

Institut Pascal ; M3G

Thesis supervisor: Evelyne TOUSSAINT (Full Professor) evelyne.toussaint@uca.fr

Co-supervisor : Yassine BELARBI (Assistant Professor), yassine.belarbi@uca.fr; Sofiane AMZIANE (Full Professor), sofiane.amziane@uca.fr

Bio-geo-based passive cooling to mitigate urban heat islands in France by 2100

Summary :

This PhD project is framed by the French national climate adaptation pathway (TRACC), which considers an average warming of about +2 °C by 2030, +2.7 °C by 2050, and +4 °C by 2100 [1,2]. Under these conditions, urban heat islands become a long-term issue for comfort, health, and continuity of use, especially during heat waves and hot nights. The project therefore focuses on passive cooling strategies for pavements, façades, roofs, and building envelopes in order to reduce dependence on active air-conditioning and to limit the associated rise in electricity demand and anthropogenic heat release in cities [3,4].

The research will investigate bio- and geo-based materials and systems able to act through several complementary mechanisms: higher solar reflectance, lower heat storage, coupled heat and moisture transfer, water retention or redistribution, and interaction with water vapour. The considered solutions will include reflective or permeable pavements, earth-based plasters, dense bio-based envelope layers, and water-efficient green systems. The objective is not only to quantify the initial cooling effect, but also to assess how performance evolves under clogging, soiling, ageing, and maintenance constraints, in line with recent work on cool pavements and vegetated systems [5–10].

The methodology will rely on a multi-scale approach combining experimental characterization, thermal and hydric monitoring, microstructural analysis, and hygrothermal modelling. Particular attention will be given to the relation between microstructural indicators, transfer properties, and cooling performance across scales. This positioning builds on previous results obtained on earth-based materials and on the hygrothermal assessment of raw-earth envelopes under contrasted climates [11–13]. The project will therefore compare different solutions within a common framework that includes thermal benefit, durability, water demand, maintenance, and environmental impact.

Beyond the assessment of existing options, the PhD aims to propose a robust comparison and selection framework for a +4 °C France, by linking materials, green systems, resource constraints, and practical implementation in urban areas. The expected outcome is the identification of passive cooling strategies that remain technically relevant, materially sober, and environmentally consistent over time.

Indicative references: [1] Météo-France, 2025; [2] French Ministry for Ecological Transition, PNACC3, 2025; [3] ADEME, Rafrâichir les villes, 2021; [4] Cerema, ISSU national project, 2024; [5] Seifeddine et al., Urban Climate, 2023; [6] Seifeddine et al., Construction and Building Materials, 2022; [7] Wang et al., Renewable and Sustainable Energy Reviews, 2021; [8] Cascone et al., Building and Environment, 2019; [9] Oquendo-Di Cosola et al., Renewable and Sustainable Energy Reviews, 2022; [10] Cascione et al., Construction and Building Materials, 2019; [11] Hamrouni et al., Construction and Building Materials, 2024; [12] Belarbi et al., Energy and Buildings, 2024; [13] Belarbi et al., Journal of Building Engineering, 2025.