

Energy demand and urban morphology: a model to include thermodynamic behavior of built-up contexts

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Abstract In recent decades, many studies have been developed to simulate the energy demand of buildings at the urban scale (UBEM) and to include the of assessment parameters related to urban morphology and, above all, climate variations, which, especially in densely built-up urban contexts, depend greatly on the built environment and the climate.

Currently, alongside existing energy models (top-down and bottom-up), hybrid models are emerging that seek to combine the complexity of physical models with the difficulty of providing complete information required for data-driven models.

Thanks to previous research experience on the relationship between energy consumption and urban morphology in some built-up contexts in the city of Rome and considering the results of the energy demand simulations conducted with bottom-up models (clustering-based method and physics-based models), the paper investigates the influence of the external environment on the overall energy balance of urban buildings and explore possible emergent behaviors in urban building clusters under various climatic conditions.

The starting hypothesis is that the spacing between buildings serves as an interaction parameter influencing their collective thermodynamic behavior. By integrating Computational Fluid Dynamics (CFD) methods and concepts from Statistical Mechanics, we develop an approximate model for urban thermodynamics.

To test this hypothesis, we first simulate a single building maintained at a constant internal temperature under different climatic conditions, measuring its energy consumption. Next, we extend the model to an ensemble of identical buildings to evaluate collective behavior with and without green spaces interspersed between structures.

Finally, we apply these insights to a realistic case study of an urban area in Rome in order to evaluate the impact on energy consumption of the different climatic conditions.

Our results indicate that, according to the proposed model, the linear regime typically observed in the allometric scaling of energy consumption can shift toward a sublinear regime by altering the use of external spaces that, therefore, could play an important role in mitigating energy demand.