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Heating and cooling energy trends and drivers in buildings

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ABSTRACT

The purpose of this paper is to provide a source of information on thermal energy use in buildings, its drivers, and their past, present and future trends on a global and regional basis. Energy use in buildings forms a large part of global and regional energy demand. The importance of heating and cooling in total building energy use is very diverse with this share varying between 18% and 73%. Biomass is still far the dominant fuel when a global picture is considered; the role of electricity is substantially growing, and the direct use of coal is disappearing from this sector, largely replaced by electricity and natural gas in the most developed regions. This paper identifies the different drivers of heating and cooling energy demand, and decomposes 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; and GDP, floor space per GDP, and specific energy consumption for commercial buildings. This paper also reviews the trends in the development of these drivers for the present, future – and for which data were available, for the past – in 11 world regions as well as globally. Results show that in a business-as-usual scenario, total residential heating and cooling energy use is expected to more or less stagnate, or slightly decrease, in the developed parts of the world. In contrast, commercial heating and cooling energy use will grow in each world region. Finally, the results show that per capita total final residential building energy use has been stagnating in the vast majority of world regions for the past three decades, despite the very significant increases in energy service levels in each of these regions.

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1. Introduction and aims

Buildings and activities in buildings contribute to a major share of global environmental concerns [1]. Environmental pressures influenced by the quantity and quality of the energy in buildings are indoor and outdoor air pollution, related and additional health risks and damages, and energy dependence and insecurity. Buildings energy use is a major contributor to energy-related challenges to sustainable development such as deaths attributable to indoor cooking, insufficient energy resources to fuel economic development, lack of access to modern energy services for everyone, and climate change.

Much of these environmental problems are due to the energy that fuel buildings and activities within them [1–3]. More concretely, in 2010 the building sector used approximately 115 EJ globally, accounting for 32% of global final energy demand (24% for residential and 8% for commercial) [4] and 30% of energy-related CO₂ emissions [5]. The building sector is also responsible for approximately two-thirds of halocarbon and approximately 25–33% of black carbon emissions [3]. Moreover, the building sector used 23% of the global primary energy and 30% of the global electricity. Literature documents (such as Levine et al. [6] and the IEA [5]) that the energy consumption in buildings is growing and is expected to grow dynamically due to many reasons. However, there is limited consistent literature on understanding how this energy use is developing worldwide on a regional basis, and how different trends that influence energy use in buildings develop both on a historical basis as well as in the future. The authors of this paper have found a major literature gap in this area when working on assessing the literature for the Fifth Assessment Report of the IPCC. Understanding underlying trends in drivers and past energy use is crucial for future projections, modeling activities, policy design aimed at addressing environmental and social problems related to energy use in buildings, etc.

Therefore the purpose of this paper is to fill in this gap by a robust, detailed review and assessment of available data and literature related to building energy use and its drivers.

Attributing trends in energy use to drivers can be done using different methods; this paper uses the Kaya identity approach, consistently with the main underlying analytical framework used in the Fifth Assessment Report of the IPCC. However, when such approach is used, decomposition is very different for building energy end-uses mainly driven by physical characteristics such as building architecture and climate, i.e. heating and cooling, as opposed to energy end-uses whose consumption is driven mainly by the number of people in residential buildings or by activity in commercial and public buildings² such as appliance use (e.g., washing machines, telephones, etc.). As a result, decomposition analysis is also different for these two categories of building energy end-uses. Accordingly, this paper focuses on thermal energy uses, mainly heating and cooling with occasional coverage of hot water when it is difficult to disentangle these; while Cabeza et al. [7] covered trends in and drivers of energy end-uses related to appliances and other electricity-using equipment. The paper serves as a comprehensive, consistent and detailed resource

² Energy use in both types of end-uses is strongly determined by behavioral and cultural factors that are not covered in most of the decomposition and driver analysis beyond affluence or GDP.

for historic, present and future data on and trends in heating and cooling energy use and its drivers on a global as well as detailed regional basis that is also consistent with the related analysis and data presented by the Fifth Assessment Report of the IPCC. The interpretation of these data and trends is left for other papers as these can be different based on different approaches, purposes and methods; this paper serves as the basis for such work.

The paper will first present the main trends in the global building energy consumption as relevant to heating and cooling. Then the methodology for the decomposition analysis is reviewed. Trends in heating and cooling energy use and its drivers are analyzed in detail in the following sections. Finally the influence of the drivers on the regional level is presented. The primary purpose of this paper is to serve a source of the data, and not to understand in detail the trends of the different drivers, which would be the purpose of further research.

2. Background: key trends in global building energy use

According to the IEA [5], Fig. 1 shows that in the commercial sector, buildings decreased the use of coal from 21% in 1980 to 3% in 2010 and the use of oil from 28% to 15%; meanwhile, the use of natural gas remained constant at about 23–25% and the use of renewable at about 2–3%, and finally the use of electricity and heat increased from 26% in 1980 to 54% in 2010. On the other hand, in the residential sector (so-called “services” in the ETP 2012), the use of coal decreased from 10% in 1980 to 4% in 2010, the use of oil decreased from 15% to 10%, the use of natural gas increased from 17% to 20% and the use of renewables stayed constant at about 41–42%; in the residential sector the use of electricity and heat increased only from 16% in 1980 to 25% in 2010. It can be seen that in 2010, the world buildings energy consumption was quite distributed in different final energy carriers (renewables, electricity and heat, and natural gas dominating), while in the commercial sector more than half of the energy used is electricity and heat, and renewables are a very small part.

Fig. 2 shows the total energy consumption in residential buildings by final energy carrier and by region [5]. It can be seen that in all OECD countries, Americas and non-OECD-Europe and Eurasia, natural gas, followed by electricity, is the mostly used energy source, while in the rest of the regions biomass and waste is the predominant energy source.

Fig. 3 shows that space heating is 32–33% of the total energy use in buildings (in residential and commercial buildings, respectively) [4]. Domestic hot water represents 24% in residential buildings and 12% in commercial buildings. This paper only deals with part of the energy use in buildings: total final energy use from 1980 to 2010 and thermal energy for heating and cooling from 2010 to 2050, including hot water (from now on, called “heating and cooling building energy use (H&C BEU)”).

3. Methodology

3.1. Drivers decomposition

Drivers contributing to significant increases in building energy use are population migration to cities, decreasing household size,

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