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Assessment of the current thermal performance level of the Swiss residential building stock: Statistical analysis of energy performance certificates

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ABSTRACT

The reduction of energy consumption in the existing building stock is a crucial element of the Swiss Energy Strategy 2050 in view of the fact that the built environment accounts for more than 44% of the final energy use in Switzerland. It is therefore necessary to characterise the Swiss building stock and in particular the residential sector at an appropriate degree of detail, distinguishing between various types of buildings (archetypes) and building elements in order to identify the untapped potential for energy retrofit. In this paper, the current thermal performance and retrofit state of the Swiss residential building stock is examined based on approximately 10,400 Cantonal Building Energy Certificates issued for individual buildings across the country. The statistical analysis of the certificates allows to estimate a thermal performance level of archetype buildings and their respective building elements as well as of the heating systems. For this purpose, we develop a method allowing to obtain typical U-Values for original and retrofitted buildings from the total U-Value distributions. Our results indicate that approximately 75% of all building elements do not yet reach the thermal performance of buildings constructed in the last 15 years. In order to reach current low-energy building standards (MINERGIE P), the U-Values of building elements constructed prior to 1990 would have to be reduced by a factor of three to more than six, from 0.5–1 W/(m²K) to 0.15 W/(m²K); windows would require an improvement by at least a factor of two, from 2.5–2 to 0.9 W/(m²K). With regard to heat supply, 50% of the surface area is still heated by inefficient and CO_2-intensive oil-fired boilers. The results of this study hence confirm the high potential for thermal retrofit in the Swiss residential building stock.

1. Introduction

In the framework of the *Energy Strategy 2050*, Switzerland has set ambitious goals for increasing energy efficiency across all sectors [1–3]. Accounting for 44% of the Swiss final energy use in 2016, the built environment is the most important energy consumer followed by transport (29%) and industry (21%) and therefore a key area for energy efficiency improvement [4,5]. The retrofitting of the existing building stock to a more energy efficient level can potentially result in considerable national energy savings, in particular in the residential sector, which accounted for around 66% of the total energy use related to space heating in Switzerland in 2014 [5].

According to recent energy scenarios for Switzerland a large portion of the residential buildings from the 1970 s would consume up to 70% less energy when retrofitted according to low energy building labels [6]. This translates to significant reductions in greenhouse gas emissions (GHG) for Switzerland, especially when the retrofit entails not only the improvement of the thermal performance of the building envelope but also the replacement of the old heating system (typically operated with fuel oil). In the framework of the Energy Strategy 2050, the Swiss Federal Office of Energy (SFOE) is therefore promoting a significant increase in retrofit rates for the building envelope, as well as rapid diffusion of efficient heating systems running on renewable energy [6]. For this purpose, the replacement of fossil fuel based heating systems is encouraged by a CO_2 tax. Since 2010, the revenues from this carbon tax are partly allocated to the Building-Programme, a federal government support scheme for encouraging energy retrofit of building envelopes and heating systems. Furthermore, the so-

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called Model Regulations for Energy Use in the Cantons (MuKEn)[1] are published on a regular basis as a guideline for cantonal energy policies including recommendations on energy performance for newly constructed buildings and enhanced retrofitting of the existing building stock [7]. The cantons themselves are encouraged to adopt these regulations as minimum requirements for building owners. In order to standardize the calculations of the energy demand in buildings, the MuKEn is based on the standard specifications of the Swiss Society of Engineers and Architects (SIA), in particular the regulation 380/1 [8]. The most recent MuKEn 2014 refers to the SIA regulations dating back to 2009 [9]. In 2016, a revised version of the SIA 380/1 was released which is gradually introduced into the different cantonal legislations [8].[2]

In order to prove that the SIA 380/1 requirements are fulfilled, there are two different calculation options [8]. The first method specifies strict minimum U-Value requirements for individual building elements such as windows and exterior walls, while the second method entails a detailed calculation of the overall heating losses and gains in the building. The latter is called system verification and it allows higher U-Values for single elements if the overall energy use per square meter is below the respective threshold calculated following the SIA 380/1. Beyond these legal requirements, the private organization MINERGIE offers voluntary certification for outstandingly energy efficient or environmentally friendly buildings in Switzerland [10]. The minimum requirements of these MINERGIE buildings include low energy (Minergie), passive house (Minergie-P) and even positive energy buildings (Minergie-A), covering both the envelope and the building equipment as well as the appliances.

But despite all these policy and institutional measures, only 0.9% of the 1.64 million residential buildings in Switzerland are actually subject to an energy retrofit each year [6]. It is therefore crucial to study the current state of the national building stock in more detail in order to identify the number and types of buildings which have not yet been renovated with regard to their envelope and/or their heating systems and could hence be raised to a higher degree of energy efficiency. When examining a large range of buildings, the building stock can typically be divided into archetypes (groups of buildings) in relation to the most common features. As pointed out by the International Energy Agency (IEA), this avoids extensive data mining for each building in the stock while still allowing a representative modelling of the overall energy demand [11]. One of the most extensive studies on archetype buildings is the Typology Approach for Building Stock Energy Assessment (TABULA) project, which was a joint EU-funded research project covering 13 EU countries [12]. In the TABULA database, the residential housing stock of each country is divided into national building typologies in relation to construction period, type of building as well as regional or structural differences, if relevant (e.g. West- or East-Germany).

At the Swiss level, three major studies have used an explicit archetype approach to evaluate the performance of the building stock. The first study by Siller et al. [13] was based on a national building stock model prepared by Wüest & Partner in 1994 [14]. The authors provided key figures of the Swiss building stock in 2007 and estimated the state in terms of building envelope and heating systems. Their building stock model was based on 21 archetypes, consisting of three building types multiplied by seven construction periods. Secondly, Heeren et al. developed a Swiss building stock model, which allows to compare different policy and technology scenarios and their effectiveness for achieving national energy savings up to 2050 [15]. As their focus was on the development of the overall future building stock over a long period of time, the current building stock was represented by only five construction periods for two different building types. Thirdly, the most recent archetype-based study of the Swiss residential building stock was prepared by Aksoezen et al. in 2015 [16]. For their model, they used four building types over four construction periods in 19 different counties or districts within the canton of Basel.

Beside these main archetype based studies, other studies have examined the current state of the Swiss building stock in general terms (e.g., via questionnaires), while not explicitly dividing the stock into representative categories [3,17–20]. On behalf of the SFOE, a survey among 600 building owners or agencies was carried out by Ott et al. in 2005 to identify the state of the envelope, previous retrofit measures, barriers and challenges that prevent higher rates of renovation in the Swiss building stock [20]. The results showed that the retrofit rates and the improvements in energy efficiency are insufficient to reach the policy targets in the built environment. A more recent study by Jakob et al. [19] showed that a retrofit addressing individual building elements did not always result in sufficient energy efficiency improvement. The authors argued that the number of retrofit measures that are significantly improving the energy efficiency of the buildings were too low in the total number of renovation measures, which indicates still a high potential for untapped energy savings in the Swiss residential building stock.

While the studies discussed above were mostly based on the results of questionnaires, the scholars of the TABULA project recommended the use of data from energy performance certificates as an alternative source for energy related studies in buildings [21]. It was claimed that energy certificates, which have already been introduced for several years, provide valuable information about mean building surfaces, U-Values and other relevant input data from large sample size of the total stock. Since the energy certificates are in most cases issued by experts in the field, they might offer a more detailed picture of the specific elements of the buildings compared to survey-based studies which are mostly filled by building owners. Moreover, the raw data of the survey-based studies for the Swiss residential building stock are often not publicly available and therefore not easily verifiable or reproducible. In the Swiss case, the Cantonal Energy Performance Certificate for Buildings (CECB) is the most widespread verification scheme for energy efficiency in buildings and the certificates are also available as a database for research activities [22]. The purpose of the CECB is to provide a clear state of certified buildings in terms of energy efficiency. This entails an assessment of the different building elements and the current thermal performance of the envelope as well as the state of the heating system by an accredited energy consultant. This information can be summarized and used to define representative archetype buildings and characterise the whole Swiss residential building stock.

The aim of this paper is therefore to provide the current thermal performance level of the Swiss residential building stock in 2015 based on an analysis of the data available from energy certificates. The evaluation is conducted at a high level of detail, i.e. by building elements and by type of heating system. In a second step, we identify groups of buildings and in particular building elements that feature an untapped energy efficiency potential compared to current Swiss renovation standards. These results can therefore serve as basis for the development of energy retrofit strategies.

2. Methods

While the Federal Register of Buildings and Dwellings (FRBD) of the Swiss Federal Statistical Office (FSO) provides an extensive

[1] Mustervorschriften der Kantone im Energiebereich (MuKEn); Modèle de prescriptions énergétiques des cantons (MoPEC).

[2] Das Gebäudeprogramm; Le Programme Bâtiments: www.dasgebaeudeprogramm.ch.