Validation of Solutions Toolkit through a Complete Building Energy Simulation: Civitavecchia Case Study,MAKING PEDs Project

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Abstract The development of methodologies that integrate digital tools, technical solutions, and environmental sustainability criteria is key to moving toward climate-neutral urban models. Along these lines, the European project MAKING PEDs aims to plan and test climate-neutral, positive energy districts (CNPEDs) through the use of Digital Twins that support participatory decision-making processes based on real-world data. The project is being implemented in four Urban Living Labs (ULLs) located in Bærum (Norway), Linz (Austria), Sant Esteve de Palautordera (Spain), and Civitavecchia (Italy). This study focuses on the validation of the Solutions Toolkit, a package of solutions in the energy category, by assessing energy performance and hygrothermal comfort through dynamic urban simulation, combining georeferenced databases following the CityGML standard and energy simulation in TRNSYS. The analysis is carried out on a multi-family housing complex built in the 1990s in Civitavecchia, selected as a representative case study of the local housing stock. The objective is to verify, in a controlled urban simulation environment, the impact of the proposed energy measures in terms of reducing energy consumption and CO2 emissions, and improving indoor thermal comfort. The methodology used uses energy simulation with hourly data to determine the current energy performance of each building and estimate its improvement after implementing interventions from the Solutions Toolkit's energy package. This simulation tool is used to perform a thermal comfort analysis based on adaptive comfort (EN16798-1-2019), complemented by the heat index for a more detailed analysis of overheating and the effect of humidity. The toolkit's solutions were analyzed using the Predicted Mean Vote (PMV) and Predicted Percentage of Dissatisfied (PPD) indicators, in accordance with ISO 7730, assessing the level of thermal comfort achieved in the different simulated scenarios. The results show that, although the building has reasonable thermal performance given its construction period, there are significant opportunities for improvement in both energy efficiency and interior comfort. The application of the toolkit's solutions allows for a significant reduction in annual energy demand and a substantial improvement in thermal comfort during the critical winter and summer months, reducing the percentage of thermal dissatisfaction under international ASHRAE 55 and ISO 7730 parameters. It is concluded that this process not only verifies the technical and energy viability of the solutions package, but also its impact on user well-being, reinforcing the validity of the Solutions Toolkit as an adaptable and scalable tool in real-life urban contexts. The Civitavecchia case thus contributes to strengthening the applicability of the MAKING PEDs approach to the sustainable energy transformation of European districts.