

Urban resource flow modeling supports sustainable town and city planning

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The Sustainable Urban Neighborhood modeling tool (SUNtool) simulates hourly urban energy, water and, waste flows to help urban designers optimize the sustainability of their master planning proposals.

The urbanized proportion of the global population recently surpassed 50% for the first time in history. This urban population is responsible for the large majority of human resource consumption, with consequent implications for stocks of natural resources and climate change. However, great opportunities exist to reduce net resource demands in towns and cities by improving the efficiency of buildings and transport systems, by reducing the circularity of resource (energy, water, and waste) flows, and by centralizing resource management (within neighborhoods and districts)—thus benefiting from economies of scale.

For politicians, planners, architects, and engineers to make informed decisions regarding ways to improve and even optimize the sustainability of new or existing settlements, they need some form of modeling tool so that alternative scenarios can be tested. This is the purpose of the Sustainable Urban Neighborhood modeling tool (SUNtool).

After entering the global coordinates (for association with climate data), the user defines a 3D representation of the site of interest. This might relate to an existing or to a proposed settlement. The type of activity accommodated by the buildings (or parts thereof) is then defined to determine default datasets relating to constructional, occupational, as well as heating, ventilating, and air conditioning systems. The user can adapt these default datasets as well as the characteristics of specific buildings or building surfaces, and whether these have embedded solar energy conversion systems. Buildings may also be connected to centralized resource management centers intended predominantly for heating, cooling, or electrical supply. When the project description is complete, it is parsed to a detailed model that solves for hourly resource flows (see Figure 1).¹

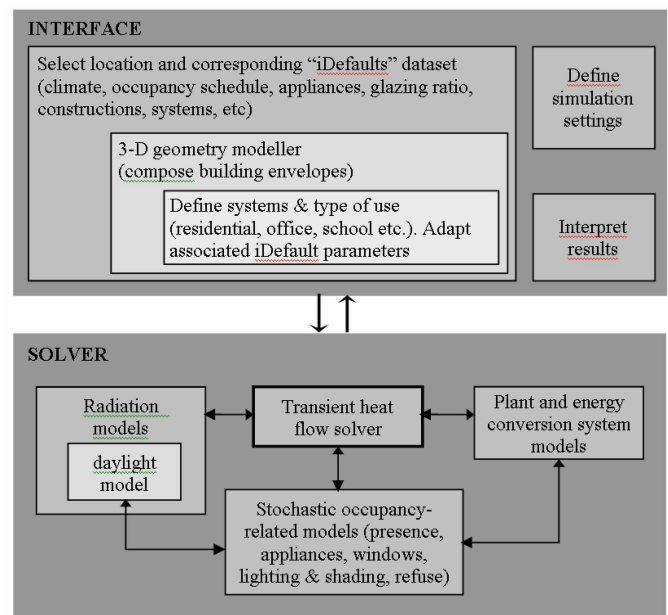


Figure 1. The conceptual structure of the Sustainable Urban Neighborhood modeling tool (SUNtool), which allows users to improve the sustainability of settlements.

At its core, this solver has a simplified dynamic *thermal* model² that simulates the energy required to maintain a defined temperature difference between each building and its outside environment. This model is also directly influenced by a *radiation* model that calculates, in an integrated way, the solar and thermal radiant exchanges at the building envelope, the daylight received within the building, and how other buildings influence these.³⁻⁵ The thermal model is also connected to a family of *stochastic* models⁶ that simulate the presence of occupants⁷ and how they interact with appliances (e.g., computers or ovens) as well as passive (e.g., windows or blinds) or active (e.g., lights or

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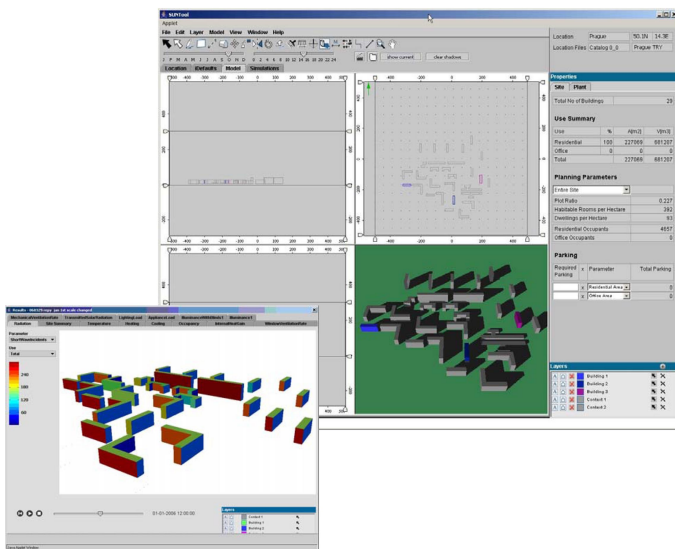


Figure 2. Example application of SUNtool to a district in Prague, Czech Republic. In the lower left is a results screen in which surfaces are false colored according to the annual solar irradiation received.

heating systems) environmental controls for work, sustenance, leisure, and comfort purposes. The stochastic lighting model is also connected to the daylight model.

Finally, a family of *plant and energy conversion system* models calculates the energy demands for space conditioning equipment and the supply of these thermal systems as well as the electrical demands of lights and appliances by renewable and/or non-renewable energy conversion systems. If capacity is insufficient to maintain the desired environmental condition, then the resultant internal state is calculated. Indeed, the end uses of both thermal and electrical energy may in principle be prioritized in cases of under-supply to maintain essential services. This is of particular interest for remote settlements that are not grid-connected, such as those in developing countries.

SUNtool's current version (see Figure 2) can describe a development of a few tens of buildings and simulate the associated resource flows within an hour. Furthermore, some of the simulation variables have been parameterized so that, for example, sensitivity of performance to façade design (e.g., insulation and glazing levels) can be determined and the optimal configuration identified.

Although SUNtool represents a substantial step forward in terms of our ability to model and optimize urban-scale resource flows, there is still a long way to go. For example, the following are not currently modeled: synergetic exchanges between buildings (e.g., waste heat from one as a source for another) and between resources (e.g., energy from waste); the urban thermal

microclimate; capital and running costs; embodied energy content of materials; industrial processes; and transport. Optimization methods are also poorly developed.

However, work currently underway at the Solar Energy and Building Physics Laboratory of the Ecole Polytechnique Fédérale de Lausanne aims to resolve many of the above limitations and to apply the models to the analysis of city districts. It is reasonable to expect that, within the next 5 to 10 years, we will be in a position to simulate the metabolism (all key resource flows) of an entire *city* and to test strategies regarding its optimization along a particular temporal trajectory, say of 50 years. This will truly enable politicians and city planners to formulate urban planning and governance strategies to secure a more sustainable urban future.

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