Simulation-Based Total Energy Demand Estimation of Buildings using Semantic 3D City Models

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ABSTRACT

The present climate and environmental policy efforts require comprehensive planning regarding the modification of the energy supply and infrastructures in cities. The strategic planning of the different measures requires a holistic approach and the combination of extensive and complex information. Within this paper, current developments in the context of the project Energy Atlas Berlin are presented. The Energy Atlas Berlin is based on the semantic information model of CityGML and provides an integrative data backbone for the common spatio-semantic representation of the city structure including energy related information of different themes. The virtual 3D city model of Berlin (mainly LOD2 building models) is used as data basis and has been enriched by information of different stakeholders and disciplines. In order to ensure the energy supply, the knowledge about the energy demands of buildings during the planning and optimization of measures is of great strategic importance. Therefore, this paper focuses on the city-wide estimation of the energy demands of buildings including heating, electricity and warm water energy in the city of Berlin using available official geobase and statistical data integrated within the Energy Atlas Berlin. It is explained in detail how the spatial and semantic properties of the 3D building models are being used to estimate these energy demands on an individual building level for the entire city.

Keywords: 3D, City, CityGML, Demand, Energy, Estimation, Models, Semantic

INTRODUCTION

Motivation “Energy Turnaround”

In order meet the climate and environmental policy objectives in Germany, various measures are being discussed, which lead to major challenges regarding the planning of energy related urban infrastructures. Planning comprises e.g. the determination of locations for new power generating facilities like photovoltaic, geothermal and decentralized combined heat and power stations, the widespread introduction of e-mobility solutions and hence the grid development as well as large-scale energetic building rehabilitations. Typically, the possible measures and the climate and environmental policy objectives contradict each other, e.g. the introduction...
of coal-fired power plants or combined heat and power stations lead to an increase in CO$_2$ and particulate emissions and the propagation of e-mobility leads to an increasing electricity demand in the inner cities, which again might be partially compensated by introducing renewable energies, i.e. photovoltaic. These examples illustrate that environmental and energy planning must be holistic in order to allow an optimisation of all measures concerning the overall balance of energy demand, production, and pollution reduction. In addition, further aspects such as the securing of energy supply, urban planning regulations, building codes, acceptance by citizens, forecasts about the urban development and the relationship between costs and benefits have to be considered during the planning phase (Kaden et al., 2012).

One major goal of the climate policy of the city of Berlin is the reduction of CO$_2$ emissions by 40 percent by the year 2020. The official Berlin Environmental Relief Program (SENGUV, 2011) focuses on the building stock and their heating energy demand, which has a share of up to 80% of the total energy consumption of a building and up to 40% of the total urban energy consumption in Berlin (AGEB, 2012). Therefore, the aim is to increase the energy efficiency of buildings and thus the reduction of CO$_2$ emissions by comprehensive energetic retrofitting measures. Furthermore, the efficiency of the electrical power and space heating production shall be increased by introducing renewable energy sources, in order to reduce the current CO$_2$ emissions.

One major requirement for the modification of energy related urban infrastructures is to ensure the energy supply of the buildings. Thus, knowledge about the specific energy demands of all buildings during the planning phase of actions is of great strategic importance, as the energy production and distribution infrastructure must be designed for the current and future consumptions and peak loads. Although actual consumption values are available within the different energy companies, these data are often not available due to privacy regulations and economic interests. However, in order to facilitate demand-optimized planning of actions, a number of approaches for the estimation of energy demands have been developed and published in the past.

**Related Work and Discussion**

The following approaches for the estimation of the heating energy demand are based on the hypothesis that there is a strong correlation between specific building and socio-economic characteristics and the heating energy consumptions. However, the approaches comprise different calculation methods and input data and have been developed for different purposes and scales. Whereas in the past estimations about energy demands have often been done on a smaller scale, e.g. for blocks, districts, or the entire city, present approaches address the building scale, allowing demand-optimised energy planning. The existing methods can be classified into two different general approaches; top-down and bottom-up.

The top-down approach is a macro-economic approach in the energy industry to model energy demand and supply, based on the study of the interaction between the energy sector and economy in general. Common input parameters are, for example, gross domestic product, energy prices, per capita income, but also general climate conditions. Top-down methods are mainly used to determine a comparative relationship between the temperatures to be expected, the annual consumption data and the respective price-fixing on a small scale, e.g. for a district, city, or state.

In contrast, the bottom-up approach is a microeconomic approach with the possibility for an individualized estimation of the energy consumption of buildings or a group of buildings. It is suitable for analyzing actions, i.e. the replacement of heating systems or building refurbishments in order to estimate, for example, the realization of CO$_2$ emission reduction targets. The bottom-up approach includes two general groups of methods, the statistical methods and the building simulation methods.
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