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Development of two Danish building typologies for residential buildings

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ABSTRACT

The aim of this paper is to present two Danish typologies for residential buildings developed in the EU-financed project TABULA. The building typologies focus on energy performance and can be used in the analyses of, e.g., political strategies for planning the future upgrading of the energy performance of the residential building stock.

Overall, the typologies consist of two types of building models—*real example models* and *average designed models*. The main purpose of developing the building typologies was to establish a tool able to calculate different energy-saving scenarios for the entire residential building stock. To make such calculations of scenarios, similar *average designed building models* were established based on extracted average values from the Danish Energy Performance Certification Scheme database. The two building typologies had the same overall composition, i.e., three main building types: single-family houses, terraced houses and blocks of flats. Each main building type is presented for nine periods representing age, typical building tradition and insulation levels.

Finally, an energy balance model of the residential building stock was devised to validate the *average designed building models*. Compared with the official statistics on energy consumption in Denmark 2010, the results showed a difference below 4%.

1. Introduction

The goal of the Danish Government's 2012 Energy Agreement is a 7% reduction of the gross energy consumption by 2020 compared with the energy consumption in 2010 [1]. In the long term, the government has a vision of becoming a fossil-fuel-independent nation by 2050. In 2010, the share of renewable energy in Denmark accounted for approximately 22% of the total climate-adjusted energy consumption (mainly biomass and windmills).

Fig. 1 shows that Denmark's final energy consumption has grown slightly (around 5%) since 1990 and with an almost constant distribution on use. The climate-adjusted energy consumption in buildings (households, trade, and service) has been approximately 40% of the total consumption throughout this period.

Over 30% of Denmark's energy consumption is attributable to private households [2]. In spite of many years with relatively strict requirements to energy consumption set by the Danish Building Regulations, the existing building stock still offers an enormous potential for achieving energy savings. Breakthroughs in this area will be crucial in supporting the government's goal to reduce energy consumption. In 2010, the households' climate-adjusted energy consumption amounted to 192 PJ, of which space heating and hot water production accounted for 160 PJ [2]. The existing 1 million single-family houses account for approximately half of this energy consumption, thus making the improvement of the energy efficiency of these buildings a key factor for the Danish reduction of CO_2 emissions.

Since 1990, the total energy consumption for heating has remained more or less constant. This implies that the effect of improved energy efficiency in existing buildings is more or less the equivalent of energy consumption in new buildings. Intensified initiatives are therefore needed for the existing building stock in order to change the energy consumption from constant to actually decreasing.

One of the most significant political initiatives is the EU Directive on the Energy Performance of Buildings. The recast of the directive [3] also includes requirements to existing buildings, Article 7: "Member States shall take the necessary measures to ensure that when buildings undergo major renovation, the energy performance of the building or the renovated part thereof is upgraded in order to meet minimum energy performance requirements set in accordance with Article 4 in so far as this is technically, functionally and economically feasible".

This has been taken into account in the current Danish Building Regulations 2010 [4], which stipulate that re-insulation should be carried out when replacing and maintaining building elements.

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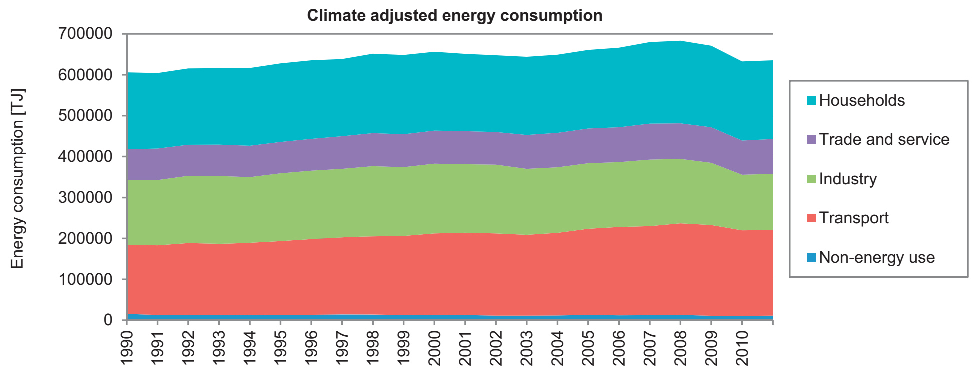

Fig. 1. Historical development of the final adjusted energy consumption distributed on use. Energy consumption for businesses and households does not include energy consumption for transportation [2].

Compliance with these requirements is crucial for a reduction of the energy consumption for the total space heating. Building typologies are therefore a suitable tool for future analyses of the necessary level for future tightening of the requirements in the Building Regulations regarding initiatives to improve energy efficiency.

1.1. TABULA project

The aim of the TABULA project [5] was to create a harmonised structure for European building typologies with a focus on the residential building stock. Thirteen EU countries participated in the project starting in 2009: Austria, Belgium, Bulgaria, Czech Republic, Denmark, France, Germany, Greece, Italy, Ireland, Poland, Slovenia and Sweden. At the end of the project (spring 2012), other EU countries also showed an interest in the project, to a greater or lesser extent (particularly Serbia and Spain). During the project, the participating countries all managed to develop harmonised typologies. These typologies are available on the TABULA website [5]. The website also gives access to a web tool that is able to calculate the performance of each model building before and after planned initiatives to improve the energy efficiency have been carried out.

1.2. Other established building typologies

The Danish building stock has previously been analysed using a similar approach as that of a building for average designed buildings [6]. Some knowledge from this work (building geometry model and boundary conditions) are maintained, however the typologies presented in this paper are more detailed and based on a much larger data material from the EPC Scheme.

Building typologies of the Greek building stock are described in [7], which also finds it to be a flexible tool for estimating the impact of energy-saving scenarios on the energy performance of the residential building stock. A similar analysis of the Greek building stock was also carried out in [8], which presents a classification of the dominating multifamily building typology together with characteristic examples studied. In [9] a typology approach has been developed based on field surveys in five municipalities in the city of Milan (Italy) for an analysis of the potential energy savings achievable by retrofitting the existing building stock.

1.3. Utilisation of typologies

A building typology can be used by energy consultants for initial advisory services to provide house owners with a quick overview of different measures for a specific example building similar to their own. Moreover, the typology can be used as a set of example buildings, e.g., in software comparison scenarios. Increasing needs for tools to analyse different scenarios for the energy upgrading initiatives of the entire building stock should be expected in the coming years. The generally limited economic resources delay the progress of energy efficiency upgrading measures in nearly all countries, thus making the order of the measures critical. Therefore the effect, magnitude and order of every energy upgrading measure needs to be known and analysed in detail, when politicians and the energy sector negotiate and plan the future upgrading of the energy performance of the building stock.

2. Methodology and data

The developed building typology was mainly established by using data stored in the two main building databases in Denmark—The Building Stock Register and the database of the Energy Performance Certificate (EPC) Scheme.

2.1. The Building Stock Register – BBR

Since 1976, all buildings and building units in Denmark have been registered in a national database called BBR [10]. Today this database contains information about all 1.6 million buildings and building units in Denmark. The BBR register contains detailed information about each building, e.g., its heated area, number of stories, type of heating installation, type of owner, etc. The register is regularly updated by the municipalities, especially through new building cases. The residential building stock accounts for approx. 80% of the total heated floor area. Table 1 lists some key values of the residential buildings stock regarding number of buildings, heated areas and the share of single-family houses, terraced houses and blocks of flats, respectively.

Privately owned single-family houses represent a significant energy saving potential in Denmark as they account for approximately 60% of the heated residential floor area.

2.2. The Danish EPC Scheme database

Since 1997, Danish law has stipulated that all properties for sale should be inspected by a trained energy consultant. The inspection is mandatory for both new buildings and existing buildings. The energy consultant prepares a short report with an energy certificate on an A to G scale supplemented with suggestions for cost-effective energy efficiency measures. All the information registered by the consultant is accumulated in the EPC database [11]. This means that the EPC database grows all the time and in April 2012 the database contained approximately 235 000 energy certificates of residential