Towards a 3D Spatial Urban Energy Modelling Approach

Jean-Marie Bahu, European Institute for Energy Research (EIFER), Karlsruhe, Germany
Andreas Koch, European Institute for Energy Research (EIFER), Karlsruhe, Germany
Enrique Kremers, European Institute for Energy Research (EIFER), Karlsruhe, Germany
Syed Monjur Murshed, European Institute for Energy Research (EIFER), Karlsruhe, Germany

ABSTRACT

Today’s needs to reduce the environmental impact of energy use impose dramatic changes for energy infrastructure and existing demand patterns (e.g. buildings) corresponding to their specific context. In addition, future energy systems are expected to integrate a considerable share of fluctuating power sources and equally a high share of distributed generation of electricity. Energy system models capable of describing such future systems and allowing the simulation of the impact of these developments thus require a spatial representation in order to reflect the local context and the boundary conditions. This paper describes two recent research approaches developed at EIFER in the fields of (a) geo-localised simulation of heat energy demand in cities based on 3D morphological data and (b) spatially explicit Agent-Based Models (ABM) for the simulation of smart grids. 3D city models were used to assess solar potential and heat energy demand of residential buildings which enable cities to target the building refurbishment potentials. Distributed energy systems require innovative modelling techniques where individual components are represented and can interact. With this approach, several smart grid demonstrators were simulated, where heterogeneous models are spatially represented. Coupling 3D geodata with energy system ABMs holds different advantages for both approaches. On one hand, energy system models can be enhanced with high resolution data from 3D city models and their semantic relations. Furthermore, they allow for spatial analysis and visualisation of the results, with emphasis on spatially and structurally correlations among the different layers (e.g. infrastructure, buildings, administrative zones) to provide an integrated approach. On the other hand, 3D models can benefit from more detailed system description of energy infrastructure, representing dynamic phenomena and high resolution models for energy use at component level. The proposed modelling strategies conceptually and practically integrate urban spatial and energy planning approaches. The combined modelling approach that will be developed based on the described sectorial models holds the potential to represent hybrid energy systems coupling distributed generation of electricity with thermal conversion systems.

Keywords: 3D City Model, Agent-Based Modelling, Energy Systems, Heat Energy Demand, Urban Planning

DOI: 10.4018/ij3dim.2014070101
1. INTRODUCTION

Today’s needs to reduce the environmental impact of energy use impose dramatic changes for energy infrastructure and existing demand patterns (e.g. buildings) corresponding to their specific context. The analysis of the building conditions such as morphology, typology, heating energy demands, etc. at a local level would allow urban planners and decision makers to target building refurbishment potentials.

In addition, future energy systems are expected to integrate a considerable share of fluctuating power sources and equally a high share of distributed generation of electricity. Energy system models capable of describing such future systems and allowing the simulation of the impact of these developments thus require a spatial representation in order to reflect the local context and the boundary conditions.

Furthermore, simulation through an Agent-Based Modelling (ABM) approach allows for representing the dynamic behaviour of the system over time, in which the different entities of the system (called agents) are represented autonomously and interact with a common environment. This approach can be then used to reflect operational strategies as well as decentralised decision making in distributed energy systems by representing the communication between the agents.

In the urban context multiple interacting systems are not only coupled by their spatial proximity but as functional units (virtual power plants). Intelligent management of resources often pursued in smart city approaches requires integrated capabilities to model interactions among the various urban resource flows.

The research focus on the spatial aspects of energy modelling for distributed energy system. In general, dynamic models provide insights into the process inherent in the evolution of a system, whereas, Geographic Information System (GIS) provide spatial databases and allow for spatial analysis, interpretation and visualization of data. Combining complex dynamic system modelling (e.g. ABM) and GIS will enable to develop a model that is both dynamic and spatially explicit. The applications and advantages of such models are widely discussed in (Despotakis & Giaoutzi, 1996; Hazelton, Leahy, & Williamson, 1992). However, with the increasing maturity of GIS and availability of 2D and 3D granular datasets, 3D GIS has emerged as an essential tool to enhance the dynamic modelling capabilities. The integration of ABM and GIS technology allow developing experimental prototype models for simulating complex spatial systems representing for example urban growth, traffic congestion as well as ecosystems such as bird migration. A detail discussion is available at (Andrew T. Crooks, Hudson-Smith, & Patel, 2010; Heppenstall, Crooks, See, & Batty, 2012).

Energy systems today are facing several challenges, due to the profound paradigm change that the sector is undergoing. Some examples to be mentioned are:

- Two-way communication between the building and responsible entity for load balancing
- Control of lighting, heating, cooling, ventilation, IT, and other energy using systems
- Optimized coordination of energy loads, on-site energy generation and energy storage - based on local or central smartness
- Automatic demand response to dynamic pricing or control signals from the grid and impact on urban energy system

Current energy system models are often static and based on linear approaches, which do not take into account the dynamics of the system. However, for many of the points mentioned above, the representation of the interactions and communication flows is essential. In addition, classical engineering tools for power systems are not always linked to the spatial dimension of the system. Availability of matured GIS technology and granular 3D GIS data impose an added value to the modelling of energy systems.

The aim of this paper is to describe two recent research approaches in the fields of geo-localised simulation of thermal energy...
Production of Landslide Susceptibility Map using Bayesian Probability Model
www.igi-global.com/article/production-of-landslide-susceptibility-map-using-bayesian-probability-model/138260?camid=4v1a

Web-Based Geospatial Services: Implementing Interoperability Specifications
www.igi-global.com/chapter/web-based-geospatial-services/70434?camid=4v1a