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Energy consumption in schools – A review paper

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ABSTRACT

Among all public buildings, on account of their educational purpose, school buildings have a major social responsibility. Therefore energy performance in this type of building is of great importance.

The overall purpose of this research is to achieve a functional benchmarking, based on the real operation conditions of school buildings, by the exploitation of the results made public, through an intensive literature survey on energy consumptions in schools.

The survey was made to gather data that is relative to energy consumption in school buildings, documented in the most diverse fields and units: global energy consumption values, electrical energy consumption; fuel consumption for heating, energy data consumption of schools expressed in annual cost per unit of heated/cooled surface area ($/m^2) or per unit of heated/cooled volume ($/m^3) or, finally, as the annual cost per student ($/student).

The literature was analyzed to determine if a worldwide comparison among the published data could be established.

The results suggest that when attempting to determine an energy benchmark some considerations should not be forgotten: standard indoor environmental conditions (IEC) for classrooms (set-point for indoor operative temperature of 20 °C in winter and 26 °C in summer as suggested in EN 15251:2007), electrical and heating consumption values should be kept separately, different education levels usually require different energy consumption values. A good way to normalize heating energy consumption is going through a climatic adjustment based on Heating Degree Days (HDD). For an impartial data comparison, based either on an operating rating or on a simulation carried out for reference conditions, benchmark reference values should be expressed in terms of billed energy data.

Contents

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1. Introduction

1.1. Aim and scope of the paper

In 2002, the Energy Performance of Buildings Directive (2002/91/EC) [1] introduced the mandatory energy certification of buildings in the EU from 2006. Within this context, all the Member States (MS) proposed different Energy Performance Certificates (EPC) exhibiting different information expressed into distinct scales. A similar process has been taking place in the US [2–6], Canada [7] and Australia [8].

Public buildings with public ownership, like schools, represent an important opportunity towards energy efficiency and suitable Indoor Climate Quality (ICQ) levels representativeness. School buildings "can be used as communication means towards pupils and their families, and can thus reach many different society groups" [9]. Because of their high number in the total state building stock, they contribute to a considerable part of the overall amount of energy consumption, and consequently of the expenses paid by the national budgets [10]. School's energy use do highly contribute to schools' running costs – after salaries of teachers and staff, energy costs are the second most significant expense [11].

Worldwide studies and publications present different energy consumption ratios on different descriptors, sometimes with different units and several energy use types. Besides, different approaches/methods lead to barely comparable values. These data characteristics have been summarized in Table 1.

Discrepancies between design estimates and actual energy use have been verified which makes the comparison of measured and calculated values substantially difficult. This is verified because a rating based upon real measured consumptions is influenced by the behavior of the occupants and the calculated values are obtained by computational simulation depending of predetermined load and occupation profiles, which in some cases are very different from the real ones [12–14]. Besides that, some simplifications assumed in simulations and the random character of weather conditions may contribute to increase the discrepancies.

The study herein presented is organized according to the methodology of literature review presented in Section 2. It summarizes and explores the peer-reviewed literature on energy

Table 1
Comparison of data characteristics used in energy consumption literature analysis.

Location	Energy type	Unit (per annum)	Reference value	Literature	Year of publication
Austria		kWh/m²		[18]	2010
Cyprus	*Billed energy*	kWh/m²	Typical :average	[19]	2014
Czech Republic	*Delivered*			[15]	2011
Denmark	Primary	kWh/m²		[15,20,21]	2011, 2013
Finland	–	kWh/m²	Average	[9,22]	2010
Flanders	–	kWh/m^2		[23] *cit in* [24]	2002, 2008
France	Primary	kWh/m²	Average	[25]	2012
Germany	Primary	kWh/m²		[26–28]	2013, 2011
Greece		kWh/m²	Average, typical and good practice	[20,29]	2011
Hungary		kWh/m²		[27]	2011
Italy	Primary	kWh/m²	Mean	[18,30–33]	2002, 2008, 2010, 2013
Northern Ireland	*Consumed energy*	kWh/m²	Typical and good practice	[34,35],	1997, 2000
Poland		kWh/m²		[27]	2011
Portugal	*Consumed energy*	kWh/m²	25% percentile median	[16,20]	2011, 2013
Slovakia		kWh/m^2		[9]	2010
Slovenia		kWh/m^2 kWh/m^3		[36]	1999
Spain		kWh/m²		[27]	2011
Sweden	Primary	kWh/m²		[20,27,37]	2011, 2013
United Kingdom (UK)	*Consumed energy*	kWh/m^2	Good practice: 25% percentile typical: median	[38,39]	2003, 2004
Argentina	*Consumed energy*	kWh/m^2	Average = mean	[40]	2000
Canada	*Billed energy*	kWh/m²		[41] *cit in* [29,42,43]	2010, 2013
USA		*kBtu/ft^2* $/m^2 $/student	Median, 25% percentile	[44–46]	2010, 2008, 2012
Hong Kong		MJ/m^2		[47]	2013
Japan		GJ/m²	Average	[48]	2008
Malaysia	*Billed energy*	kWh/m²	Best practice	[49]	2012
South Korea	*Consumed energy*	MJ/m^2 MJ/student	Average	[50]	2012