

Public summary of PhD-thesis of Yasin Toparlar

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Designing the climates of cities

Buildings are responsible from roughly 40% of the global energy consumed. Due to growing concerns over energy resources, improving building energy efficiency has gained importance over the past years. An energy-efficient building is typically designed by making changes to the building itself, such as implementing shading devices. Instead of focusing on buildings themselves, researcher Yasin Toparlar developed a model aimed to analyze and reduce building energy consumption by changing city climates.

Building energy demand depends on various factors such as occupants, building installations, building envelopes and the microclimate around the building. For buildings located in cities, there is the added factor of the urban heat island (UHI) effect. The UHI effect denotes the fact that temperatures inside a city are typically higher than the temperatures in its surrounding rural areas. Since the UHI effect elevates temperatures in cities, it can lead to increased energy use for cooling. In the past, various statistical studies linked urban climate data with energy consumption data. However, the microclimatic conditions inside a city are not the same everywhere in the city, rather the contrary. To consider this complexity, an experimental approach that would require a large number of sensors distribute all around the city will often not be feasible. Therefore, as an alternative, numerical approaches can be considered to simulate the current and future climates of cities.

One of the most suitable numerical approaches is Computational Fluid Dynamics (CFD). With CFD simulations, it is possible to geometrically model a city and then to compute how wind flow and heat transfer occurs in and around the city. In this PhD research, Yasin Toparlar created a CFD model capable of simulating the urban microclimate of any city of interest. The model was tested for replicating the air temperatures measured in Rotterdam and in Antwerp and it showed a high accuracy with air temperatures within 0.9°C of corresponding measurements.

The model is also capable of testing different potential future urban designs. In this thesis, the model was used to evaluate the microclimate of Antwerp based on three design scenarios: 1) A base scenario with the Stadspark of Antwerp present; 2) An alternative scenario where the Stadspark was replaced by an urban square; 3) Another scenario where the Stadspark was replaced by representative buildings. The study showed that the park was capable of decreasing air temperatures in Antwerp by up to 3.4°C. Moreover, a minimal cooling effect of 0.1°C was found still 500 m away from the park.

Noticing this remarkable effect, the research progressed by simulating the microclimate of Antwerp for an entire month (July 2013). The resulting microclimate data was then used to analyze the energy demands of buildings at different locations inside and also outside of Antwerp. The results showed that an office building inside central Antwerp can use three times more energy than an office building with the same properties located outside of Antwerp. In addition, buildings close to the Stadspark of Antwerp had up to 40% less daily cooling demands than buildings away from the same park.

The model produced within the scope of this research can be used to establish city-specific guidelines on energy efficient buildings. In addition, the model can be used to design cities to obtain the best microclimatic conditions for energy efficient building operation.

Title of PhD-thesis: A multiscale analysis of the urban heat island effect: From city averaged temperatures to the energy demand of individual buildings. Supervisors: Bert Blocken (TU/e, KU Leuven), Gertjan van Heijst (TU/e), Bino Maiheu (Flemish Institute for Technological Research).