Project description prospective CIM PhD student

Project title: Urban microclimate modeling in future cities

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Project description

In the ambition to attain a fossil-free society, future smart cities can play a significant role by increasing energy efficiency and local renewable energy generation combined with smart control of interconnected systems. Such future smart cities need to be theoretically modeled and studied in detail to provide pertinent information for municipal and governmental city planners. This is further motivated by the Swedish governmental research directive [Gov], which proposed that smart and sustainable cities should be one of the main research directives set up by the Swedish government over a ten year period 2017-2027.

MIT Sustainable Design Lab recently established a key role model for energy analysis of cities known as urban building energy model (UBEM) for Boston, USA [MIT]. The model draws the required information from existing urban structures and generates the hourly energy demand of the whole city to be used in urban energy planning and sustainable urban development. Within this context, a similar research is also undertaken at the division of Civil Engineering and Built Environment, where research into solar power, electrification of transport and energy efficiency has been conducted using (and developing) advanced mathematical, statistical and machine learning models, see [Luthander, Munkhammar, Lingfors].

To integrate the smart city approach, the suggested UBEM at the division of Civil Engineering and Built Environment demonstrates not only the energy analysis of buildings but also its interdependencies with occupants’ behavior and urban human activities, district energy systems (i.e., electricity grid and district heating networks), and renewable energy resources (particularly solar power) as well as smart control strategies. Yet, the interconnection of the urban microclimate with the energy performance of buildings is still to be investigated.

The proposed PhD project would extend UBEMs with microclimate simulations for building clusters as well as the entire city. This work implies utilizing numerical analysis of heat and mass transfer using computational fluid dynamics (CFD) and applying this to the complex terrains of cities and later collaborating in integration of the urban microclimate model into UBEMs.

To advance the field of CFD urban microclimate modeling, a recent review of 183 previous studies [Topalarlar] came to the conclusion that both theoretical and practical advances need to be made. This task is highly suited for an interdisciplinary CIM PhD student. Among the theoretical advances mentioned are, in general, improved reliability and predictive capability, and, more specifically, a need for developing LES (Large eddy simulation) instead of RANS (Reynolds-averaged Navier-Stokes) simulations for cities. LES is potentially more accurate but attempted in very few of the previous works. Further advances on turbulence modeling are also required, in particular statistical modeling of variability of heat in space and time. The development of approximating mathematical models that could model essential parts of the system would be part of the project as well, as these could be used to avoid heavy simulations and yet achieve useful results. On the practical side, more detailed model validation is needed and more urban locations need to be considered, as well as applications to urban design and case studies.
This work will be closely related to the work of Fatemeh Johari, who is a PhD student at the division of Civil Engineering and the Built Environment, working on Urban Building Energy Modeling. A recent example of research from our group on this topic is [Fatemeh], in which different simulation tools can be possibly used as a core in UBEM were evaluated. Fatemeh is part of the research project “Activity based energy- and mobility modeling on city level for planning of future cities”, funded by Viable Cities, which is a collaboration between Uppsala University, KTH, WSP, Vattenfall RnD, Borlänge Energi, Borlänge municipality.

The funding for the new PhD student will, in addition to the funding from CIM, be primarily faculty funding from the division of Civil Engineering and Built Environment. Other sources of funding may also come from closely related research projects.

The Built Environment Energy Systems Group within the division of Civil Engineering and Built Environment has a long tradition of investigating the potential for renewable energy integration and energy efficiency in the built environment by using advanced mathematical models and simulations. This opportunity is a chance for the new PhD student to take the next step in urban energy modeling by integrating it with state-of-the-art mathematical models for microclimate analysis in cities in order to obtain state-of-the-art models for this. The intention is that the PhD student will also collaborate with international researchers at other universities on these topics.

References


