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Article

Residents' Perceptions of a Smart Technology Retrofit Towards Nearly Zero-Energy Performance

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Abstract
Coping with global climate challenges requires changes in both individual practices and the technical infrastructure in which people operate. Retrofitting existing buildings with smart and sustainable technologies shows the potential in reducing the environmental impacts of the housing sector and improving the quality of life for residents. However, the efficiency of these means depends on their individual and societal acceptance. This calls for the need to incorporate social practice theories into the discussion of smart cities and technology adoption. This study aims to understand how smart retrofit intervention in an extensive pioneering smart city project in Estonia is perceived among the residents with different dispositions towards the environment and technology in an early phase of the intervention. We interviewed the residents of 18 Soviet-era apartment buildings which underwent a complete retrofit into nearly zero-energy buildings equipped with smart technologies. The results showed that pro-technology residents expressed high interest and trust towards smart retrofit intervention, while residents with environmentally inclined dispositions conveyed more critical arguments. This indicates that individuals' underlying dispositions may result in different social practices and that a diverse set of engagement approaches are crucial for the success and social acceptance of large-scale pioneering projects in the housing sector.

Keywords
environmental sustainability; nearly zero-energy renovation; smart city; smart retrofit intervention; technology adoption

Issue
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1. Introduction

To meet the international climate goals in the housing sector, changes are required both in our lifestyles and in the ways we manage our residential environments. The building and construction sector is responsible for 37% of greenhouse gas emissions globally (United Nations Environmental Programme, 2021). The transition towards nearly zero-energy buildings has been recognised as one of the key pathways to decarbonising building stock and tackling climate change (Esser et al., 2019). The smart city framework, which combines sustainability aims with the means of digitalisation, provides tools and technology for the smart retrofit of existing housing stock (Haarstad & Wathne, 2019; Kramers et al., 2014). Smart retrofit incorporates technological advancements with the efforts of residents to reduce energy demand and improve the quality of housing (Al Dakheel et al., 2020; Hargreaves et al., 2018), which, however, entails several social challenges (Vanolo, 2016). Achieving nearly zero-energy performance with the help of smart technologies requires a systematic socio-technical transition with new forms of collaboration between citizens, governmental institutions, and service providers (Kivimaa et al., 2019). Social practice theories (Reckwitz, 2002; Røpke, 2009; Shove, 2010) provide a framework to conceptualise the behavioural change envisaged by the transition. Social practices necessary for the uptake of smart technologies by residents are formed and transformed in social systems, accompanied by the meaning residents ascribe to the technologies, and supported by the competence to practice smart technology use. Thus, the perceptions people carry and share about smart technologies and smart retrofit may explain the success of the transition.

The possible technologies applied in the smart retrofit range from smart grids to smart home panels (Al Dakheel et al., 2020). Smart technology provides real-time data collection and decision-making options on resource use and system performance on the level of apartments, buildings, and a city (Al Dakheel et al., 2020; Kivimaa et al., 2019). In response to user behaviour, smart technology automates and optimises operations, which helps to reduce carbon emissions and use resources more efficiently (Haarstad & Wathne, 2019; Kramers et al., 2014). However, a rapid uptake of digital technology involves a high risk of citizen exclusion from decision-making, limited use of applied technologies, and poor materialisation of environmental promises (Evans et al., 2019; Haarstad & Wathne, 2019; Hargreaves et al., 2018). A technocratic approach to smart cities and smart retrofit may trigger new types of inequalities in urban life instead of empowering citizens and improving their quality of life (Vanolo, 2016).

Acknowledging peoples' perceptions about the environment and technology and their engagement with technology will help embed sustainability goals within a smart city agenda (Martin et al., 2018). This relies on two assumptions. First, people should be willing and able to practise environmentally conscious lifestyles because technological fixes are not sufficient for attaining sustainability goals (Baum & Gross, 2017; Røpke, 2009). Second, people should be willing and able to adopt smart technologies that facilitate an overall reduction in resource use in their everyday routines. On the one hand, the acceptance and adoption of these technologies largely depend on people's subjective perceptions of sustainability and the usefulness, ease of use, and reliability of the technology (Sepasgozar et al., 2019). On the other hand, top-down implementation of smart technologies in everyday environments accompanied by empowering collaboration between respective public bodies, businesses, and citizens may help overcome people's lack of competence with or fears of technological transition (Berntzen & Johannessen, 2016; Viale Pereira et al., 2017).

In this article, we lean on the theories of social practice (Reckwitz, 2002; Røpke, 2009; Shove, 2010) to analyse the perceived meaning of smart and sustainable technologies being implemented in residential environments to facilitate the transition towards nearly zero-energy buildings and the role of social interaction in shaping those perceptions. We tackle the potential uptake of smart and sustainable technologies in the context of a pioneering smart retrofit intervention, which targets 18 outdated khrushchyovkas, i.e., five-floor apartment buildings designed in the Soviet era for mass housing, in Tartu, Estonia. We examine the perceptions of the intervention among the residents of those buildings. Specifically, we investigate the perceptions among people with different dispositions towards the environment and technology, which have been detected based on their previous social practices. Drawing from Axsen et al. (2012), Mahmoodi et al. (2020), and Sepasgozar et al. (2019), we believe that the underlying dispositions to the environment and technology affect the perceptions of the sustainability, usefulness, and ease of use of the technologies implemented in the smart retrofit intervention and thus the success of the intervention at large. We learn from the experience of the early phase of the intervention before smart and sustainable technologies were implemented into the structures of the buildings and the homes of people. Based on social practice theories, previous practices can affect the prevalence to develop new practices related to sustainable technologies. We evaluate this through the meanings assigned to the technologies and observe the role of social interaction in the process of assigning meanings to the technologies. The assigned meanings allow us to foresee the risks related to the uptake of smart technologies within the retrofit intervention. Furthermore, understanding people's perceptions is crucial for the engagement and collaboration activities within this project and for the overall success of large-scale smart city projects more broadly. Specifically, we address the following research questions in this article:

1. How do residents with different dispositions to environment and technology perceive the meaning of smart and sustainable technologies that are being implemented in a smart retrofit intervention?
2. How does social interaction mediate people's perceptions of smart and sustainable technologies?

2. Theoretical Background

Behavioural change towards sustainable human activity, if supported by relevant contextual opportunities, is believed to be a crucial goal for addressing global sustainability challenges (Barr et al., 2011; Baum & Gross, 2017). As individual consumption decisions are always made in the context of existing consumption spaces and settings, conceptualising behavioural changes needs to occur at the level of social systems (Labanca & Bertoldi, 2018; Røpke, 2009). Adopting technologies can be one example of such behaviour. The diffusion of smart and sustainable technologies implemented in nearly zero-energy housing largely depends on whether and how people adopt the technology in the context of different technological, individual, and social considerations. While the theory of the technology acceptance model (Davis, 1989) describes how technology is accepted on an individual level, social practice theories focus on human behaviour and its evolution in the context of social systems (Reckwitz, 2002).

The technology acceptance model states that people intend to use technology according to its perceived usefulness and perceived ease of use (Davis, 1989; Venkatesh et al., 2003). While possible savings in cost, time, or energy might be important considerations for the uptake (Sepasgozar et al., 2019), several barriers also exist. The barriers can be related to the technology, such as the feeling that the technology has low rates of perceived usefulness, is too complex for use, and has a small relative advantage over its predecessors; or to the individuals as they may lack experience and skills to use the technology, question its reliability, security, and impacts on their privacy, and be resistant to change in general (Balta-Ozkan et al., 2013; Hargreaves et al., 2018; Hong et al., 2020; Marikyan et al., 2019; Sepasgozar et al., 2019).

In addition to individual considerations, people evaluate the benefit of technology in a social context. The acceptance of technology occurs over time through iterative and reflexive social processes, which shape the widespread perception of the meaning of technology (Axsen & Kurani, 2014). Members of innovator and early adopter groups use communication networks to disseminate information to consumer groups that later adopt the technologies (Axsen & Kurani, 2014; Axsen et al., 2013). Individuals may conform due to social norms, social practices, and the behaviour of other people (Axsen et al., 2012; Venkatesh et al., 2003). The influence of social context is also evident in how people perceive themselves when using technology and in how such perceptions are formed concerning other people. For example, individuals may be motivated to adopt new technology for the perceived outcomes to their (self-)identity and social status rather than for the (perceived) functional or (perceived) environmental outcomes of the technology (Axsen & Kurani, 2014; Noppers et al., 2015).

As such, the adoption and consumption of technology are social practices related to a group of people rather than to an individual alone (Nilsson et al., 2018). Social practice theories provide a framework for understanding the evolution and reproduction of human behaviour and its implications for sustainability. This framework understands behaviour as a dynamic and complex interaction between social, material, and individual settings (Hargreaves, 2011; Røpke, 2009; Shove, 2010; Warde, 2005). A social practice is a routinised type of behaviour, which consists of an integrated set of bodily-mental activities that have meanings, are materialised by necessary artefacts, and are practised through the embodied competence of the practitioner (Reckwitz, 2002; Røpke, 2009). Meanings help to define the purpose of the practice and reflect beliefs, understandings, and emotions related to it (Røpke, 2009). Therefore, to understand technology use, one must also understand the meaning that people assign to technology-related practices (see also Warde, 2005). The material element of a practice includes the material artefacts and human bodies involved in the practice (Røpke, 2009). Material objects may involve technologies, infrastructure, or building configurations that are significant for the practice and its development (Bartiaux et al., 2014; Gram-Hanssen, 2010). In cases where a building-related intervention is not directly visible, the acceptance of and adaptation to the intervention is dependent on its visibility through communication and dialogue (Chiu et al., 2013, as cited in Lowe et al., 2018, p. 478). Competence comprises the skills and embodied knowledge of the practitioner (Røpke, 2009) as well as the knowledge contained in repositories, such as manuals or the internet (Watson & Shove, 2008). Competence is obtained through experiences and training and is shared socially (Røpke, 2009; Warde, 2005). Because any social practice is a configuration of these three elements—meanings, material objects, and competence (Røpke, 2009)—the elements also relate to the consequences of the practice. Thus, the environmental outcomes of social practices depend on the meanings people ascribe to the practice, material settings in which the practice is embedded, and competencies embodied in the practitioner or present in social settings. Furthermore, social systems (re)produce and transform social practices, including pro-environmental behaviour and technology adoption, through communication networks, media, and social norms (Hargreaves, 2011; Røpke, 2009; Shove, 2010). Therefore, recognising the impact of social interaction is crucial for understanding the evolution and reproduction of social practices in social systems.

In the context of smart retrofit intervention, understanding these three elements—meanings, material objects, and competence—of intended behaviour and their formation through social interaction gives insights into the process of technology adoption among residents, the environmental outcomes of the behaviour, and the overall success of the intervention. People are willing to adopt smart technologies in their daily life if they perceive them as useful and straightforward (Larsen et al., 2019) and feel control over their features due to possessing necessary skills (Hargreaves et al., 2018). People's involvement in technology adoption may also depend on whether they perceive the technology as pro-environmental. Research has suggested that people representing different dispositions towards technology and the environment may consider different actions as pro-environmental, despite sharing the general intention to contribute to sustainability goals (Axsen et al., 2012). Mahmoodi et al. (2020) suggest that pro-environmental consumer decisions may have radically different meanings for different types of consumers. For instance, a person might conserve household energy for environmental or for financial reasons. Also, involvement influences the environmental outcomes of the intervention and a lack of engagement with sustainable technologies may result in a reverse effect. For example, Strengers and Nicholls (2017) argue that the use of smart-home systems to automate energy use may not meet the goals of energy reduction because the systems are marketed with the promise of convenience ("set-and-forget") that exaggerates the laziness of users rather than encourages their active engagement in energy-saving practices. Finally, active citizen engagement through communication and dialogue is recognised as "a crucial factor in mediating occupants' acceptance of, adaptation to, and satisfaction with retrofit technology" (Chiu et al., 2013, as cited in Lowe et al., 2018, p. 478). According to Sørensen (2006), people construct their technology-related practices in interaction with other people's practices. Thus, social learning can help diffuse competence and innovations at large (Bandura, 1977).

3. Methodology

3.1. Smart Retrofit Intervention in the Pilot Area

Khrushchyovkas are a key part of the Soviet-era housing heritage and are made of prefabricated large blocks or bricks with up to five stories. Built from the late 1950s to the 1980s as an inner-city infill to accommodate people in the post-war housing deficiency (Hess & Tammaru, 2019), they contain small, up to 40 m^2 apartments with one or two bedrooms (see Figure 1). Most of the housing stock in Estonia is privately owned. Residential buildings are managed by apartment associations, which consist of individual owners with equal rights for a majority vote. At present, khrushchyovkas have typically poor sanitary conditions, insulation, ventilation, and heating systems, resulting in an extensive need for renovation (Ahas et al., 2019). The extent of renovation depends largely on the investment capability of residents and available bank loan guarantees (Hess & Tammaru, 2019).

We conducted our research in Tartu, which is the second-largest city in Estonia. The research is centred on a pioneering, smart retrofit project "SmartEnCity—Towards Smart Zero CO_2 Cities across Europe," funded by the European Union programme Horizon 2020. The project aimed to retrofit 18 outdated Soviet-era apartment buildings (khrushchyovkas) to nearly zero-energy smart buildings equipped with smart home technology. The project carries a "lighthouse project" designation because it is the first large-scale retrofit project in which smart and sustainable technologies were applied to privately owned Soviet-era apartment buildings. In addition to European Union funding, the housing association had to apply for a reconstruction grant from the KredEx financing institution and take a bank loan with a repayment period of 15 to 20 years (Ahas et al., 2019).

The project involved building-level interventions, such as adding insulation, implementing a heat recovery ventilation system, and installing solar panels; as well as apartment- and room-level interventions, such as installing CO_2-sensors and smart home panels that provide automated, on-demand heating and ventilation controls (see Figure 2). The smart home panels allow residents to monitor and adjust room temperatures and airflow intensity using pre-defined settings; monitor electricity and water consumption, and solar energy production; and compare monthly resource use rates with those of the apartment block.

3.2. Data Collection, Classification of Respondents, and Data Analysis

During 2017–2019, we conducted 18 semi-structured and six in-depth interviews with residents who lived in khrushchyovkas within the project area. Our goal was to understand their perceptions of the smart retrofit intervention at an early phase of the project. The socio-demographic characteristics of respondents are presented in Table 1. There are more women than men as well as more respondents with higher education in the sample. However, in terms of age and income, the sample is heterogeneous.

We conducted semi-structured interviews after the apartment associations had been invited to the project, but before they decided to participate. This timing enabled the identification of residents' perceptions about the retrofit before they had a real-life experience of the outcome. The interviews lasted an average of 45 minutes, were audio-recorded, and later transcribed. The interviews covered residents' current

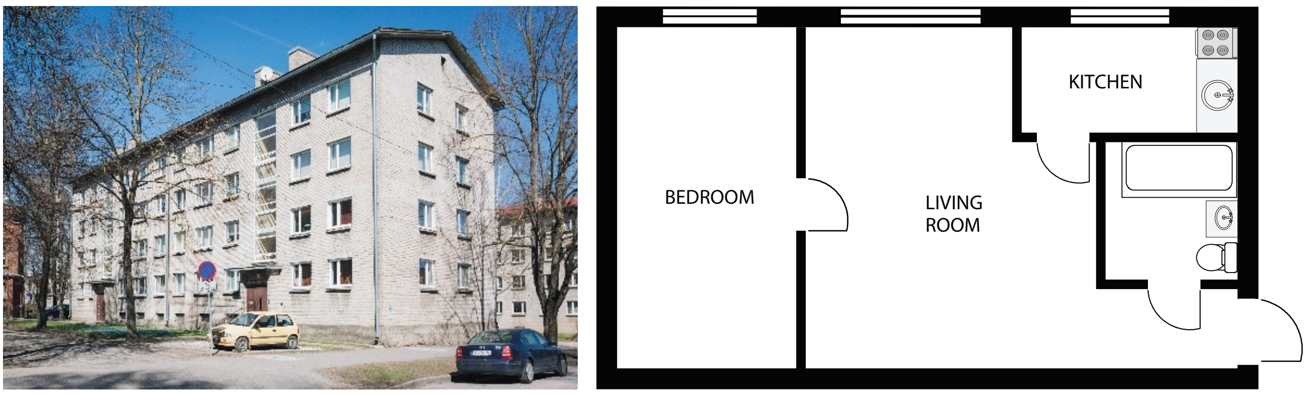

Figure 1. A khrushchyovka-type apartment building in Tartu (left) and a floor plan of a typical apartment in a khrushchyovka (right). Source: Photo courtesy of Silver Siilak.

Figure 2. Smart home panel installed in the khrushchyovka-type apartments, 2021. Source: Courtesy of SmartEnCity project team.

pro-environmental and technology-related practices, attitudes towards environmentally sustainable consumption practices, willingness to use new technologies, and perceptions about the SmartEnCity project. Semi-structured interviews allowed us to identify the thematic categories of meanings assigned to technologies. The semi-structured interviews involved both multiple-choice questions (28 questions) and open-ended questions (29 questions). The questions about pro-environmental and technology-related practices enabled the differentiation of respondents according to their dispositions to the environment and technology. Pro-environmental disposition was identified from questions about consumer practices, such as buying organic products, as well as domestic practices, such as switching off the lights when leaving a room. Questions informing about technology-related disposition targeted the use of electronic household appliances and other electronic devices and interviewees' engagement with digital apps. The respondents used a five-point scale

Table 1. Socio-demographic data of respondents.

Group	Interview Code	Semi-Structured Interview	In-Depth Interview	Gender	Age*	Education	Monthly Income Per Household Member (€)
Bio-greens	2	+		F	55	Higher	321–640
	6	+		F	82	Secondary	**
	7	+		M	28	Higher	**
	9	+		F	80	Secondary	641–959
	10	+		F	63	Higher	641–959
	11	+		M	39	Higher	≥1,601
	13	+		F	30	Higher	≤320
	14	+		M	32	Secondary	321–640
	15	+	+	M	36	Secondary	641–959
	17	+	+	F	54	Higher	≥1,601
Techno-greens	4	+		F	26	Higher	960–1,280
	5	+		F	34	Higher	321–640
	8	+		F	47	Higher	641–959
	16	+	+	F	46	Higher	≥1,601
	18	+	+	F	58	Higher	1,281–1,600
Technocrats	1	+	+	F	51	Higher	641–959
	3	+		M	32	Higher	641–959
	12	+	+	M	38	Higher	321–640

Notes: * Age as it was in the first contact with the respondents in 2017; ** refused to answer.

from "never" to "every day" to report the frequency of individual practices. We aligned the respondents along environmental and technological axes based on their reported average frequency of respective practices. This resulted in the grouping of respondents across the four quadrants of a two-dimensional graph (see Figure 3). We identified pro-environmental technology users as "techno-greens,'' pro-environmental technology non-users as "bio-greens," and environmentally ignorant technology users as "technocrats." None of our respondents was identified as an environmentally ignorant technology non-user.

In the next phase, we approached two respondents from each identified group to conduct in-depth interviews. The six in-depth interviews occurred after respective apartment associations had accepted the invitation to participate in the project. In the interviews, participants were able to freely talk about how they perceived the project and smart technologies without a (direct) influence by the researcher. These interviews were less structured, and the interview guide consisted of open-ended questions about the main topics: (a) the likely outcomes of the project for the respondents, the city, and the environment more broadly; (b) respondents' opinions of the planned retrofit action both on the building and on the apartment level, including the smart home system; and (c) respondents' likely future engagement with the smart home system, including their skills and competence to handle the technology. In addition, the interviews addressed social interaction, which the respondents were engaged in and which mediated their understanding of the project. With the data from the in-depth interviews, we were able to provide explanations to the perceptions that the respondents assigned to the technologies and the intervention more broadly and relate the perceptions to the potential uptake of the technologies in the future. All the quotes were taken from in-depth interviews. The in-depth interviews lasted an average of 60 minutes.

For the data analysis, we applied the summarising type of qualitative content analysis with inductive thematic coding of interview data. We extracted and coded

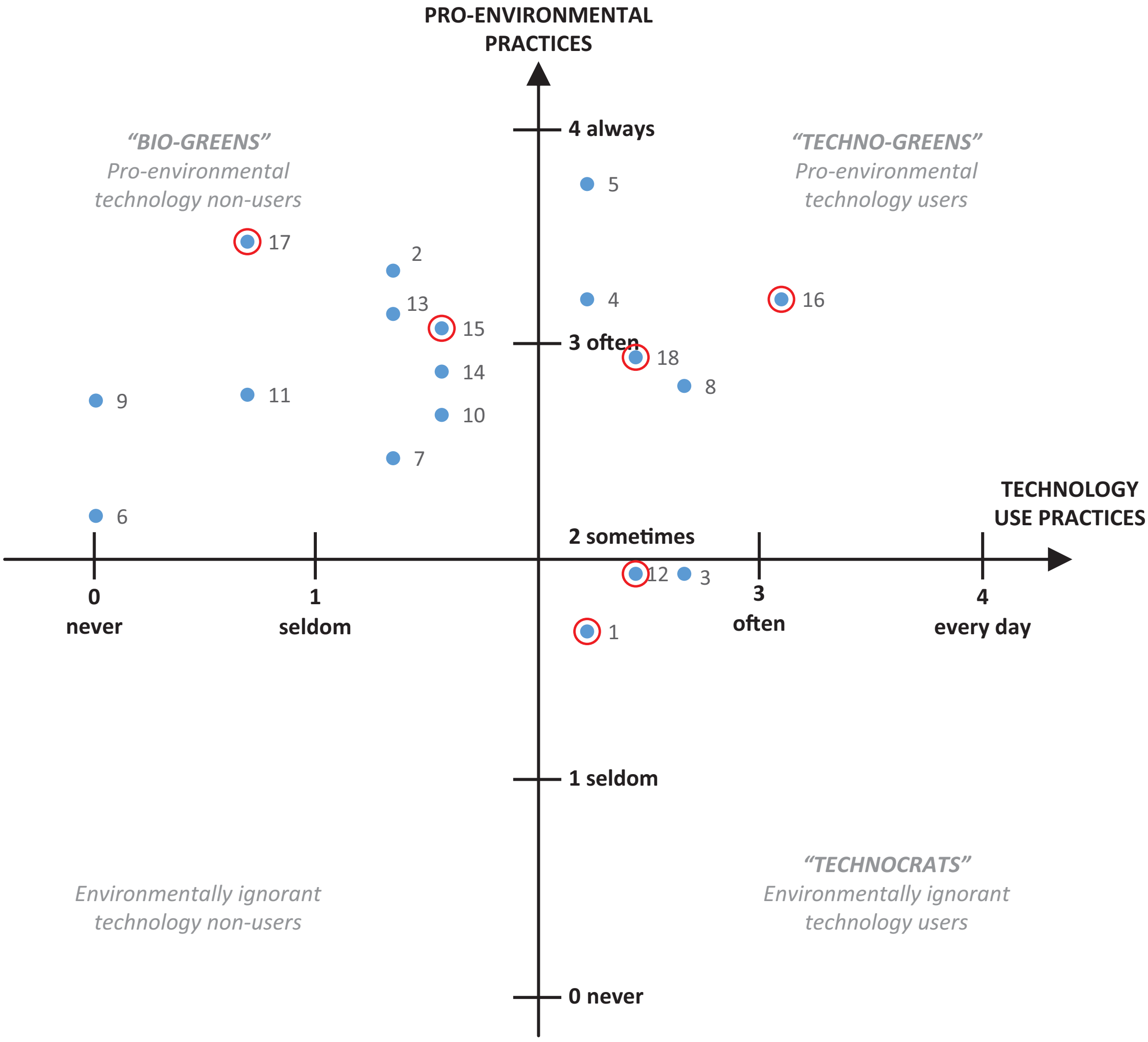

Figure 3. Respondents' positions on the axes of pro-environmental and technology use practices. Blue dots indicate respondents and red circles indicate those who also participated in the in-depth interviews.

excerpts of the interview transcripts to identify respondents' perceptions about the intervention and to analyse the role of social interaction as a mediator for technology acceptance. Because of the timing of the interviews, the respondents had not yet developed new social practices for adopting smart and sustainable technologies. Therefore, we distinguished the meanings people assigned to the forthcoming intervention and analysed them as an indicator of the meanings they might also assign to the social practices required for accepting the technologies.

4. Results

4.1. Meanings Assigned to the Adoption of Technologies Among Respondents With Different Dispositions

We identified six domains of meanings that respondents assigned to the smart retrofit intervention based on the semi-structured interviews (see Figure 4): (1) environmental impacts, (2) health impacts, (3) technological concerns, (4) financial considerations, (5) usefulness and personal comfort, and (6) symbolic and emotional values. We used the in-depth interviews to provide further clarification and reasoning to the meanings, indicated by respondent quotes below.

4.1.1. Environmental Impacts

Residents showed both trust and scepticism towards the potential environmental impacts of the smart retrofit intervention. In general, technocrats tended to emphasise the intended positive effects of the intervention by acknowledging that it would produce sustainable energy and improve the energy efficiency of the buildings. Respondents in both the bio-green and technocrat groups pointed to the benefits for land use: The retrofitted housing would reduce the need to develop new residential areas at the expense of urban greenspace.

In addition to the identification of the positive effects, bio-green and techno-green respondents also expressed environmental concerns about the intervention. They were not always convinced that smart and sustainable technologies, rather than traditional solutions, had environmental benefits. They argued that the production of such technologies requires more resources than would be saved by their use. They also pointed to the low durability and short life cycles of smart technologies, which are driven by market forces, quick obsolescence of IT systems, and consumer preferences, and result in unnecessary pressures on the environment:

> Well, the benefits of technology depend on how the technology is produced and how long it lasts. Excessive innovation is certainly more harmful to the environment than living without technology. (Female participant, 34 years of age, a techno-green)

Respondents from the bio-green and techno-green groups claimed that the total environmental impact of the intervention depends not only on what technologies

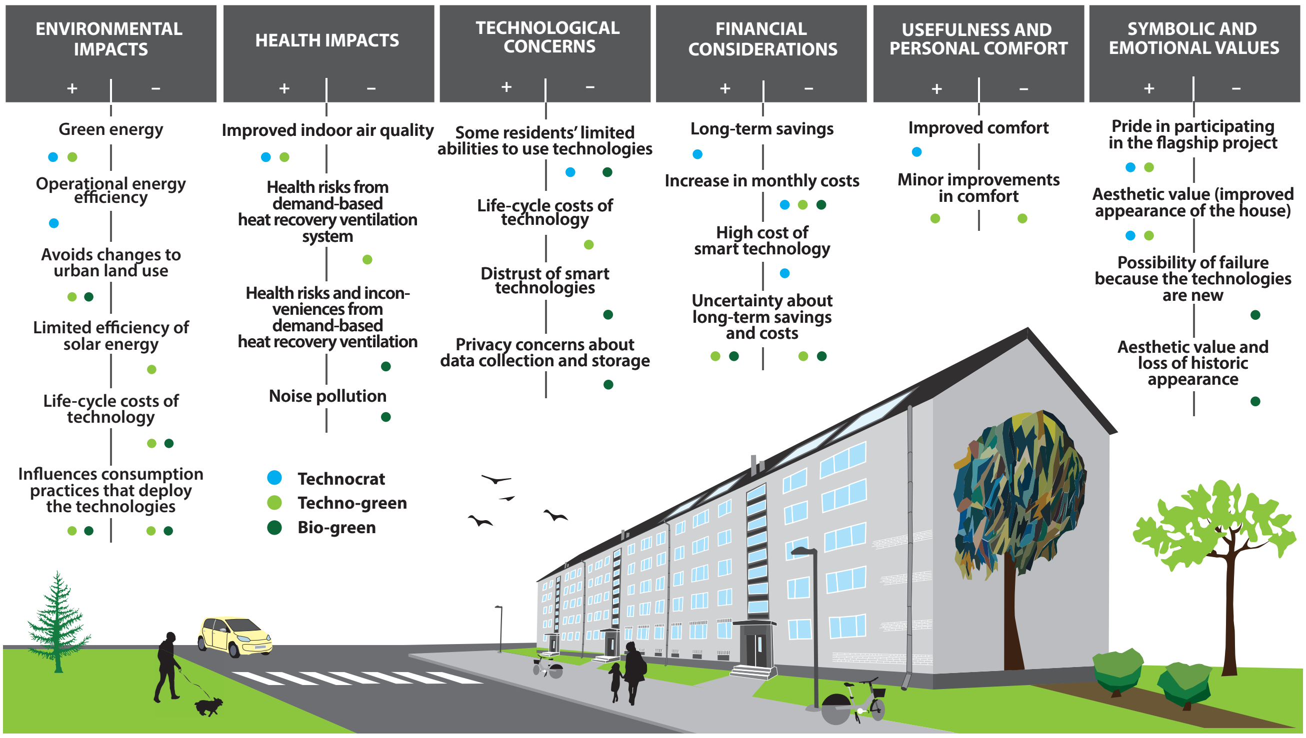

Figure 4. Meanings assigned to the smart retrofit intervention from respondents with different environmental and technological dispositions. The symbol "+" indicates a positive attitude and "–" indicates a negative attitude.

are implemented but also on how residents use the technologies:

> I think that technology has its advantages and disadvantages because it contributes to saving the environment, but it can also harm the environment. However, technology as such cannot be solely blamed for environmental damage; there is always a human aspect involved, such as individual awareness and economy. It is important to find a balance between social and environmental aspects. (Male participant, 28 years of age, a bio-green)

4.1.2. Health Impacts

Views on health impacts due to the changed indoor climate shaped respondents' overall perceptions about smart technology intervention. Technocrats and some techno-greens believed that the intervention would significantly improve indoor air quality because the Soviet-era apartment buildings had poor air circulation:

> This project provides better air quality to the residents because some apartments do not have fresh air, and some are so humid because of poor ventilation. All in all, the retrofit will improve the life quality afterwards. (Female participant, 26 years of age, a techno-green)

Most bio-green and some techno-green respondents questioned the positive health outcomes. They believed they would experience considerable inconvenience in terms of indoor air quality, noise pollution from the automated ventilation system, and consequent unintended health impacts. For example, one bio-green respondent stated their preference for natural ventilation and their belief that the air produced by a demand-based heat recovery ventilation system would not be as fresh as the outside air.

4.1.3. Technological Concerns

Respondents in all groups raised concerns about developing the necessary practices and the required degree of technical experience to deploy and interact with smart technologies. Several respondents perceived the intervention, especially the smart home system, as unnecessary, unreliable, socially exclusive, or a threat to privacy. A few bio-green respondents were worried about the potential abuse of their personal consumer data either by those who stored it or due to illegal access to the smart home system and their data:

> Many people can actually cope with technology, but they just can't accept the change mentally. Alright, they will learn and use it, but then there will be an update that will completely change the situation. And people get a mental block…and develop negative attitudes. It's not all about skills but how you make sense of the technology for yourself. (Female participant, 51 years of age, a technocrat)

One bio-green respondent (female participant, 54 years of age) highlighted the importance of considering specific users' needs and preferences when designing technology to enhance its utility. She pointed out that the design should consider the technological competencies of older people, including their preference for large icons and easy navigation menus, as a user-centric design would improve their willingness to use the technologies.

4.1.4. Financial Considerations

Respondents from all groups were aware that their monthly expenses would increase during the loan repayment period. However, the groups had different understandings about the net costs or benefits of the retrofit, partly because of uncertain future energy prices. In general, the technocrats expressed a belief in net savings in the long run. Bio-green respondents on the other hand tended to believe in no notable changes to their energy bills once the construction had finished. Although they agreed that the new insulation would decrease the heating costs, a few in the bio-green group were concerned about an increase in electricity costs due to the demand-based heat recovery ventilation system. Techno-green respondents expressed mixed attitudes towards changes in monthly expenses with similar arguments as expressed by other respondents.

The technocrat and techno-green respondents believed that the extensive energy-efficiency intervention would result in an increased value of their real estate. However, several bio-green respondents expressed doubts about the potential increase in real-estate prices. Respondents from each group appreciated the European and local funding that enabled the extensive retrofit of the buildings, including its technical systems, facade, windows, doors, and staircases. Without external support, the housing associations could not have afforded to renovate the buildings to nearly zero energy.

4.1.5. Usefulness and Personal Comfort

Those in the technocrat group frequently cited improvements to personal comfort that would come from using sustainable technologies in support of their future use of smart technology. They identified benefits from the smart metering and automated operation system because they would be less involved in adjusting the heating or ventilation settings:

> A smart home panel with monthly consumption feedback will definitely change my life. It is important to me that I can set home systems to operate automatically with less effort. (Female participant, 51 years of age, a technocrat)

While bio-green respondents did not comment on comfort-related benefits, techno-green respondents recognised the reduced need to adjust the heating and ventilation system. However, they did not emphasise comfort as an important factor in preferring smart technologies and instead noted their low practical value:

> Maybe I just don't appreciate all those nice things enough, for example, that bathroom ventilation automatically starts when I take a shower. It's probably good that everything can be adjusted from a distance with a smartphone. But I don't need it. I don't need to be able to regulate heating and see the meters' information from a tablet—it's like a duplicated system. (Female participant, 58 years of age, a techno-green)

4.1.6. Symbolic and Emotional Values

All groups expressed a range of symbolic and emotional values about the intervention in general, which could also affect the mindset towards the applied smart technologies specifically. Most respondents found the renovated buildings to be visually attractive and aesthetically appealing. Some in the technocrat and techno-green groups appreciated the pioneering state of the project to retrofit Soviet-era residential buildings as this would encourage future retrofitting initiatives:

> It's very nice that such khrushchyovkas will be retrofitted and that the project deals with old, not new houses. There are many khrushchyovkas in Estonia and this project could initiate a motivation for other housing associations to retrofit their buildings into nearly zero-energy houses as well. (Female participant, 26 years of age, a techno-green)

However, a bio-green respondent (male participant, 32 years of age) questioned the pioneering aspect of the project and worried that residents were test subjects for technological solutions that had not yet been tried elsewhere. He preferred to opt out of the experiment and to use more tried and tested solutions.

4.2. Social Interaction Shapes the Meanings Assigned During the Intervention

Respondents in all groups stressed the importance of receiving information and user guidelines about the project, its outcomes and impacts, and the technologies to be installed. They referred to four types of social interaction throughout the interviews: (1) contacts with the project team, (2) attending apartment association meetings, (3) relying on informal networks, and (4) researching on the internet.

The official source of the information was the *project team*, through multiple informative and instructive visits to each building during the planning and implementation phases of the project. However, our respondents expressed their concerns about the lack and ambiguity of information about the project throughout its multiple stages, and their wish to be more engaged throughout the process. The poor quality of information created confusion, negative feelings, and distrust, especially in several bio- and techno-green respondents:

> At the moment, someone designs something, somebody builds something, but without discussing it with residents. Some people take this construction process as a frightful bore. I believe that this is because of the lack of communication between residents, construction companies, and the apartment association board. (Female participant, 46 years of age, a techno-green)

The main forum for discussing the intervention was the *apartment association meetings*. Respondents' technology-related dispositions either reinforced trust (among technocrats) or uncertainties (among bio-greens) about the project, resulting in heated discussions. People who had less trust in technology felt that their concerns were not addressed equally during the meetings because technology-oriented members were claimed to close down any discussion of the possible disadvantages of the project.

> We have argued a lot in the meetings. Nobody talks about the disadvantages and threats that accompany the retrofit. I understand that it is proud to be part of the pilot, but many people are not heard. Not everyone confirmed to participate in the project. This decision was made by a majority vote.... These people went for the retrofit in the faith that technology helps. Actually, they have no proof that it does. (Female participant, 54 years of age, a bio-green)

Respondents believed that the development of a meaningful understanding of the technologies involved in the intervention was time-intensive. Due to the uncertainties in project communication, residents had to allocate their time to acquire information through *informal networks* and *the internet*. Bio- and techno-greens frequently discussed the financial, environmental, and health effects of insulation with their friends and acquaintances. The perceptions of their peers shaped their understanding of the technologies. Nevertheless, several bio- and techno-green respondents were concerned that pro-environmental practices would not be developed given the low level of social cohesion and community support that they claimed to prevail in khrushchyovka-type housing.

5. Discussion and Conclusions

The meaning of the smart retrofit intervention to provide nearly zero-energy housing is heavily affected by people's previous dispositions towards technology and the environment. Dispositions are the "foundations" that indicate how information is processed and trusted and how people perceive technology, making them important prerequisites for developing social practices (Hargreaves, 2011; Røpke, 2009; Shove, 2010). The promises of energy efficiency and implementation of solar energy solutions create affection towards the intervention among respondents with pro-technology dispositions as the solutions are perceived as beneficial to the environment. Yet, pro-environmental dispositions tend to raise concerns about the overall environmental impact of the intervention due to its uncertain life-cycle costs. The identified differences in respondents' perceptions about the environmental impact of the project corroborate the discussion of Axsen et al. (2012) who refer that the term "pro-environmental" varies in meaning among people with different environmental and technological dispositions. Specifically, they consider the variation of meaning in the field of mobility behaviour: While "techies" might buy electric vehicles to reduce their environmental impact, "low-tech greens" might prefer to reduce their overall mobility instead. Such differences, in turn, shape the development of pro-environmental practices: The meaning residents assign to the smart retrofit intervention in general and the deployed technologies in particular influence their individual processes of adjustment to the intervention in their everyday life.

The meaning is also perceived through usefulness, financial considerations, symbolic values, and health impacts. Personal gains from smart technologies, such as comfort, improved indoor climate, and long-term net financial savings attract people with stronger pro-technology dispositions. Comfort-related incentives of smart technologies are frequently identified in the literature as aspects supporting technology adoption (Marikyan et al., 2019). However, previous research has suggested that comfort-related benefits, such as "set-and-forget" type of solutions, may in the long-run decrease people's engagement with energy-saving practices and technology (Strengers & Nicholls, 2017). Increasing personal comfort through automation reduces personal responsibility in energy savings and may thus undermine individuals' role in achieving the sustainability goals of the project (Barr et al., 2005).

Unfamiliarity with technology and social exclusion risks raise concerns about the adoption of a smart home system. Respondents with pro-environmental dispositions were concerned about the adoption of and physical engagement with smart home systems, especially concerning the ease of use, reliability, and privacy of the technology. Specifically, respondents believed that the smart home panel used to control the system was not suitable for older residents. Previous research has highlighted the role of competency in obtaining new social practices: Limited technical skills, lack of interest in, and fears of the technological features act as barriers to technological transition and prevent people from accepting and adopting new technology (Hargreaves et al., 2018; Hong et al., 2020; Marikyan et al., 2019). A co-design approach could help tailor the design and thus avoid possible social exclusion from the start (Hargreaves et al., 2018; Lowe et al., 2018).

Knowledge acquisition and community support are prerequisites for creating new collectively shared practices. Our interviews demonstrate that residents followed different social interaction strategies to develop a meaningful understanding of the retrofit intervention. Social interaction with the project team and peers from the housing association and informal networks helped residents collectively ascribe meanings to the intervention and related technologies. According to Røpke (2009), the development of new social practices is a dynamic process that incorporates gradual changes in the competencies of practitioners and the meanings people attach to practices through social interaction. The results of this and previous research (e.g., Chiu et al., 2013; Lowe et al., 2018) indicate the importance of communication and engagement with the residents throughout the reconstruction process towards nearly zero energy performance. Social learning (Bandura, 1977) can help to diffuse competence as well as innovations in general.

This study contributes to the human-scale approach to smart cities. Critics of the smart city approach emphasise that the framework lacks a true citizen perspective (e.g., Evans et al., 2019; Vanolo, 2016). Our results indicate that people's dispositions towards technology and the environment should receive more attention than scholars of smart and sustainable technology have previously allowed. The connection between dispositions, innovative technological adoption, and pro-environmental behaviour of people is the collective development of social practices that—if targeted wisely—promise to make a human-scale, smart city approach acceptable to people with various backgrounds, understandings, and beliefs. This approach bridges two often non-overlapping goals: "going smart" and "going green" (Gazzola et al., 2019), and, thus, enables planners to embed sustainability goals such as nearly zero-energy performance into a smart city agenda (Evans et al., 2019).

The limitations of the study call for further research. We acknowledge that grouping respondents based on their pro-environmental and technology-related practices is a simplification of people's conceptions of the environment and technology, and how these develop over time. A follow-up study after the project is completed would provide valuable knowledge of the true social acceptance of smart retrofit intervention and its technologies. To reach a complete understanding of the human perspectives of a smart retrofit intervention, an in-depth examination of the perceptions of other stakeholders, such as the project team and representatives of the apartment associations, is needed.

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Conflict of Interests

The authors declare no conflict of interests.

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