





Evaluating Buildings' Green Retrofitting to Improve Urban Environment at District Level [†]

Cecilia Ciacci , Neri Banti , Vincenzo Di Naso  and Frida Bazzocchi 

Department of Civil and Environmental Engineering, University of Florence, 50139 Florence, Italy

* Correspondence: cecilia.ciacci@unifi.it; Tel.: +39-0552758861

† Presented at the Innovations-Sustainability-Modernity-Openness Conference (ISMO'22), Bialystok, Poland, 26–27 May 2022.

Abstract: In the context of sustainable cities and communities, to meet the European aim of a carbon-free economy by 2050, and to tackle the current climate change, the retrofitting of the Italian residential building stock, as well the green regeneration of urban districts, is essential. The research aims at assessing the influence of some cooling strategies applied in a defined hypothetical but realistic urban grid located in Florence, evaluating multistorey and tower building types, respectively. Using ENVI-met software, several micro-climate parameters were evaluated. The most significant outcomes were related to the substitution of the current dark asphalt (reference case) with cool pavements as an improvement strategy. This measure resulted in an average reduction of external air temperature equal to 1.5 °C. Otherwise, the application of green façade technology on buildings noticeably influenced both the wall surface temperature (reduction of around 12 °C) and the wall energy balance (reduction of about 60 W/m²) with respect to traditional external wall configurations.

Keywords: sustainable retrofitting; ENVI-met; environmental redevelopment; residential buildings; green urban district



Citation: Ciacci, C.; Banti, N.; Naso, V.D.; Bazzocchi, F. Evaluating Buildings' Green Retrofitting to Improve Urban Environment at District Level. *Environ. Sci. Proc.* **2022**, *18*, 7. <https://doi.org/10.3390/environsciproc2022018007>

Academic Editors: Iwona Skoczko, Dorota Anna Krawczyk and Ewa Szatyłowicz

Published: 29 August 2022

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1. Introduction and Background

The Italian residential building stock is nowadays aged and obsolete. This is because 25% of Italian houses were built before 1950 [1] without any standards concerning energy saving or emissions. According to the ENEA report of 2020, in Italy, a total of 40% of primary energy demand is needed for civilian use [2] and about 26% of the Italian residential building stock is classified with an energy efficiency class lower than C (1.2 EP_{gl,nren,rif,standard(2019/21)} reference building global energy performance index for non-renewable < global energy performance index for non-renewables EP_{gl,nren} < 1.50 EP_{gl,nren,rif,standard(2019/21)}) [3]. Due to climate change, Tootkaboni et al. [4] affirm that a significant increase of about 255.1% for cooling demand will occur in the near future for densely built existing residential districts.

It has been proven that the urban environment design and especially the use of effective cooling strategies can tackle climate change and the external air temperature rise, avoiding an increase in energy needs during the summer season and overheating effects inside buildings.

The research discussed in this paper aims at assessing the influence of implementing green roofs and façades (as retrofitting measures for existing residential buildings) and some single external cooling strategies and a combination of them on micro-climate conditions at both the building and urban level using ENVI-met software [5]. The goal is to provide useful indications for designers to choose the most suitable and effective retrofitting strategy for green urban redevelopment interventions in the context of sustainable cities and communities. In the literature, there are many studies concerning a systematic review

on ENVI-met software to validate its use in the evaluation of some micro-climate parameters typical of the urban environment, affecting both users' external thermal comfort and their building's energy performance [6–8].

2. Method

The methodology to assess the possible configuration for a green urban district is the following. Firstly, the possible typical scheme of an Italian urban district was identified. An urban grid of 80 m × 80 m was outlined in ENVI-met spaces and located in Florence. The district configuration was assumed as invariant. Secondly, multistorey residential building types were defined to be introduced into the delineated urban grid. Thereafter, different cooling strategies at both buildings and urban levels were outlined. For the former, the use of vertical greenery for south-oriented walls combined with green roof technological solutions were proposed. Green façades were used in different configurations with changing degrees of greening: for multistorey buildings 20%, 30%, and 50% of greenery with respect to the total southern wall surface were investigated. Thereafter, some green urban strategies were evaluated in the different configurations of the considered urban district: integration of green flowerbeds (grass 25 cm thick) (45% with respect to asphalt pavement—Albedo 0.20), combinations of the latter with trees (amount of 56 rancho tree 8.63 m height), and use of cool pavements (concrete pavement light—Albedo 0.80 for 100% with respect to asphalt pavement). Finally, different micro-climate parameters with respect to the different strategies modeled were evaluated: external air temperature, relative humidity (RH), wall surface temperature, external temperature outside the wall, and energy balance (the last 3 only for greenery strategy). For the ENVI-met set up, the climate files created by Italian CTI (Italian Thermotechnical Committee) and referred to the city of Florence were used. In addition to the nesting grids already set up by the software (5 grid), 3 empty grid rows (6 m) were added on each side of the model area to avoid errors related to uncertainties on boundary conditions. The buildings were modeled according to typological features widely spread in the Italian context, in terms of geometry and envelope characteristics.

3. Results and Discussion

The graph in Figure 1 shows the number of points [%] in the considered urban grid that are characterized by a specific value of the external air temperature. It is worth noticing that ENVI-met performed the analysis for over 2400 points in the outlined grid. The results highlight that for the reference case, distinguished by the presence of dark asphalt for the whole external pavement, about 8% of points (highest and therefore representative value) are characterized by a temperature equal to 27.9 °C. In this case, the higher value of the external air temperature was calculated for the external points in the nesting grid where there were not shadows by buildings. This happens for all the considered cooling strategies. The configurations with the presence of flowerbeds, and the latter combined with trees, did not result in a significant decrease in the average of the external air temperature. In fact, about 8% of points were characterized by a temperature equal to 27.6 °C with a slight reduction of 0.6 °C with respect to the reference case. This is probably related to the evaluation point of the external air temperature fixed at 1.5 m (man height to evaluate urban external comfort), while trees are about 9 m tall.

It is worth highlighting that the most significant result was related to the layout characterized by cool pavements. This solution is the most advantageous considering the external air temperature parameter. The decrease in the average external air temperature is equal to about 1 °C and as previous graph shows (Figure 1) 15% of points (representative amount) have a temperature equal to 26.9 °C. Consequently, a significant reduction of about 1.5 °C occurs. Even according to literature [9] the use of cool pavements is the most advantageous cool strategy also with respect to the introduction of green flowerbeds. This should be analyzed and verified also in terms of CO₂ emissions.

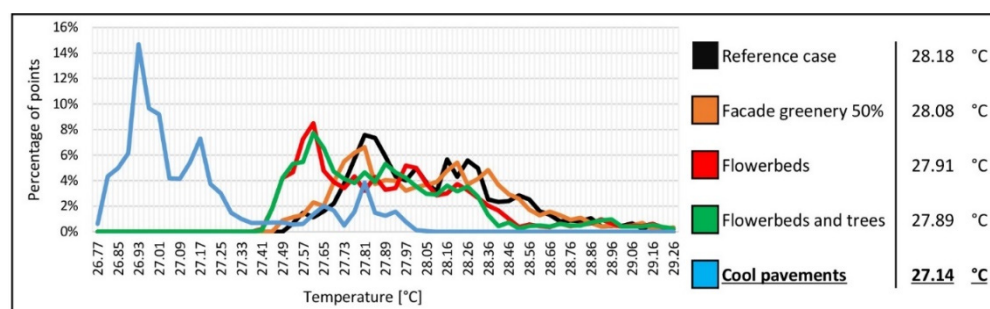


Figure 1. Percentage of points included in the urban grid with respect to the external air temperature. On the right, the average of the external air temperature for each analyzed cooling strategy.

It is important to highlight that the vertical greenery on façade (50%) does not significantly affect the value of air external air temperature at 1.5 m height. Consequently, to evaluate the benefit of this building's redevelopment intervention, the surface temperature is considered.

Figure 2 illustrates the results related to the variation of the buildings' surface temperature (southern wall), the external air temperature outside the wall and the energy balance [W/m^2] with respect to longwave radiation incoming (LWin) and outgoing (LWout) by the southern wall. As regarding the southern-wall surface temperature, green portions are characterized by a temperature of $22.3\text{ }^{\circ}\text{C}$, while in the traditional façade it amounts to $34.3\text{ }^{\circ}\text{C}$. At the same time, an observation related to the roof surface temperature is needed. In the central buildings, where the green roof technology is applied, the roof surface temperature varied between $26.5\text{ }^{\circ}\text{C}$ and $28.5\text{ }^{\circ}\text{C}$. While on the other buildings, with traditional roof stratigraphy, the temperature significantly increased above $42\text{ }^{\circ}\text{C}$. Both green façades and roofs inevitably affect the users' indoor thermal comfort and the building's energy performance, especially considering cooling energy needs during the summer season. As for energy balance, a significant decrease ($\sim 40\text{ W}/\text{m}^2$) in the LWin parameter occurs between green and traditional façade. The results show that the difference between LWin ($\sim 414\text{ W}/\text{m}^2$) and LWout ($\sim 390\text{ W}/\text{m}^2$) for a green façade is equal to about $24\text{ W}/\text{m}^2$. It is worth noticing that if the southern-wall total surface is considered (1152 m^2), a reduction in energy balance of about 14 kW occurs for 50% of green surfaces, while for 20% and 30% a slight decrease of around 5.5 kW and 8 kW occurs, respectively. Furthermore, if the variation of LWout is considered along the wall height, the solution with green façade is less affected by variation of emitted radiation ($\sim 1\text{ W}/\text{m}^2$). Finally, with respect to the external air temperature outside the wall, it is worth noticing that they are lower for a higher area considering vertical greenery at 50%. Additionally, as regards the results concerning the variation of the relative humidity for the different cooling strategies adopted for the analyzed urban grid, it is proven that the vertical greenery (50%) on the façade is the most influential. In fact, an increase in relative humidity of around 1.6% occurs with respect to the reference case (65.50% average of RH). This is probably due to the evapotranspiration of the green façade. The other cooling strategies are comparable in terms of the relative humidity parameter.

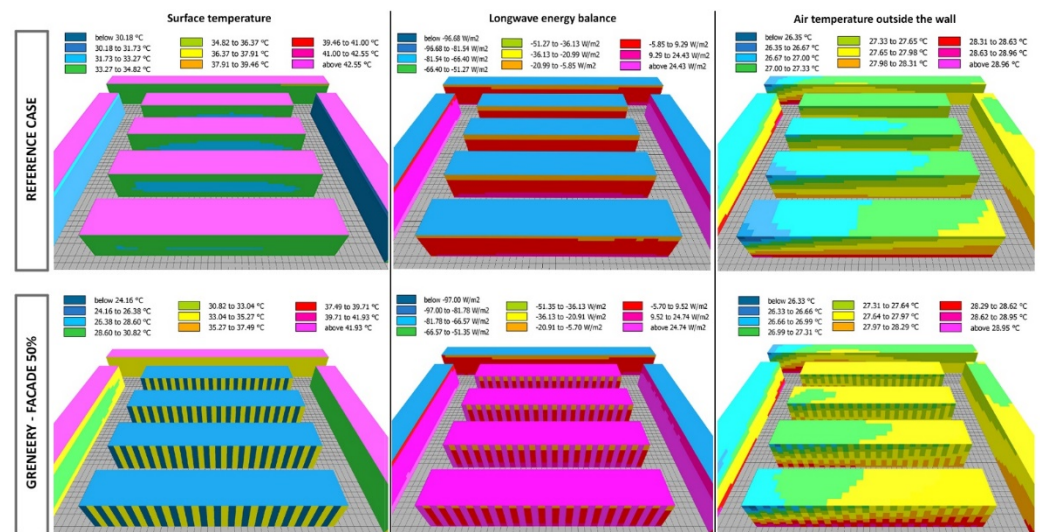


Figure 2. Distribution of surface temperature [°C], longwave energy balance [W/m²] and air temperature outside the wall [°C] (southern) for both reference and vertical greenery at 50% cases.

4. Conclusions

In conclusion, multistorey building types on a typical Italian urban grid were analyzed with respect to some sustainable and cooling improvement strategies for both buildings and urban layouts considering different micro-climate parameters. The most advantageous measure proves to be the substitution of the dark asphalt with a lighter one. This results in a significant decrease in average external air temperature of about 1 °C for multistorey buildings and 1.5 °C for towers. Otherwise, the application of greenery on the southern façade mostly affects the external surface temperature and the energy balance of buildings. For multistorey buildings, the vertical greenery at 50% leads to a reduction in LWin equal to about 14 kW, due to the difference of the external surface temperature equal to 34.3 °C and 22.3 °C for green and traditional façades, respectively. This certainly influences the cooling demand of the building. Finally, for future developments, courtyard building types could be analyzed and some different Italian climate zones could be considered to understand if there are different performances of several cooling strategies.

Author Contributions: C.C. and N.B. conceived and designed the experiments; C.C. and N.B. performed the experiments; C.C. and N.B. analyzed the data; C.C. and N.B. wrote the paper; supervision was by F.B. and V.D.N. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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