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Assessing tools relevance for energy simulation at the urban scale: towards decision-support tools for urban design and densification

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Abstract

Urban densification is a way to restrict the world’s urban sprawl but it can strongly impact existing buildings’ energy balance. Dynamic Thermal Simulation (DTS) programs are mainly used at a single building scale and tools made for district-scale or city-scale studies mentioned in the literature are unsuitable for high performance building designers. Therefore, building professionals involved in urban densification projects would greatly benefit from a decision-support design tool able to make an energy evaluation of the involved area, taking into account interactions between the new building and the existing district. This paper presents a district-scale intercomparison of three DTS programs that have various capacities to consider local microclimate effects. The results of this study are used to put emphasis on leading heat transfer modes at a district scale and to estimate tools relevance for urban densification projects design aid.

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1. Introduction and state of the art

World’s population urbanization often goes along with an urban sprawl whose health and environmental consequences are harmful, for instance through destruction of woodlands, wetlands and farmlands [1]. Urban densification can restrict this phenomenon. However, the higher the urban density of a district is, the stronger it is affected by the Urban Heat Island (UHI) effect. Climate change will increase this issue [2]. Moreover, integration of a New Building (NB) in an urban block can strongly impact the neighboring buildings energy balance, modifying their solar potential and radiative balance. Some tools allow to take into account more or less accurately the impact of the surroundings on a NB project, but rarely the opposite. Therefore, it seems useful to develop an appropriate tool able to assist building professionals in upstream design process of urban densification projects.

The analysis of a building’s energy balance can be made in a simplified way with tools that only study the project compliance with the local thermal regulation. In France, the model used for it is not suitable for buildings with various thermal zones, and even less for the energy analysis of a district. More detailed models are implemented in Dynamic Thermal Simulation (DTS) tools like EnergyPlus [3] (E+) or Pleiades+COMFIE [4] (P+C). These programs have been mainly used for studies at a single building scale. They are convenient for professionals that want to quickly know the thermal behavior of a building during a year. Simulation tools like ENVI-met [5], SOLENE-Microclimate [6], EnviBatE [7] and UMET [8] are more appropriate for district-scale studies since they allow to accurately take into account local urban environment effects. However, their calculation complexity made them more turned towards researchers. CitySim [9] is a powerful urban simulation tool that used a detailed district radiation model and can estimate the annual energy demand of each building of a district or even a city. Its simplified building energy model may though be unsatisfying for high energy performance building designers.

DTS integration in a densification projects design aid method seems to be of interest in order to provide a tool that can be understandable by non-specialist professionals. That leads us to the following question: which program to choose for this use? Numerous works have been carried out to compare DTS tools capabilities, concerning a large number of features [10], focusing on the relevance for low-energy building analysis [11] or treating one characteristic more precisely, like the way thermal mass effects are considered [12]. So far as we know, some papers explore opportunities given by new urban building energy models [13] but it is hard to find comparison of well-spread DTS tools ability to conduct district scale energy analysis.

Going from the building scale to the district scale requires to consider among others the UHI effect, characterized by higher temperature in urban areas than in rural areas. This microclimatic phenomenon is the sum of the following factors: urban street canyon geometry - inducing shortwave radiation (SWR) trapping and reduction of longwave radiation (LWR) losses toward the sky -; urban greenhouse effect; thermal properties of exterior surfaces (buildings, ground…); anthropogenic heat; diminution of evapotranspiration and wind velocity alteration [14].

2. District-scale intercomparison of DTS tools

2.1. Tools choice and performances

In order to compare DTS tools performance for urban densification project energy analysis, we selected P+C for its wide use in France, E+ for its international reputation and the Modelica library BuildSysPro [15] (BSP) that can be used either with OpenModelica or Dymola (OM/Dym) to perform DTS. The latter is particularly interesting due to the International Energy Agency research project “Annex 60” aiming to federate – among others – the building energy community around Modelica language and Functional Mockup Interface standards [16]. We used these tools to calculate, by DTS, annual heating and cooling needs of buildings’ models described below. About UHI effect modelling, we focused on solar masks and SWR reflection but do not modelled alteration of local outdoor temperature.

2.2. Test case

For this study we have chosen a students’ work from ENSAV architecture school (Versailles, France), which is involved in the ANR MERUBBI project [17]. They modelled a part of an existing residential district of Strasbourg
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