Energy and Buildings 131 (2016) 172–183

Contents lists available at ScienceDirect

Energy and Buildings

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

Electrical energy consumption and utilization time analysis of hospital departments and large scale medical equipment

Nils Christiansen[a,*], Martin Kaltschmitt[a], Frank Dzukowski[b]

[a] Hamburg University of Technology (TUHH), Germany
[b] Klinik Facility-Management Eppendorf GmbH (KFE), Klinik Medizintechnik Eppendorf GmbH (KME), Germany

ARTICLE INFO

Article history:
Received 8 July 2016
Received in revised form
11 September 2016
Accepted 12 September 2016
Available online 17 September 2016

Keywords:
Hospital energy consumption
Internal loads
Electrical equipment
Medical equipment

ABSTRACT

Predicting the loads of electrical devices is an important part of modeling the energy flows in buildings. In non-residential buildings these loads can have a significant impact on heating and cooling requirements. In the case of hospitals this holds true particularly for areas directly connected to diagnostics and medical treatment. Even though the amount of information concerning these loads has increased in recent years, detailed information based on measured data remains scarce. Thus, within this paper over 20,000 h of measured data for operating theaters, intensive care units, examination and treatment rooms as well as large scale medical equipment are analyzed and evaluated. The used methodology allows for the determination of area-specific operating hours and a prediction of time-dependent electrical loads in different hospital departments. It was found that a differentiation of weekdays and weekend days is not appropriate for intensive care units, while the examined operating suites show surprisingly strong similarities with regular “office hours” within the assessed hospital. The presented values extend findings from other recent studies in this field and give a more detailed separation of individual contributions from lighting and different classes of medical equipment.

© 2016 Elsevier B.V. All rights reserved.

1. Introduction

The German government’s plan to reach a “nearly climate-neutral building stock” by the year 2050 is based on two pillars: a high share of renewable energies within energy provision and a highly efficient use of energy [1]. This appears to be a very ambitious target, as building users can be assumed to demand rather higher than lower comfort levels in the future [2]. Thus to reach this overarching political goal, the main target of building energy optimization must be the delivery of similar or increased (energy related) functionalities with continuously reduced greenhouse gas (GHG) emissions. To reach this goal, based on the respective local circumstances, an (economic) compromise between higher shares of renewable energies on the one hand side and improved efficiency measures to reduce demand on the other hand side is always required. Such an economically driven GHG emission reduction strategy might be needed to be adjusted over time with technical progress due to innovations [3].

It is beyond dispute that identifying appropriate measures for increased energy efficiency in buildings and elsewhere requires a profound understanding of the current energy demand situation. This implies the necessity to provide well-founded information that enables facility managers to evaluate their respective buildings. The main challenges for providing such reliable reference values for energy consumption even in buildings of the same category (e.g. hotels, offices, hospitals) are their individual composition, their site specific characteristics as well as their different usage patterns [4]. Additionally, the actual output of the invested building energy is difficult to measure [5], which leads to the requirement of an adequate breakdown of the overall energy demand. Making load models available for a variety of building types and subdivisions is thus an important step towards increased transparency and easier identification of efficiency potentials [6]. This is particularly true for heterogeneous building types like hospitals, which are known to show a very large variety of area specific energy consumption [7] that remains largely unexplained despite increasing research activity in the past decade.

One of the main factors that complicate hospital buildings’ energy evaluation is the scarcity of reference values aimed at the primary aspect which sets them apart from other building types like office buildings or hotels: the vast variety of medical equipment, which increased steadily in recent years. While the necessity to include such load data in energy flow calculations is in general widely accepted [8], the availability of reliable and clearly defined

* Corresponding author.
E-mail address: nils.christiansen@tuhh.de (N. Christiansen).

http://dx.doi.org/10.1016/j.enbuild.2016.09.023
0378-7788/© 2016 Elsevier B.V. All rights reserved.

data is still very limited and their elicitation requires cumbersome empirical assessments.

Against this background, the work presented here shows the results of the evaluation of a large collection of measured data together with a methodology that allows for an analysis of how well such data collections represent a certain category of electrical energy consumers and in what way representative utilization hours can be inferred. The data encompasses over 20,000 h recorded in a large German University Medical Center and offers detailed insight into the various loads in operating theaters, intensive care units, examination and treatment rooms and of large scale equipment like linear accelerators and MRI[1] scanners.

2. State of knowledge

Energy related evaluation and benchmarking in non-residential buildings have been under investigation for many years and a large number of publications is available in this field (e.g. [9–12]). Used methodologies range from empirical analysis of building data on a macro level (e.g. [13]) to detailed modeling and simulation of selected building parts (e.g. [14–16]).

With respect to hospitals and other buildings in the healthcare sector, the availability of sample figures is naturally far more limited. Furthermore, it appears that there are no generally accepted operating parameters like utilization hours. Some publications even expect hospitals to work on a 24 h schedule [17] for simplification; some authors found that daily load fluctuations in an examined hospital were very low [6]. This leads to the questions what factors are causing the still existing fluctuations and whether such a continuous energy demand is truly justified or rather owed to poor building controls.

A satisfactory and justified answer is difficult to find and as a result, scientific publications that deal with energy efficiency in hospitals often revert to focusing on efficiency measures that are not only related to hospitals but which are valid for all kinds of buildings. For instance, a reference hospital was simulated with basic load data under different climatic influences and configurations and mainly lighting, ventilation and fenestration measures have been identified to be most important for the overall energy demand [18]. These same results have been found in [19], also without much consideration of hospital-specifics. Whereas the results certainly have validity under the specific circumstances of the investigated buildings, the question remains in how far they can be transferred to other cases.

A good illustration of this transferability problem are the results presented in Refs. [20,21], where lighting demand in the investigated hospitals was found to make up for 12 % and 36 % of total electricity demand, respectively. Both figures may very well be correct and justified, but it seems doubtful that the whole building level, at least without additional adjustment parameters, is an appropriate choice for general statements about hospital energy consumption. And this is only one example of numerous others to be found in literature.

This uncertainty is particularly relevant in terms of electrical energy consumption, whereas thermal modeling is a well-established discipline which relies more on easily-available meteorological data than on isolated loads inside the buildings. A strong focus on electricity is yet becoming more and more important, because the demand for electricity has been on the rise for several years due to increasingly extensive treatment equipment [22] and will most likely continue to do so due to more advanced equipment with improved performance to be installed in the years to come [23]. Nowadays, hospitals in industrialized countries are practically unable to function without electricity [24]. The fact that this electrical equipment increases the internal heat load adds to the necessity of providing more accurate predictions especially in modern well insulated buildings.

Being able to predict, assess or evaluate the energy demand in hospitals (electrical as well as thermal) will be increasingly dependent on improved knowledge of the internal load and the patterns that govern their use. It was found that even widely acknowledged target values especially for energy intensive hospital areas like operating theaters and laboratories can significantly underestimate actual consumption [25]. Without more information on the breakdown of electrical energy consumption it may not be possible to identify the reasons for these discrepancies and consequently to achieve more reliable assessments that enable the exploitation of existing efficiency potentials.

The highest level factors into which consumption can be divided are load and utilization time. Whereas the most prominent loads, medical equipment and lamps, are mainly dependent on their manufacturers' technological implementations, the way they are operated is in most cases determined by the users and the respective tasks that need to be performed.

Findings that a major share of large scale imaging equipment is only used during daytime [26] prove that at least in certain areas hospital energy consumption does indeed follow a non-steady pattern and a 24 h operation is not always a given. It is widely known that user behavior has a significant impact on the extent to which energy is consumed [27], and it would appear surprising that this could be fundamentally different in hospitals. One approach to explain how constant consumption and user influence might be connected can be drawn from a study of science laboratories, in which it was found that scientists considered their task to be too important to pay attention to energy conservation [28]. This indifference to energetic issues has also been observed in hospitals and may well be only partly owed to safety concerns. Other reasons might be a lack of incentives, which is obvious in an environment where users usually have no monetary gain from realizing savings, limited or no information about the magnitude of consumption and the necessity to share equipment with colleagues, leading to the impression that one's own impact is rather limited [29]. More detailed information about the use of electrical energy in hospitals will thus not only give a better understanding of the loads from the multitude of technical devices, but also allow for a better understanding of the patterns in which medical staff uses them.

3. Methodology

Prior to starting measurements of electrical energy consumers in buildings it is necessary to define the types of equipment and consequently the targeted level of detailing. The most relevant limitations for such an assessment are resource and accessibility constraints. Resources include the available time for the measurements, the existing measuring equipment and the useable manpower. Accessibility refers to safety restrictions on the one hand and physical access to power lines on the other hand. When preparing an empirical study involving measured data the methodological approach should be adjusted accordingly. Fig. 1 presents an orientation for the focal shift depending on the respective constraints. A very basic goal of practically any research activity lies in the expansion of the current state of knowledge. The question is then, how this goal can best be served under the given circumstances.

[1] MRI: Magnetic Resonance Imaging.

Download English Version:

https://daneshyari.com/en/article/4914295

Download Persian Version:

https://daneshyari.com/article/4914295

Daneshyari.com