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Heating and cooling energy trends and drivers in Europe

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ABSTRACT

This paper aims to complete and complement the information available on the past trends of thermal energy consumption in residential buildings and its drivers for Europe, as a continent and for the different countries. This paper follows the drivers identified in a previous one for the heating and cooling energy consumption, decomposing this energy demand into key drivers based on a Kaya identity approach: number of households, persons per household, floor space per capita and specific energy consumption for residential heating and cooling. Results show that all drivers did follow a consistent trend at global, regional and country level during the studied period of time, but the heating and cooling energy consumption did not follow the same trend if it was considered at global, regional or country level, showing that the energy consumption is very much influenced by all its drivers and does not follow the same trend as the specific energy consumption. Moreover, similar trends for each indicator can be found when evaluated at country or regional level, therefore as expected when aggregating data trends can be seen but details and particularities (both for the different countries and for the different studied years) are lost.

1. Introduction

Trends in heating and cooling energy consumption and their drivers in Europe cannot be found in the literature. But there are other related studies in energy trends as for example, that of Li et al. [1] that presented a study of the energy consumed and its drivers in high-performance office buildings in USA, Europe, China, and other parts of Asia. The drivers considered were the impact of climate, the impact of building size, the impact of building technologies (lighting-related, envelope, and HVAC technologies related to space cooling and heating). The paper also lists other driven factors, such as operation hours, the number of occupants, and the building functions (space use type: mixed use, data centres, commercial, cooking), highlighting the lack of data of those factors (or drivers).

Streimikiene [2] analysed theoretical issues of the main drivers of residential energy consumption, the residential energy consumption trends in Lithuania, comparing these trends with other EU member states, defined the main drivers of residential energy consumption by applying a correlation analysis, and analysed policies aiming to reduce energy consumption in residential buildings and their impacts on GHG emission reduction. Results from 2001 to 2009 showed that the residential energy consumption per capita in Lithuania is significantly lower than in old EU member states because of the lower income per capita and lower living standards. The drivers used in this paper are distinguished between economic factors (income) and non-economic factors, such as technological, policy and others (cultural, psychological and institutional).

Authors also found some studies where the energy consumption of buildings and its main drivers were studied in a specific country, like in De Rosa et al. [3] where authors calculated the heating and cooling degree days for several Italian cities for the period 1978–2013 based on daily meteorological data. Their analysis was based on historical climatic data and the methodology followed in their calculations was based in a literature review of the methods adopted by different researchers to calculate degree-days. Jones and Lomas 2015 [4] focused their research in determining socio-economic and dwelling factors that contribute to

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electrical energy demand in UK residential buildings. Authors highlight some socio-economic factors as key elements that affect the energy consumption in buildings being higher in households that have more children and teenagers and in households with high annual incomes. On the other hand, floor areas higher than 100 m^2, the use of electricity as the main source in space and water heating are dwelling factors that strongly affect the electrical energy consumption. Jia and Lee 2016 [5] identify the factors and drivers responsible for the increase in cooling energy consumption in residential buildings between 2004 and 2013 examining 64 dwellings in Hong Kong. Authors found the increase of population as a key element. However, the increase of the energy consumption for cooling space conditioning was moderate due to the positive role of using more efficient unit and smaller window-to-wall ratios.

A recent publication by Ürge-Vorsatz et al. [6] presented not only complete past, present and future trends of the heating and cooling energy consumption in buildings, both residential and commercial, and on a global and regional basis, but also defined the drivers of heating and cooling energy consumption based on a Kaya identity approach. The drivers identified were number of households, persons per household, floor space per capita, and specific energy consumption for residential heating and cooling; and GDP, floor space per GDP, and specific energy consumption for commercial buildings. The biggest problem when carrying out the work was that the data on floor area (m^2) for the past was not available for most of the world areas. Moreover, another recent review by Nejat et al. [7] reviews the status and current trends of energy consumption, CO_2 emissions, and energy policies in the residential sector globally for the world, and for the top ten CO_2 emitting countries (China, USA, India, Russia, Japan, Germany, South Korea, Canada, Iran, and UK). Authors found that global residential energy consumption grew 14% from 2000 to 2010, which are consistent with results presented in Ürge-Vorsatz et al. [6]. Nejat et al. [7] conclude that most of this increase has occurred in developing countries, where population, urbanization and economic growth have been the main driving factors.

Worldwide data regarding heating and cooling energy consumption in buildings has been analysed from global, regional basis and in the highest CO_2 emitting countries [6,7]. However, a complete and detailed set of data is not available in the literature for residential buildings in Europe in order to deeply assess the trends of heating and cooling energy consumption in each country, region and from a European global basis. This is why, this paper presents for the first time the trends in heating and cooling residential energy consumption for the past and its drivers for Europe in a complete data set, to serve as a useful source and to shed light on the longer term perspective in order to enable more informed modelling and planning of heating and cooling energy use. Authors would want to highlight that the purpose of the present study is to serve as a source of data. Therefore, understand in detail the trends of the different drivers would be the purpose of further research.

2. Methodology

2.1. Drivers decomposition

The decomposition followed in this paper is the same as in a previous one [6] and is based on the Kaya decomposition. In this type of decomposition, the factors commonly used are CO_2 intensity, energy intensity, structural changes, and economic activity, or the IPAT approach (Income–Population–Affluence–Technology approach) (Fig. 1) [8–11]. This concept has been used by the authors in order to define the heating and cooling energy trends by identifying the activity drivers (A), use intensity drivers (TEI – technological energy intensity), and energy intensity drivers (SEI – structural/systemic energy intensity). It should be highlighted that carbon intensity (CI) driver is not considered in the present study. Authors consider as mandatory the evaluation of GHG emissions so as to properly and deeply assess energy efficiency of buildings. For this reason, authors point out that energy efficiency analysis is not addressed in the present study.

Heating and cooling and domestic hot water energy consumption, from now on heating and cooling energy consumption, in residential buildings can be decomposed in several drivers following the Kaya identity methodology, as shown in Eq. (1):

$$E_{resid}[\mathrm{kWh}] = h \cdot \frac{p}{h} \cdot \frac{A}{p} \cdot \frac{E}{A} \quad (1)$$

where:

E_{resid} is the energy consumption for heating and cooling in residential buildings,
h is the number of households,
p/h is the number of persons living in each household, also called household size,
A/p is the floor area [m^2] per person, and
E/A is the energy [kWh] consumed for heating and cooling in each unit of floor area [m^2], also called *specific energy consumption*.

2.2. Regional distribution

All results are presented either globally for Europe, for the different regions grouped by United Nations, or for each country. Considered regions are:

- Western Europe: Austria, Belgium, France, Germany, Luxembourg, Netherlands, and Switzerland.
- Eastern Europe: Belarus, Bulgaria, Czech Republic, Hungary, Poland, Republic of Moldova, Romania, Slovakia, and Ukraine.
- Southern Europe: Albania, Bosnia and Herzegovina, Croatia, Greece, Italy, Malta, Portugal, Serbia, Slovenia, Spain, and TFYR Macedonia.

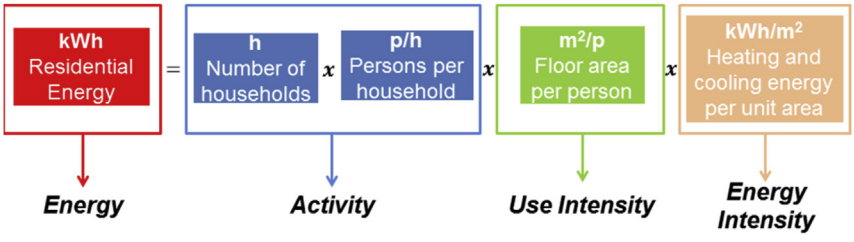

Fig. 1. Kaya identity methodology scheme.