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Measured energy consumption of educational buildings in a Finnish city

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ABSTRACT

This study measures energy consumption in existing educational buildings. The study provides an overall picture of energy consumption and assesses the factors that are used in evaluating measured energy. The studied buildings are day care centres, schools and university buildings located in southern Finland.

The energy efficiency requirements in Finnish building regulations have become significantly stricter in recent years. This study shows that in different educational building type, the newer buildings consume less heating. However, such a clear correlation not found for electricity consumption. In the day care centres and school buildings studied, the primary heating consumption as a function of the age of the buildings has a decreasing trend. In turn, the primary electricity consumption has a slightly rising trend. However, in different building types, the primary heating and electricity consumption varied significantly between the buildings e.g. in day care centres variation was 83%, in schools 84% and in university buildings 76%. This study shows that even though Finnish climate is cold the primary electricity consumption is higher than primary heating in educational buildings constructed in the 2000s. This means that in the design phase, there is a need to find ways to influence the electricity consumption in particular.

1. Introduction

Energy efficiency in buildings is controlled by a number of directives, regulations, and strategies on both international and national level. In December 2008, the European Commission implemented a strategy for Climate Action. According to the strategy, the European Union has set an indicative objective to reduce its primary energy consumption by 20% in relation to the projected 2020 energy consumption [1].

Buildings account for approximately 40% of the total energy use in Europe [2], and for about 36% of the EU's total CO_2 emissions [3,4]. The Directive on energy performance of buildings [5] outlines measures that require Member States to set minimum requirements and develop methods for determining the energy performance of buildings. Cities play a key role in mitigating climate change as most of the construction and transportation occurs in urban areas. For example in Finland, the built environment accounted for 59% of the final energy use and 56% of the greenhouse gas emissions in 2007 [6,7].

Cities and municipalities have an important role in producing public services, meaning also construction and management of these services. Energy consumption in schools and day care centres is usually high, and it has an impact on the communities energy consumption and thereby the energy bill [2,3,8–11]. It was reported that UK schools could reduce energy costs by around £44 million per year, which would prevent 625,000 tonnes of CO_2 from entering the atmosphere [12].

1.1. Comparison between European countries

In recent studies, typical annual heating consumption for some European school buildings is reported to be 96 kWh/m^2 in Ireland [13], 192 kWh/m^2 in Slovenia [14] and 157 kWh/m^2 in the UK [15]. According to a study from Serbia [16], energy consumption (kWh/m^2) in Serbian buildings is 3–4 times higher.

In an earlier study [17], the mean annual heating consumption of school buildings in Greece was estimated to be 67 kWh/m^2 and electricity consumption 26 kWh/m^2. In that study, the buildings were not air-conditioned. According to more recent studies [18,19], the mean annual heating consumption of school buildings

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in Greece was estimated to be close to 31 kWh/m^2 and 46 kWh/m^2 for the coldest climatic zone of Greece. The latest study [20] investigated 77 school buildings located in northern Greece. In this study, the mean energy consumption of all buildings was recorded to be approximately 84 kWh/m^2.

In central Italy, the energy consumption of 42 schools located in Perugia [21] and 117 schools located in the Province of Torino were analyzed [22]. The aim of these studies was to derive energy consumption indices. The obtained average annual consumption for space heating was 100 kWh/m^2.

In a study from southern Finland [23], six schools and two day care centres energy and primary energy use were analyzed. The results showed that decisions made in the design and construction phase influenced the overall energy performance of the building compared to existing building stock of similar building type. The studied buildings had lower heating consumption compared to existing building stock. However, such a correlation could not be found in terms of the electricity consumption. The study also showed that some of the buildings in the existing building stock reached the same level in primary energy use. This shows the importance of the building use and its users' impact on primary energy use.

1.2. The role of Finnish municipalities in energy savings

In Finnish municipalities, municipal federations and public corporations owned by the municipalities possessed altogether 35,471 buildings in 2005. Out of these buildings, 65% are other than residential buildings, i.e. public buildings such as schools, elderly home, corresponding to 85% total floor area of owned buildings. The largest building type of public buildings in terms of floor area and volume are elementary schools and high schools which total 25% of the building stock [24,25].

The public sector should lead the way in the field of energy performance of buildings. The leading role requires not only fulfilling expected demands of the EU Directive and national legislation, but also setting an example to other actors [26]. Municipalities and property owners have been encouraged towards energy efficiency by educational and financial incentives, as well as by various energy surveys [27]. During 2008–2012, Finnish municipalities have implemented 1738 measures, with a total energy saving effect of 179.9 GWh/a. The investment costs of these measures were reported to be approximately EUR 43 million [27]. In spite of these actions, energy efficiency has not increased to the desired level. In addition, there is a need for increased implementation of the EU Directive on Energy Efficiency [1] within the context of the public sector.

Finland's Energy Audit Programme (the EAP) is one of the oldest national energy efficiency grant schemes in place. The EAP started as a subsidy policy in 1992 and was developed into a programme level activity in 1993 [28]. During the period 1992–2011 over 3300 buildings have been audited in the municipal sector, corresponding to about 60 million m^3. In these audits the saving potential of heating energy was circa 444 GWh/a and for electricity circa 90 GWh/a [28].

Energy certificates have been used in Finland since 2008 [29]. Certificates provide the proportionate gross number for energy efficiency and determine a building's energy class, graded between A and G. The energy certificate is compulsory for new buildings and a large proportion of existing buildings. In public buildings the energy certificate must be displayed in a noticeable place to show the energy efficiency of the building in question.

More than 20 years, the City of Espoo has participated in the projects and signed agreements to conserve energy in their operations and to encourage energy conservation [30]. A good recent example is the Julia 2030 premises project, where the aim was to demonstrate how public sector services can reduce greenhouse gas emissions by improving the use of premises and energy efficiency in procurements from 2009 to 2011 [31]. The project clearly demonstrated that active measures focusing mainly on changing patterns of use can bring about reductions in the greenhouse gas emissions of buildings over a relatively short time span [31].

1.3. Development of energy consumption in educational buildings

According to the City of Espoo's energy statistics since 1994, the energy consumption of Espoo's public building stock had fallen by 5.8% (kWh/m^3) by 2010. The biggest change occurred in heating consumption, which fell by 4.8% during this period. In turn, especially in the 2010s, electricity consumption has a strong upward trend. Since 1994, the consumption of electricity has increased by 30%. In the City of Espoo, the annual energy costs of the public service building stock are approximately EUR 16 million. Major share of City of Espoo's owned public buildings (60%) are educational buildings such as schools and day care centres. Their share of energy costs are approximately EUR 11 million.

According to the Aalto University's energy statistics, the building stock energy consumption (kWh/m^2) increased by 0.3% from 2006 to 2013. During the same period heating consumption has rose by 1% and in turn, electricity consumption has fell by 0.4%. Aalto University Properties annual energy costs are approximately EUR 6 million.

In Finnish statistic [32] the heating consumption include space heating, domestic hot water and heating of ventilation air. Electricity consumption includes all electricity used in a building, e.g. ventilation, appliances and lighting.

Real-time energy monitoring and management is an increasing service in new buildings and in renovated buildings [33]. Typically, the energy consumption monitoring and management system covers electricity, heating and domestic water. According to a summary made by Brambley [34], the annual energy savings achieved by using the energy monitoring and management system has been between 4% and 15%.

In terms of public spaces, it is typical that there can be found daily and weekly variations and rhythms in usage profiles. In the study by Airaksinen [23], the normalized heating consumption was quite similar in all the buildings studied during many years, indicating that the heating consumption is rather stable and there are no great changes or complaints from the users. However, the difference between electricity consumption between studied buildings was substantial in day care centres.

1.4. Objective of the study

This study focuses on energy consumption and primary energy consumption in existing educational buildings. The aim is to study the overall energy consumption of the building stock and to find out differences between heating consumption and electricity consumption.

In this study the evaluation is based on the actual measured energy consumption. The heating consumption includes space heating, domestic hot water and heating of ventilation air. Electricity consumption includes all electricity, e.g. ventilation, appliances and lighting.

2. Research methods

This study was conducted using the statistical method. Regression analysis was used to analyze trends in the energy consumption. A regression line was used to find out the factors, e.g. construction year, affecting energy consumption. The regression line helped