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Benefits and risks of smart home technologies

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ABSTRACT

Smart homes are a priority area of strategic energy planning and national policy. The market adoption of smart home technologies (SHTs) relies on prospective users perceiving clear benefits with acceptable levels of risk. This paper characterises the perceived benefits and risks of SHTs from multiple perspectives.

A representative national survey of UK homeowners (n=1025) finds prospective users have positive perceptions of the multiple functionality of SHTs including energy management. Ceding autonomy and independence in the home for increased technological control are the main perceived risks. An additional survey of actual SHT users (n=42) participating in a smart home field trial identifies the key role of early adopters in lowering perceived SHT risks for the mass market. Content analysis of SHT marketing material (n=62) finds the SHT industry are insufficiently emphasising measures to build consumer confidence on data security and privacy.

Policymakers can play an important role in mitigating perceived risks, and supporting the energy-management potential of a smart-home future. Policy measures to support SHT market development include design and operating standards, guidelines on data and privacy, quality control, and *in situ* research programmes. Policy experiences with domestic energy efficiency technologies and with national smart meter roll-outs offer useful precedents.

1. Introduction

Smart homes are one of the EU's 10 priority action areas in its Strategic Energy Technology Plan: "*Create technologies and services for smart homes that provide smart solutions to energy consumers*". Behind this strategic policy objective lies *"the Commission's vision for the electricity market [which] aims to deliver a new deal for consumers, smart homes and network, data management and protection"* (EC, 2015). A wide range of publicly-funded projects across the EU are designed to engage consumers in this vision (Gangale et al., 2013). Underlying the EU's strategic goals for a smart home future are clear assumptions that households seek a more active role in the energy system. The Commission argues that *"Communities and individual citizens are eager to manage energy consumption …"* (EC, 2015; EESC, 2015). From this policy perspective, smart homes are enabling technologies to meet a latent demand by households for home energy control and management. As such smart homes are seen as an integral part of a future energy efficient system, helping to reduce overall demand as well as alleviating supply constraints during periods of peak load (Lewis, 2012; Firth et al., 2013). As in the EU, widespread diffusion of smart homes in the UK has already been anticipated in policy documents (DECC, 2009; HMG, 2009) and is seen as an important 'building block' of the smart grid (DECC-OFGEM, 2011). Smart home experts agree that "*climate change and energy policy will drive UK smart home market development*" (Balta-Ozkan et al., 2013a).

Smart home technologies (SHTs) comprise sensors, monitors, interfaces, appliances and devices networked together to enable automation as well as localised and remote control of the domestic environment (Cook, 2012). Controllable appliances and devices include heating and hot water systems (boilers, radiators), lighting, windows, curtains, garage doors, fridges, TVs, and washing machines (Robles and Kim, 2010). Sensors and monitors detect environmental factors including temperature, light, motion, and humidity. Control functionality is provided by software on computing devices (smartphones, tablets, laptops, PCs) or through dedicated hardware interfaces (e.g., wall-mounted controls). These different SHTs are networked, usually wirelessly, using standardised communication protocols. The diversity of available SHTs means the smart home has many possible configurations and by implication, 'smartness' (Aldrich, 2003). In this paper,

Abbreviations: SHTs, smart home technologies

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'smart homes' is used as a generic descriptor for the introduction of enhanced monitoring and control functionality into homes.

SHTs are increasingly on sale both off-the-shelf and with professional installation. Examples available in the UK include British Gas' HIVE system for controlling heating and hot water systems, and RWE's SmartHome system for heating, appliances and lighting. The global market for smart appliances (including fridges, washing machines, tumble dryers, dishwashers and ovens) is projected to grow 650-fold from $40 m in 2012 to $26bn in 2019 (IEA, 2013). Global consumer research carried out in seven countries worldwide, including the UK & Germany, suggests a high level of market support (GfK, 2015). Over half the consumers surveyed expressed a general interest in smart homes, and 50% believe SHTs will have an impact on their lives over the next few years (GfK, 2016). Market forecasts project over half a million households in Germany will have smart appliances or devices by 2019, driven by widespread adoption of smart phones (Harms, 2015).

However, actual levels of uptake of SHTs are still low, and smart product sales are dominated by internet-connected TVs (Harms, 2015). Market growth will ultimately depend on prospective users clearly perceiving potential benefits with acceptable levels of risk. In terms of benefits, SHTs can provide not just enhanced energy management, but also improved security and security, enhanced leisure and entertainment services, and extended personal independence through healthcare provision and assisted living (Chan et al., 2009; Nyborg and Røpke 2011).

Communicating these benefits alone is insufficient. SHT developers are already recognising the challenge of gaining the trust and confidence of prospective users (Harms, 2015). Market research has found the most significant barrier to adoption is upfront cost, followed by lack of awareness and privacy concerns (GfK, 2016). Several studies have examined prospective users' concerns about SHTs in more depth using small samples in technology demonstration labs, deliberative workshops, or focus groups (Paetz et al., 2012; Balta-Ozkan et al., 2013a, 2014). These studies have confirmed interest in the energy management potential of smart homes, but have also identified potential market barriers to adoption including cost, privacy, security, reliability, and the interoperability of different technologies. Privacy and trust-related issues have delayed or halted smart-meter rollouts (AlAbdulkarim and Lukszo, 2011; Hoenkamp et al., 2011). Similar issues may arise with data collected by internet-enabled SHTs within the home (Cavoukian et al., 2010; Balta-Ozkan et al., 2013b). A wider set of sociotechnical concerns with SHTs includes an increased dependence on technology, electricity networks or outside experts, and the proliferation of non-essential luxuries inducing laziness in domestic life (Balta-Ozkan et al., 2013b).

This suggests prospective users are more circumspect about SHTs than policymakers. Market analysis finds that "*market players, industry and retailers need to collaborate to create awareness of smart homes and to communicate the features, but especially, the benefits of these systems*" (Harms, 2015). Early adopters attracted by the novelty of SHTs are particularly important for differentiated marketing and sales strategies (Moore, 2002). Early adopters 'seed' market growth by trialling and testing innovations and communicating their benefits and functionality to the more risk-averse majority of consumers (Rogers, 2003). The profile of potential early adopters willing to take greater risks in being the first movers to adopt SHTs is largely unknown. Yet policies to support SHTs need to be particularly sensitive to early adopters' distinctive characteristics (Egmond et al., 2006).

Three important questions characterise the potential market for SHTs and shape the smart home policy environment:

Q1. How do prospective users perceive the *specific benefits* and *risks* of SHTs?

Q2. Do *early adopters* have distinctive perceptions of SHTs?

Q3. Is industry marketing of SHTs *aligned* with the perceptions of prospective users?

This paper answers each of these questions by analysing three new data sources: a national market survey of prospective SHT users (n=1025); an early adopter survey of SHT field trial participants (n=45); content analysis of SHT industry marketing material (n=62). The two surveys were conducted in the UK, a major consumer market into which smart meters are currently being rolled out, and SHTs are becoming commercially available. The content analysis of industry marketing material focused on the SHT industry active in EU markets, with a subsample of smaller UK-focused companies.

This paper makes novel contributions to the important policy challenge of enabling smart technology diffusion into homes throughout the UK and Europe. First, perceived benefits and risks of SHTs are comprehensively assessed, providing a strong evidence base for policy to address areas of consumer concern while reinforcing SHTs' potential contribution to energy system objectives. Second, the characteristics of SHT early adopters are distinguished, enabling targeted policy to help initiate market growth. Third, inconsistencies between industry, prospective users, and policymakers' vision for smart homes are identified, pointing to critical areas in which policy leadership can shape the development of the SHT market. These policy implications are addressed in detail in the concluding section. This follows an explanation of data collection methodology and sampling, and then the presentation of key results and analysis.

2. Methodology and data

This section provides details of the different datasets used in the analysis, the data collection instruments and sampling procedures, and the sample characteristics of each dataset. SPSS version 22 was used for all the survey data analysis; Microsoft Excel was used for the content analysis of industry marketing material.

2.1. National survey

A survey instrument was developed by the research team to measure prospective users' perceptions of the benefits, risks, and design attributes of SHTs, as well as general issues of consumer confidence in SHTs.

The survey instrument was structured in two parts. Part One contained socio-demographic questions (respondent age, respondent gender, household size, household income, home tenure) and a basic question on smart home awareness used to screen respondents. The screening question was included to minimise hypothetical response biases from homeowners with no prior knowledge about SHTs. The screening question was "*Do you know what 'smart home technologies are?*". Response options ranged from "*no idea*", "*vague idea*", "*general idea*", "*good idea*" to "*already have some installed*". Respondents answering "*no idea*" were screened out and did not continue the survey. All other respondents passed the screening question and moved on to Part Two.

Part Two of the survey began with an open-ended question asking respondents to provide a few words "*that first come to mind when you think about 'smart home technologies'?*". Respondents were then asked about the information channels through which they had found about SHTs (6 response options). The remainder of Part Two comprised detailed questions measuring perceptions of SHTs. Perceptions were measured on a 5 point Likert scale (from 1=strong disagree to 5=strongly agree) with an additional "don't know" response option. Questions measuring prospective users' perceptions were ordered as follows:

- the main *purposes* of SHTs (9 response options);
- the potential *benefits* of SHTs (12 response options);
- the relevance of SHTs for specific domestic *activities* (8 response options);
- the *design* features of SHTs (7 response options);