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Smart home technologies in everyday life: do they address key energy challenges in households?

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Smart home technologies (SHTs) enable new ways of using and managing energy in the domestic sphere. This paper interrogates their contribution to the ambitious carbon emissions reduction efforts required under the 1.5°C mitigation pathway set by the Paris Agreement and their suitability for energy poverty alleviation goals. In contrast to aspirational claims for a 'smart utopia' of greener, less energy intensive, and more comfortable homes currently present in market and policy discourses, we argue that SHTs may reinforce unsustainable energy consumption patterns in the residential sector, are not easily accessible by vulnerable consumers, and do little to help the 'energy poor' secure adequate and affordable access to energy at home.

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Introduction

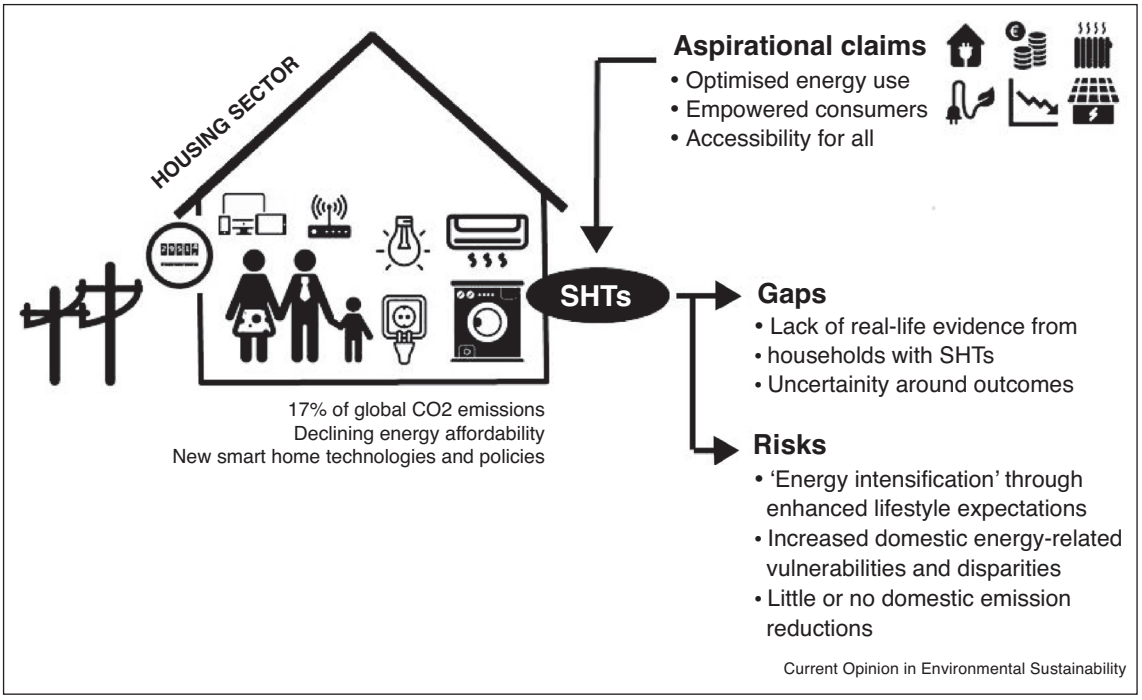
Aggressive mitigation is needed to avoid dangerous climate change as acknowledged by the 'well below 2°C above pre-industrial levels' target adopted during the 2015 COP21 Paris Agreement [1,2]. To meet COP21 agreement commitments, European and other developed countries must deliver significant reductions in final energy consumption including via more efficient use of energy in the buildings sector. The importance of reducing consumption and emissions in buildings is evidenced by the fact that this end-use sector contributes one third of global final energy use and energy-related CO_2 emissions [3]. Within that, the residential housing sector represents around 25% of global energy consumption and 17% of global CO_2 emissions [4].

At the same time, calls for a 'universal access to affordable, reliable and modern energy services' as stated in sustainable development goals (SDGs) [2] highlights the relevance of energy poverty as an issue of global significance closely related to the climate challenge. Understood as a condition in which households are unable to access socially- and materially-necessitated levels of domestic energy services, energy poverty is seen as a 'planetary problem' that refers both to lack of access and affordability of domestic energy [5]. Global data indicate that one in five people worldwide are not yet connected to the electricity grid and that almost 3 billion people rely on traditional fuels for cooking and heating [6]. In affluent regions such as the EU or Australia, a significant percentage of the population — though not a majority — suffer from excessive energy burdens, struggle to heat their home adequately or to pay their energy bills on time [7–9].

Addressing the interrelated global energy challenges of energy emissions and affordability requires a large scale transformation in how societies live, capture and provide energy. This shift is primarily aimed at significantly reducing the carbon (and other) footprints of final energy use and also needs to confront the deeply embedded underpinnings of energy-related injustice and deprivation [10,11,13–15]. Households are at the center of this double endeavor and are expected to play a more active role in managing and reducing their energy use with new 'tools' such as smart home technologies (SHTs) (Figure 1).

SHTs incorporate ICTs, sensors and networking capability to automatically and/or remotely control the operation of home appliances like lights, heating and air conditioning systems. This is usually done via smartphone apps, some other kind of touchscreen panel or interface, or through digital voice assistants (e.g. Google Home and Amazon Alexa). Initially developed for luxury 'smart homes' [12•], SHTs are now marketed more broadly as home electronics 'accessories' and devices, where they promise to 'significantly enhance domestic comfort, convenience, security and leisure whilst simultaneously reducing energy use through optimized home energy

Figure 1



Graphic abstract of the paper.

management' [13]. They are also being sold and operated in tandem with cognate devices such as smart meters, in-home displays (IHD) that are expected to help households visualize data and gain knowledge on their own energy consumption patterns.

The relevance of SHTs in future energy system imaginaries is made clear in the EU's 2015 Strategic Energy Technology Plan, which states the need to 'create technologies and services for smart homes that provide smart solutions for energy consumers' in order to 'give consumers in homes, companies and public administration control to optimize their energy consumption (and production)' [14]. The vision of a 'smart EU energy system' involves 'innovative service providers and start-ups delivering user user-friendly interfaces/tools for energy management [. . .] as part of a smart home service bundle' [15]. Along similar lines, the Australian Energy Market Commission says that 'smart appliances and smart meters will provide opportunities for consumers to better control and manage their electricity' [16].

Although energy efficiency and mitigation are not their main *raison d'être*, SHTs are anticipated to provide both residential emission reductions and associated benefits for households experiencing energy poverty, as the above excerpts indicate. In order to stimulate discussion on these issues, this paper critically assesses these claims by focusing on the lived experiences of households with SHTs in developed countries, where the market for SHTs is growing rapidly. In doing so, we provide a viewpoint informed by selected social science academic literature with a focus on two developed world regions (the EU and Australia) that are leading the deployment of SHTs worldwide. We focus specifically on two areas of this literature: first, reviews of SHTs that consider their implications for household energy consumption and energy poverty; and second, empirical studies of SHTs in real life household situations. This significantly narrows down the scope of our review, given that only 20 per cent of peer-reviewed research on 'smart home users' was recently found to be published in the social sciences [17]. A further limitation noted by Paetz [18] is that 'up to now, hardly anyone has seen, experienced or lived in an environment that offers the full range of ICT-based energy management solutions'.

With this focus in mind, we continue by providing an overview of the ways SHTs shape domestic energy use and daily routines followed by an evidence-based assessment of their contribution to climate change mitigation and their role in addressing energy-related vulnerabilities and inequalities. The paper concludes with critical reflections on the scope for SHTs to address these energy challenges.

Understanding how SHTs shape everyday life

As part of a broader trend in Internet-enabled consumer electronics and infrastructures (e.g. the 'Internet of

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