

# **“Home is where the smart is”? Evaluating smart home research and approaches against the concept of home**

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## **Abstract**

This article develops concepts of what the home is and reflects on smart home technology and the research literature on smart homes in relation to these concepts. The focus is on the aspects of smart home technologies related to energy management within the home (end-uses) and at network or grid level (system). Four aspects of a home are distinguished: a place for *security and control*, for *activity*, for *relationships and continuity*, and for *identity and values*. These aspects of home are used to discuss approaches to, and ideas of, the smart home, as reflected in the research literature. It is shown that technical and ‘prospective’ research literature focuses on aspects of security and control in the home as well as on activities, whereas research papers that are more conceptual and evaluative are more likely to include questions of relations, values and identities. The paper concludes that a broader understanding of the home in all aspects is needed when conducting research into smart homes. This can be valuable when evaluating how smart home technologies work in real homes, as well as in the more technical and prospective approaches to developing new socio-technical configurations.

## **Keywords:**

Smart energy; DIY; meaning of home; energy management;

## **Introduction: energy consumption, homes and smart homes**

Given the extensive research literature on energy in housing, it is striking how little there is on the home. Even though recent socio-technical studies within energy start to include notions of what the home means to people (Aune, 2007; Ellsworth-Krebs, Reid, & Hunter, 2015) there is still room for expanding this area. The concept of home is largely absent from the thousands of papers in which building functions are analysed and modelled and the ‘behaviours’ of occupants are dissected and discussed. However, in sociology (Mallett, 2004), geography (Blunt & Dowling, 2006), anthropology (Mechlenborg, 2007; Sjørølev, 2008) and architecture (Després, 1991), there is a longer tradition for working on ideas, concepts and practices of home. Here we learn that a house (that is, a building) and a home are two fundamentally different things; and that there are discussions on how people appropriate houses and thus turn them into homes, and discussions on whether home should be thought of as a place, a feeling or a practice.

On the other hand, we also have within the energy related literature a growing interest in whether, and if so how, ‘smart homes in smart grids’ might be part of a more sustainable future (Balta-Ozkan, Davidson, Bicket, & Whitmarsh, 2013a; Christensen et al., 2016; Hargreaves, Hauxwell-Baldwin, &

Wilson, 2015;). There is no fixed definition of a smart home, but an understanding that smart homes incorporate digital sensing and communication devices. Crucially, these devices *communicate with each other seamlessly* in the smart home ideal, in order to provide one or more of the following services: more sophisticated control of energy (the primary interest in this paper); greater security against break-ins; innovations in home entertainment and ambience; health monitoring and independent/assisted living arrangements.

There are many great expectations to how these networked technologies will transform our homes and everyday life but they often seem far from reality (Rihar, Hrovatin, & Zoric, 2015; Wilson, Hargreaves, & Hauxwell-Baldwin, 2015). As The Economist magazine commented “*The fanfare has gone on for years (...) But so far consumers have been largely resistant to making their homes “smart”*” (The Economist, 2016). The Economist used the example of Google buying Nest (makers of ‘learning thermostats’) to show how companies have shown huge interest in developing smart home technology and also as an example of disappointing sales figures for smart home products. Market analytics have established that only a few percent of US households have smart (networked) appliances and the vast majority of UK households have no plans to buy any (Ibid., 2016). Explanations for the reluctant homeowners are diverse but include questions of reliability, cost, control, privacy and security (Balta-Ozkan et al., 2013a; Balta-Ozkan, Davidson, Bicket, & Whitmarsh, 2013b).

Not only private companies but also public authorities have shown huge interest in smart home technologies, especially relating to health care and to energy consumption and management. The latter is for instance seen in the European Union H2020 funding schemes, including the SET (Strategic Energy Technology) plan and its integrated roadmap.<sup>1</sup> This sets out the goal of secure, affordable and sustainable energy and states that this goal can only be reached through the use of new smart energy technologies. The active participation of citizens is considered crucial to this strategy and it is made clear that citizen participation and engagement form part of smart solutions in the home, although the documents tend to be vague about the form that this engagement should take. As Skjølsvold and Lindkvist illustrate, user engagement can be woefully tokenistic, even when there is an aspiration to include users in the design stage of a smart energy technology project (Skjølsvold & Lindkvist, 2015).

Some of the main questions raised in the smart homes literature are data security, locus of control in the household, and the extent to which smart homes offer greater understanding and ability to manage energy to occupants on the one hand and greater system efficiency on the other. Implicit in all these is a further question about boundaries: for example, is it sufficient to describe a smart home as an ‘inclusive, two-way communication system between the house and its occupants’ (Saul-Rinaldi, LeBaron, & Caracino, 2014, p. 5) when that system may bring a home into the ambit of others traditionally kept on the doorstep – utilities, government – by setting up new data-sharing and control mechanisms?

Bringing discussions on *what a home is* into the field of residential energy consumption, with its growing interest in smart homes as a low-carbon and grid-management ‘solution’, thus seems highly relevant. In this paper we bring together discussions on the nature of the home with some research approaches to smart homes, and use this exercise to identify possible absences in the smart home literature and policy approaches.

## The concept of home

The home is a concept with many different connotations. An often-cited review of the concept of home lists ten of these meanings (Després, 1991). To make a more workable categorization

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<sup>1</sup> <https://setis.ec.europa.eu/archive/technology-roadmaps>

we will combine these ten concepts into four broader categories, based on different aspects of home as reviewed by Després and others (Després, 1991; Mallett, 2004; Somerville, 1997). These categories in no way exclude each other: rather they should be seen as complementary and intertwined, as also established by several authors (Després, 1991; Mallett, 2004; Somerville, 1997). Also the orders in which we present them are arbitrary, as their importance may depend highly on the context and vary with different groups.

First is *home as security and control*. In opposition to workplace, institutions and cities or wild nature, home is the place where you are in control and can feel safe, even though, or maybe precisely because, the home might be surrounded by a hostile society. The home in this understanding is thus also associated with a safe haven and a refuge from the surroundings. Després talks about security and control as one aspect of home and a refuge from the outside world as another aspect, whereas in our terminology we combine them into one as we see them as two sides of the same experience. From a sociological perspective (Mallett, 2004) it can, however, be objected that home is not always a secure place, for instance for abused women and children, and that, for example, many teenagers might not feel that home is where they are in control of their own lives. The importance of home as control and safety can maybe best be understood, paradoxically, when studying those who have to live in places which do not accommodate this notion of the home, such as marginalised people living in rooming houses (Mifflin & Wilton, 2005).

Second is *the home as a site of activity*, either in the form of the many different activities of cooking, cleaning, eating and sleeping which constitute everyday life, or in the form of actually working on and with the home, physically transforming the home to make it the place that best accommodates our activities and ideas. In the categories from Després (1991), she mentions three different meanings of the home including the home as something to act upon and modify, the home as a centre of activity and the home as a material physical structure, whereas we in our approach combine these three into one aspect of the home as a physical place for activities. Within practice-theoretical studies there has been considerable focus both on the everyday practices (see e.g. Gram-Hanssen, 2008, 2011; Hand & Shove, 2007; Røpke, Christensen, & Jensen, 2010; Shove, Watson, Hand, & Ingram, 2007) and on the practices of transforming the home (Bartiaux, Gram-Hanssen, Fonseca, Ozoliņa, & Christensen, 2014; Hand, Shove, & Southerton, 2007; Horne, Maller, & Dalton, 2014; Maller, Horne, & Dalton, 2012). Although none of these studies has specifically addressed the question of the concept of home, it is reasonable to infer from them that the idea of a home as a site for activity is well-established. Not only practice-theoretically- oriented researchers have however worked with this aspect of the home as a site of activities. The anthropologist Gullestad has called the home the centre of everyday life, as it is from this we depart and to this we return, as well as where we perform most of our everyday activities (Gullestad, 1984).

Third, *the home is a place for relationships and continuity*. One of Després' ten meanings of the home is about continuity and permanence, indicating that home is a temporal process, changing over time but also relating back to what was before. Permanence and continuity relate to the question of family in the way houses have been handed from one generation to another (Sjørøsløv, 2008), but also to our childhood memories of our birth home and generally to a sense of belonging and having roots (Després, 1991). Another meaning of home according to Després refers to relationship with families and friends, with a strong connotation of home as a place to strengthen relationships with people one cares for. This was also found in a Danish study, where qualitative interviews were exploring meanings of the home and found that whenever asked about the home, residents answered with tales of the family and their relations (Gram-Hanssen & Bech-Danielsen, 2004).

The fourth and final category of ideas of the home deals with *the home as identity and values*. It combines three meanings from Després (1991), including home as a reflection of one's ideas and values, home as an indicator of social status, and home being a property to own. The status and identity can be understood in the language of Bourdieu, expressing how we reflect our lifestyle to ourselves and show it to others through our possessions, unconsciously guided by our habitus (Bourdieu, 1986). Higher social classes distinguish themselves from lower through their cultural and economic capital and new ideas of highbrow consumption continuously engender new questions of what an 'ideal home' should look like. The decoration of our homes not only signals to others who we are but also works as a reflection of and dialogue with ourselves of what is important and right to us. What people do to their homes, in the form of retrofitting, decorating and furnishing them, might thus reflect different understandings of consumer cultures (Gram-Hanssen & Bech-Danielsen, 2004). Housing researchers argue that the home is increasingly becoming an expression of the residents and their values and lifestyles (Lewin, 2001) and that the house with its interior decorations and other equipment can be seen as a microcosm reflecting the residents' social values and identities (Gullestad, 1984).

In the above we have identified four different concepts that cover important aspects of what a home is. The review from Després (1991) which inspired this list is however more descriptive than analytical, and what might be missing from this approach is an understanding of how different social groups relate differently to meanings of home, and how these different meanings of home relate to socio-economic differences and societal power relations. Furthermore, it is important to state that these different ideas of the home are in no way a checklist which applies in all cases. However, as a guide to aspects to discuss in relation to questions raised by smart homes, they might be useful.

The four concepts described above build on a strong relationship between home and dwelling, where 'home' related to the meanings that the residents ascribe to the physical building which they inhabit. It can be argued that historically and cross-culturally there is not always this strong relation between the concept of home and the physical building, and that this mode of thinking is rooted in the Enlightenment of the seventeenth century (Mallett, 2004). Home can, however, also be understood in terms of concentric circles radiating out from the dwelling into the neighbourhood, region or nation. Although homes in the western world today are often spoken of in terms of the dwelling itself, empirical studies show that neighbourhoods are also part of how people feel 'at home', in places and with social relations outside the narrow bounds of dwelling and immediate family (Gram-Hanssen & Bech-Danielsen, 2004; K. Gram-Hanssen & Bech-Danielsen, 2012).

Finally many of the concepts of home described above may sound quite traditional, and thus also call for investigation into what happens to the idea of the home in our postmodern globalised world, where the home is connected directly to the rest of the world through modern communication media. It has been argued that in the globalised world the home is, like everything else, an object for negotiation, disruption, construction and reconstruction (Mechlenborg, 2007). The concept of home itself thus also calls for continuing examination in order to situate the concept of smart home more accurately in relation to traditional and new connotations of home.

### **Concepts of a smart home**

The concept of a smart home for comfort and convenience can be traced back some distance, at least as far as the introduction of electricity into the homes of wealthy people towards the end of the 19<sup>th</sup> century. Display homes in 1930s America offered automation with 'unprecedented levels of

luxury, relaxation and indulgence, with excessive consumption on display ... the benefits of modern living with less effort from householders' (Strengers, 2013, p. 25). But the concept of the low-effort, highly-automated smart home only took shape for a mass market in the final quarter of the twentieth century, as both computing power and automated appliances became more widespread. At roughly the same time, equipment in electricity transmission grids was being 'smarted' through computer-aided control. This process spread to lower-voltage distribution networks and to large industrial customers, until it became feasible to consider relatively small end-uses as ripe for automation, interconnection and remote control. (Electrical storage heating is an early example.) User-centred and system-centred visions of automated control were thus coming together to some extent by the end of the 20<sup>th</sup> century.

Two broad approaches to defining and discussing smart homes can still be identified, depending on whether they start with homes themselves or with electricity systems. First, as residences equipped with Information and Communication Technology (ICT) and with connected appliances that can be remotely monitored and controlled while responding to householder needs (Balta-Ozkan, Boteler, & Amerighi, 2014). Second, and on a broader scale, smart homes and other buildings are seen as flexibly-connected and interacting elements of energy systems (BPIE, 2017). These two discourses can be seen in terms of utility to households themselves and to the electricity system as a whole; also in terms of demands made on households and systems (Darby, 2017). At the individual household level, 'smarting' may integrate electrical devices and services (for example, heating, lighting, security, photovoltaic generation, electric vehicle charging) for remote control by the occupants or some other agent (Robles & Kim, 2010); moving beyond this, sensors and processors can also 'acquire and apply knowledge' about a home, acting independently of direct human agency to change control settings (Das & Cook, 2005, p. 337), in applications such as the 'learning thermostat' (Yang & Newman, 2013). In aggregate, electrical devices in homes have the potential to assist with network and grid management, as elements in systems that rely increasingly on distributed generation, storage and demand response – that is, changes from normal patterns of demand in response to supply availability (Darby & McKenna, 2012; Saele & Grande, 2011). One rationale for smart homes is that they can promote *system efficiency* by helping to reduce peak demand and to match demand with supply in real time. This assists the integration of more distributed renewable generation into electricity systems.

There is an underlying assumption in much energy academic and grey literature that 'smart' is closely related to energy efficiency<sup>2</sup>, something that can be quickly confirmed by putting the three words smart, energy and efficiency into a search engine. An example comes from the Buildings Performance Institute Europe:

*A smart building is highly energy efficient and covers its very low energy demand to a large extent by on-site or district-system-driven renewable energy sources. A smart building (i) stabilises and drives a faster decarbonisation of the energy system through energy storage and demand-side flexibility; (ii) empowers its users and occupants with control over the energy flows; (iii) recognises and reacts to users' and occupants' needs in terms of comfort, health, indoor air quality, safety as well as operational requirements. (BPIE 2017, p.3).*

These are confident and sweeping claims, ascribing great agency to the building itself, which will not only enable system decarbonisation and give users control over energy flows but will be intelligent enough to learn how to anticipate their needs. Later in the report comes a note on the evolving concept of the smart home, one in which the term 'home' is (perhaps revealingly) equated implicitly with 'building': *'When the concept [of the smart home] was launched, the level of intelligence within*

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<sup>2</sup> Efficiency is a *ratio* of one metric to another and it is often unclear which metrics are being used. But energy efficiency is commonly understood as the ratio of useful output from a process/end-use to the energy input for that process. Even so, definition raises a number of methodological issues (Patterson, 1996).

*a smart building was very basic. The intelligence is much more sophisticated in today's (smart) buildings. The next step is ambient intelligence... the building is sensitive and responsive to the needs of occupants and the energy system' (ibid., p6).*

But a home is, by definition, occupied by humans and the way in which it is occupied has a major and well-documented effect on energy outcomes (Gram-Hanssen, 2013; Sanquist, Orr, Shui, & Bittner, 2012). We can therefore expect the distribution of smartness/ intelligence and agency between technology and humans to be an important influence on consumption, responsiveness to system conditions and occupant satisfaction. It is misguided to assume that handing over agency to ambient intelligence will be straightforward (for example, it is not clear how enhanced user control will fit with machine intelligence that anticipates user needs), or that it will inevitably improve social or energy outcomes. If a smart home system is seen as primarily for convenience and comfort, then this undermines assumptions of resource efficiency and demand reduction within a home. Strengers and Nicholls point out inherent contradictions between convenience and energy saving, noting how energy has noticeably less significance in the smart home discourse (the nature, scale and timing of end-uses may be sidelined) than in discourses about smart grids or smart cities, where system considerations are to the fore (Strengers & Nicholls, 2017).

There are questions as to how much ICT-enabled technology, and what types of technology, qualify a home as smart. Adoption of remote controls and ICT is not new, and a smart TV or a smartphone could be seen to qualify a home as smart, as they enable communication between the home and the outside world. But for the purposes of this paper, a high level of device connectedness *within and beyond* the home, along with reliance on that connectivity for everyday operations, are seen as crucial when defining whether a home may be called 'smart'. The definition offered here is tied to physical and operational factors and assumes functionality beyond the usual boundaries of the home:

*A smart home is one in which a communications network links sensors, appliances, controls and other devices to allow for remote monitoring and control by occupants and others, in order to provide frequent and regular services to occupants and to the electricity system.*

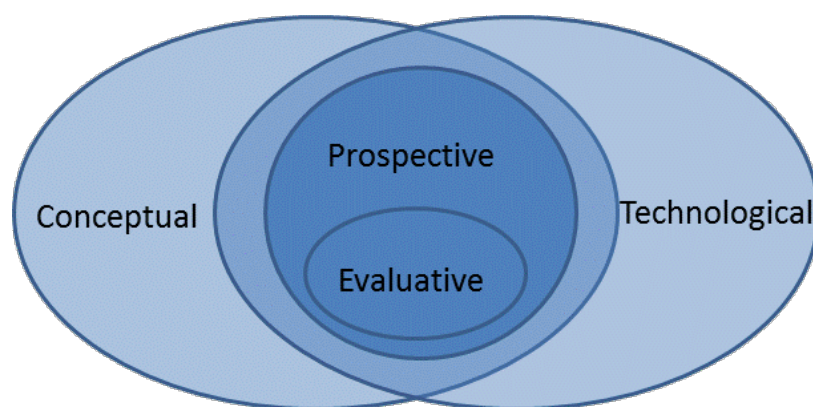
Note that the definition does not make any assumptions about energy outcomes. Also, that it allows for human agency within the home but does not make any explicit reference to occupants other than as monitors, controllers and recipients of energy services: the electronically networked nature of the home is what makes it smart. This can be consistent with the claim that occupants are 'designed out' of the smart home expert vision, which typically assumes them to be unable or unwilling to make changes in lifestyle (Cherry, Hopfe, MacGillivray, & Pidgeon, 2017).

The question of how occupants/users are constructed is a live one. A recent systematic review of the peer-reviewed literature dealing with smart homes, users and technology found that 'a clear understanding of who ... users are and how they might use smart home technologies is missing from a field being overwhelmingly pushed by technology developers' (Wilson et al., 2015, p. 463). The reviewers noted a general lack of user-centric perspectives and a tendency to treat householders as essentially passive: people were to adopt the automated solutions provided and use them as intended by the designers (ibid.). Based on empirical work, Ballo notes how prevailing imaginaries of a smart grid in Norway also construct energy consumers in a limited way, as economic actors with little knowledge of, or engagement with, the systems to which they are connected (Ballo, 2015). There is clearly scope for more research to develop our understanding of all actors in electricity systems and what they are capable of, not least the occupants of homes and other buildings. This is an urgent matter, given the pace of technological and commercial developments in these systems.

Although a factual definition of the smart home has been adopted for this discussion, it is important to note how the term ‘smart’ is associated with emotive and affective meanings such as cleverness and neatness<sup>3</sup> and also with negative connotations such as loss of privacy, loss of control and risks to health, as instanced in reactions of American electricity customers to the prospect of smart meters and smart grids (Raimi & Carrico, 2016). These associations matter when attempting to analyse what smart homes might be and how they might work in practice, just as affective dimensions of ‘home’ matter when analysing what happens within homes and between homes and the world beyond them.

### How far are ‘home’ and ‘smartness’ compatible?

Clearly there are different ways of understanding the properties of smart homes, depending on theoretical standpoints and intentions. These are demonstrated in the striking differences in content and style between research papers written from differing standpoints. However, it is sometimes possible to identify some points of contact between these modes of understanding, for example when scenarios are being developed, or when smart homes are evaluated and it is necessary to set out metrics and indicators for success or failure. In the figure and table below we categorise smart home studies under four broad headings and offer examples of each. We should stress that this categorisation does not stem from a systematic review of the literature but from smart home studies that we have come across in the course of our work on energy in buildings (particularly in homes) in the sociological, engineering, computer science, energy systems and interdisciplinary energy studies literature. It is indicative, not representative, and offered with the aim of stimulating further cross-disciplinary study.



**Figure 1: Types of smart home studies, and how these types relate to each other, either by overlapping or by laying the ground for other types of studies. Thus evaluative studies can only be carried out with reference to all the other types of inquiry, whereas technological or conceptual studies can be undertaken in a ‘standalone’ way. Note that the size of the fields in the diagram does not reflect the quantity of research in each category (although there is indeed less ‘evaluative’ research than any of the other types).**

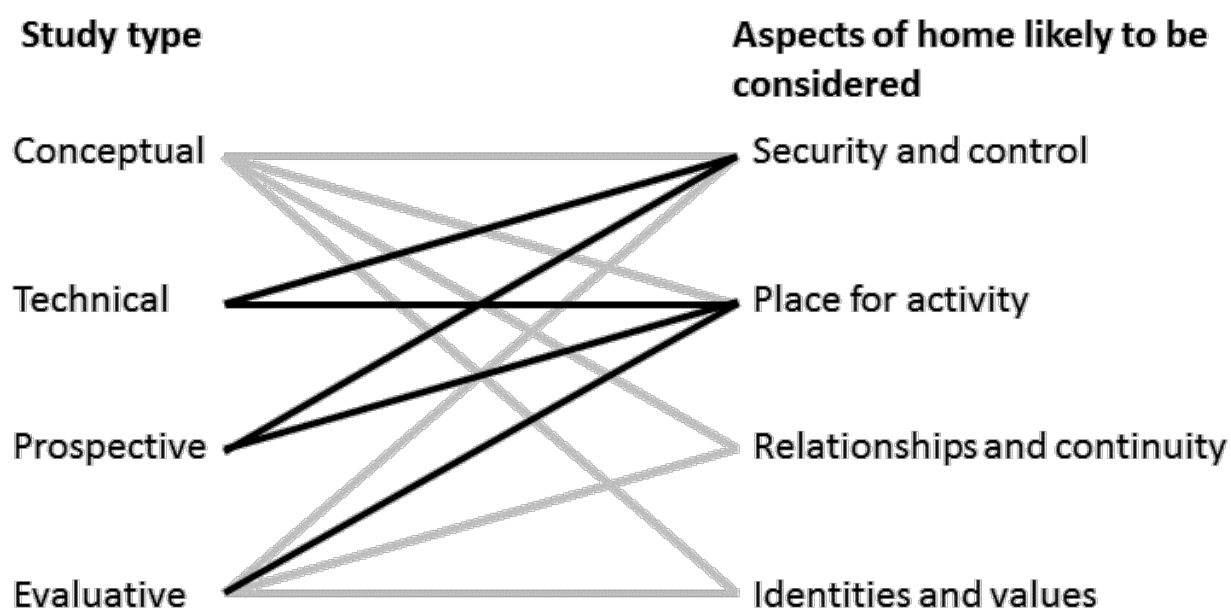
<sup>3</sup> See Oxford English Dictionary definitions

**Table 1: Types of smart home study and what they can tell us**

<b>Study type, with examples</b>	<b>What they tell us</b>	<b>Comments</b>
<b>Conceptual</b> (Green & Marvin, 1994; Strengers & Nicholls, 2017; Wilson et al., 2015)	Meanings ascribed to smartness; situating technologies in relation to time, space, activities, agendas and actors.	Reflecting on the ideas and potentials for different smart configurations, these generally (but not always) take a critical approach to concept and implementation.
<b>Technical</b> (Han, Choi, Park, Lee, & Kim, 2014; Rashidi & Cook, 2009; Wu, Liao, & Fu, 2007)	How system elements can communicate with each other; what a system looks like; algorithms to optimize system efficiency.	The largest single category, dealing with aspects of design, interoperability, system security etc. Generally optimistic in tone.
<b>Prospective</b> (Balta-Ozkan et al., 2013b; Atzori et al., 2014; Skjølsvold & Ryghaug, 2015)	How smart homes might fit within smart systems; what types of smart systems are possible and how they might be configured and operated.	While technical issues are often foremost, these studies set out or imply scenarios that include some 'home' issues: for example, user priorities and willingness to cede control.
<b>Evaluative</b> (Andersen & Christiansen, 2013; Nyborg & Røpke, 2013; Woodruff, Augustin, & Foucalt, 2007)	How smart homes work in practice (routines, meanings, tech and knowledge), including relational aspects and functionality.	Few in number, but important in order to assess how smart technology works in particular contexts.

These types of study do not map directly on to the four concepts of home that we set out above, but there are some interesting correspondences. As the figure below indicates, only conceptual and (qualitative) evaluative studies typically address all four sets of 'Home' meanings. Technical and prospective studies both tend to emphasise control and activity/end-uses for electricity, while prospective analysis also takes some account of relationships between actors.





**Figure 2: Different types of smart home study and the elements of home life that they tend to prioritise. Black indicates a stronger relationship, compared to gray.**

We have indicated how some aspects of ‘home’ may be side-lined in smart home discourses, especially the more technical accounts. Below, we take a look at each aspect of the home in turn and comment on its relationship with the developing concepts of the smart home. We thus compare the smart home research literature with concepts of home to find absences in the smart home literature, especially related to energy issues, and thus to point at where more research could be developed and new approaches included.

### *Smart homes, security and control*

The concept of security plays a prominent role in the development and marketing of smart home technology, and some companies have moved into the smart homes market in order to develop their businesses on the basis of expertise in security systems and a reputation for reliability. There are also interests in developing in-home health monitoring and technology for assisted living for people with chronic illness or disability. But to adopt smart technology is to open up data flows within the home and between it and the outside world, and privacy concerns have been a factor limiting enthusiasm for smart home technology (Naus, Spaargaren, van Vliet, & van der Horst, 2014). The extent to which householders trust their technology and energy providers, along with the extent and nature of their social networks, is likely to influence where they wish to draw the boundaries of ‘home’ as a secure place. A survey from Austria found that, while residential and commercial respondents did trust their energy supplier to manage their energy data, there were concerns about privacy and security issues, posing challenges in designing interfaces, data storage arrangements and appropriate administration (Döbelt, Jung, Busch, & Tscheligi, 2015). There may be tensions between social and personal safety and security. For example, while load-shifting may help to keep a neighbourhood electricity network stable, there may be safety concerns about operating appliances while the householder is absent (e.g. Darby & Pisica, 2013).

While homes have throughout history been places for argument and conflict as well as harmony and caring, smart home visions are somehow presented as conflict-free. Yet new technology can

redistribute control within households, towards the person who best understands new controls or who most wants to operate household equipment (Wilson et al., 2015). This redistribution may be in addition to shifts in control between the occupant(s) and 'outside' agents such as the network operator. If direct (industry) control of certain electrical loads is involved, there is an understandable wish to know that control is delegated to a trustworthy agent (Fell, Shipworth, & Huebner, 2015).

One way for occupants to keep control of their homes might be through DIY approaches to smart homes. On a hobby basis, it is seen how computer-minded people themselves think it is interesting to work with installation of smart technologies to control part of their home (Demeure, Caffiau, Elias, & Roux, 2015; Takayama, Pantofaru, Robson, Soto, & Barry, 2012). However, the same studies also report that most often there will be other people in the households who can feel that they are losing control, and there is often a strong gender aspect to this. Still, these hobby DIY approaches to smart homes diverge interestingly from what was previously described as an 'infantilising' of occupants in the visions of 'fit and forget' approaches to smart technology (Robins & Hepworth, 1988). In the DIY approach, occupants are taking control through the technology to a much higher degree.

Essentially, smart connections can redraw home boundaries if they allow for direct load control of some functions by the supplier or a third party. Whether the occupants feel more or less secure as a consequence may have a lot to do with how they feel about the people, systems or organisations they share information with (Fell et al., 2015) and their perceptions of what constitutes a threat to security.

### *Smart homes as places for activity*

Homes have always been sites for activities, including activities directly related to daily operation of the home itself, the topic of this section. Digital interconnections can add a new dimension to such activity – for example, the frequent use of smartphones for messaging and information alongside other activities such as conversation, TV watching or reading. They can also substitute for traditional activities, for example temperature regulation, keeping an eye on family members, and some of the routine checking and tweaking of household equipment.

As noted above, smart technology developers may assume that automated systems can learn our routines and adapt to them. Whether this works well for householders will depend in part on how well the technology can distinguish between routines and one-off adjustments for particular situations such as sickness in the family or accommodating guests. Woodruff et al., (2007) offer a fascinating account of how home automation came to support strict Sabbath and holy day observance by Orthodox Jewish families – that is, a tightly-prescribed set of routines. In such a situation, machine learning could perhaps be effective in finessing the automation service (although, in this case, it was not attempted; instead, the families themselves adapted to some extent to the automation). In homes with less predictable patterns of activity, the potential for machine learning and coordination is likely to be far smaller; experiences with the 'learning' NEST thermostat indicate the type of problems that can arise when trying to coordinate information from both human and machine activity<sup>4</sup>. Some of these problems may stem from technical incompatibilities between different pieces of equipment, but there may also be fundamental frustrations when a machine is seen to be incapable of acting as effectively to manage temperature levels as a human – some DIY homeowners have directly expressed their view that a smart home needs to do things better than you can do it yourself, otherwise it is not smart (Mennicken & Huang, 2012) – or simply when a human realises that they wish to be in control directly, not to delegate that control. That is, the activity of tending the home and changing it to meet the needs of the moment is satisfying in itself – a part of being 'at home'.

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<sup>4</sup> <http://fortune.com/2016/01/21/nest-issues/>

A home can be 'something to work on' that is appropriated while working on and changing it (Gram-Hanssen & Bech-Danielsen, 2004). In this respect smart homes might be separated into smart homes which were built smart and homes which are equipped with smart technologies in the process of retrofitting. As reported in Mennicken & Huang (2012), smart home installations were previously built in from the beginning or along with a major renovation as some smart technologies needed their own channels for wiring. However, different types of DIY-smart home components could make it possible in future to introduce smart home technologies without making big changes in buildings (Woo & Lim, 2015), and thus allow dwellings to be made smart in smaller steps and as part of an ongoing experimentation: part of being active within the home. The growth in wireless connections enables this step by step integration as well, though problems with different systems not communicating well with each other may still support an argument for making homes smart as part of deep building renovations.

The question of activity is a vexed one in smart discourse, not least because it is often unclear who or what is active; for example 'active' (as in 'active demand') can mean automated, or externally controlled, rather than involving human activity. For the person who understands home as a site of activity, smart technology may be unsatisfactory unless it offers scope for interaction and responds well to human control, or unless the technology can be directly programmed and installed by a DIY smart home owner.

#### *Smart homes and places for relationships and continuity*

An acceptable smart home in terms of continuity may be a home that offers flexibility as well as reliability to new residents: one where they are not 'locked in' to practices that they dislike or do not understand. This most likely means that there need to be iterations while programming is tried out and adjusted until it works for specific households. A man who had smart home technologies installed thus gave an example of this:

*"In the beginning, until the shutters worked properly, until the light worked, I actually modified it on a daily basis and adjusted it and tried to get it running. Now that I have the basic functionality (working) the time (between modifications) is getting longer"* (Mennicken & Huang, 2012, p. 153)

In some homes these iterations might, however, not take place because of lack of knowledge or lack of interest from the household members. Some occupants might find themselves accepting installations which are not working optimally according to their actual wishes and needs, or rejecting them, because they are either not interested in, or capable of, undertaking this kind of iteration themselves, and having someone coming on a daily basis to help with modification seems quite unrealistic (Hargreaves, Wilson, & Hauxwell-Baldwin, 2017).

If a home is (ideally) a place where family members take care of each other and themselves, the question arises as to whether smart home technologies can be part of this as well? In a study of DIY experiences with smart home technologies there are some interesting examples of what this caring could include. A young woman explains, for instance, how she feels happy when she arrives home late in the evening and the light turns on automatically. She expresses it as a feeling that she is welcomed home, even though it is automatic, because she knows that her father programmed the light to do this (Woo & Lim, 2015). The same woman also expresses how other automated functions in the house can give her this nice family feeling:

*"At night, the humidifier operated alone in the living room. It reminded me of my dad, like a trace of my father stayed here"* (Woo & Lim, 2015, p. 788)

Home, however, does not only relate to the dwelling. As described previously, feelings and practices of home can relate to wider geographical areas as well. Questions of smart home technologies could

thus also relate to a community level, managing and communicating social relations as well as energy issues. At an EU level, energy demand-side management (DSM) projects increasingly take a community-oriented approach, including forms of social comparison and competitions, community rewards, social marketing and establishing trusted actors (Mengolini, Gangale, & Vasiljevska, 2016). A future approach for smart home technologies might thus follow a line of helping communities as well as individuals in managing storage, production and consumption of energy, as well as communicating with each other about energy and other interests. A study including user-driven innovation with participation from eco-communities did follow this line and showed how types of feedback can be developed that might respond well to communities of users (Peacock et al., 2017). This study included people with a high interest in energy and sustainability, and although this is a very special type of user, more general lessons can be learned about engaging with communities rather than individuals, and developing ways of co-designing these smart technologies. Another project, maybe less ambitious in the co-designing effort, but helping a community use locally-produced PV power with load-shifting and local storage, included a wide range of householders in terms of knowledge, resources, housing types and interest in energy (Boait, Snape, Darby, Hamilton, & Morris, 2017). This study shows how effort put into developing and communicating a system can be rewarded in terms of effectiveness at shifting consumption to match available supply.

### *Smart homes and reflection of identity and social status*

A home may be seen as temporary or permanent, complex or simple. In any case, it reflects the life of the person or people living there, from a migrant worker's shared room or a nomad's shelter to a luxury city apartment or a manor house that has belonged to a family for centuries. From a sociological consumption perspective, the house reflects the identity and shows the status of its residents and thus a smart home might also be considered according to what it signals to the residents and their peers. With all new technologies which are brought into everyday life there are first movers who are interested in the sense of newness and social status that can be part of having new technologies, and this may be seen as a general driver of still more consumption (Røpke, 1999, 2001). However, in the longer run there often follows a normalisation, when these new technologies become widespread and they lose their distinctive power (Gram-Hanssen, 2008; Røpke, 2001).

Studies on who are first movers with smart home technologies and what drives them make an interesting contribution to research into smart homes. For example, a qualitative study of some professionals who sold and installed smart home technologies, along with interviews with users, reveals some indications of motivation among first movers in the market (Mennicken & Huang, 2012). This article refers to the idea of the Modern Home as one of the main drivers. People who want to express through their home that they are modern, also think smart home technologies are a part of this: they go together naturally, so to speak, with the idea of being modern. The professionals in the interview survey had an example of an older couple who bought a new modern house and wanted it to be smart, although they had never even had an internet connection before (ibid.). Other motivations mentioned here include the smart home as a hobby, something also mentioned in other studies and probably one of the main drivers, especially among DIY smart home owners (Demeure et al., 2015; Takayama et al., 2012; Woo & Lim, 2015). Studies of DIY smart home owners generally report them as having a background within programming, so part of the motivation can be seen as a hobby, where ideas of programming are tried out in their own home (Demeure et al., 2015; Takayama et al., 2012; Woo & Lim, 2015), and this hobby can thus also be seen as a way of reflecting one's own identity in the home.

Following this, one of the studies on DIY smart home owners is explicitly interested in how people can use smart technologies to personalise and make their home more *homey* (Takayama et al., 2012). Building on qualitative studies, the authors found questions of impressing others, "giving it a WOW factor": personalising the home through the smart technologies, making the home more like a

reflection of one's sense of self, in an aesthetic as well as a technical and functional way (Takayama et al., 2012). For some occupants the 'smart' can thus be something supporting an aesthetic approach to the home and a reflection of the people living there, though the opposite is also very possible, that people prefer *not* to have smart technologies because they may not match their home and themselves aesthetically.

### Summary and conclusions

We have examined some of the ways in which the concepts of 'home' and 'smart home' have been addressed by researchers, adopting a functional definition of smart homes as homes that contain a complex communications network, allow for remote monitoring and control, and provide services to both occupants and electricity system operators. We have noted how the concept of home can stretch beyond the walls and roof of a building and how the smart home is conceived by energy researchers as something that can assist with system management, again beyond the boundaries of a building. Developments in ICT has led not only to the introduction of new individual devices into the home but to new possibilities for networking them and for remote control, and it is these possibilities that are most closely related to the concept of the 'smart home' and that we have been most interested in addressing.

First, we can note that it is interesting that the term 'home' only arrives fully in energy discourses at a time when the place where we live becomes a site for energy technology that changes its nature, possibly making it less homelike. Conversely, though, the word 'home', with its strong emotional weight, may be able to domesticate the term 'smart'. In the idea of the 'smart home', there seems to be an attempt to make the terms flow together in order to produce some sort of functional, satisfying hybrid, combining positive associations of both concepts. Is this attempt viable or fundamentally unworkable? Our provisional answer has more to do with interpretations of the older concept – home – than with the newer and still-shaky concept of smartness; and it is based on the somewhat skewed nature of research into smart homes that we discovered.

We selected four expressions of what home can mean (a place of security and control; activity; relations and continuity; identity and values) – and four modes of doing research in and analysing the nature and performance of smart homes (conceptual, technical, prospective, evaluative). Looking at the research literature on smart homes, we find most of it is made up of technical and prospective studies that focus on security and control, with a secondary emphasis on activity. This emphasis draws attention to the perceived *boundaries* of home and how they may shift when a home becomes connected through digital technology to new physical, commercial and social networks, situated in cyberspace as well as in three-dimensional space and time. We have to turn towards more conceptual and evaluative studies in order to find an analysis of continuity, relationships and identity in homes and in places where people feel 'at home'.

Our analysis suggests that, while 'smartness' is not always opposed to traditional aspects of home life, it may be hard to reconcile with others, particularly where the boundaries of the home and locus of control are concerned. Maintaining a home has always been a social matter to some extent, but the advent of 'smart' can add urgency to this sociality: for example, activity supported by electrical power such as vehicle charging sometimes has to be coordinated with other actors in real time for the sake of maintaining electrical system stability (Darby & McKenna, 2012). It is hard to see how this can happen without changing some of the identity, continuity and affective dimensions of home life, or the distribution of agency and power within and beyond the home.

By bringing ideas of what home means into the discussions of smart home development we have, however, not only pointed out possible problems and places where the concepts might clash. We have also pointed out where smart home technologies could have more, or other types of, success compared to what is seen so far. One approach here is the idea of developing smart home

technologies, not only for the single family home but also for local communities. Ideas of home in contemporary western understandings may localise home primarily in the space of the dwelling, but this is not in opposition to including a wider geography, e.g. the neighbourhood. This could be especially interesting from an energy studies perspective, as the significance of local networks and their governance in a future with distributed, renewable generation is increasingly recognised (Wolsink, 2012).

Another approach which is pointed out in this paper is to open the often black-boxed nature of many smart home concepts and packages, in order to allow for much more interaction, playing and personalising of the technology to the home occupant. In this way some of the alienation and security aspects which may be felt around smart home technologies could be coped with.

Personalising technologies has been a major feature of personal ICTs such as smart phones, ipads and computers. So smart home technologies could possibly also benefit from this approach; indeed, as noted earlier, there is already evidence of DIY smart energy initiatives in homes and communities.

There are still considerable gaps in the research literature, as already noted, on who smart home technology users are and how they use their technologies. To this we would add that concepts of home itself – an aggregation of people, things, meanings and activities – will influence how people use, generate and store electricity in future, and where the boundaries of control and cooperation are drawn. As yet, we have few evaluative studies from which to judge how far smart homes live up to the claims made for them and the estimates of their impact in technical and prospective studies. In future evaluative studies of smart homes – sorely needed – we suggest the inclusion of questions about how meanings of the home might change along with new technologies, following the ideas presented in this paper. We also suggest that scholars who are interested in what homes are and how ideas and notions of home might change along different social lines also will include questions of how different types of smart home technologies may influence practices, roles and identities.

## Acknowledgment

This research formed part of the UserTEC project (User Practices, Technologies and Residential Energy Consumption) ([www.sbi.dk/usertec](http://www.sbi.dk/usertec)), which was financed by Innovation Fond Denmark. A previous version of the paper was presented at the DEMAND conference 2016 in Lancaster. We would like to thank the audience at that occasion for many relevant comments. The article has also been discussed at the Sustainable Housing and Cities group at The Danish Building Research Institute, and we thank colleagues for valuable input at this occasion as well.

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