# Identification of technology adoption paths for smart technologies

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***Abstract****. Smart technologies are a key technology to ensure a transformation towards a decarbonized, decentralized and digital energy market. Therefore, we explored the technology adoption paths of smart home and smart energy technologies. Based on a mixed-methods approach, both qualitative and quantitative data were collected on the chronological order of adoption of different smart technologies in households. The results aim to provide insights on how to design and promote new products and services. Thus, by knowing which technologies are already adopted, co-adoption concepts can be established between the offered products and the existing technologies.*

**Keywords.** Energy transition, Smart home technologies, Smart energy technologies, Technology adoption path

## 1 Introduction

With the Green Deal, the European Union strives to strengthen economic resilience by transforming into a climate-neutral continent. The decarbonization is also called a "twin transition" because this overarching goal is to be achieved on the one hand through digitalisation (i.e., development of a fully integrated, interconnected, and digitized EU energy market) and on the other hand through decentralization (i.e., diffusion of renewable energy sources) (European Commission, 2022). At the household level, decentralization and digitalization can be seen, among other things, through the adoption of renewable energy technologies such as photovoltaics (PV) in combination with digital technologies, which are mentioned in the context of the concepts smart home or smart energy (Paukstadt, 2019).

Smart home technologies (SHT) include sensors, networked devices, and integrated systems (i.e., ICT) that provide services to residents (e.g., monitoring, control from a distance, automatic control) with the purpose of satisfying different needs to enhance quality of life (Balta-Ozkan, et al., 2014). These needs include comfort, health, safety, support, entertainment, or efficiency (Marikyan et al., 2019; Aldrich, 2003). In contrast Smart Energy Technologies (SET) are defined as technologies "[…] serving either one of the two common system goals of 1) increasing energy efficiency or 2) increasing the integration of renewable energy sources" (Gimpel et al., 2020). In respect to the Green Deal, households are seen as active contributors in the energy transition who, with their adoption and decision to use SET, can significantly hinder or promote the mentioned potential (BMNT, 2019).

The smart home as buzzword for the digitalization of the domestic environment holds a functional, instrumental and socio-technical perspective according to the literature. While the functional perspective describes various services that a smart home fulfils (e.g., enhancing security, support elderly, improve comfort, manage energy), the instrumental perspective takes a focus on the smart home as instrument to achieve energy efficiency. The socio-technical understands the smart home as an overall transformation of living and thus, refers to a future perspective (Wilson et al., 2015). The functional perspective is more related to definitions of SET in a broader sense, i.e., functions of smart home to meet user needs such as cost efficiency, comfort, emotion, security, or health (Marikyan et al., 2019). In contrast, the instrumental perspective relates more to the definition of SET, i.e., individual devices to system solutions that provide feedback on energy use, manage energy consumption, and control home appliances and applications (Karlin et al., 2015).

Based on these two perspectives for SHT and SET the question arise what do technology adoption paths (TAP) of households look like? There are hardly any studies that have examined in more detail when, which type of technology found its way into a household and for what reason. Sanguinetti et al. (2018) examined, based on quantitative survey, the path to smart home adoption by clustering user segments in respect to awareness, interest, and ownership of smart technologies. Thus, they considered SHT as well as SET along the decision-making process, but did not question the chronological order of adoption in respect to only the already owned technologies.

An investigation of the chronological order of adopting different SHT or SET (e.g., smart voice assistant, smart heating, smart TV) can provide additional understanding of TAP. The results aim to guide companies in designing new product bundles to successfully enter or penetrate the market.

The rest of the paper is organized as follows. Section 2 gives an overview of the related research. Here classifications and characterizations of SHT and SET are presented, and more insight is given to the adoption literature. Section 3 explains the empirical research design – a mixed methods approach – to elaborate the research question. Findings are described in section 4, while section 5 discusses them finally.

# 2 Related Research

## 2.1 SHT & SET

In Europe, the penetration rate, i.e., the number of smart homes as a proportion of the total number of European households, is (estimated) at 18% in 2022. Austrian households are above this at 26.6%. A subcategory of smart home is energy management (excluding lighting and smart home appliances), which is only 7% in Europe and 11.5% in Austrian households. Future penetration rates are expected to increase. (Statista, 2022). Thus, a variety of different technologies will characterize the smart home.

In the literature, there are different categorisations and characterisations of this multitude of different products, services, and system solutions for a smart household. Sovacool and Del Rio (2020) assign 267 SHT on the UK and EU markets in 2019 to 13 categories: household appliances, lighting, energy & utilities, entertainment, health & wellness, safety & security, baby & pet monitors, clothes & accessories, vehicles & drones, home robots, gardening, integrated solutions, and “others”. In addition, SHT are grouped into different categories as part of market analyses. Thus, the Smart Home Study conducted by GfK (2016) grouped the variety of smart home devices in the categories: smart domestic appliances, smart entertainment & connectivity, smart energy & lighting, smart security & control and smart health. In comparison Statista (2022) groups SHT in the six segments: smart appliances, home entertainment, control & connectivity, energy management, comfort & lighting and security. Pritoni et al. (2018) focus directly on SET – i.e., smart home technologies with the purpose of energy management – and characterise 308 technologies on the US market in 2015-2016 according to categories such as product components, hardware, software, communication, information - feedback. In their database they divide the technologies into the following components: smart appliances, smart thermostats, smart lighting, smart plug/switch, smart hub, in home display, energy portal, load monitor and embedded display (Pritoni et al., 2018). In contrast Marikyan et al. (2019) characterise smart homes, suggesting a grouping by type of service (control/monitor, energy management, support and assistance, anticipate and respond), and addressed user needs (cost efficiency, comfort, emotion, safety, health, quality of life, sustainability), in addition to a purely technology-based classification into sensors, devices and integrated systems.

Studies on the classification of individual products in the smart home sector revealed that all these different technologies contribute to different levels of smartness. These levels of smartness range from traditional homes without the installation of smart devices, to stand-alone separate smart applications with varying degrees of interconnectedness, to fully integrated system solutions that adapt to the context. The degree of smartness is related to the degree of human interaction with smart technologies. While energy savings and efficiency with separate smart devices or smaller device bundles are mostly based on feedback mechanisms and subsequent behavioral decisions, more connected system solutions can implement this via automation and ultimately AI-supported control (Sovacool & Del Rio, 2020; Marikyan et al., 2019). Thus, there are two important characteristics of smart devices in terms of energy management on the one hand the level of smartness - i.e., the degree of connectivity - and on the other hand the energy saving potential.

A positive correlation between the degree of smartness and the savings potential is postulated in existing studies (Strother et al., 2013; Williams & Matthews, 2007). Ford et al. (2017) argue that feedback mechanisms, and thus behaviour-based energy savings, have less potential for energy savings than automation or load-shifting mechanisms. Technologies out of the categories of lighting, household appliances, integrated systems or energy management systems have a good energy saving potential on behavioral and/or operational level. Technologies providing feedback with a display, or a connected app help to save energy on behavioral side. Technology using remote, scheduled or rule-based control helps to reduce usage and enable savings. On operational level automation of control, sensor-based control or intelligent learning algorithms drive energy savings and efficiency (Ford et al., 2017).

## 2.2 Adoption of smart technologies

The literature contains many studies that examine factors that determine acceptance and adoption of smart technologies (e.g., Kastner et al., 2015; Mashal et al., 2023). The focus lies on the explanation of the intention or the actual adoption of separate devices (e.g., adoption of PV by Tanveer et al., 2021; smart heating and smart meter by Große-Kreul, 2022) to product categories (e.g., adoption of smart home by Shuhaiber & Mashal, 2019; of HEM by Chen et al., 2020; of green technologies by Girod et al., 2017). The testing of existing theories (e.g., Technology Acceptance Model (TAM), Unified Theory of Acceptance and Use (UTAUT)) show, the impact of predictors such as perceived usefulness or perceived ease of use (Mashal et al., 2023).

According to the decision-making process in respect to the diffusion of innovation theory compatibility in terms of values, norms, preferences and experiences play an essential role in adoption (Rogers, 1995; Saaksjarvi, 2003). Compatibility and knowledge about a technology significantly influence the interest in considering adoption in the first place. Based on the analogical learning theory, consumers not only need knowledge in the main technology group, but also knowledge that has been made about a supplementary technology category influences adoption (Saaksjarvi, 2003). This leads to the assumption that interest in SET can also be stimulated via adoption of SHT and vice versa.

A deeper understanding of reasons and motives for using smart home is shown by qualitative research results, where energy management and saving energy by controlling appliances is named as one of the most important benefits or purposes of smart home. Others are comfort and convenience, financial savings, health benefits from mediation management to taking care of personal hygiene, entertainment and enhancing leisure by providing fun or interacting with others remotely, aesthetics and symbolic value, free services or promotional gifts (FakhrHosseini et al., 2021; Sovacool & Del Rio, 2020; Li et al, 2021; Wilson, 2017).

While many studies have characterized and categorized smart technologies and examined their drivers and barriers in terms of acceptance and adoption, there are hardly any studies that have examined TAP in respect to the chronological order of different technology types. Under the term "co-adoption," sporadic previous literature examines the adoption and use of multiple technologies at the household level in terms of product bundles. For example, Lagomarsino et al. (2023) show the potential of low-carbon technologies (i.e., PV solar system, heat pump, hybrid and electric vehicle, stationary battery) in co-adoption and the existence of co-adoption patterns over time. In the present article, a step further is taken by considering different SHT and SET in their chronological adoption order.

# 3 Methods

For this study we used a mixed methods approach, first having a qualitative part with interviews followed by a quantitative part with a quota-representative online survey. The aim was a triangulation of data to achieve a comprehensive understanding regarding the type of technologies adopted, the chronological order of adoption and reasons.

As basis for both, the qualitative and quantitative part a list of smart technologies that can potentially be adopted by households has been developed. Therefore, a typology of smart technologies (i.e., SHT and SET) at the household level was created based on literature review (e.g., Pritoni et al., 2018, GfK, 2016 and Sovacool and Del Rio (2020). The potential smart technologies were assigned to a categorization and degree of interconnectivity.

In the qualitative part, semi-structured interviews were conducted with 16 individuals. A convenient sample (Patton, 1990) was used. Criteria for selecting subjects were ownership of SHT or SET and heterogeneity in age, sex, education, and living situation, see table 1.

**Table 1.** Characteristics of the subjects interviewed. Following abbreviations are used: m = masculine, w = feminine, w/o = without higher education, degree = with at least high school degree

| ID | Age | Sex | Education | Home ownership | No. of persons in the household |
|---|---|---|---|---|---|
| I1 | 42 | m | degree | apartment | 2 |
| I2 | 40 | m | w/o | house | 4 |
| I3 | 46 | m | degree | apartment | 3 |
| I4 | 38 | m | degree | house | 3 |
| I5 | 29 | m | degree | house | 2 |
| I6 | 36 | m | degree | apartment | 2 |
| I7 | 37 | f | degree | apartment | 4 |
| I8 | 49 | f | w/o | house | 1 |
| I9 | 20 | f | degree | rent | 2 |
| I10 | 36 | m | degree | rent | 1 |
| I11 | 58 | f | w/o | house | 2 |
| I12 | 46 | m | degree | house | 2 |
| I13 | 51 | m | degree | house | 1 |
| I14 | 21 | f | degree | rent | 6 |
| I15 | 51 | m | degree | house | 5 |
| I16 | 36 | m | degree | apartment | 4 |

In the information phase, the aim of the interview was presented, and data protection aspects were explained in order to obtain informed consent. It was further explained that the interview is about smart devices in general, i.e., both SHT and SET. In the main phase, the interviewees were shown cards on which 35 different technologies were written. After that, they were asked to select those cards that included technologies that were already present in their households. The interviewees were asked in what temporal order the technologies were adopted and they should place the cards accordingly. Based on the TAP laid, individuals were asked to talk about reasons for adopting each technology. Depending on the mentioned reasons, a further question was, if the adoption of one technology had caused the adoption of another technology. Finally, they were asked which technologies should be acquired in the future and why. The last part of the interview included a short survey about sociodemographic aspects and attitudinal characteristics according to the sampling criteria.

The interviews take place from November 2022 to January 2023 face-to-face. The interviews were recorded and then transcribed. Important visual findings, such as TAP, were captured through photos. The transcripts and photos were analysed using qualitative content analysis according to Mayring (2015) with the assistance of MAXQDA software.

Second, an online survey was conducted out among the Austrian population to complement the qualitative results. Quota sampling was chosen as the sampling method. For the characteristics age, gender and education, quotas were set according to Statistics Austria for a representative sample of the Austrian population.

The questionnaire comprised 2 parts. In the first part, sociodemographic characteristics (i.e., age, gender, education, employment status, state, type of housing, number of people in the household, income) were asked. In the second part, subjects were asked to select from a list those smart technologies that are present in their household and then to sort these selected technologies (if more than 2) according to their time of acquisition. For the technologies that have not yet been adopted, respondents were asked to what extent they were interested in purchasing them, measured on a 5-point Likert scale from (no interest to highly interested). In contrast to the interviews a limited number of technologies were asked due to usability reasons.

The survey was implemented online using the software Unipark and was conducted by a third-party provider (i.e., market research institute Norstat GmbH) with an online panel from February 13 to February 24, 2023. The results were analysed descriptively. A total of 848 people were interviewed across Austria, of which 59.2% were male, 48.9% female and 0.8% diverse. The average age is 40 years. 66% are without high school degree and 34% with high school degree.

# 4 Results

The list of different smart technologies (see table 2) included SHT (e.g., voice assistant, smart watch, smart fridge, smart entertainment) and SET (e.g., smart meter, smart heating, air conditioning, LED, etc.). These were assigned to 6 technology categories, that reflect different energy management potentials.

- Entertainment & Personal Technology & Health
- Safety & Security
- Appliances & Robots
- Lighting
- Energy Management
- Energy Production & Storage
- Mobility

Furthermore, we defined three integration levels: (i) enabler technology, (ii) integrated systems (not professional) and (iii) highly integrated systems (professional installation). These integration levels indicate that different degrees of interconnectedness can exist for one technology from the categories (e.g., voice assistant can stand alone, but also can control devices from the different categories as a system solution).

The results of the 16 interviews show according to table 2 that the respondents especially have acquired smart technologies in the areas of "lighting" (31) and "energy management" (35) on the one hand, and " appliances & robots" (34) and "entertainment & personal technology & health" (36) on the other. In respect to the category “appliances & robots”, there are many different mentions, with vacuum cleaners and lawn robots being more common. In the “entertainment & personal technology & health” category, smart watch and smart entertainment were most frequently mentioned. Smart meters, smart heating and smart thermostats are frequently mentioned in the “energy management” category, while smart lighting and motions sensors are common adopted technologies in the category “lighting”.

The temporal order of adoption shows that the mentioned technologies, which were acquired as first, second, or third, account for 44% of the total mentioned smart technologies. Smart heating and thermostats and motion detectors or smart lighting are particularly noteworthy, but smart entertainment (i.e., smart TV), smart watches, and voice assistants also fall into this early adoption phase of the respondents. Thus, SHT as well as SET are named, that find their way into the home at an early stage and thus function as basic technologies.

The technology adoption paths described by respondents show differences in the number of technologies adopted and the number of technologies purchased at any one time. For example, one interviewee describes the acquisition of 15 different technologies at 13 successive points in time. Another interviewee, on the other hand, describes the acquisition of 19 technologies at 5 successive points in time, whereas another person states having acquired 5 technologies at 2 successive points in time. On the one hand, this shows the extent to which the different technologies have already found their way into the household and which group of technologies is predominant.

In a few cases, a direct link between the experience with one technology and the decision to adopt another technology from the same or different technology category based on that experience was mentioned. Two interviewees got a voice assistant as a promotional gift and mentioned that they were interested in the features of and possibilities with this technology. Subsequently both invested in smart lights. While trying out the new technologies security and privacy concerns arose. One statement was: *„The heating via heat pump has quite triggered the purchase of PV, […] and the PV can dampen the electricity costs a little over the year.”*, which represents an example for co-adoption. Another interesting finding is that, one mentioned that the smart home was intended to control blinds, lights and heating, but because having such system, future investments in technology were made in consideration to the existing system and therefore influenced the purchase decisions. The smart phone was also mentioned twice as trigger for smart watch and general interest in smart technologies.

**Table 2.** Absolute frequencies of technologies mentioned in total, and technologies adopted first, second and third

| Category | Technology | Total | Order | | |
|---|---|---|---|---|---|
| | | | **1.** | **2.** | **3.** |
| Entertainment & Personal Technology & Health | Smart entertainment | 13 | 3 | 5 | 3 |
| | Voice assistant | 9 | 1 | 3 | 1 |
| | Smart watch | 12 | 2 | 1 | 2 |
| | Smart health and assistance systems | 2 | - | 1 | - |
| Safety & Security | Smart security devices/systems | 5 | - | 1 | 1 |
| Appliances & Robots | Smart coffee maker | 1 | - | - | - |
| | Smart kettle | 2 | - | - | 2 |
| | Smart food processor | 2 | - | 1 | - |
| | Smart fridge | 1 | - | 1 | - |
| | Smart washing machine | 4 | - | - | - |
| | Smart dishwasher | 1 | - | - | - |
| | Smart oven/stove | 2 | - | 1 | 1 |
| | Smart tumble dryer | 4 | - | - | 1 |
| | Lawn robot | 6 | 1 | 1 | 1 |
| | Robot vacuum cleaner | 10 | 1 | - | 2 |
| Lighting | Motion sensor | 10 | 3 | 5 | - |
| | Dimmer | 11 | 3 | 1 | - |
| | Smart lighting / LED | 10 | 1 | 2 | 1 |
| Energy Management | Smart meter | 7 | 1 | - | 1 |
| | Smart air conditioner | 1 | - | - | - |
| | Smart heating | 10 | 3 | 1 | 1 |
| | Smart thermostat | 8 | 3 | 1 | - |
| | Smart plug | 4 | - | 1 | - |
| | Smart water boiler | 3 | - | 1 | 1 |
| | Smart blinds | 3 | - | 1 | - |
| Energy Production & Storage | PV system | 6 | - | - | - |
| | Solar thermal system | 4 | 2 | 1 | - |
| | Power storage | 1 | - | - | - |
| Integrated Systems | HEM system | 2 | - | - | - |
| | Smart home system | 3 | - | 2 | - |
| Mobility | E-Car | 1 | - | - | - |
| | E-Bike/E-Scooter/similar | 8 | - | 1 | - |
| Total (absolute) | | 166 | 24 | 32 | 18 |
| % share of all technologies adopted | | | 14 | 19 | 11 |

The reasons for adopting the SHT and SET were manifold. In addition to the enthusiasm for the technology and statements like "*I bought it simply because I think it's cool*" the following reasons were broadly summarized:

- Energy saving or energy efficiency
- Practical reasons such as facilitation and time savings
- Comfort and convenience
- Monitoring
- New acquisition without a focus on smart features, as these features were included in the product
- Already present in the building at the time of house/apartment purchase
- Gift from friends/family or from the manufacturer (as part of a product test)
- Specific problem-solving like:
    - Targeted control of devices at home (e.g., aquarium pump, Christmas lighting)
    - Remote control of devices (e.g., simulating presence during vacation, controlling heating or blinds)

In the case of adoption without attention to smart functions, some respondents explained that there was no alternative/non-smart technology available, and in order they were forced to buy something smart/energy-saving. Other respondents mentioned that it was simply not consciously intended because other selection criteria were in focus during the purchase. Some interesting quotes from the interviews in this respect are: “*I didn't want that to happen*” or “*[...] with the TV it is simply a development. It was more of a necessary evil to buy a smart TV*” or “*the smart thing just came along at some point without actively wanting it*". Thus, the findings show, that a quarter of respondents have devices with smart features, but do not use them and a quarter of respondents use the smart features of the device, although it was purchased without attention to them.

Even in the case of the voice assistant, the decision to use it is not always supported by all household members or generally actively decided. When asked whether a voice assistant was owned, one respondent mentioned: "*[...] social pressure in the family. From my point of view, we wouldn't have anything like this, but kids and wife wanted an Alexa*".

Interesting thoughts regarding the purchasing because of energy saving are *“[...] because we want to produce our own energy and also try to consume this energy ourselves and to align our consumption with the production of this energy, so we can save energy”* or *“[...] not the smart features were in the focus, but the* *quality and energy consumption of the device"* or *"[...] you can certainly make the energy consumption more efficient and there is potential for savings"*. Some respondents even indicated on their own that they would have purchased a smart meter without compulsory installation by energy providers.

There were also respondents indicating that they own and tried a smart device, but the features are now no longer used, based on privacy concerns or lack of interest.

The results of the survey (see figure 1) show that smart entertainment and household technologies, as well as smart lighting, emerge as pioneers in many households. In contrast e-cars and smart home solutions or energy management systems are still not present. When a technology is not yet present in a household, we inquired about the level of interest in potential adoption. In addition to the aforementioned technologies, there is a clear trend of interest in energy management technologies such as electricity production and storage. Smart heating and lighting systems are also of interest. However, there is relatively little enthusiasm for electric vehicles and smart home solutions. Interestingly, although voice assistants are already well-established in households, the interest in them is relatively low.

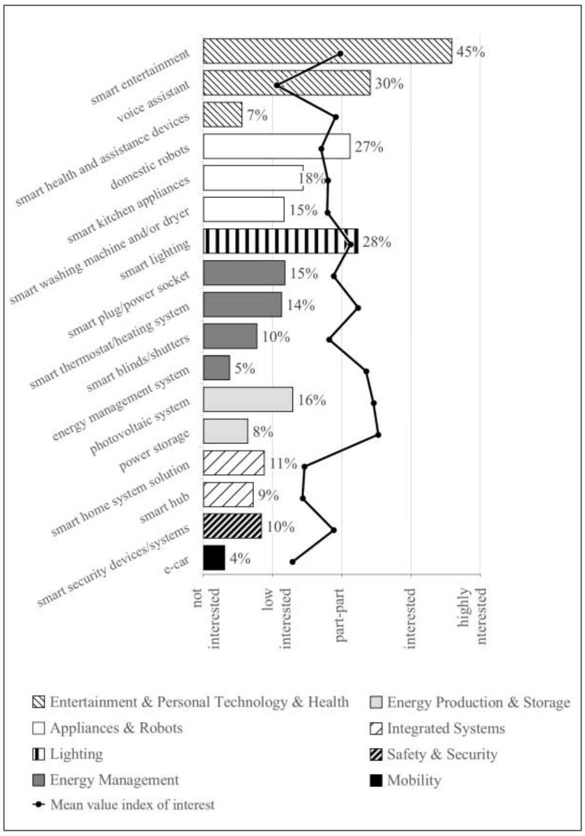


**Figure 1.** Percentage of people who already own technology and mean index of interest in technology

Table 3 shows that from the temporal order of adoption, it appears that respondents invested especially in smart entertainment and voice assistants first. In addition, domestic robots (e.g., lawn robot, robot vacuum cleaner) find their way into the household at an early stage. In terms of SET, smart lighting is the first item to be purchased.

**Table 3.** Excerpt from the chronological order of technology adoption

| Technology | Frequencies Adoption order | | | | | |
|---|---|---|---|---|---|---|
| | 1. | 2. | 3. | 4. | 5. | 6. |
| smart entertainment | 146 | 79 | 34 | 12 | 11 | 6 |
| voice assistant | 80 | 63 | 35 | 12 | 4 | 9 |
| domestic robots | 59 | 47 | 30 | 22 | 13 | 6 |
| smart lighting | 58 | 58 | 35 | 20 | 10 | 5 |
| smart kitchen appliances | 44 | 25 | 17 | 17 | 11 | 3 |
| smart washing machine and/or dryer | 30 | 26 | 18 | 10 | 8 | 5 |
| photovoltaic system | 30 | 28 | 9 | 9 | 9 | 6 |
| smart thermostat/heating system | 29 | 17 | 19 | 8 | 2 | 6 |
| smart home system | 29 | 12 | 10 | 12 | 9 | 2 |
| smart plug | 22 | 26 | 20 | 19 | 8 | 5 |
| smart blinds/shutters | 22 | 9 | 10 | 10 | 8 | 2 |
| smart security devices/systems | 20 | 11 | 14 | 10 | 6 | 5 |
| smart hub | 18 | 7 | 15 | 8 | 6 | 3 |
| smart health and assistance devices | 14 | 7 | 6 | 9 | 4 | 1 |
| HEM system | 12 | 3 | 5 | 3 | 2 | 2 |
| power storage | 11 | 9 | 9 | 4 | 7 | 2 |
| e-car | 3 | 2 | 5 | 9 | 1 | 1 |

# 5 Discussion & Conclusion

This study investigated TAP of smart technologies at the household level. The aim was to understand the chronological order of adoption and reasons for the adoption of different SHTs and SETs. The results showed that both SET and SHT are at the beginning of TAP. Smart entertainment, voice assistant and smart lighting were often ranked first, second or third in the interviews as well as in the survey. While smart heating and smart thermostats were also mentioned in the interviews, smart appliances and robots were a frequently mentioned technology at the beginning in the survey. Ultimately, the TAPs described are very heterogeneous in terms of technologies. Nevertheless, the insight into the various technology adoption paths provides a deeper understanding of households' actual decision-making behavior. In addition to the technologies already adopted by households, there is a clear trend of interest in energy management technologies.

Reasons for adoption such as comfort, energy savings, or promotional gifts are similar to the reasons given in existing studies such as that of Sovacool and Del Rio (2020). Interestingly, the adoption of smart devices was often not intended. The need for smart technologies, and thus the decision to adopt them, can be caused by the technology itself (Rogers, 1995). This can be seen in the example of the adopted smart TV. The initial trigger for buying the smart device was that the old device was broken, with the smart functions being secondary. The experience with the new smart device then created a need for smart functions.

On the one hand, the interviews show an example of co-adoption, i.e., a technology adoption path was characterized by the fact that the adoption of a heat pump prompted the adoption of PV as a complementary technology (i.e., adoption of technologies in the SET category). On the other hand, another interview revealed an example of adoption of different technology categories. Due to the voice assistant (i.e., SHT) that was introduced into the home as a promotional gift, the interest for smart lighting was aroused (i.e., SET since this technology enables more efficient energy consumption). Nevertheless, the interviews only rudimentarily showed that a conscious decision for one technology is made on the basis of another specific technology, regardless of the technology category.

By knowing which technologies are already adopted by the households, targeted points of connection can be created between the products offered and already adopted technologies. Thus, the findings can be utilized for targeted marketing strategies, enabling companies to effectively promote their offerings based on the specific technology adoption patterns observed. On the scientific side, scenarios for the diffusion of smart technologies could be developed based on the results - i.e., information on ownership and interest in smart technologies (smart home and SET).

Although a heterogeneous group of people for the interviews were recruited, there are still limitations. Additional interviews could provide better theoretical saturation and thus shed light on the trends regarding the influence of one technology (category) on another technology (category) in the TAP. In addition, future research could identify patterns based on the quantitative data on TAPs. The aim would be to use statistical analysis to determine whether the likelihood of adoption increases with the ownership of another technology.

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## References

Aldrich, F.K., 2003. Smart Homes: Past, Present and Future. In Harper, R. (ed.), *Inside the Smart Home* (17-39). Springer.

Balta-Ozkan, N., Boteler, B., & Amerighi, O. (2014). European smart home market development: Public views on technical and economic aspects across the United Kingdom, Germany and Italy. Energy Research & Social Science, 3, 65–77.

Bundesministerium für Nachhaltigkeit und Tourismus (BMNT). (18. Dezember 2019). Integrierter nationaler Energie- und Klimaplan für Österreich. Retrieved from https://energy.ec.europa.eu/system/files/2020-01/at_final_necp_main_de_0.pdf

Chen, C., Xu, X., Adams, J., Brannon, J., Li, F., & Walzem, A. (2020). When East meets West: Understanding residents’ home energy management system adoption intention and willingness to pay in Japan and the United States. *Energy Research & Social Science, 69*. https://doi.org/10.1016/j.erss.2020.101616

European Commission. (18. 10 2022). Digitalising the energy system - EU action plan. Retrieved from https://ec.europa.eu/info/law/better-regulation/have-your-say/initiatives/13141-Digitalising-the-energy-sector-EU-action-plan_en

FakhrHosseini, S., Lee, S.-H., Rudnik, J., Son, H., Lee, C., & Coughlin, J. (2021). User Needs of Smart Home Services. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting, 65*(1), 457-461. https://doi.org/10.1177/1071181321651218

Ford, R., Pritoni, M., Sanguinetti, A., & Karlin, B. (2017). Categories and functionality of smart home technology for energy management. *Building and Environment*, *123*, 543–554. https://doi.org/10.1016/j.buildenv.2017.07.020

GfK. (2016). GfK Future of Smart Home Study: Global Report.

Gimpel, H., Graf, V., & Graf-Drasch, V. (2020). A comprehensive model for individuals’ acceptance of smart energy technology – A meta-analysis. *Energy Policy*, *138*. https://doi.org/10.1016/j.enpol.2019.111196

Girod, B., Mayer, S., & Nägele, F. (2017). Economic versus belief-based models: Shedding light on the adoption of novel green technologies. *Energy Policy*, *101*, 415–426. https://doi.org/10.1016/j.enpol.2016.09.065

Große-Kreul, F. (2022). What will drive household adoption of smart energy? Insights from a consumer acceptance study in Germany. *Utilities*

*Policy*, *75*. https://doi.org/10.1016/j.jup.2021.101333

Kastner, I., & Stern, P. C. (2015). Examining the decision-making processes behind household energy investments: A review. *Energy Research & Social Science*, *10*, 72–89. https://doi.org/10.1016/j.erss.2015.07.008

Lagomarsino, M., van der Kam, M., Rahmani Azad, Z., Parra, D., & Hahnel, U. J. (2023). Co-Adoption Pathways Toward a Low-Carbon Energy System. Advance online publication. https://doi.org/10.2139/ssrn.4443494

Li, W., Yigitcanlar, T., Erol, I., & Liu, A. (2021). Motivations, barriers and risks of smart home adoption: From systematic literature review to conceptual framework. *Energy Research & Social Science*, *80*, 102211. https://doi.org/10.1016/j.erss.2021.102211

Marikyan, D., Papagiannidis, S., & Alamanos, E. (2019). A systematic review of the smart home literature: A user perspective. *Technological Forecasting and Social Change*, *138*, 139–154. https://doi.org/10.1016/j.techfore.2018.08.015

Mashal, I., Shuhaiber, A., & AL-Khatib, A. w. (2023). User acceptance and adoption of smart homes: A decade long systematic literature review. *International Journal of Data and Network Science*, *7*(2), 533–552. https://doi.org/10.5267/j.ijdns.2023.3.017

Mayring, P. (2015). Qualitative Inhaltsanalyse: Grundlagen und Techniken (12., überarbeitete Auflage). Beltz.

Patton, M. Q. (1990). *Qualitative evaluation and research methods* (2nd ed.). Sage Publications, Inc.

Paukstadt, U. (2019). A Survey on Smart Energy Services for Private Households. *Proceedings of the 14th International Conference on Wirtschaftsinformatik*, 1448-1462. Retrieved from https://aisel.aisnet.org/wi2019/track12/papers/7/

Pritoni, M., Ford, R., Karlin, B, & Sanguinetti, A. (2018). Home energy management (HEM) database: A list with coded attributes of 308 devices commercially available in the US. *Data in Brief*, *16*, 71-74. https://doi.org/10.1016/j.dib.2017.10.067.

Rogers, E.M. (1995). Diffusion of Innovations. 4th Edition, the Free Press, New York.

Sanguinetti, A., Karlin, B., & Ford, R. (2018). Understanding the path to smart home adoption: Segmenting and describing consumers across the innovation-decision process. *Energy Research & Social Science*, *46*, 274-283. https://doi.org/10.1016/j.erss.2018.08.002

Saaksjarvi, M. (2003). Consumer adoption of technological innovations. *European Journal of Innovation Management*, *6*(2), 90–100. https://doi.org/10.1108/14601060310475246

Shuhaiber, A., & Mashal, I. (2019). Understanding users' acceptance of smart homes. *Technology in Society*, *58*, 101110. https://doi.org/10.1016/j.techsoc.2019.01.003

Sovacool, B. K., & Del Furszyfer Rio, D. D. (2020). Smart home technologies in Europe: A critical review of concepts, benefits, risks and policies. *Renewable and Sustainable Energy Reviews*, *120*, 109663. https://doi.org/10.1016/j.rser.2019.109663

Statista (2022). Smart Home. Retrieved from https://de.statista.com/outlook/dmo/smart-home/oesterreich#market-shares

Strother, N. & Lockhart B. (2013). In-home Displays, Networked Hem Systems, Stand-alone Hem Systems, Web Portals, and Paper Bill Hem Reports, Global Market Analysis and Forecasts, Navigant Consulting Inc, Chicago, IL.

Tanveer, A., Zeng, S., Irfan, M., & Peng, R. (2021). Do Perceived Risk, Perception of Self-Efficacy, and Openness to Technology Matter for Solar PV Adoption? An Application of the Extended Theory of Planned Behavior. *Energies*, *14*(16), 5008. https://doi.org/10.3390/en14165008

Williams, E.D. & Matthews, H.S. (2007). Scoping the potential of monitoring and control technologies to reduce energy use in homes. *Proceedings of the IEEE International Symposium on Electronics and the Environment*, 2007, 239-244.

Wilson, C., Hargreaves, T., & Hauxwell-Baldwin, R. (2015). Smart homes and their users: a systematic analysis and key challenges. *Personal and Ubiquitous Computing*, *19*(2), 463-476. https://doi.org/10.1007/s00779-014-0813-0

Wilson, C., Hargreaves, T., & Hauxwell-Baldwin, R. (2017). Benefits and risks of smart home technologies. *Energy Policy*, *103*, 72–83. https://doi.org/10.1016/j.enpol.2016.12.047