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Towards a Taxonomy of Smart Home Technology: A Preliminary Understanding

Short Paper

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Abstract

While there has been increased digitization of private homes, only little has been done to understand these specific home technologies, how they serve consumers, among other issues. "Smart home technology" (SHT) refer to a wide range of artifacts from cleaning aids to energy advisors. Given this breadth, clarity surrounding the key characteristics and the multi-faceted impact of SHT is needed to conduct more directed research on SHT. We propose a taxonomy to help outline the salient intended outcomes of SHT. Through a process involving five iterations, we analyzed and classified 79 technologies (gathered from literature and industry reports). This uncovered seven dimensions encompassing 20 salient characteristics. We believe these dimensions/characteristics will help researchers and organizations better design and study the impacts of these technologies. Our long-term agenda is to use the proposed taxonomy for an exploratory inquiry to understand tensions occurring when personal and sustainability-related outcomes compete.

Keywords: Smart Home Technology, Outcomes, Private Household, Sustainability, Green IS, Taxonomy, NVM method

Introduction

An unusual COVID year with self-quarantine measures within private homes has changed the residential energy consumption and the intensity with which technology is used in homes (IEA 2020; Quby 2020). Further, there is an interesting trend of Tech Giants increasingly focusing on private homes (Forbes 2020; The Economist 2019), with an overall integration rate of smart home technologies (SHT) is expected to more than double within the next five years (i.e., 10% to 21%; Statista 2020). As "digitalization and smart controls enable efficiency gains that reduce emissions from the buildings sector by 350 Mt CO2 by 2050" (IEA 2021, p. 142), the ongoing domestic digitization, also shifted the attention of scholars in the field: With the early focus on organizational impact (e.g., Melville 2010; Seidel et al. 2013), we are increasingly observing studies on technology in the private home space (e.g., Tiefenbeck et al. 2018; Wunderlich et al. 2019). While academia often associates SHT with its ecological advantages (e.g., Kroll et al. 2019; Paetz et al. 2012; Schill et al. 2019; Shin et al. 2018) in practice, these technologies have been predominantly associated with convenience, economic gains, and security (e.g., Deloitte 2018; PwC 2017). Consequently, it resulted in an ambiguous use of the term and an incomplete picture of why individuals use these technologies. Without clearly differentiating why individuals use or not use SHT can be detrimental to the future of these technologies, thus, paving the need for a taxonomy.

One major impediment for ecologically impactful research is that "innovative new products or ideas in IS […] cannot be integrated into a theory right away but rather need to be understood empirically before" (Lehnhoff et al. 2021, p. 220). Thus, a conceptual understanding of SHT is a fundamental prerequisite for developing an effective behavioral theory of such a phenomenon. While a few taxonomies have been developed in this domain, they focus primarily on the technical components, resulting in a narrow understanding of what SHT is about and what it actually can do. Little has been done towards understanding service benefits (Time, Money, Flexibility, Quality; Rau et al. 2020) or their value propositions (Hedonic, Functional, Social; Paukstadt et al. 2019). Drawing on literature focusing on the individuals' needs within their private home, like comfort, quality of life, etc. (e.g., Aldrich 2003; Marikyan et al. 2019), it is clear that these current taxonomies lead to an inconclusive, superficial understanding, failing to address what smartness is used for in homes.

Our current study attempts to address the shortcomings discussed above by disentangling what SHT intends to deliver to individuals. By highlighting the unique outcome-focused characteristics we hope to unveil key behavioral determinants (for expected outcomes see Bandura 1986; Venkatesh et al. 2003). Our examination will also help to answer the overarching question of what individuals are willing to give up to achieve technology-related desired outcomes within their private homes. Given that much of the SHTs are also related to sustainability, the results from our study will help understand what individuals are willing to sacrifice to make their homes more environmentally sustainable, which can be valuable for energy companies, governments, consumer products developers, to name a few. Our specific research question is: *what are the different outcome-focused characteristics of SHT?* Developing a taxonomy on what SHT can deliver will provide clarity for the process of theorizing and serve organizations to apply our comprehensive set to more precisely design *for* the individuals and consequently convey the ultimate benefits.

Conceptual Background

For decades, *smart home* referred to technology-enabled automation within private residences to meet the occupants' needs such as comfort, convenience, security, and entertainment (e.g., Alam et al. 2012; Aldrich 2003; Gann et al. 1999). However, with the advancement of the IoT (Internet of Things; Risteska Stojkoska and Trivodaliev 2017) and fifth-generation networking (e.g., Hui et al. 2020), the potential that technology offers within the private home has been boosted. Given the terminological ambiguity surrounding SHT, and the lack of a comprehensive definition within the IS literature, this section aims first to provide a clearer picture of SHT.

Smartness refers to technology that "performs and controls functions that attempt to produce useful results through activities that apply automated capabilities and other physical, informational, technical, and intellectual resources for processing information, interpreting information, and/or learning [..which ranges from] from scripted execution [..to] unscripted invention" (Alter 2020, pp. 384–385). Within the household, functions typically refer to monitoring, sensing, controlling, and automating appliances and tasks (Risteska Stojkoska and Trivodaliev 2017; Wilson et al. 2015). This includes personalized experiences, expanded cooperation (Kim et al. 2019), and management, support, or responsive services (Marikyan et al. 2019). In short, *smart refers to the typical human capabilities performed by technology*.

Home basically, is any form of a private residence, like standalone houses or apartments (Aldrich 2003; Balta-Ozkan et al. 2013). More broadly, it refers to a "place for security and control, for activity, for relationships and continuity, and for identity and values" (Gram-Hanssen and Darby 2018, p. 94). The home is particularly protected, next to privacy and family, by Article 12 of the Universal Declaration of Human Rights. According to Brown et al. (2015), understanding individuals' behaviors within their private homes underlies a sheer complexity owing to not only the interactions of utilitarian and hedonic themes, but also because the household lifecycle plays a crucial role. Thus, *private homes is a unique context where technology is applied.*

Technology in the context of smart home consists of hardware and software components, including sensors and home appliances (Marikyan et al. 2019, p. 144). Within the IS discipline, sustainable household technologies refer to tangible goods paired with innovative services and applications (Wunderlich et al. 2019, p. 674).

For the remainder of this manuscript, we refer to SHT *as a separate entity comprising of connected physical and intangible components, which provides an extensive set of applications aiming to enhance individuals' capabilities for a desired outcome within their private residence*. It needs to be noted that both practice and academia view SHT as providing the benefits of *convenience* and *sustainability* (e.g., Paetz et al. 2012; PwC 2017). Drawing on Berry et al. (2002), we consider *convenience* as an individuals' required time and effort to achieve a desired state within the home. For *sustainability,* we follow Malhotra et al. (2013) and focus on the environmental aspect in terms of individuals' responsible resource use and good citizenship. Both conceptualizations have been well-established within the IS community (e.g., Seidel et al. 2017; Trenz et al. 2020).

Although our literature review resulted in a lack of a systematic classification of SHT, we identified a set of taxonomies related to smart services (Brogt and Strobel 2020; Fischer et al. 2020; Paukstadt et al. 2019; Rau et al. 2020), the IoT (Oberländer et al. 2018; Püschel et al. 2016), or smart manufacturing machines (Scharfe and Wiener 2020). However, these have a much broader focus. For example, Fischer et al. (2020) classify products and services related to health, homes, work, and infrastructure. Likewise, Oberländer et al. (2018) identify six different patterns on how businesses interact with smart things. Looking at interaction patterns from another angle, we found classifications of mechanisms for enhanced user-engagement (e.g., Corbett 2013; Oinas-Kukkonen and Harjumaa 2009). For instance, Corbett (2013) suggests a set of 36 design principles to increase employees' environmental behaviors. Further, our review uncovered two IS-centric classifications (Paukstadt et al. 2019; Rau et al. 2020). These, however, draw on three or four rather generic service benefits or value propositions without emphasizing any of the technical features or components.

Summarizing, previous work has touched on *what´s in for the consumer* merely on an abstract level. Thus, instead of pursuing the prevailing focus on salient design characteristics, this work concentrates on disentangling the outcomes - what purpose technology was designed *for*. On top of that, our taxonomy explicitly reflects on private homes, as no existing scheme reflects on this unique setting (for a review on household technologies see Wunderlich et al. 2019).

Method and Iterations

The purpose of this taxonomy is to structure SHT among their salient intended outcomes. We followed the guidelines of Nickerson et al. (NVM, 2013) to develop a systematic classification scheme. Such schemes help to delimit work within a research domain and lay an important foundation for generalization (Steininger et al. 2021). The so-called NVM method is the most well-established guidance within our discipline (Oberländer et al. 2019). This method comprises of seven major steps, with the first two being generally applicable and the remaining five being part of an iterative process *(see Figure 1)*.

Following our research question and the conceptual background on private interaction with SHT for an apparent desired result, we determined our meta-characteristics as the *salient intended outcomes of private smart home technology applications*. In the second step, we clarified when to terminate the iterative process. Therefore, we adopted the objective and subjective ending conditions proposed in the method paper (see *Figure 1*).

To obtain a comprehensive *sample* of real-world objects, we collected SHTs from both literature and practice. In our initial conceptual iteration, 18 objects were identified from previous work, such as appliances, security equipment, energy equipment, etc. (i.e., Hubert et al. 2019; Mamonov and Benbunan-Fich 2020; Marikyan et al. 2019; Schill et al. 2019; Wunderlich et al. 2019). For the subsequent iterations, we added a sample of state-of-the-art real-world objects, observed on the market. We systematically identified 61 objects derived from the *key promoters* of the *Connected Home over IP (CHIP)* working group within the Zigbee Alliance. Amongst others are Amazon, Apple, Google, Ikea, Samsung, Wulian, etc.

Obtaining website data is common in IS taxonomy research, where long- and shortlists can help make the data manageable (Steininger et al. 2021). In doing so, we initially obtained 83 SHTs from 22 organizations in our longlist consisting of technologies offered to the consumer and representing the latest and most mature generation within a series. For each, we carefully read the descriptions line-by-line to select 61 SHTs for our shortlist, which appeared to meet our conceptual understanding of SHT. As outlined in the NVM guidelines, we split the empirical shortlist into subsets for the iterative analysis (I2 = 20, I3 = 20, I5 = 21). However, before we started with our empirically grounded iterations, we inductively highlighted outcome-relevant text passages with the help of the qualitative data analysis software MAXQDA, to increase our upfront understanding. Previous researchers applied content analysis approaches to thematically analyze and structure the identified textual data (e.g., Al-Debei and Avison 2010).

Figure 1 provides an overview of our iterative data analysis according to the NVM method. It shows which approach was applied, how dimensions were merged or split, and at what point we met certain ending conditions.

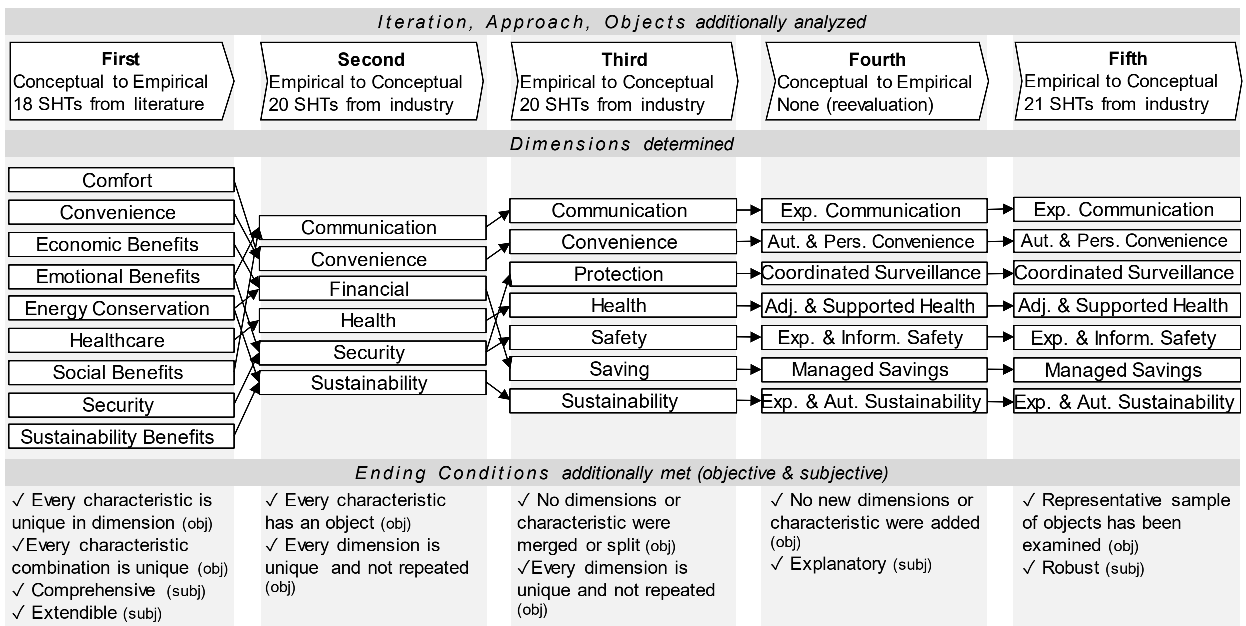

Figure 1. Iterative Taxonomy Building Process

We opted for the conceptual-to-empirical approach for our *first iteration* because the literature review appeared to provide a comprehensive set of articles in the smart home domain. This resulted in nine relevant dimensions (derived from Alam et al. 2012; Aldrich 2003; De Silva et al. 2012; Marikyan et al. 2019; Risteska Stojkoska and Trivodaliev 2017). As nuanced characteristics could not be identified, we followed the recommendations of Oberländer et al. (2018) by creating dummy characteristics: *applicable* and *not-applicable*. To evaluate the taxonomy, we used 18 technologies identified in previous papers.

For our *second iteration,* we analyzed 20 SHTs from our sample. A better understanding of the characteristics resulted in merging the previous nine into six dimensions. Adding another 20 SHTs from our shortlist, we performed the *third iteration* again following the E2C approach. This resulted in seven dimensions and 20 characteristics. For instance, we observed that the intended outcome previously considered as social is rather about communication in two ways: interaction and entertainment. Further, we split the security dimension into two: surveillance and safety, because one of the outcomes refers to functional outcomes whereas the other is rather of superordinate nature.

For the *fourth iteration,* we went back to the C2E approach. Accordingly, we evolved our empirically grounded dimensions and characteristics with conceptual knowledge on *smartness*. To do so we built on previous contributions as outlined in the preluding section (i.e., Alter 2020; Gann et al. 1999, etc.). Approaching the dimensions from another angle revealed particular smart dimensions. For instance, we revised the financial outcome to managed savings (Wunderlich et al. 2019) because the smart outcome refers to the technology being in charge of financial potential. To reevaluate the taxonomy, we applied the full set of 58 objects from the previous iteration. Since also this iteration brought changes to our dimensions, the check for robustness was still outstanding. As there were collected empirical objects still not examined, we carried out another iteration.

In the *fifth iteration,* we analyzed the remaining 21 objects of our shortlist and we agreed to have reached an adequate level of saturation. At this stage, we also analyzed websites for other technologies. Since this yielded no further insights, we consider our sample representative and the ending conditions to be met.

Preliminary Results

Table 1 shows our conceptually based and empirically grounded taxonomy. We divided them into two categories, seven dimensions and 20 characteristics. The categories refer to their outcome immediacy within the home. The *specific* outcomes are those that individuals in a household can directly recognize. On the other hand, the *overarching* outcomes occur less frequently within the home and refer to superordinate intentions when applying *smart* technology. We describe them below:

<table>
<tr><th colspan="2">Dimensions</th><th colspan="4">Characteristics</th></tr>
<tr><td rowspan="3">Specific (NE)</td><td>Expanded Communication</td><td>None (60)</td><td colspan="2">Social Interaction (14)</td><td>Entertainment (12)</td></tr>
<tr><td>Automated and Personalized Convenience</td><td>None (45)</td><td colspan="2">Comfort (19)</td><td>Chore (16)</td></tr>
<tr><td>Coordinated Surveillance</td><td>None (48)</td><td>Supply (6)</td><td>Property (15)</td><td>Inhabitants (19)</td></tr>
<tr><td rowspan="4">Overarching (ME)</td><td>Adjusted and Supported Health</td><td colspan="2">None (70)</td><td colspan="2">Enhanced (9)</td></tr>
<tr><td>Expanded and Informed Safety</td><td colspan="2">None (63)</td><td colspan="2">Major (16)</td></tr>
<tr><td>Managed Savings</td><td>None (44)</td><td colspan="2">Incidental (23)</td><td>Substantial (12)</td></tr>
<tr><td>Expanded and Automated Sustainability</td><td>None (66)</td><td colspan="2">Responsible Consumption (6)</td><td>Good Citizenship (7)</td></tr>
<tr><td colspan="6">NE = not exclusive; ME = mutually exclusive; (x_n) = number of SHT, n = 79</td></tr>
</table>

Table 1. Taxonomy of Smart Home Technology

Expanded Communication

One key outcome of SHT is the expansion of individuals´ communication capabilities within, inwards and outside of the home. We could observe such an expanded communication in two ways. On the one hand, it influences the *interaction* with other people or organizations. On the other hand, SHT can leverage entertainment experiences by personalizing *entertainment* or engaging in conversations. Typical examples that fit in this dimension are assistant speakers/displays, streaming boxes, or consumption sensing devices that directly communicate with organizations.

Automated and Personalized Convenience

The application of SHT is often related to an increase of convenience through automation of tasks within the household. This dimension appears to be a central intended outcome as “for most people, Smart Home systems could be considered as one of the simply offered additional convenience in everyday activities” (Gann et al. 1999, p. 19). In our sample, we observed technologies offering applications automating formerly manual tasks. First, SHT automatically adjusts to the inhabitant´s *comfort* needs, including better adapted environmental conditions, like temperature or lighting. Second, we frequently evaluated technologies designed to decrease the effort to do the *chores* by either fully or at least partially automating tasks. That includes housekeeping, gardening, cooking etc. For instance, a detergent-dosing laundry machine, vacuum robot, or an expiration date management fridge.

Coordinated Surveillance

This dimension is about preventing undesirable states within the private home. This is “where the data captured in the environment are processed to obtain information that can help to raise alarms, in order to protect the home and the residents from burglaries, theft and natural disasters like flood etc.” (Alam et al.

2012, p. 1190). The salient intended outcome of applying smart technology refers to useful coordination of the information gathered from the subjects, objects, and processes under surveillance. Accordingly, we distinguish between three focal characteristics: *Supply* is about monitoring domestic utilities and deriving actions from the information. This comprises of applications like load management to ensure a stable electricity supply. In terms of *property*, we observed technologies applied to protect the users' belongings or the residence at large. Here SHT can range from parcel boxes to locks or surveillance systems. Finally, the characteristic *inhabitants* comprise the intended outcome of physically protecting human integrity concerning individuals, partners, and families. On the one side, this helps in guarding against intruders (e.g., face-recognizing alarm system), while also securing a harmless physical environment (e.g., carbon aware air purifier).

Adjusted and Supported Health

Against the backdrop of expanded communication (i.e., elderly and child care), this dimension particularly focuses on the overarching intended health outcome. That relates to applications "that help[] users lead a healthy life based on the data on user diet and physical activities combined with medical and healthcare knowledge" (Kim et al. 2019, p. 301). Thus, it is about health support that adjusts to the physical conditions. We observed SHT that facilitates healthy conditions through monitoring and recommending or acting, summarized under the characteristic "*enhanced*." Examples meeting this characteristic are sleep trackers, robots for rehabilitation, humidifiers, or disinfection installations.

Expanded and Informed Safety

Applying SHT for safety is basically about remote access. Instead of a mere functional aspect like securing supply, property, or the inhabitants through physical acting/ coordination, we observed SHTs particularly addressing psychological outcomes (e.g., peace of mind, better sleep, no worries, etc.). Therefore, this dimension focuses on a major satisfaction increase of inhabitant´s safety desire because the home is "in opposition to [anywhere else] the place where you are in control and can feel safe" (Gram-Hanssen and Darby 2018, p. 97). Typical examples are informing security systems or detectors. These technologies offer expanded safety as they provide information (accessible from anywhere) that positively contributes to individuals´ calm.

Managed Savings

The financial aspect is of great importance in the private technology context (e.g., Venkatesh et al. 2012). Our analysis brought forward two major characteristics related to financial savings. First, there are technologies offering applications that increase efficiency as a side-effect. We consider these as *incidental* SHT, which are typical consumer appliances that use advanced mechanisms to save. Typical examples are detergent controlling washing machines or scene-adapted lighting. Second, SHT may offer applications with *substantial* potential for our homes to save money, such as energy management systems or thermostats.

Expanded and Automated Sustainability

In terms of environmental protection, the sustainability dimension is closely intertwined with economic incentives (e.g., Wunderlich et al. 2019), but fundamentally different regarding its intention. In the smart home context, this means that technology can be applied to improving domestic resource *consumption responsibly*. We observed that applications recommend and automatically adjust resource consumption—for instance, thermostats or home energy management systems. As the impact of these technologies is limited, a second characteristic manifested that goes beyond domestic boundaries are characterized as *good citizenship*. SHT that meets this characteristic includes automated responsible resource consumption and expands its positive impact on the environment. Typically, this refers to the active provision of grid flexibility that helps with the integration of renewable energy sources (e.g., thermostats, electric vehicle charging stations, integrated energy management systems).

Discussion and Outlook

This paper systematically organizes the fuzzy domain of SHT by unfolding its salient outcome focused-characteristics. While previous research expanded upon only on the technical components, in developing the current taxonomy, we focused on what a particular technology offers to a consumer in terms of impacts.

Therefore, we developed a taxonomy following the NVM method. Our classification reveals two categories and seven unique dimensions that differ among 20 characteristics.

Our taxonomy helps to differentiate SHT from other traditional technologies by highlighting its nuanced impacts. This is important because individuals may purchase, apply, and even bond to technologies for day-to-day purposes (e.g., doing the chores, consuming entertainment, etc.) in a different manner compared to those serving overarching outcome categories (e.g., economic wealth, personal health, etc.). Hence, researchers can apply this classification to determine the scope of the impact of SHT. As Alter (2020) argues, a single entity may not make the whole system smart. For instance, a vacuum robot does not make the entire home smart but contributes to convenience by automating a chore. Our outcome-focused taxonomy can be used in future studies to select the specific type of SHT one wishes to study, and thereby provide more nuanced and deeper knowledge surrounding its impacts.

While we believe that our working taxonomy has many benefits, we would like to acknowledge some of the limitations. The empirical sampling approach is well-documented. Still, it may be that within the CHIP group, some classes of technologies may be over-represented than others. Our conceptual foundations stem from an extensive literature search within the areas of smartness, smart home, connected home, IoT, smart service, convenience, and sustainability. Even though we most carefully selected the relevant articles within an extensive literature review, we are by no means claiming that it is a comprehensive taxonomy. Given the design-process nature of creating a taxonomy, it is likely that similar additional efforts may arrive at a slightly modified set of characteristics (Nickerson et al. 2013). Finally, we respectfully recognize that this is a work in progress, and we are currently in the process of collecting qualitative evidence for outcome validation, which is a common approach for evaluating taxonomies (Szopinski et al. 2019).

Specifically, we will conduct in-depth interviews with residents who apply SHT within their homes. For that, we adopt an inductive approach, as it promises to reveal important insights, especially on both the desirable and undesirable outcomes. Our hope is that the proposed taxonomy will serve as *upfront theory* within our qualitative inquiry (Sarker et al. 2018). This will also help to address the uniqueness and complexity of the private setting appropriately, like the lifecycle stage, cognitive biases, etc. (Brown et al. 2015; Shimoda et al. 2020).

In conclusion, our goal in this study was to help uncover an emerging phenomenon as more and more individuals are digitizing their homes. We have conceptualized SHT as a private multipurpose technology class with significant potential for sustainability by providing a clear and parsimonious set of outcome-focused characteristics. We hope that this taxonomy will improve the understanding of our community and help advance theory in the domain, paving the way for behavioral implications using SHT to combat climate change.

References

Alam, M. R., Reaz, M. B. I., and Ali, M. A. M. 2012. "A Review of Smart Homes—Past, Present, and Future," *IEEE Transactions on Systems, Man, and Cybernetics, Part C (Applications and Reviews)* (42:6), pp. 1190–1203.

Al-Debei, M. M., and Avison, D. 2010. "Developing a unified framework of the business model concept," *European Journal of Information Systems* (19:3), pp. 359–376.

Aldrich, F. K. 2003. "Smart Homes: Past, Present and Future," in *Inside the smart home*, R. Harper (ed.), London ; New York: Springer, pp. 17–40.

Alter, S. 2020. "Making Sense of Smartness in the Context of Smart Devices and Smart Systems," *Information Systems Frontiers* (22:2), pp. 381–393.

Balta-Ozkan, N., Davidson, R., Bicket, M., and Whitmarsh, L. 2013. "Social barriers to the adoption of smart homes," *Energy Policy* (63), pp. 363–374.

Bandura, A. 1986. *Social foundations of thought and action: a social cognitive theory*, Englewood Cliffs, N.J: Prentice-Hall.

Berry, L. L., Seiders, K., and Grewal, D. 2002. "Understanding Service Convenience," *Journal of Marketing* (66:3), pp. 1–17.

Brogt, T., and Strobel, G. 2020. "Services Systems in the Era of the Internet of Things: A Smart Service System Taxonomy," in *ECIS 2020 Proceedings*.

Brown, S. A., Venkatesh, V., and Hoehle, H. 2015. "Technology adoption decisions in the household: A seven-model comparison," *Journal of the Association for Information Science and Technology* (66:9), pp. 1933–1949.
Corbett, J. 2013. "Designing and Using Carbon Management Systems to Promote Ecologically Responsible Behaviors," *Journal of the Association for Information Systems* (14:7), pp. 339–378.
De Silva, L. C., Morikawa, C., and Petra, I. M. 2012. "State of the art of smart homes," *Engineering Applications of Artificial Intelligence* (25:7), pp. 1313–1321.
Deloitte 2018. *Smart Home Consumer Survey*. Retrieved 2. January, 2021, from https://www2.deloitte.com/de/de/pages/technology-media-and-telecommunications/articles/smart-home-studie-2018.html.
Fischer, M., Heim, D., Hofmann, A., Janiesch, C., Klima, C., and Winkelmann, A. 2020. "A taxonomy and archetypes of smart services for smart living," *Electronic Markets* (30:1), pp. 131–149.
Forbes 2020. *Rethinking What's "Smart" For The Next Generation Smart Home*. Retrieved 24. September, 2020, from https://www.forbes.com/sites/forbestechcouncil/2020/04/02/rethinking-whats-smart-for-the-next-generation-smart-home/.
Gann, D., Barlow, J., Venables, T., Chartered Institute of Housing, and Joseph Rowntree Foundation 1999. *Digital futures: making homes smarter*., Chartered Institute of Housing.
Gram-Hanssen, K., and Darby, S. J. 2018. "'Home is where the smart is'? Evaluating smart home research and approaches against the concept of home," *Energy Research & Social Science* (37), pp. 94–101.
Hubert, M., Blut, M., Brock, C., Zhang, R. W., Koch, V., and Riedl, R. 2019. "The influence of acceptance and adoption drivers on smart home usage," *European Journal of Marketing* (53:6), pp. 1073–1098.
Hui, H., Ding, Y., Shi, Q., Li, F., Song, Y., and Yan, J. 2020. "5G network-based Internet of Things for demand response in smart grid: A survey on application potential," *Applied Energy* (257. 113972).
IEA 2020. *Covid-19 impact on electricity*. in *International Energy Agency* Retrieved 10. February, 2021, from https://www.iea.org/reports/covid-19-impact-on-electricity.
IEA 2021. "Net Zero by 2050: A Roadmap for the Global Energy Sector."
Kim, S., Christiaans, H., and Baek, J. S. 2019. "Smart Homes as Product-Service Systems: Two Focal Areas for Developing Competitive Smart Home Appliances," *Service Science* (11:4), pp. 292–310.
Kroll, T., Paukstadt, U., Kreidermann, K., and Mirbabaie, M. 2019. "Nudging People to Save Energy in Smart Homes with Social Norms and Self-Commitment," in *ECIS 2019 Proceedings*, Stockholm & Uppsala.
Lehnhoff, S., Staudt, P., and Watson, R. T. 2021. "Changing the Climate in Information Systems Research," *Business & Information Systems Engineering* (63:3), pp. 219–222.
Malhotra, A., Melville, N. P., and Watson, R. T. 2013. "Spurring impactful research on information systems for environmental sustainability," *MIS Quarterly* (37:4), pp. 1265–1274.
Mamonov, S., and Benbunan-Fich, R. 2020. "Unlocking the smart home: exploring key factors affecting the smart lock adoption intention," *Information Technology & People* (ahead-of-print).
Marikyan, D., Papagiannidis, S., and Alamanos, E. 2019. "A systematic review of the smart home literature: A user perspective," *Technological Forecasting and Social Change* (138), pp. 139–154.
Melville 2010. "Information Systems Innovation for Environmental Sustainability," *MIS Quarterly* (34:1), pp. 1–21.
Nickerson, R. C., Varshney, U., and Muntermann, J. 2013. "A method for taxonomy development and its application in information systems," *European Journal of Information Systems* (22:3), pp. 336–359.
Oberländer, A. M., Lösser, B., and Rau, D. 2019. "Taxonomy Research in Information Systems: A Systematic Assessment," in *ECIS 2019 Proceedings*, Sweden.
Oberländer, A. M., Röglinger, M., Rosemann, M., and Kees, A. 2018. "Conceptualizing business-to-thing interactions – A sociomaterial perspective on the Internet of Things," *European Journal of Information Systems* (27:4), P. Ågerfalk and V. Tuunainen (eds.), pp. 486–502.
Oinas-Kukkonen, H., and Harjumaa, M. 2009. "Persuasive Systems Design: Key Issues, Process Model, and System Features," *Communications of the Association for Information Systems* (24).
Paetz, A.-G., Dütschke, E., and Fichtner, W. 2012. "Smart Homes as a Means to Sustainable Energy Consumption: A Study of Consumer Perceptions," *Journal of Consumer Policy* (35:1), pp. 23–41.
Paukstadt, U., Strobel, G., and Eicker, S. 2019. "Understanding Services in the Era of the Internet of Things: A Smart Service Taxonomy," in *ECIS 2019 Proceedings*, Stockholm & Uppsala.
Püschel, L., Röglinger, M., and Schlott, H. 2016. "What's in a Smart Thing? Development of a Multi-layer Taxonomy," in *ICIS 2016 Proceedings*, Dublin.

PwC 2017. *Smart home, seamless life: Unlocking a culture of convenience*. Retrieved 10. August, 2020, from https://www.pwc.fr/fr/assets/files/pdf/2017/01/pwc-consumer-intelligence-series-iot-connected-home.pdf.

Quby 2020. *What self-quarantine does to household energy usage*. Retrieved 13. February, 2021, from https://www.quby.com/news/2020/4/14/what-self-quarantine-does-to-household-energy-usage-while-others-guess-quby-measures.

Rau, D., Perlitt, L.-H., Röglinger, M., and Wenninger, A. 2020. "Pushing the Frontiers of Service Research – A Taxonomy of Proactive Services," *ECIS 2020 Proceedings*.

Risteska Stojkoska, B. L., and Trivodaliev, K. V. 2017. "A review of Internet of Things for smart home: Challenges and solutions," *Journal of Cleaner Production* (140), pp. 1454–1464.

Sarker, S., Xiao, X., Beaulieu, T., and Lee, A. S. 2018. "Learning from First-Generation Qualitative Approaches in the IS Discipline: An Evolutionary View and Some Implications for Authors and Evaluators (PART 1/2)," *Journal of the Association for Information Systems* (19), pp. 752–774.

Scharfe, P., and Wiener, M. 2020. "A Taxonomy of Smart Machines in the Mechanical Engineering Industry: Toward Structuring the Design Solution Space," in *ICIS 2020 Proceedings*.

Schill, M., Godefroit-Winkel, D., Diallo, M. F., and Barbarossa, C. 2019. "Consumers' intentions to purchase smart home objects: Do environmental issues matter?," *Ecological Economics* (161), pp. 176–185.

Seidel, S., Chandra Kruse, L., Watson, R. T., Albizri, A., Butler, T., Chandra Kruse, L., et al. 2017. "The Sustainability Imperative in Information Systems Research," *Communications of the Association for Information Systems* (40), pp. 40–52.

Seidel, S., vom Brocke, J., and Recker, J. 2013. "Sensemaking and Sustainable Practicing: Functional Affordances of Information Systems in Green Transformations," *MIS Quarterly* (37:4), pp. 1275–1299.

Shimoda, Y., Yamaguchi, Y., Iwafune, Y., Hidaka, K., Meier, A., Yagita, Y., et al. 2020. "Energy demand science for a decarbonized society in the context of the residential sector," *Renewable and Sustainable Energy Reviews* (132. 110051).

Shin, J., Park, Y., and Lee, D. 2018. "Who will be smart home users? An analysis of adoption and diffusion of smart homes," *Technological Forecasting and Social Change* (134), pp. 246–253.

Statista 2020. *Smart Home Report 2020*. Retrieved 8. October, 2020, from https://de.statista.com/statistik/studie/id/41155/dokument/smart-home-report/.

Steininger, D. M., Trenz, M., and Veit, D. J. 2021. "Taxonomy Development for Business Research: A Hands-On Guideline," in *Market Engineering*, H. Gimpel, J. Krämer, D. Neumann, J. Pfeiffer, S. Seifert, T. Teubner, et al. (eds.), Springer.

Szopinski, D., Schoormann, T., and Kundisch, D. 2019. "Because Your Taxonomy is Worth It: Towards a Framework for Taxonomy Evaluation," in *ECIS 2019 Proceedings*, Sweden.

The Economist 2019. "Tech firms think the home is the next big computing platform," (Sep 14th).

Tiefenbeck, V., Goette, L., Degen, K., Tasic, V., Fleisch, E., Lalive, R., et al. 2018. "Overcoming Salience Bias: How Real-Time Feedback Fosters Resource Conservation," *Management Science* (64:3), pp. 1458–1476.

Trenz, M., Veit, D. J., and Tan, C.-W. 2020. "Disentangling the Impact of Omnichannel Integration on Consumer Behavior in Integrated Sales Channels," *MIS Quarterly* (44:3), pp. 1207–1258.

Venkatesh, V., Morris, M., and Davis, G. 2003. "User Acceptance of Information Technology: Toward a Unified View," *MIS Quarterly* (27:3), pp. 425–478.

Venkatesh, V., Thong, J. Y. L., and Xu, X. 2012. "Consumer Acceptance and Use of Information Technology: Extending the Unified Theory of Acceptance and Use of Technology," *MIS Quarterly* (36:1), pp. 157–178.

Wilson, C., Hargreaves, T., and Hauxwell-Baldwin, R. 2015. "Smart homes and their users: a systematic analysis and key challenges," *Pers Ubiquit Comput* (19), pp. 463–476.

Wunderlich, P., Veit, D. J., and Sarker, S. 2019. "Adoption of Sustainable Technologies: A Mixed-Methods Study of German Households," *MIS Quarterly* (43:2), pp. 673–691.