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The Implications of Demand Response Measures and Electrification of Transport on UK Household Energy Demand and Consumption

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Abstract

This study has been undertaken to gain a better understanding on how the residential electricity demand and consumption values might evolve in the medium term in a future built environment benefiting from renewable energy systems and storage technologies. Analysis and modeling of winter and summer electricity demand and consumption data in four scenarios for 2030 was performed, after the establishment of a baseline scenario in 2015 (BS 2015). The scenarios in 2030 included the business as usual scenario (BAU 2030), a scenario assuming electrification of heating and energy efficiency measures (EE 2030), a scenario in which demand response measures are also considered (DR 2030) and a scenario in which one electric vehicle (EV) is assumed for each house as well (Te 2030). Electricity demand and consumption ranges for different scales at the distribution level for each scenario were derived. It was concluded that properties with currently low peak demand values are bound to experience a much higher peak in the early morning hours in winter under the Te 2030 scenario than properties with already high peak demand. This would signify a new peak at a new time. In terms of electricity consumption in 2030, the energy efficiency measures would counterbalance the increase of electricity consumption due to the inclusion of the EV in winter, so the consumption in Te 2030 is found to be similar to the consumption in BAU 2030. The analysis also demonstrated the need to explore the potential role of thermal storage versus electricity storage in buildings.

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1. Introduction

In the last two decades, sustainability and the irreversible depletion of natural resources has been the subject of

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constant debate in a global scale. The energy sector today is mainly responsible for the greenhouse gas emissions. Emissions coming from energy-related activities accounted for 68% of the global emissions in 2005 [1] and the building sector is found to be in charge of over 40% of the total energy consumption in Europe [2]. Identifying opportunities to reduce this consumption has become a priority in the global effort to deal with climate change. In addition, an ambitious target set by the EU entails reduction of greenhouse gas emissions by at least 40% by 2030 compared to 1990 levels [3]. An increasing demand in the electricity sector is anticipated in the upcoming years due to the extension of the electrification of different regions worldwide, the increase in energy consumption due to economic growth, the use of electrical energy for heating and cooling and the use of electricity in the transport sector [4]. Electricity is therefore likely to become a universal and versatile source of low carbon energy for the building sector, but at the same time this is debatable due to scenarios that favour an energy mix in the domestic energy consumption [5-7]. Therefore, the exploration of the evolution of electricity demand and consumption in buildings according to different scenarios would be central to identifying opportunities to reduce their carbon footprint. This exploration in electricity use could also serve as a basis to investigate the potential integration of renewable energy technologies and energy storage technologies in buildings, as such technologies are considered to be key components of a decarbonized future built environment [8, 9]. This study focused on the exploration of the evolution of the electrical energy use in the UK residential sector through scenario modelling, in order to identify possible impacts. In the UK, about 33% of total electricity consumption is by residential consumers [10], holding the biggest share among commercial, industrial, agriculture, public administration and transport sectors. In addition, due the cool temperate climate, space heating is the dominant energy demand in this sector [11].

2. Energy use scenarios in the UK residential sector

Several studies have explored the evolution of the peak demand and the electricity consumption of the UK residential sector based on scenario modeling, such as [12-14]. However, these studies were performed on a national scale and looked at the long-term impacts of the proposed scenarios, for example for a timescale to 2050. Eyre and Baruah [15] also explored four broad qualitative socio-technical scenarios regarding space heating demand and consumption. Although these scenarios were over simplistic, the intention was to map the space within which actual futures are likely to fall, and they also addressed a national scale. In addition, various top-down or bottom-up models have been proposed for residential energy demand projections [16-19]; yet these models represent the entire UK housing stock. Therefore, to the best of the authors' knowledge, the literature currently lacks recent studies on energy use through scenario modeling addressing smaller building scales and medium-term scenarios, which are of interest to architects, building physicists and relevant disciplines. The presented work could facilitate making informed design decisions for an energy supply or energy storage system in the medium term from the end-users' point of view.

3. Methodology

Analysis and modeling of residential electricity demand and consumption data in 4 scenarios in 2030 was performed, based on the data obtained for a baseline scenario in 2015, addressing different building scales, such as individual buildings and communities. Electricity demand and consumption ranges in winter and summer for the scales of interest were derived for each scenario considering gas heated and electrically heated properties. The electricity demand profiles for a typical weekday in winter and summer were drawn for each scenario for a single household based on the assumptions discussed below and on typical residential half-hourly profiles provided by ELEXON [20]. It should be noted though that as in the UK summer peaks are lower than winter peaks [21], the winter values are expected to inform the supply or storage system's design, which would be used all year round. The summer values are thus provided for a better understanding of electricity use throughout the year.

3.1. Scales of interest

The study focuses on the final level of distribution, which is the 400/230V electricity network. The average number of residential buildings that are supplied at this level was sought via Distribution Network Operators (DNOs). Western Power Distribution (WPD), Scottish and Southern Electric Power Distribution (SSEPD) and UK Power Networks