Energy & Buildings 164 (2018) 254–265

Contents lists available at ScienceDirect

Energy & Buildings

journal homepage: www.elsevier.com/locate/enbuild

Methods for optimising energy efficiency and renovation processes of complex public properties

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ARTICLE INFO

Article history:
Received 30 August 2017
Revised 20 November 2017
Accepted 23 December 2017

Keywords:
Assessment tools
Optimisation of renovation processes
Climate-neutral
Energy efficiency
Building physics
Sustainable renovation

ABSTRACT

The HoEff-CIM-project aims at developing automated inventory and evaluation tools, which support portfolio managers to plan and perform energy efficiency measures within large properties, considering their highly heterogeneous usages and structural specifications. The project covers models and tools, which facilitate the assessment of existing building stocks and the recognition of state of the art energetic reliance and renovation concepts. These concepts are then automatically adapted to different structural, technical and usage dependent parameters. The tools will help to analyse building physics and building services but also to empower strategic planning and energy distribution schemes. Therefore, an intuitive dataflow was needed that streamlines the process from data acquisition (building inspection), evaluation of buildings and renovation measures to the elaboration of specific building energy reports; all resulting in master plans for building complexes as well as systematic renovation strategies for larger properties. Particular emphasis was put on the determination of joint influences of building construction and building services on potential energy savings. Accompanying this quantification process, uncertainty and sensitivity analyses have been performed via Bayesian Network theory and statistical analytics. Different renovation concepts have been analysed, modelled and evaluated regarding their energy saving potential, usability as well as ecologic features. A ranking system was developed to assess specific energy demands of different building usages and to identify the most effective renovation measures. The result is a fully transparent, interactive and easy to understand decision-making methodology. The holistic approach contributes to create climate neutral building stocks and consequently to reach the energy saving and environmental goals defined by national and international governmental institutions (e.g. EED).

1. Introduction and aim of the project

In the context of worldwide climate change and intensive energy consumption, the German environmental goals demand to reduce greenhouse gas emissions by 80%–95% until 2050, related to the emissions of 1990. The building sector in Germany accounts for more than 40% of these greenhouse gas emissions. One approach to reach this goal is to increase the amount of energy efficient buildings and to develop a high share of up to 60% of renewable energies of the total energy supply [1].

The HoEff-CIM-project (“Energieeffiziente Hochschule – Campus Information Modelling”; eng. Energy Efficient University – Campus Information Modelling) has developed data collection and assessment tools, strategic support schemes and a recommendation model to empower and engage portfolio managers to implement more holistic energetic and sustainable renovation measures on the most suitable buildings with minimised cost, time and expertise. The tools streamline renovation processes by organising and ranking buildings and energy efficiency measures according to their energy saving potentials. On the case study of the Ludwig-Maximilians-Universität München (LMU), the tools and methods were validated and it could be shown on a real case, how the transformation of large and heterogeneous properties can contribute to the ambitious environmental goals. The presented project tries to weight and quantify the joint interactions of building-usage, building physics, building services and the energy management of a great number of heterogeneous buildings. The developed strategies are adjustable and therefore applicable for other universities as well as large and complex private properties with various usages.

The starting point of the project was the development of a web-based data acquisition tool (QuickCheck-Tool, QCT) which provides a structural assessment of single buildings and entire building ensembles. The tool optimises and facilitates the inspection

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https://doi.org/10.1016/j.enbuild.2017.12.060
0378-7788/

procedure for complex properties. The QCT contains preliminary information of the building: e.g. location, building age, construction type and architecture. This sets the basic data for the on-site visit, which helps to optimise and accelerate the workflow to collect current information about the building. The preliminary data and new collected on-site data, like specific construction types and their conditions, are processed automatically and condensed into a specific report. In the subsequent step, this information is attached to energy related parameters, like U-value or air-tightness, in order to determine energy demands, usage profiles, influence of building physics and buildings services. In addition, renovation and modernisation measures were incorporated into the model.

The HoEff-CIM project is based on the forerunner project HoEff (completed in 2012), where 16 energy classes were defined by analysing 1600 different usage profiles of the LMU. In HoEff-CIM the newly developed reference room method (RRM) uses the previously developed energy classes in combination with recent collected building information (QCT) to calculate energy demands and potential energy savings. The RRM dynamically implements the QCT data into the open source building simulation software EnergyPlus of the U.S. Department of Energy (DOE) [2] in order to perform immediate building performance simulation. Via RRM the energy demand of single rooms of various usages and distributions is calculated, combined and extrapolated to full building size, which accelerates and facilitates the simulation process significantly. As a summarising output, all findings have been condensed in an energy master plan using LMU properties as a case study. The findings and mentioned tools are published and available to the public under www.hoeff.info.

2. State of the art

This project builds on results of the previous HoEff project (University of Applied Sciences Munich, [3]). Before HoEff, the institute "Wohnen und Umwelt GmbH (IWU)" had carried out a project, which allows a simplified, static analysis of energy demand of non-residential buildings. With the help of the so-called TEK-Tool standard building usages can be modelled and their energy performance impact can be calculated and benchmarked against reference values. Insufficient information on specific building ages was handled via statistical data analysis [4]. Disadvantages of the tool are the oversized data pool with too many reference values and the fact that results refer exclusively to the final energy demand [5]. Some of these aspects have been improved in HoEff-CIM.

Another tool, which follows a similar approach as the HoEff-CIM QCT is the Excel-based tool "EnerCalC". Started as a European research project in 2011, EnerCalC calculates energy demands and energy generation frameworks for non-residential buildings. It creates multiple-zone reference buildings and estimates the energy demand according to the German standard DIN V 18599. The project team developed a scientific approximation method that reduces the amount of input building data and thereby the effort and cost for building owners when collecting data. A big difference to the QCT, which assesses only existing building stocks, is the focus on the energy assessment of buildings in the early design phase [6].

Another project dealing with data collection, data evaluation and intelligent building data analysis of large properties, is the Epiqr project of Fraunhofer IBP [7]. Likewise QCT, it was designed to inspect and evaluate large building stocks in short time to provide a detailed renovation and energy-efficiency action plan. After the project ended, the tool was transformed into a commercial software, which is now mainly applied on private building stocks. The QCT on the other hand, is designed as freeware and to be adaptive and flexible for any requirements of future users and applications.

Another approach to estimate the energy consumption, the life cycle impact and financial value of renovation measures, is the so-called "ASCOT" calculator. Based on the ISO 12790, the steady state tool assesses the current energy consumption and renovation improvements based on adjustable data pools (e.g. modifiable U-values or adjustable air-tightness). It furthermore incorporates life cycle analysis, which helps to assess the ecological potential of renovation measures and materials [8]. The tool also features a cost/benefit optimisation based on the value of energy saving and predefined cost data. Similar to the ASCOT framework, the QCT relies partly on a steady database to use, for example generalised thermal bridge assumptions. However, HoEff-CIM implements additional dynamic simulation and a web-based client, which helps to inspect the buildings on-site and recognise damages, concerning the current building condition and usage-characteristics.

Seen from an implementation perspective, some case studies of the "International Energy Agency's – Energy in Buildings and Communities Programme" (IEA-EBC Annex 51) show that communities and public stakeholders can lead in energy efficient transition and take the responsibility to perform lighthouse projects [9]. The focus of these case studies is mainly the reduction of energy demand of communities and quarters via an optimisation of renovation strategies and regional energy frameworks by supporting decision makers [10]. One purpose of HoEff-CIM is to assist regional governments in how to handle local energy and local climate policy decisions and perform effective planning of energy concepts for the municipal sectors.

3. Methodology

HoEff-CIM covers all phases of energy efficient building renovation (see Fig. 1). It eases the data collection and building assessment through the Quick Check Tool (QCT). The core of the project is a guided inspection system, which can be installed on mobile devices and should support even unexperienced users. The QCT incorporates sustainability criteria in early planning and design phases. The whole data collection is closely related to predefined parameters, which were proven to have significant influence on the comfort and energy performance of buildings. Uncertainty analysis via statistical models has been used to validate and rank these variables and to avoid an agglomeration of unnecessary data. With its built-in analysis and reporting tools, the QCT accelerates the intake of data, facilitates the weak-point analysis and helps to identify the building with the highest energy saving or renovation potential in a building stock. Additionally, several tools and databases were developed to allow a quick and reliable energy and thermal assessment of specific buildings. The underlying algorithms were adapted to the needs of facility managers of universities and heterogeneous building specifications and usages.

The main operator in the framework is the so-called Reference Room Method (RRM). RRM combines the QCT with the simulation tool EnergyPlus and performs dynamic energy simulations on defined type-rooms. It extrapolates these rooms to calculate the full energy demand of a building. The type-rooms are defined by parameters like characteristic usages, structural specifications or installed building services, which values are collected via the QCT. The results help to rank single buildings according to their potential for energy savings and possibilities for deep renovation measures. The simplicity and transparency of these automated tools and decision-making schemes will motivate and engage portfolio managers and owners to implement energy efficient measures. The methods and tools were closely coordinated with the office for energy management of the LMU.

By assessing the requirements and characteristics of the LMU, the QCT and RRM have been adjusted to practical criteria. The LMU building stock was categorised according to typical building ages,