Energy and Buildings 129 (2016) 186–198

Contents lists available at ScienceDirect

Energy and Buildings

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

A proposal of energy performance indicators for a reliable benchmark of swimming facilities

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ARTICLE INFO

Article history:
Received 10 August 2015
Received in revised form 13 May 2016
Accepted 13 July 2016
Available online 18 July 2016

Keywords:
Benchmarking
Buildings
Energy efficiency
Energy use
Energy performance indicator
Swimming facilities

ABSTRACT

The main research question tackled in this work is which energy performance indicator should be used to benchmark energy usage in swimming facilities. After the design and administration of a survey, data from 43 Norwegian swimming facilities were collected. A quality assurance process was applied to the collected data, which were than stored in a database, resulting in 176 datasets. A correlation and multiple linear regression analysis were carried out to identify (i) to what extent a number of independent variables characterising swimming facilities are singularly related to energy performance and (ii) to what extent the identified independent variables can together explain the variation in energy performance. Unlike in residential and commercial buildings, climate does not drive the total energy performance of swimming facilities. Instead, overall water usage of the facility was observed to be most strongly correlated with the energy usage, followed by the number of visitors attending in a year, the usable area of the facility and the water surface of the pool(s). It is difficult to obtain accurate values for any of these variables except for the water surface. A multiple linear regression analysis showed that the number of visitors is the variable that explains most of the variation in the energy performance of swimming facilities. Therefore, the authors conclude that, for benchmarking purposes, the energy usage of swimming facilities, shall be preferably normalised with respect to the number of visitors. If no reliable visitor count is available, then water surface can be used.

1. Introduction

Buildings account for approximately one-third of worldwide energy use [1,2]. A building category that has received little attention in the literature is sports facilities, among which ice rinks and swimming facilities consume exceptionally high amounts of energy [3]. Fig. 1 shows the average delivered energy (DE) for the ten largest building categories in Norway [4]. Energy use in sports facilities can range between 150 and 300 kWh/m^2 of useable area (UA), and swimming facilities are reported to use between 400 kWh/m^{2}UA and almost 1 600 kWh/m^{2}UA [3,5–9]. Swimming facilities are defined in this paper as at least one artificial indoor pool filled with water to enable swimming or other leisure activities, plus its required additional facilities (e.g., changing rooms, entrance hall etc.). Pools can be classified according to several different features. They can be either public or private, located indoors or outdoors and built in-ground or aboveground. They are typically permanent fixtures but can also be temporary or collapsible structures. Even if a formal classification is not provided by any standards, pools may be grouped into several clusters, such as private pools, public pools, competition pools, exercise pools, therapy pools and hot tubs and spa pools, etc. The swimming facilities covered in this study all have public, indoors, in-ground and permanent pools and range from small school pools to leisure pool facilities (with hot tubs, spa pools, zero-entry swimming pools, competition pools, exercise pools etc.).

Generally, high energy use in buildings is related to weaknesses in building design and maintenance [11,12]. Energy benchmarking is a useful measure for identifying and eliminating possible flaws [13] and to push towards more sustainable solutions [14]. Moreover, benchmarking energy usage of buildings serves two main purposes. First, energy classification is important for comparing similar buildings, which can encourage owners to improve the energy efficiency of their buildings. Second, energy performance diagnosis is the next step of an energy analysis. Whereas energy

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http://dx.doi.org/10.1016/j.enbuild.2016.07.033
0378-7788/

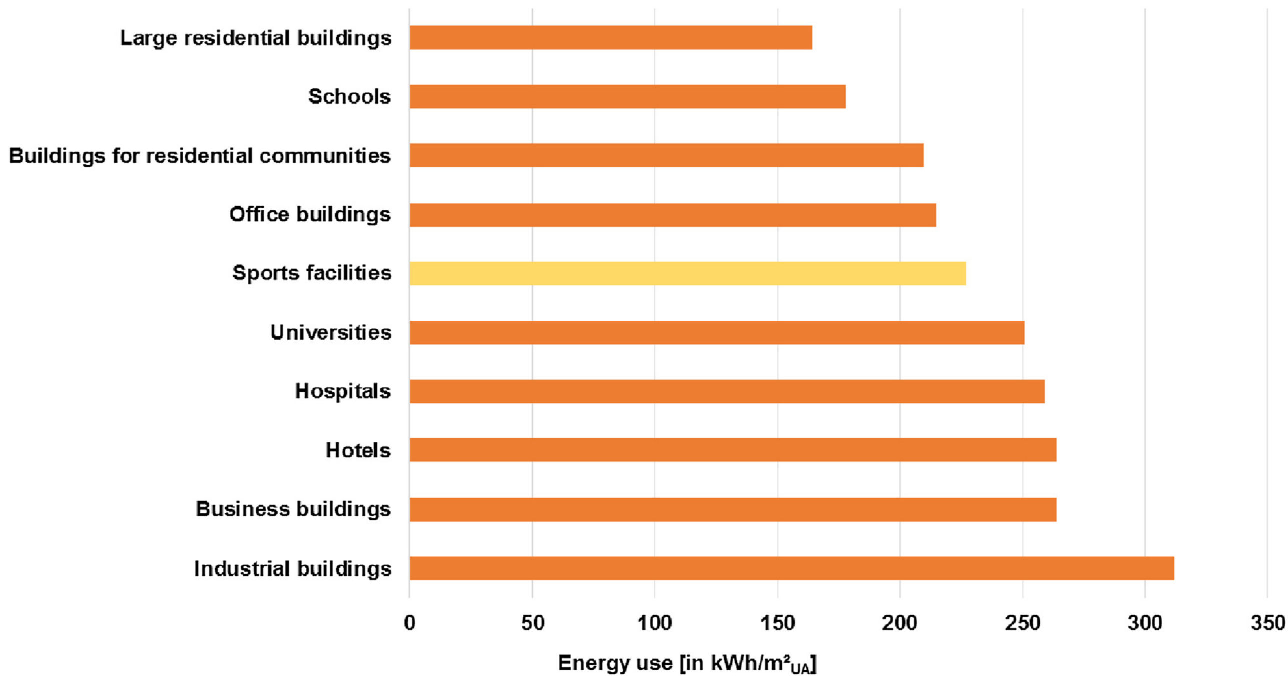

Fig. 1. The annual energy performance [10] of the ten largest building categories in Norway expressed in DE normalised with respect to UA (kWh/m^{2}UA) [4].

classification indicates the performance of a whole building, the energy performance diagnosis provides more detailed information and can allow for the detection of the causes of energy losses [13].

The Directive of the European Parliament and Council on the energy performance of buildings, published in 2002 [15] and its recast in 2010 [16] requires all Member Countries of the European Union to introduce laws for the regulation and energy certification of buildings [17]. To monitor the effect of these policies, significant energy performance indicators (EPIs) are essential [13], particularly for energy-intensive building types [18].

There are accepted EPIs for the majority of building types, but there is almost no reasoning or discussion regarding whether or why these EPIs are the best to use [18]. Furthermore, Goldstein & Almaguer [19] emphasise that EPIs should be meaningful and easy to derive and explain. In addition, to the best of the authors' knowledge, no papers have been published regarding benchmarking of energy use in swimming facilities. Some publications address improving energy efficiency in swimming facilities, but none of them states anything about which indicator to use and for what reason [7,20–22].

2. Literature review

To describe the energy performance of swimming facilities, most statistics and publications normalise energy use with respect to useable area, e.g., kWh/m^{2}UA, [3,5–8,23,24] and/or to water surface (WS), e.g., kWh/m^{2}WS [3,7–9,23,25–27].

Statistics Norway reported that 21 Norwegian swimming facilities had an average DE of 280 kWh/m^{2}UA [24]. According to a publication by Bøhlerengen et al. [5], the DE of 27 Norwegian swimming facilities varies between 180 kWh/m^{2}UA and 860 kWh/m^{2}UA with an average of 401 kWh/m^{2}UA. In a third Norwegian study, Røkenes [8] investigated three swimming facilities in the Oslo area, reporting an average DE of 515 kWh/m^{2}UA. A report from the Swedish municipalities [3] is in accord with the findings of Bøhlerengen et al. [5], showing that 17 Swedish swimming facilities have an average DE of 403.4 kWh/m^{2}UA. The five Greek swimming facilities investigated by Trianti-Stourna et al. [7] were found to have a slightly higher average of 450.1 kWh/m^{2}UA. British Swimming [6] reported values of 725 kWh/m^{2}UA for good practice and 1573 kWh/m^{2}UA for typical practice without specifying the reference features of a good or typical facility.

A main issue associated with comparing the described data is that most of the authors do not properly describe the facilities examined. Indeed, only the scientific papers of Røkenes [8] and Trianti-Stourna et al. [7] comprehensively describe their sample. Data from Statistics Norway [24], Bøhlerengen et al. [5] and from the Swedish municipalities [3] do not include essential data for comparing buildings' performances.

Another factor that makes it difficult to compare the DE of swimming facilities is the use of different EPIs. Whereas the above-mentioned sources normalise with respect to the useable area of each facility, several publications [3,7–9,26,27] normalise with respect to the water surface of pools, using, e.g., kWh/m^{2}WS or both. Whereas the lowest average value of 1 302.7 kWh/m^{2}WS is reported by Swedish municipalities [3], the highest average value is 4 481 kWh/m^{2}WS, as reported by Øen [26] using the dataset from Bøhlerengen [5]. In this context, it is also interesting to analyse the ratio of WS and UA for the articles expressing DE with both discussed EPIs. Swedish municipalities [3] found the UA to be 3.23 times larger than the WS, representing the lowest reported ratio, whereas the data published by Bøhlerengen [5] and analysed by Øen [26] indicate that the highest ratio is 11.17. Trianti-Stourna et al. [7] and Røkenes [8] reported intermediate values of 3.43 and 7.57, respectively.

Based on a review of the literature, it is not possible to identify which EPI should be used for a benchmarking purpose. No investigations showing relationships between UA or WS with DE have been published. Additionally, Øens [26] data show a large spread, regardless of which EPI is used.

The most commonly used EPI for buildings is kWh/m^{2}UA, which can be problematic when used for swimming facilities. The data will be skewed if, for example, leisure pool facilities are compared with smaller swimming facilities. The EPI must be chosen such that buildings are comparable and data are used as a basis for energy certification and further energy performance diagnosis. Using com-