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European smart home market development: Public views on technical and economic aspects across the United Kingdom, Germany and Italy

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ABSTRACT

Smart homes will enable the new services and capabilities offered via smart grids and smart cities to be realized by householders. Yet, whilst there is a wealth of research on smart grids' contribution to achieving Europe's ambitious climate change and energy policy goals, smart homes are not studied to the same extent. The aim of this paper is to illustrate differences and similarities in technical and economic drivers and barriers to smart home market development in three European countries characterized by different policy and socio-economic contexts. The research reveals key barriers to the adoption of smart homes such as reliability, data privacy, and costs of smart home technologies across the countries studied. On the other hand, housing stock characteristics, both age of buildings and tenure, reveal deeper cross-country differences in attitudes and perceptions towards these technologies. The research highlights the need for smart home services that go beyond energy consumption and management services. Only when such a holistic approach is adopted, where other applications such as health or security, suited to the householders' needs and making positive contribution to their daily lives, are enabled, will the benefits of smart homes become clear to the consumer.

1. Introduction

The threat of climate change, uncertainties in the price of energy and security of supply concerns necessitate finding new ways of producing, delivering and consuming energy. It is in this regard that smart grids (and smart cities) have gained increasing attention in both the policy and academic communities across Europe and many other industrialized countries. At the domestic level, smart homes might enable new services and capabilities offered via smart grids (and smart cities) to be fully realized by householders such that their needs, requirements and preferences are met in tandem with the grid constraints. Through the ability to control all devices and appliances within a home from a single control unit remotely or manually, smart homes might allow consumers to control and manage their energy use more efficiently whilst increasing their comfort and convenience for a variety of household activities. These activities might vary from space heating (via thermostat settings adjusting automatically to actual weather temperature) to water heating (via providing hot water at a required temperature instantaneously) to lighting (via lights switching off automatically as the occupants leave a room).

Yet, echoing the prospects of social sciences to make as much contribution to the development of a sustainable energy system as technology and natural sciences [1,2], social aspects of smart homes remain largely understudied. An extensive body of literature focuses on technical aspects, including optimal load management strategy [3–5], modelling of user comfort against physical constraints like energy price and power limitations [6], embedding solar and storage energy in smart homes [7], as well as how the demand response might affect wider energy system characteristics [8–10]. Social aspects mostly focus on the effects of user interface on energy demand [11,12], yet the need to incorporate socio-cultural and environmental values alongside intelligent technological systems [13] has not been addressed. An exception is by Jeong et al. [14] whom noted cultural differences for smart home design and operation preferences between Americans and Koreans on issue like smart appliances and their control, environmental connection, physical safety and security. Otherwise, wider socio-cultural aspects have been largely ignored despite identification of a wide range of challenges facing the smart home industry

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over a decade ago. Edwards and Grinter [15] drew attention to interoperability, administration, reliability, systems intelligence and behaviour inference, and security as key issues limiting the growth of smart homes into a mass market. More recent research highlights retrofitting existing homes, interoperability, costs and usability [16] as well as a lack of understanding of user needs and of infrastructure solutions (i.e. technical skills and capacity to install them) as key barriers [17]. While technical factors (i.e. retrofitting existing homes, interoperability, reliability and security) will determine whether and to what degree functionalities and capabilities offered at grid level can be integrated into the householders' lives, economic factors are likely to play a significant role for the actual adoption of these technologies and services. At the intersection of these factors lies the usability; services that smart homes provide to the users (like assisted living, security, remote monitoring, energy management, etc.[1]), enabled by the mix and integration of technologies in the system (sensors, communication platforms, appliances, etc.) and the relevant user interfaces as well as being subject to the socio-cultural context and values. We argue that a more fundamental challenge for the development of the smart home market is the treatment of these different smart home services in *silos* – as distinct sectors, developed by different vendors and studied across disparate disciplines, with poor cross-fertilisation of practices and innovations. This sectoral approach ignores the fact that home is an expression of identity [18] and that a smart home's technology and services should be well integrated into the design, lifestyle and general sense of home [19].

By building on rich data from public deliberative workshops in the three selected countries, the aim of this paper is to assess the role and relevance of technical and economic factors on the development of the European smart home market. As a result, our study contributes to addressing gaps in a number of research themes identified in the first issue of this journal. Reflecting on fifteen years of energy scholarship, Sovacool [1] reports that very few studies employ human centred research methods. He further notes a lack of comparative case studies to understand both conceptions of energy services across different cultures as well as the evolution of energy technologies. Rather than conceptions of energy services, our study focuses on understanding perceptions and attitudes to smart home technologies and services across different cultures. On the latter, he asks '*what different social groups may benefit from the use of a particular energy system?*' (p. 25), which has not been addressed in the context of smart home technologies. Our study reveals perceived benefits of these technologies by touching upon different social groups in urban and small town contexts, across different cultures. Sovacool [1] further notes that 64.7% of articles he reviewed has no sponsor which, he argues that, might limit their relevance to real world problems. In this regard, we highlight that our study is funded by industry in an international competition, titled 'Smart Home a New Customer Relationship with Energy'.[2]

More explicitly, our study focuses on the United Kingdom (UK), Germany and Italy that are characterized by distinctive characteristics[3]: Italy is the first European country that rolled out smart meters nationally. Germany has a more decentralized network with lots of renewable energy production taking place at the household level. Of 53 GW installed renewable electricity generation capacity in 2010, only 7% is owned by the four biggest utilities in Germany, whilst the private persons' share is 40% [20]. The UK stands somewhere between the two where a centrally generated, high carbon electricity grid is challenged by a very ambitious emissions reduction target, resulting in the development of a variety of policy schemes including a national roll-out of smart meters by 2019 to initiate demand response. On the other hand, as revealed in a recent Eurobarometer survey, interest in new scientific discoveries and technological developments varies significantly across the UK, Germany and Italy (43%, 32%, 16% respectively, compared to the EU27 average at 30%) [21]. These striking differences open up interesting questions around how perceptions of technical and economic aspects of smart homes vary in these countries, characterized by different levels of acquaintance with innovative technologies and energy systems, and whether they are country-specific or common. Understanding these drivers and barriers in turn can be used to inform debate regarding appropriate European policy in areas such as smart homes and smart grids. Another novelty of the research is its holistic approach to smart home services (avoiding the above-mentioned 'silos' problem), with a view to drawing out conclusions for energy consumption and management services.

The paper is structured as follows: Section 2 reviews the literature regarding the definition of smart homes and key challenges. Section 3 sketches out the national policy contexts as well as relevant socio-economic and demographic characteristics of the three countries. Sections 4 and 5 outline the methodology and results from public deliberative workshops; and Section 6 is devoted to conclusions.

2. Background: smart homes and key challenges

2.1. Smart homes definition

A smart home is a residence equipped with a communications network, linking sensors, domestic appliances, and devices, that can be remotely monitored, accessed or controlled [22] and which provide services that respond to the needs of its inhabitants [23,24]. In principle, the term 'smart home' may refer to any form of residence, for example, a standalone house, an apartment, or a unit in a social housing development. In this definition, sensors are devices used to detect the location of people and objects, or to collect data about states (e.g. temperature, energy usage, open windows). Domestic appliances refer to white goods such as washing machines and refrigerators. Devices can be electronic, for example, phones, televisions, computers, or electric, referring to the more simple toasters, kettles, light bulbs, etc.

The network, connecting and coordinating these various technological features (i.e. sensors, devices, appliances) and information, is central to the concept of the smart home [22,25]. It is the existence of this home network that distinguishes the smart home from a home merely equipped with standalone, highly advanced technological features [26]. In a smart grid enabled environment, a home network will ensure the delivery of smart home services subject to grid constraints in real time, either to ease congestion at local level or to contribute to national balancing, be it managed, accessed and controlled by a single party (e.g. energy company) or third parties managing different services (e.g. heating vs management of electricity demand via demand side response programmes). In a smart city context, a home network will communicate with other sectors like transport or e-health in real time to optimize service delivery.

A smart home network (or more commonly 'home area network', HAN) is made up of two elements: a 'physical' connection

[1] For a list of services please see Balta-Ozkan et al. [58].

[2] http://www.eon.com/en/about-us/innovation/research-initiative/research-topic-2012.html.

[3] Sovacool [1] highlights further research questions on the selection of comparative case studies, whether they should be extreme or unique, representative or typical, static or longitudinal, etc. In our case, while our case studies are significantly different from each other, our selection criterion was dictated by our industry funder's operational base.