Improving energy efficiency of buildings metabolism and promoting local food production through integrated rooftop greenhouses (i-RTGs)

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Introduction

The **Fertilecity** project analyzes from a technological and sustainability viewpoint, a new agricultural production system for Mediterranean urban areas through the **integration of greenhouses on the roof of buildings** (iRTG). **The ICTA Rooftop Greenhouse (LAU)** (Figure 1), located on the rooftop of the ICTA-ICP building (**UAB** campus, Bellaterra, **Spain**), **integrates and takes advantage of the CO_2 concentrations, rainwater collected from the rooftop and energy** (e.g. reusing ventilation air from other spaces of the building) **in the metabolism of the building to maintain ideal conditions for crop growth** (14-26°C).

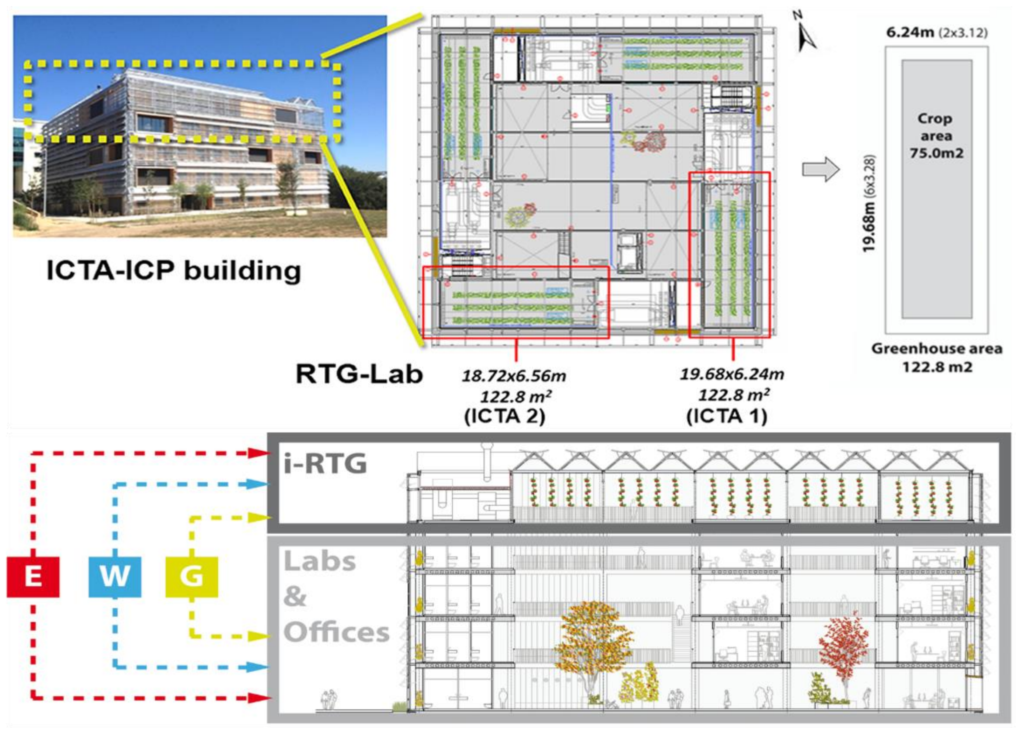

Figure 1: LAU building ICTA-ICP, location, size and exchange flows indoor conservatory building.

This contribution presents the **preliminary results of the energy efficiency of the LAU** (i.e., using **during 2 first tomato crops along the year** , Figure 2): residual heat from buildings) Summer season crop (Feb-Jul 2015), Winter season crop (Sept 2015 - Feb 2015) and the consequent environmental benefits in order to have a cleaner production of food products in cities

Figure 2: Tomato crops in the LAU.

Methodology

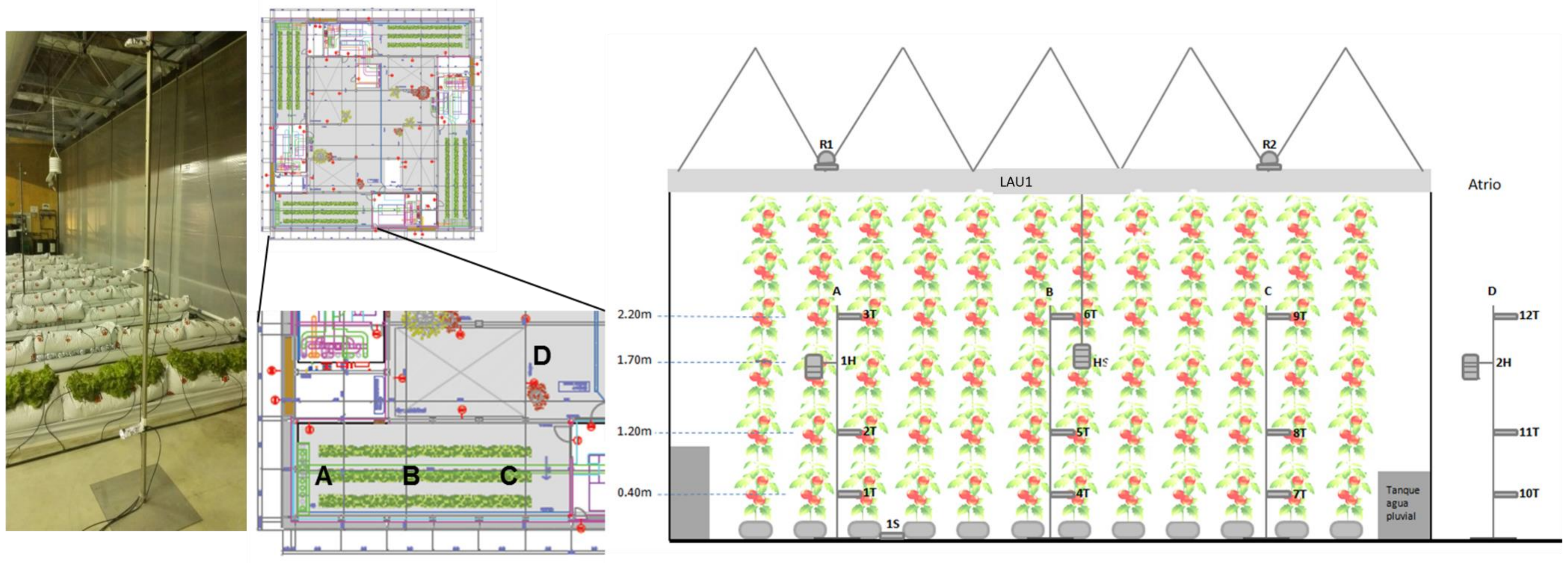

Figure 4: Location sensors for energy monitoring.

The greenhouse and outdoor environments are **monitored in terms of temperature and other climatic variables** (T & %RH probe. It also has air velocity, solar radiation and heat flow sensors, among others).

The monitoring design consists of **instruments uniformly distributed inside the LAU and in other spaces of the rooftop level of the building,** which are located at four vertical supports and each vertical support has 3 temperature probes.

Measurements are **taken every 5 seconds and an average is done every 10 minutes**.

Results & Discussion

SUMMER CROP – 10 Feb al 23 Jul 2015 – High solar radiation
WINTER CROP – 15 Sept al 4 Mar 2016 – Low solar radiation

	Winter 21 Dec. 2014 19 Mar. 2015		Spring 20 Mar. 2015 20 Jun. 2015		Summer 21 Jun. 2015 22 Sept. 2015		Autumn 23 Sept. 2015 20 Dec. 2015		Winter 21 Dec. 2015 19 Mar. 2016	
	ICTA-iRTG	Outside	ICTA-iRTG	Outside	ICTA-iRTG	Outside	ICTA-iRTG	Outside	ICTA-iRTG	Outside
Average Temperature (° C)	16.5	7.5	21.6	16.7	25.9	24.4	18.8	13.1	17.7	9.4
Maximum Temperature (° C)	29.6	22.8	34.5	34.6	39.7	38.1	31.0	29.2	28.3	20.8
Minimum Temperature (° C)	6.3	-3.6	13.5	1.2	15.7	18.3	10.2	-2.3	10.8	-1.5

Winter 2014-2015 – **Difference inside-outside: 9 degrees**
Winter 2015-2016 – **Difference inside-outside: 8 degrees**

Figure 5: Summary of temperatures along the two crops conducted.

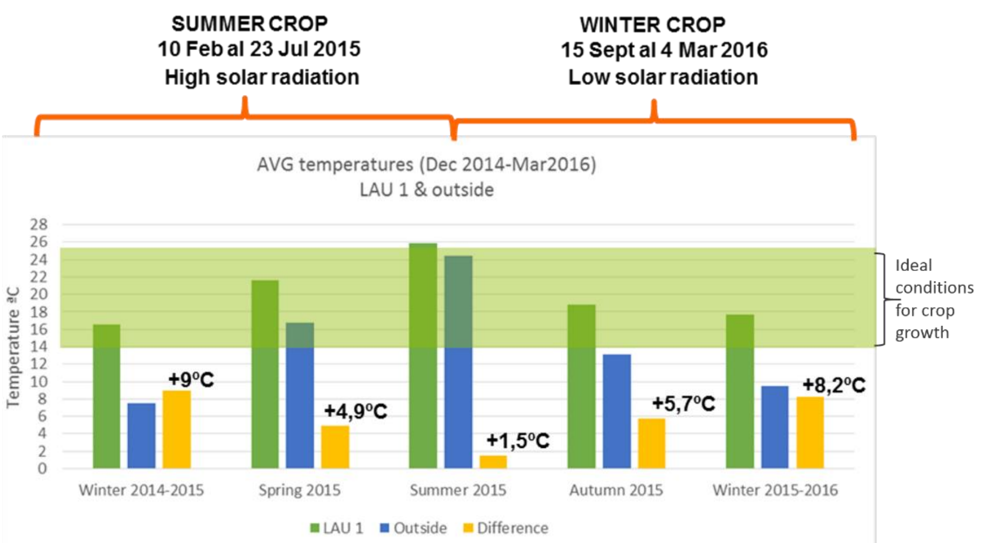

Figure 6: Thermal performance 2014-2015-2016, thermal differences inside vs outside LAU.

Seasonal average temperatures range from 16.5°C in winter to 25.9°C in summer, with minimum winter and maximum summer punctual temperatures of 6.3°C and 39.7°C, respectively (Figure 5). **Average LAU temperatures are within FAOs recommended/optimum average temperatures of 14-26 °C in Mediterranean horticultural close systems.**
The LAU temperatures differ an average of 9 ºC compared to winter outside temperatures, 5 °C to spring, 6 °C and **5°C compared to summer temperatures** (Figure 6) **recorded outside the building**.
This **difference seems to be mainly a consequence of the thermal inertia of the building and its materials** (especially because of the concrete slab floor).
Usually, in traditional greenhouses, during winter nights reach negative temperatures in the study geographic area and thereby increase the risk of crop loss.
This LAU´s characteristic for the agro-urban productivity is ideal in winter, because it eliminates the need for mechanical heating and high CO_2 emissions. But in summer it´s a problematic factor because a slight overheating occurs that can affect the crop.

Conclusions

The effect of the thermal inertia in the thermal behavior of the LAU resulted in an interesting source of heat during winter nights, because **offering a thermal advantage when compared to conventional greenhouses**, where to maintain productivity is necessary to use mechanical heating.

The residual heat from the building to the greenhouse can increase the productivity of a horticultural production in urban areas and also maintain comfort conditions in the building, especially **in extreme winter season.** The high productivity of LAU is reflected in generating **15kg / m² *cor de bou*** -beef heart- **tomatoes**, this value is similar to the heated industrial production.

Further research will quantify the energy metabolism of LAU year-round, identify the sources of residual heat and thermal inertia, and account for the environmental benefits of integrated RTGs in terms of avoided energy consumption.

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