Gender, expertise and control in Dutch residential smart grid pilots

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Abstract

Recent work has shown that technologies to enable residential demand-side flexibility are not value-neutral, that the ability to provide demand-side flexibility is not evenly distributed across societal groups, potentially deepening existing divisions and undermining societal support for the energy and climate transition. One such division relates to gender. Based on work for the IEA User TCP Task on Gender & Energy, this paper aims to contribute to recent discussions on gender and smart grid developments, through a brief literature review and an analysis of empirical materials collected in two Dutch smart grid pilots, where we conducted interviews and focus groups with residential participants. The paper discusses the gendered differences in the build-up of interest and expertise in household smart grids, in connection to experiences of control, comfort, safety and trust. Based on a brief literature review and empirical analysis, we show that although other factors such as age also affect the uptake of smart grid expertise, gendered roles in housekeeping stand out because it can result in a situation whereby female household members lose out in terms of control. Consequentially women become more dependent on others for the management of basic energy services in the home than they were before (the introduction of the smart grid solution) – which in cases results in their disengagement and withdrawal. With the advent of residential smart grids, more is asked from in terms of energy literacy, due to an increasing number and diversity in installations for energy generation and storage in and around the home. On top of that, a digital layer consisting of both hardware devices and software to monitor and manage the flows of information and energy within the home and the community is making demands in terms of their digital literacy. Combined, these two developments present a formidable challenge to most household end-users, yet more to women than to men. While this paper is exploratory, we argue that the challenge arises out of the combined impact of limited energy and digital literacy. For subsequent empirical work, we suggest a further unpacking of the notions of literacy and expertise in relation to gender, in a co-creative approach with both residents and smart grid technology developers. And for policy, as the digitalisation of our energy systems advances, energy transition policies should anticipate unevenly distributed impacts of this digitalisation and attend to how the ability to participate intersects with gender, age and other socio-economic factors.

Introduction

Demand-side flexibility has been used to great effect in industrial large-scale sectors and is expanding at the meso-level (e.g., blocks-of-buildings) (Crosbie et al., 2017). Its expansion into households looks all but inevitable with the growing challenge to balance the grid. At the moment though, residential smart grids exist mostly in (an increasing number of) pilots and projects. There is a growing literature on household engagement in demand-side flexibility, with the emphasis on moving from questions about what is needed to get households to respond

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Text box 1. Technical components of a smart grid.

Smart grids facilitate energy consumption reduction or shifting. Based on a generic understanding of smart energy grid configurations, we can distinguish between the following elements:

- Energy monitoring and management systems (EMS) enable optimisation between generation, storage, distribution, and consumption based on a selected set of variables and decisions about their relative importance (captured by an algorithm)
- Renewable Energy Sources (RES) at a decentralised level (e.g., solar panels)
- Other decentralised appliances such as heat pumps
- Storage systems (such as electric vehicles and stand-alone individual or collective batteries) store energy when not needed and then release it when the need is greater, e.g., during peak loads.
- Smart contracts and technologies ((distributed ledger) databases) enable peer-to-peer energy trading
- Smart apps and interfaces that translate the information of the EMS to the user (which can be accompanied by tips, advises, and suggestions)

(e.g. Stromback et al., 2011) to questions of how smart grid innovations affect household practices (Mechlenborg & Gram-Hanssen, 2020; Smale et al., 2017; Verkade & Höffken, 2018), as well as questions about how smart grid innovations can contribute to realising values for households and communities (Hansen & Hauge, 2016; Mourik et al., 2020; Skjølsvold et al., 2017; Van Summeren et al., 2020) .

In this paper, we zoom in on gendered roles in housekeeping and household practices in the context of smart grid pilots (see Text box 1). We aim to contribute to the recent discussions on gender and smart grid developments, by providing an analysis of empirical materials collected in two Dutch smart grid pilots, where we conducted interviews and focus groups with residential participants. These pilots are part of two EU Horizon2020 projects (NRG2Peers and Hestia)[2]. While both projects include attention to end-user needs and their participation, the structure of these projects is such that the main focus is on (digital) technological implementation challenges, rendering the achievement of a good match with household- and community needs and values a significant challenge. The analysis presented in this paper is furthermore part of ongoing work for the IEA UsersTCP on Gender and Energy.[3] As such, it provides a point of departure for the next phase of empirical inquiries.

Below we first present a brief literature review on gender and smart grids, with attention to user representation in smart grid design, and the discussion on digital housekeeping expertise within households. From this literature we deduce our analytical categories for the empirical analysis. We then introduce the smart grid pilot projects, methods used, scope and limitations. Next, we move to the qualitative analysis of the two Dutch smart grid pilots, followed by conclusions and a reflection on the relevance of the conclusions for energy transition policies as well as suggestions for further work.

In discussing gendered roles and practices, it is easy to fall into the trap of unintended stigmatisation, re-iteration of gendered roles, and exclusion of those that do not fit into the type of households that we describe. Being aware of this is a necessary first step but does not provide a direct solution to these challenges. Therefore, it might be useful to directly provide some context in terms of the scope and limitations of this paper. The scope of our empirical inquiry and argument is limited to North-Western European family households that are headed by two-gendered couples. Because our pilots mostly include these types of households, our conclusions have most relevance for these household segments. In addition, our conclusions refer to the Northwestern European geographical-cultural context – to the extent that shared cultural understandings of conventional gendered household practices are present. This means that our conclusions may not be of relevance for households that are organised differently or where the (gendered) division of labour within the household relies on different cultural norms.

Gender and smart grids

USER REPRESENTATION IN SMART GRID DESIGN

In the design and implementation of smart grid solutions, the operation of devices and appliances has received more attention than the ways in which these solutions impact end-users (Hansen & Borup, 2018; Haunstrup et al., 2013; Nyborg & Røpke, 2013; Skjølsvold & Lindkvist, 2015). Smart grid designers/developers mostly use quantitative and technical measurements (e.g., energy consumption) as the main techniques for user representations (Hansen & Borup, 2018) and refrain from including 'real user' inquiries into their design scenarios (Breukers et al., 2019). 'User-centred design', in fact, does not necessarily involve actual interaction and engagement with the users (Skjølsvold & Lindkvist, 2015). Developers often rely on their own assumptions and personal experiences, and since the engineering, computer and energy sector is male-oriented, female user perspectives remain underrepresented. The reference model for the end-user likely resembles Strengers' 'Resource Man', a male individual who is interested in monitoring energy consumption and prices, who understands the language of kWh and energy pricing, and who responds to incentives and information as if his life consisted of 'winning' an energy game (Strengers, 2014). Silvast et al. (2018) confirm that this envisaged end-user is also the model for smart grid designs. Other studies that refer to situations where developers *did* engage with users, mention how the collected data were not disaggregated according to gender, as it was not considered a variable

2. The HESTIA project (https://hestia-eu.com/) has received funding from the European Union's H2020 programme under Grant Agreement No. 957823; the NRG-2Peers project (https://nrg2peers.com/) has received such funding under Grant Agreement No. 890345.

3. The work is part of subtask 3 of the Gender and Energy task (https://userstcp.org/task/gender-energy-annex/) with a focus on enabling gender-sensitive technology design.

that would impact the user-product relationship (Hansen and Borup, 2018; Nyborg & Røpke, 2013). An exception was an international service provider for energy-efficient smart heating solutions, which consciously designed energy efficiency tools that integrate gender perspectives in order to increase their sales to female customers (Smart Energy Solutions, 2018).

The dominant user representation as described above is problematic for several reasons. First, this modelled user does not match most real users. Solutions that work for the modelled user are therefore not likely to work as well for real users (Strengers, 2014; Breukers et al., 2019). In addition, the single generic model user leaves little room to consider intra-household dynamics and differences between household members in terms of their (gendered) roles and practices within households and their varying ability and willingness to respond to demand response (DR) requests (Tjørring et al., 2018; Westskog et al., 2011). As a consequence, real-world users interact with smart grid technologies in ways unintended by the designer, which can undermine their effectiveness in contributing to a more efficient use of energy and energy infrastructure. Also, when the solutions do not match with actual end-user needs, preferences and capabilities, it is unlikely that their uptake will increase – and indeed, as Strengers et al. (2019) observe, the uptake of smart home technologies has been much lower than expected by the providers of these technologies, and especially among women. In short, when smart grid solutions provide value neither for large segments of residential end-users nor for the grid, the result is what we would call a lose-lose scenario.

Digital and cognitive housekeeping and the build-up of expertise

Recent work that addresses intra-household dynamics distinguishes between digital and cognitive/material housekeeping. As a 'new' domain of housekeeping, digital housekeeping refers to the work and understanding needed to maintain a networked home (Kennedy et al., 2015). This involves a broad variety of activities, tasks and skills, such as the ability to set-up, use (and adapt) preconfigured digital systems, the management of the digital networks and digital contents, and the exchange of knowledge about all this among household members. Cognitive housekeeping refers to the organisation, planning an execution of material housekeeping work – e.g., cleaning, cooking, washing, provision of care, home making etc. Like cognitive housekeeping, digital housekeeping is unevenly distributed across genders. While cognitive and material housekeeping are more likely to be performed by women, home maintenance and digital housekeeping are more the domain of men. The distinction is interesting as it points towards different areas of expertise, and towards different gendered routines and practices with corresponding energy consumption patterns. A study by Tjørring et al. (2018) among Danish households revealed how men and women responded differently to DR requests to shift consumption, as they had different repertories for action. Women had more options to respond to DR requests than men because of their more active role in material and cognitive housekeeping.

Research on digital housekeeping in relation to social identity shows how, generally, technology is associated with masculine identity while feminine identity is associated with domesticity (Kennedy et al., 2020; Sinanan & Horst, 2021). Studies have addressed the question as to how digital housekeeping changes the gendered distribution of household tasks (Kennedy et al., 2015; Sinanan & Horst, 2021). While it can reinforce and reproduce existing gendered patterns and roles, this is not necessarily the case. While norms and expectations about gendered roles affect the organization of digital and technological management and expertise within the home, there is also room for (re)negotiation. Yet, the overall picture is that it is men that take on digital housekeeping, with Strengers and Nicholls arguing that "one outcome of these unforeseen and currently underacknowledged gendered smart home dynamics could be more work for father" (2018:79).

In their discussion on how gendered task divisions in digital housekeeping evolve, Kennedy et al., (2015) identify mechanisms of interest and (evolving) expertise. They argue that constructions of expertise are inscribed with certain values and expertise is motivated by gendered desires and interests. Digital housekeeping expertise is valued differently by different household members and is unevenly acquired across members of the household (Kennedy et al., 2015). Personal interest is important in the acquisition of digital expertise. Expertise evolves through a self-perpetuating cycle of personal interest, as others defer the work of digital housekeeping to the interested household member, who thus builds his experience and expertise further – not necessarily supporting other household members in getting to grips with the complex system. There are examples of digital home systems (e.g., to manage and operate lighting, music, etc) that have effectively locked out other members of the household, who became dependent on the 'expert' for turning on the light or music (Strengers and Kennedy, 2021).

Limiting ourselves to North-Western European family households that are headed by two-gendered couples, we argue that it is likely men who engage most with the digital dimensions of the smart energy grids – in line with the above-mentioned argument on the build-up of digital housekeeping expertise. In addition, and in line with their role in technical maintenance housekeeping, it is to be expected that men engage more than women with the physical energy technology dimensions of the smart grid. Scarce research on energy literacy and gender points out that energy literacy levels are higher among men than among women (Martins et al., 2021). The same goes for digital literacy, yet to a smaller extent (e.g., in the Netherlands, digital skills vary with age, educational background and to a lesser extent with gender) (CBS, 2020; Non et al., 2021).

Smart grid solutions combine digital and energy technologies, and the supportive digital technologies for householders (such as dashboards and other digital interfaces) are designed mostly with the resource man model in mind. However, while it may be men who predominantly engage with the smart energy grid, they are not the ones who perform the energy-related housekeeping tasks that need to change (i.e., shift demand). This may result in a 'gap' between digital and material housekeeping practices, that is, when those who are expected to shift housekeeping practices are not the ones that engage with the smart home digital technologies. It is therefore important to be mindful of gender, to not run the risk of contributing to the aforementioned lose-lose scenario.

So far, we have discussed how overall, designers and developers of residential smart grid systems base their design on a modelled user which shows resemblance to at best a very small proportion of real users, and which does not include gender

considerations (and does not reflect the often-gendered roles and practices in housekeeping). Furthermore, literature on digital housekeeping shows how it tends to reproduce existing gender norms.

With the advent of residential smart grids, more is asked from householders in terms of energy literacy, with an increasing number and diversity in installations for generation and storage in and around the home. On top of that, a digital layer consisting of both hardware devices and software to monitor and manage the flows of information and energy within the home and the community is making demands in terms of their digital literacy. Combined these present a formidable challenge to most household end-users, yet more to women than to men.

Both in terms of energy literacy and digital literacy levels, women are lagging behind. This has to do with educational backgrounds and – levels. Next, as a result of the former, these arrears relate to the predominance of technologies that are designed by and for men that work in these tech sectors.

While routines and practices in housekeeping are not fixed, the more ingrained they become, the more difficult it will be to renegotiate and change these, including the distribution of tasks and expertise (Kennedy et al., 2015). Hence, it makes sense to take a close look at smart grid pilots, being examples of not-yet-ingrained patterns and practices, to see how interest in and expertise about residential smart grids builds up for different members of the household. In particular, we are interested in the accumulation of such knowledge and expertise relates to issues of experienced control, comfort, safety and trust and in how far these experiences are gendered.

Gendered experiences – analytical approach and research questions

Since our empirical material is collected from smart grid pilots, our research provides an interesting view on (gendered) user experiences in the technology adoption phase. This phase is of particular importance, because new roles and routines are adopted by users and then become embedded (or not). Another distinguishing characteristic of pilot settings is that whatever the technology providers (fail to) learn gets encoded into the product or service (and will likely be more difficult to extricate later if it turns out ineffective).

We will inquire into residents' experiences of smart energy technology in terms of comfort, control, safety and trust. These are specific to the pilot contexts, yet also relate to the particular technologies (physical and digital) and the way they are implemented and subsequently adopted, abandoned, or adapted by household users. The experiences are recorded in the (early) adoption phase, providing a snap-shot because they are not fixed. These experiences might change, for better or worse, for instance when concerns are addressed and solved by the project developer and/or technology providers. Based on the reported (gendered) user experiences, we attempt to identify gendered patterns of uneven distribution of smart-grid related expertise within households.

CONTROL, COMFORT, SAFETY AND TRUST

Control over smart grid solutions is related to understandability and user-friendliness of these solutions. Feeling in control is about being able to understand; able to steer/operate/turn appliances on or off; and feeling capable to assess malfunctioning. It also refers to what the introduction of new technologies in the home means for being in control of the homely environment (Aggeli et al., 2021).

Control in relation to smart home technologies is related to the gendered roles in technical maintenance and digital housekeeping. Generally speaking, there is a visible trend showing that men are more 'in control' when it comes to the digital monitoring and management of energy in the home (Gram-Hanssen & Darby, 2018; Kennedy et al., 2015). This issue intersects with age and educational background – i.e., elderly women are more likely to lack adequate technical and digital skills than younger women.

Losing control in the smart home can happen when various services in the home – e.g. lighting, temperature, music, but also energy – are increasingly managed by smart appliances, whereby the interest and expertise in managing them lie mainly with another person. A digital lock-out can occur on top of the already existing technological lock-out relating to the physical energy appliances and installations for generation, storage and distribution of energy.

The experience of comfort varies across time and space. It can relate to issues such as temperature, air quality, lightning, but also to cultural meanings – e.g., in relation to home-making (Ellsworth-Krebs, 2015). Research on energy DR showed that women talked about their experiences often in terms of comfort, whereby comfort was strongly associated to home-making and caring practices (ensuring comfort for others in the home, including provision of emotional care). Men, on the other hand, talked about their home less in terms of comfort and more in terms of technologies they use (Dunphy et al., 2017). Women overall prefer higher indoor temperatures in winter and lower temperatures in summer, compared to men. In addition, women were more adamant about being able to open and close windows without constraints; and had stronger ideas about the need to have lighting inside and outside of the house. Since smart grids can have a direct impact on temperature, lighting and ventilation, they are therefore likely to cause more stress for female householders when the settings are not in line with their needs and wishes, and/or when they are not in control due to digital technologies that are administered more often by men (Karjalainen, 2007; Tiller et al., 2010).

A lack of experienced control over smart grid technologies can impact feelings of safety (e.g., in relation to privacy, health, financial costs) and this negatively impacts comfort and wellbeing. In the context of residential smart energy systems, there is a lot of trial-and-error. This is different from experiences with individual appliances or installations. With smart grid configurations, it is not only the functioning of the individual appliances but the whole network of appliances, because their reliability depends also on (their interoperability with) the many parts that together have to form an interconnected, intelligent system. In addition, such systems, because of their complexity, tend to lack transparency (Kloppenburg & Boekelo, 2019). Especially in the early phases, when things do not work as intended, this can undermine trust in the technologies (Boekelo et al., 2022). Since residential smart grids are still to a large extent based on promises and expectations, undermining trust can have serious repercussions for the further engagement of households in smart grids.

Table 1. Empirical material from two smart grid pilots.

Smart grid pilot	Focus groups/workshops
SchoonSchip (H2020 NRG2Peers project)	2x focus groups with in total 13 residents (5 female; 9 male; 12 households)
	1 user interview (male)
	2 interviews tech-developers (male)
Voorhout (H2020 Hestia project)	10 interviews with households (7 female; 7 male; 9 households)
	3 interviews with technology developers (male)

Text box 2.

Voorhout Pilot:
Almost three years ago, a real-estate development company and an energy services company realized a small positive energy district in the village of Voorhout, a neighbourhood of 33 homes (recently extended by another 18). The neighbourhood is divided in two roughly equal parts: one for senior-adapted homes, the other homes most suitable for (young) families. The buildings were designed to be energy net-positive. They were outfitted with PV, a home battery, heat pump, insulation, passive/active cooling, and some additional smart home features like automatic or remote-controlled air circulation and a Velux window as safety valve for air quality.

The preceding considerations brings to the following overarching question: to what extent and how can we identify gendered patterns of uneven distribution of expertise within households can how do they affect overall experiences with the smart grid? We can break this question down into these two sub-questions:

1. In the (envisaged) engagement with the smart grid arrangements, what are the gendered experiences related to the build-up of expertise and skills? To what extent is smart grid expertise (likely to become) concentrated with one person within the household?
2. In the (envisaged) engagement with the smart grid arrangements, what are the gendered experiences related to comfort, control, safety, and trust (in the technology and the technology providers)?

PILOT SMART GRID PROJECTS

The empirical analysis is based on data collected in two Dutch residential smart grid projects. The collection of those materials was intended to gain insights into a variety of user-experiences in relation to the residential smart grid developments so far.[4] The pilot research was not designed to inquire specifically into gender-related aspects, but had a broader scope – addressing how end users experienced the smart grid project so far, their main concerns and needs. Yet in both pilots we have explicitly invited female residents to participate in the focus groups and interviews. In addition to interviews and focus groups with residents, there have been interviews with technology developers of both pilots as well – providing information to contextualise the findings (Table 1).

We analysed the transcribed interviews and focus group reports using the research questions, first collecting broader findings for the categories interest/expertise, comfort, control, safety and trust. Next, we looked at how men and women responded differently or not within each category, in order to identify gender-specific aspects in these experiences. In addition, our own observations during the interviews and focus groups also pointed to gendered roles in some cases.

Gender and household practices and roles are likely to vary across culture, race, geography and social class (Mechlenborg & Gram-Hanssen, 2020). The pilots include Northern-European middleclass homes. In both projects, the majority of households were mostly headed by couples. In one pilot, SchoonSchip in Amsterdam (Text box 2), several of the couples had children living with them as well. In the other pilot, in Voorhout, which involved mainly pensioners who moved to this particular smart neighbourhood to enjoy the next phase of their lives, this was not the case. The two pilots differed in terms of age and phase in life. Finally, in the Amsterdam pilot, it was largely made up of progressive urban residents characterised by a DIY attitude and lifestyle, while this was not the case in the Voorhout pilot (Text box 3).

FINDINGS VOORHOUT

Expertise, engagement, interest

In the Voorhout case, it is men that talk mostly about technology and smart energy aspects during the interviews. Their wives are explicitly invited (by the interviewer) to join the conversation several times during the interview, to give their opinion and talk about their experiences. Overall they remain rather reserved. Apparently, the accumulation of interest and expertise in the smart energy home lies with the male householders.

4. We were tasked with the social science-based field work to assess user needs and support the user engagement process within the H2020 projects NRG2Peers (https://nrg2peers.com/) and Hestia (https://hestia-eu.com/).

Text box 3.

SchoonSchip
SchoonSchip was initiated (the first ideas developed in 2013) with the aim to develop a sustainable neighbourhood in a formerly polluted industrial area. Currently, 46 households live at SchoonSchip – on 30 arks (15 arks with two houses). Homes are equipped with PV, solar thermal panels, home batteries, and heat pumps. SchoonSchip is an energy community, and as a cooperative making use of policy sand-box exemptions, it is allowed to act as energy supplier within the community, enabling peer-to-peer energy supply (self-consumption). The neighbourhood has one connection to the grid and the aim is to be energy neutral; enable self-consumption and in future connect to other smart grid projects in the neighbourhood.
At SchoonSchip there is an energy working group, which consists of male residents only. Yet previously, the female energy working group member was the most active person.

While overall, the female respondents are explicit about how they like the idea of an energy positive home, they state that they understand very little of how it all works. Several female respondents elaborate on how they feel that they should become more proficient in understanding how it all works.

> However, I also need to understand some things, in case he is not around or away or whatever…then I also need to understand it all a bit. So I do sometimes dive into the fuse-box… because he (her husband, SB) is willing to explain it to me…. but I also need to understand it in my own way. (Anne)[5]

Another respondent explains that she is happy that her husband takes the lead in digital and technical housekeeping, however adding that

> ...because of his stories, I now understand it a little better and I can trust it more. (Claire)

While he is 'the expert', he is also sharing his insights enabling her to come to grips with the smart grid system as well. In one household, due to her husband's illness, Esther has no other choice than becoming the expert, and she is supported in this by a neighbour: She states:

> I have zero knowledge about these things,

to add later on in the conversation:

> I think I already learned quite a few things. Haha. But certainly not everything. (Esther)

A neighbour helped her turn off the battery when it got overheated. Several female respondents talk about how shifting the use of the washing machine from night to daytime because in their new homes it's best to wash when the solar panels generate electricity (Anne, Aafke).

Control, comfort, safety and trust

Main issues around comfort mentioned relate to the spatial impact of installations in the home, the ventilation and indoor climate management. Female respondents more often mentioned the need to let in fresh air by opening windows, something that is confirmed by the literature. Gendered experiences around comfort did not come up as an important issue from the empirical material.

Control however was a major issue that relates to both the introduction of various new technologies in the homes, the problems with the performance of appliances and the difficulty to assess performance. This complexity is overwhelming:

> What we had not expected/foreseen, is that there would be so much technology in the house that we don't understand anything about. (Esther)

A smart home and energy monitoring app was provided and several male respondents used it, in order to gain better insight into their generation and consumption patterns and volumes. In fact, some of the male respondents undertake all sorts of actions in order to improve their insight in how the smart energy solutions work (if everything works as intended; how it works; what the causes of under-or non-performance are). And not only those that are technically and digitally well-versed. Based on discussions with neighbours, his own inquiries and common sense, Peter decides that it is the battery system where the fault lies, not with him:

> So, I think that this is not possible… But I do see this happen (…). It is turned off now because the fuses were burnt… so I think: this is just not right! (Peter)

Peter tries to get to grips with the complexity of the smart energy system, and feels sufficiently confident to make this statement. Karen and several other women continue to feel out-of-control.

> Why is the battery not working? I have no idea… Why did we need a new thermostat? I have no idea…. (…) My take is: I will look at the results. If the results are going to be good, I will simply accept it all. (Karen)

She has given up trying to understand and simply is hoping for the best. However, it is not only the women that feel out of control. Carl:

> We definitely need to have some, some additional training and guidance on how everything is to be used. And yeah, that's basically the main thing and main reason that we don't touch most of the equipment, obviously, but because we simply just don't know how to use it and when to use it.

Safety issues relate to the battery which gets really hot. It is placed in a closet underneath the stairs and Esther remarks:

> ...you can boil eggs in the closet. The glue of the stairway steps melted at our neighbours'… (…) So I was glad that my

5. The names used are not the real names of the residents.

> neighbour turned it all off and that the house has not caught fire… But well, that is a dangerous situation of course.

Several residents worry about fire risk and some (men) state that the battery needs to be placed outside the home. Overall, the female respondents feel less 'in control' and in one case this goes as far as making her want to move elsewhere if the husband is no longer there. Martha:

> These homes were supposed to allow you to be independent (longer), but that's not how I feel here. (....) I mean, I need to be self-reliant and then I would like to stay here. But eh….if things stay the way they are now, and he passes away (I hope not)…but in any case, then I will be gone. Then I will leave.

All respondents like the house very much, they feel really lucky, they appreciate how the house is prepared for old-age, the space (not too big, not too small, ground floor), the garden, the view, the neighbours. In general, there is appreciation for the project developers and their commitment. Yet all the issues with the smart energy system and appliances have taken their toll. Respondents understand that they are part of an innovative project:

> I realise that I am a Guinee pig and that everything cannot go right directly… everyone in in a learning phase. I do not mind at all. (Peter).

Yet they feel increasingly annoyed because they are 'left in the dark'. They don't know what is up next and they feel that they are not informed properly, which causes frustration. The initial sympathy towards the project developers (one is a family business with a good reputation, the other an idealist smart energy company) is at risk of turning into distrust and frustration. This is also a result of insufficient and ineffective communication and support:

> (….) if they only could let us know, like 'we know we are a bit later but we will come and fix it'…that would be reassuring." (…) And so at some point, the heat pump stopped….I don't know if it was in fact the heat pump but we did no longer have any heating….I still don't know if that is fixed now because in this time of the year you won't notice. (Karen)

> Yes, so here we have the additional buffer vessel….(…) so that was just placed here, with no explanation …nothing…. so well….whatever… (Esther)

The guidance that was promised never was provided and as a result….

> ...we are just messing around ourselves, not really having a clue. (Harriet)

She states that it would be better if they could take some action themselves, for instance when the heat pump is not working.

> You always need to call someone, and then you get sent back and forth...so you need to call someone else…and then someone else…and then I think: never mind, leave it. I will just spend another weekend in the cold…. (Harriet)

Conclusion on Voorhout

The image in Voorhout is that experiences in relation to the build-up of expertise and skills are to a certain extent gendered. Male respondents considered themselves to be the main spokespersons for their household in relation to the smart grid experiences when invited for an interview. Most respondents are not highly energy-and digitally skilled, yet the few that are, are men, not women. In all other cases, both men and women are aware about the need to learn how things work, yet they need guidance. Several women indicate how they feel good about their own efforts to acquire some basic understanding about how things work. Smart grid expertise is something that female respondents recognise as important.

When it comes to experienced control, the picture that emerges is one in which female respondents more strongly expressed feeling 'lost'. Male respondents showed a stronger inclination to take back control, actively trying to understand what is happening and acting upon it. Where male respondents were more likely to blame the smart energy system and/or the project developer, the female respondents were more likely to withdraw and take their loss, and hope for the best. Furthermore, underperformance of the technologies, safety issues (batteries), a lack of comfort (issues with the heat pump) in combination with a lack of communication and support showed that the trust that residents feel towards the project developer and smart grid provider has its limits and that these are almost reached.

These findings do not provide conclusive outcomes, yet we do see that the female respondents risk to become dependent others when trying to manage basic energy-related services in the home as part of their daily practices. Their male counterparts take a more active role in accumulating expertise and know-how about digital and technical housekeeping. The quote of one respondent stating that she will need to move in case her husband dies is a wry illustration of this. For the promise of these smart, comfortable and safe senior-home to materialise, more work is needed to address the gendered experiences of control, safety and trust.

FINDINGS SCHOONSCHIP

Expertise, engagement, interest

Based on the focus group at SchoonSchip, which is a highly engaged and relatively young community of urban pioneers, well-resourced in terms of educational background, income, relations and networks, time and commitment, it became clear that the acquirement of expertise related to the smart grid is unevenly distributed, yet not strongly along gendered lines.

Focus group participants mostly confirm that digital and the cognitive/material housekeeping tasks are not evenly distributed. One participant indicates that while the material housekeeping tasks are quite evenly divided between herself and her male partner, it is her partner who engages with the smart grid stuff. Another (male) participant who is (professionally) quite knowledgeable about smart grids, actively tries to connect the digital information provision to the housekeeping tasks such as using the dishwasher – so in his household, digital and smart grid expertise also is concentrated along gendered roles. Yet in the other focus group, it was a woman who explained the workings of the hot-fill device to a male community member. Although she is handling all the technical and digital stuff at home, she doesn't feel as if she has any expertise:

> I am 'forced' to deal with the digital stuff in our home, but I also don't know much about it. (Karina)

The app that provides information on generation and consumption, is not considered user friendly by any of the participants. The respondents that know of the app and that have used it, are mostly men.

All participants expressed the need for better and more tailored support in monitoring and managing their generation, consumption and storage of energy. However, their preferences were quite diverse. Several participants would like to receive frequent, detailed and clear information on (the impact of) their consumption. Two respondents indicated that both they themselves and their partners engage as little as possible with the digital smart grid housekeeping and that they would like to keep it that way. They preferred rules-of-thumb:

> Rules-of-thumb, great! When I hear that it works better if I use appliances when the sun is shining .I can live by such rules. (Jolanda)

Both these respondents (Jolanda and Mees) do have a clear idea about the value that the SchoonSchip smart grid can help generate for the community and society at large:

> (…)creating value by decreasing the burden for the grid. (Jolanda)

Their app-aversion is an explicit (lifestyle) choice. This is different for one (single) female householder, who explains how she has feelings of shame about not understanding how it all works, for example the hot fill device for the washing machine:

> My first feeling is that of failure, I feel it is my responsibility because others can do it and I cannot. (Hanneke)

In her case, a lack of expertise and know-how is increasing (not knowing how to access the app; not knowing how to assess if the hot fill-device for the washing machine actually works) because she feels uncomfortable asking her neighbours for help in this.

> How nice would it be if someone can just tell me briefly, like once a month, how I am doing. Or that this person tells me what I should do differently, get some tips… (Hanneke)

Control, comfort, safety and trust

While some respondents feel not in control due to a lack of understanding, these experiences were not limited to women. Yet the person most at ease in understanding the smart grid current and future possibilities, was someone professionally knowledgeable and skilled in smart grid issues (and male). And the person least comfortable with the smart grid was a woman.

In terms of comfort, the main issues discussed during the focus group meeting concerned the batteries in relation to overheating and the spatial impact (not being able to use the space because it gets really hot in there). Feelings of not being in control were in some cases related to having to discover by yourself that things are not working properly – rather than being informed about this by the technology providers.

> (…) Because of the battery it gets bloody hot in that room (…) During winter this is not a problem, but in summer it is… We have not been informed about that beforehand (…) So, we have a sustainability problem (loss of heat, SB) caused by a sustainable living project! (…) That is not sustainable. (Karina)

There were several issues related to trust, mainly related to the technology providers (those providing the architecture of the smart grid system; and the algorithms in the EMS). Disappointment at the individual household level with the performance of the battery contributes to distrust as the technology provider has not warned about or discussed this with the householders.

> For them this (overheating of the battery, SB) is normal, I don't think this is normal. I feel awful about it. (Karina)

The lack of trust also relates to the complexity of the smart grid and the lack of (technical) knowledge on the part of the residents.

> If the batteries work so badly, they should say: 'guys, something is not going well. It is really hard that we don't understand the technicalities of it all sufficiently in order to be able to provide feedback at that level… (Wiebe)

Conclusion on SchoonSchip

Based on the focus group discussions, we see uneven patterns in the distribution and build-up of smart grid expertise in the community. These are to some extent gendered. Accumulation and concentration of expertise follows the expected gendered lines in most, but certainly not in all the respondents' households. In the expressed needs regarding engagement with the smart grid and building up expertise, we did not find a strong gendered pattern. It appeared that male participants were more interested in detailed information provision, yet not all of them. Both male and female participants liked the idea of rules-of-thumb for energy management.

Participants recognized that any gaps between digital and material/cognitive housekeeping need to be solved – by ensuring that all residents receive the type of information and support that fits with their needs. Also, with regard to experiences of control, comfort, safety and trust, we did not see strong gendered patterns.

Conclusion: gendered experiences of competence

Expertise and the lack thereof can both build up over time. Among the respondents in both pilots, digital energy expertise and know-how tended to be concentrated in one person in each household. Especially among the Voorhout respondents, this concentration was quite strongly gendered – with few exceptions. This resonates with the literature on digital housekeeping (Kennedy et al., 2015). Several female respondents did underline the importance of improving their understanding of the smart grid. The SchoonSchip pilot showed a more mixed picture, with a slightly stronger male engagement with the digital energy-related housekeeping tasks.

Those that felt competent to assess the situation were more likely to act on it (blaming the technology in cases) compared to those that that did not feel competent. The latter tended to emphasise their own lack of knowledge and insight. While the former were more likely to act upon this – e.g., expressing their indignation; filing a complaint with the technology provider or project developer – the latter are more likely to disengage with the technology and with the technology providers. The experience of not being in control was gendered in Voorhout, yet less so in SchoonSchip. However, in both cases the most extreme

examples of self-perpetuating lack of expertise were expressed by women (feeling ashamed and therefore not asking for support; and/or already having thoughts about moving elsewhere when the husband might die in the future). Further research would be needed to verify if this is a pattern that bears out in larger samples as well. Yet, based on both cases and the literature review, it can be argued that more generally, the complexity of the smart grid systems has created new dependencies for residents, whereby householders become dependent on their partner or neighbours.

We have discussed the gendered differences in the build-up of expertise and interest, in connection to experiences of control, comfort, safety and trust. The empirical analysis and the brief literature review show that there is reason to pay more explicit attention to the ways in which gendered nature of housekeeping is likely to translate in a gendered concentration of smart grid related expertise and skills within households headed by two-gendered couples.

Milchram et al., (2020) point out that "lacking knowledge of and about such systems might be a greater barrier for inclusiveness than the knowledge needed to operate them" (2020:9; see also Reis et al., 2021). We now understand that this barrier is directly tied to the intersection of energy and digital literacy. With the development of smart grids, a digital layer is added to monitor and manage energy supply and demand at decentralised levels. This digitalisation adds complexity to the extent that it may increase risks of exclusion – particularly since overall women lag behind in terms of energy and digital literacy. Even the respondents who were well-resourced in terms of financial, educational, and social resources, did not appear exceptionally energy or digitally literate. Most of them experienced 'barriers' to understanding and acting in accordance with the smart grid system.

The question of inclusiveness becomes even more pressing when smart grid projects are replicated in energy poor or vulnerable neighbourhoods. Because women's comparative lack of proficiency in these areas also depends on age, educational background and socio-economic backgrounds (Non et al., 2021), then if gender-inequalities in smart grid design are not addressed, smart grids are likely to deepen the gender-divide. Women have a higher representation in numbers in these neighbourhoods, and they are less technically- and digitally proficient, which creates a situation where there is limited ability to provide flexibility.

Therefore, we need to invite female residents more actively in the design, implementation and monitoring of smart grid experiments[6] as it will contribute to an enhanced understanding of gender – in intersection with other factors such as age, educational and socio-economic background. Since smart grid pilots offer an opportunity to collect relevant user experiences, it is key that user feedback is collected from women and men alike and that both are engaged in co-creation trajectories. While this paper is exploratory, we argue that the challenge arises out of the combined impact of limited energy and digital literacy. For subsequent empirical work, we suggest a further unpacking of the notions of literacy and expertise in relation to gender, in a co-creative approach with both residents and smart grid technology developers, in order to assess where the main difficulties lie, to what extent and for whom that is considered problematic (and why), what can be done to ameliorate the situation and what the possibilities are to encourage a more shared accumulation of interest and expertise.

With input from such research, we can start adapting household smart grid solutions to better fit with diverse and gendered needs, interests and expectations. This will contribute to improved recognitional justice, but also to more effective household smart grids that result in a more efficient use of energy and energy infrastructure.

6. At the time of writing, two focus groups are being planned with women in Voorhout to further discuss these issues. Later this year, workshops with technology providers will follow.

DISCUSSION: LESS IS MORE…

Not only can residential smart grids contribute to a more efficient use of the energy grid, they also support an increase in the share of installed renewable energy capacity. Smart grids can thus contribute to a decrease in fossil fuel consumption. Residential smart grids enable a shifting of energy demand, yet may also encourage a decrease in energy demand (e.g., DR encourages a reduction of energy consumption during a set period which may be achieved by shifting or reducing energy demand, depending on the activity).

However, when the most effective residential smart grids are achieved (theoretically) by an enormous increase in technology and corresponding complexity, we need to ask what this means for residents. Trust in technology and control over one's own household is not aided by ever-increasing complexity and opacity. Overengineered smart grids do not match with 'simple' ideas and preferences that people may have about living sustainably. As an illustration (and harbinger?) of this, the app-aversion and inclination to engage as little as possible with the smart grids digital services that two residents expressed as a life-style choice can be read as a preference for a less technology-dominated path towards enhanced wellbeing and sustainability. Their preference for rules of thumb or off/peak tariffs makes sense since these are simpler, more predictable and still allow space for meaningful, intentional, 'responsible' energy consumption.

As for policy, as the digitalisation of our energy systems advances, energy transition policies should anticipate unevenly distributed impacts of this digitalisation better. Part of this is attention to how the ability to participate in smart grid arrangements intersects with gender, age and other socio-economic factors. Energy transition policies need to ensure that the existing unequal access to affordable energy services, which is strongly gendered (Dunphy et al., 2018; Feenstra & Özerol, 2021) is not further increased with the ongoing residential smart grid innovations.

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