Environmental assessment of hydroponic tomato crops in a urban building integrated rooftop greenhouse using LCA

David Sanjuan-Delmás[1], Mireia Ercilla[1], Pere Llorach-Massana[1], Ana Nadal[1], Pere Muñoz[2] , J. Ignacio Montero[2], Gara Villalba[1], Maria Rosa Rovira[1], Alejandro Josa[3,4], Xavier Gabarrell[1,5], Joan Rieradevall[1,5]

[1]Sostenipra Research Group (SGR 01412), Institute of Environmental Sciences and Technology (MDM-2015-0552), Z Building, Autonomous University of Barcelona (UAB), Campus UAB, 08193 Bellaterra, Barcelona, Spain
[2]Institute of Research and Technology in Agrifood Sector (IRTA), Environmental Horticulture, 08348 Cabrils, Barcelona, Spain
[3]Department of Civil and Environmental Engineering (DECA), School of Civil Engineering (Escola de Camins), Universitat Politècnica de Catalunya, UPC, Jordi Girona 1-3, 08034 Barcelona, Spain
[4]Institute of Sustainability (IS.UPC), Universitat Politècnica de Catalunya, UPC, Jordi Girona 34, 08034 Barcelona, Spain
[5]Department of Chemical Engineering, Universitat Autònoma de Barcelona (UAB), Campus UAB, 08193 Bellaterra, Barcelona, Spain

***Corresponding author:** David Sanjuan-Delmás, Email: david.sanjuan@uab.cat

www.fertilecity.com/en

Introduction

Food production and climate change are closely linked due to the uncertainty generated by climate change in agriculture and also by the emissions derived from the agriculture sector, which makes it a key issue in climate change mitigation.

The goal of this study is to analyze the carbon footprint of an **integrated rooftop greenhouse (i-RTG)** located in the Mediterranean area of Barcelona. This innovative **vertical farm** is **connected** with the building in terms of **water, residual energy, air (CO_2) and food**, taking advantage of this connection to increase resource efficiency. The system was developed in the framework of the Fertilecity project **[1]**.

Methodology

The ICTA-ICP building in Barcelona holds a pilot integrated rooftop greenhouse of 85 m^2 of productive area that takes a symbiotic advantage of residual building flows (heat, water and CO_2) (**Figure 1**). Three tomato crops were conducted from 10/02/2015 to 08/03/2016 (**Figure 2**). In this system tomato crops can be grown all the year (not only during spring-summer) due to the mild temperatures of the greenhouse produced by the integration with the building.

The carbon footprint of these crops was quantified using the LCA methodology, the Ecoinvent (v 3.3) database for the environmental information and the software Simapro (v 8). The functional unit selected for the assessment was 1 kg of tomato at the consumption point including the whole life cycle of the system from materials extraction to the end of life.

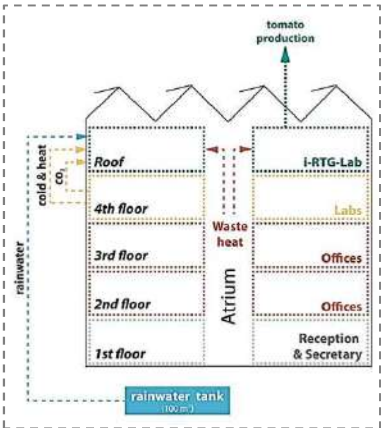


Figure 1. Diagram of the synergies between the building and the i-RTG.

Figure 2. Timeline of the crops conducted and pictures of the evolution of the crops.

Results

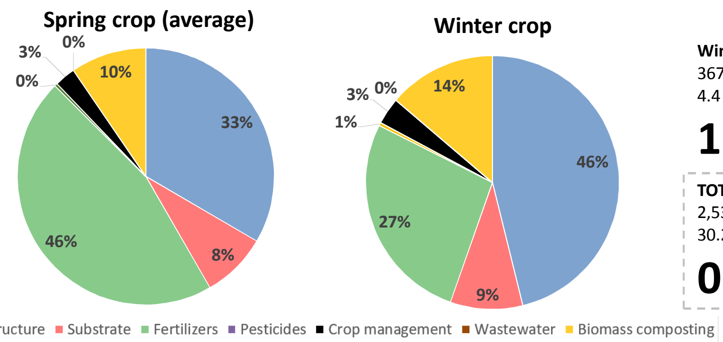
As can be observed in **Figure 3,** the most impacting elements of the i-RTG are the infrastructure, due to the materials used, and the fertilizers, due to the high impacts of their production. This is in accordance with previous LCA studies analyzing hydroponic crops in conventional greenhouses **[2]**. In average, the carbon footprint of tomatoes produced in the i-RTG is nearly 50% lower in comparison with conventional production, which emits **1.54 kg of CO_2 eq. per kg of tomato [3]**. This is due to the lower needs for packaging and transport for i-RTG production. Spring crop 1 and winter crops showed being less efficient than spring crop 2 due to exceptionally high temperatures that year (that increased evapotranspiration and hence fertigation) and for a lower solar radiation, respectively. However, the impacts were similar to those observed in tomato consumption from conventional production.

Spring crop 1 (164 days)
1,288 kg of tomato
15.3 kg/m^2

0.82 kg of CO_2 eq. per kg of tomato

Spring crop 2 (135 days)
883 kg of tomato
10.5 kg/m^2

0.56 kg of CO_2 eq. per kg of tomato



Winter crop (172 days)
367 kg of tomato
4.4 kg/m^2

1.41 kg of CO_2 eq. per kg of tomato

TOTAL CROPPING PERIOD (15.5 months)
2,539 kg of tomato
30.2 kg/m^2

0.81 kg of CO_2 eq. per kg of tomato

Figure 3. Contribution to the global warming potential of each element of the i-RTG and agricultural and environmental results for each of the crops conducted

Conclusions

The study has proven the feasibility of the i-RTG as a food production system, with significant amounts of food during the period assessed (around 1.6 tones per year). Provided that it is a pilot case study, the system is not optimized, and it is expected that future improvements will increase its efficiency reducing the carbon footprint of production nearly 50%. The application of the i-RTG technology in urban areas can increase local food production while mitigating the contribution to climate change.

References and acknowledgements

[1] *Fertilecity. Sostenibilidad agrourbana mediante invernaderos en cubierta. Ecoinnovación en flujos residuales de energía, agua y CO2 para la producción de alimentos. http://fertilecity.com/*

[2] Anton A, Montero JI, Muñoz P, Castells F (2005) Identification of the main factors affecting the environmental impact of passive greenhouses. In: Proceedings of the International Conference on Sustainable Greenhouse Systems. Volume 2.

[3] Sanye-Mengual E, Oliver-Sola J, Montero JI, Rieradevall J (2015) An environmental and economic life cycle assessment of rooftop greenhouse (RTG) implementation in Barcelona, Spain. Assessing new forms of urban agriculture from the greenhouse structure to the final product level. Int J Life Cycle Assess 20:350–366. doi: 10.1007/s11367-014-0836-9

The authors are grateful to the Secretaria d'Universitats i Recerca del Departament d'Economia i Coneixement de la Generalitat de Catalunya for awarding a research scholarship (FI-DGR 2014) to David Sanjuan Delmás.

The authors would also like to thank the Spanish Ministry of Economy and Competitiveness (MINECO) for the financial support to the research project "Integrated rooftop greenhouses: a symbiosis of energy, water and CO2 emissions for buildings. Towards urban food security in a circular economy" (CTM2016-75772-C3-1/2/3-R ,AEI/FEDER, UE).

http://www.sostenipra.cat/