EUPHOROS project [1].

For the analysis we suggested an increase of 20% in crop yield according to the benefits of root zone temperature control found in literature [2,3].

4 Results & discussion

For scenario A, the PCM generates, in average, the 93% of environmental impact concerning the selected impact categories (figure 2). The remaining 6'9% of the impact is generated by the LDPE for the encapsulation (figure 2). Disposals of the PCM and the LDPE for encapsulation are not relevant as their environmental impact is lower than 0'1% (figure 2).

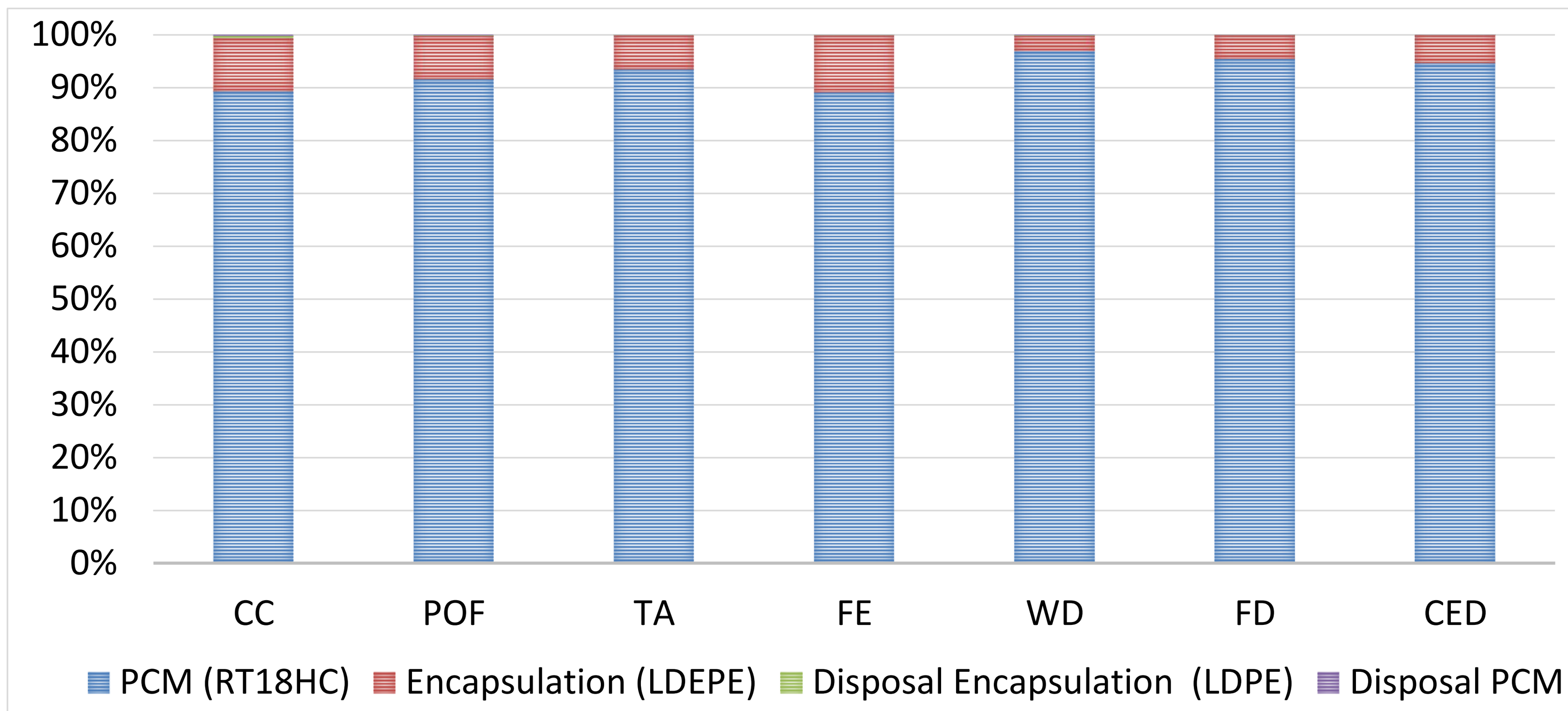

Figure 2. Environmental impact distribution, of the specific inventory added to EUHPHOROS reference scenario [1] to create Scenario A (PCM for solar energy storage) for the following impact categories: climate change (CC); photochemical oxidant formation (POF); terrestrial acidification (TA); freshwater eutrophication (FE); water depletion (WD); fossil depletion (FD); and cumulative energy demand (CED).

As shown in figure 3, scenario B has a higher environmental impact for all impact categories than scenario A. For scenario B, oil consumption represents in average 98'8% of the environmental impact.

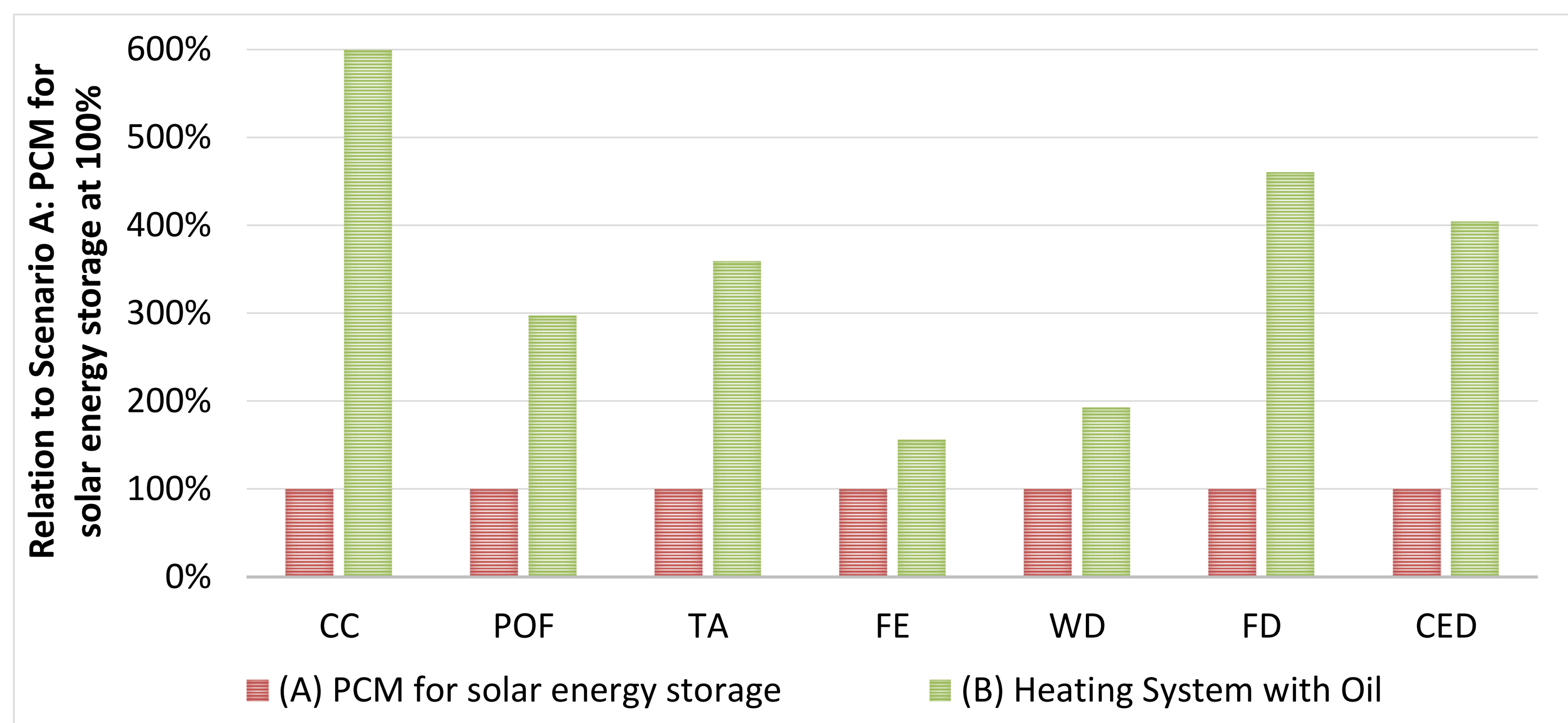

Figure 3. Scenarios A (PCM) and B (conventional root zone heating) environmental impact refered to scenario A at 100% for the following impact categories: climate change (CC); photochemical oxidant formation (POF); terrestrial acidification (TA); freshwater eutrophication (FE); water depletion (WD); fossil depletion (FD); and cumulative energy demand (CED).

5 Conclusions

•PCM has a great environmental potential to substitute conventional root zone heating systems. PCM application provides environmental benefits for all the analysed impact categories, especially for climate change. Nevertheless, its effectiveness in increasing crops yield at 20% should be verified.
•The optimization of PCM production, or the use of more environmentally friendly PCM, could reduce the environmental impact of Scenario A, PCM application.
•Economic costs and eco-efficiency indicators of using PCM in substitution of conventional root zone heating system should be subject of further study.

Acknowledgements

We would like to acknowledge the Catalan Government, La Generalitat de Catalunya, for awarding a research **scholarship FI-AGUAR 2015** to Pere Llorach Massana; and to the Spanish Ministry of Economy and Competitiveness its support to our research by founding the project: ***"Fertilecity: Agrourban sustainability through rooftop greenhouses. Ecoinnovation on residual flows of energy, water and CO2 for food production (CTM2013-47067-C2-1-R)"***

References

[1] Montero JI, Antón A, Torrellas M. EUPHOROS deliverable 5. Report on environmental and economic profile of present greenhouse production systems in Europe 2011:1–51.
[2] Gosselin A, Trudel MJ. Interactions between root-zone temperature and light levels on growth, development and photosynthesis of Lycopersicon esculentum Mill. cultivar "Vendor." Sci Hortic (Amsterdam) 1984;23:313–21.
[3] Kawasaki Y, Matsuo S, Kanayama Y, Kanahama K. Effect of Root-zone Heating on Root Growth and Activity, Nutrient Uptake, and Fruit Yield of Tomato at Low Air Temperatures. J Japanese Soc Hortic Sci 2014;83:295–301.

sostenipra
Sostenibilitat i Prevenció Ambiental

UAB
Universitat Autònoma de Barcelona

icta

ELISAVA
Barcelona School of Design and Engineering

IRTA
RECERCA I TECNOLOGIA AGROALIMENTÀRIES

MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD