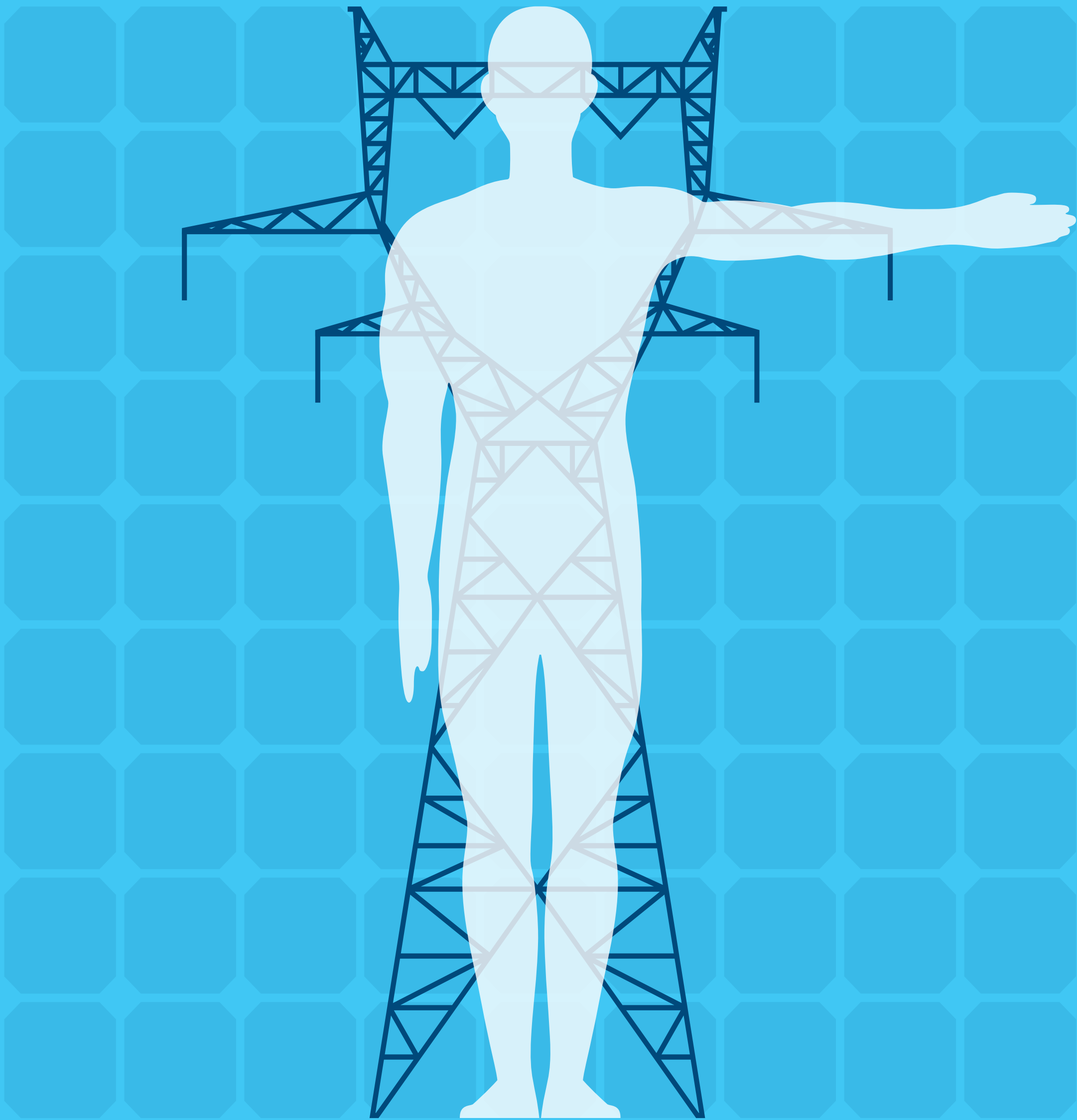
SMART GRIDS THE HUMAN SCALE

Investigating householder participation in the decentralization, digitalization and decarbonization of energy grids in the Netherlands

ROBIN SMALE



Propositions

1. The emerging significance of the timing of energy use and generation in domestic settings inspires new forms of householder agency and householder-energy system collaboration.
(this thesis)

2. Smart grids upend established consumer roles, practices, and power relations.
(this thesis)

3. The urgency of the climate crisis requires greater participation by young people in local sustainability transitions.

4. Infographics are underutilized as a means of making social science more accessible to a wider public.

5. Traditional, low-tech and modernist, high-tech solutions for low-carbon lifestyles can co-exist and both contribute to achieving sustainability goals.

6. PhD research is an emotional journey as well as an intellectual one.

Propositions belonging to the PhD thesis, entitled:

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Investigating householder participation in the decentralization, digitalization and decarbonization of energy grids in the Netherlands

Robin Smale

Wageningen, 2 December 2021

Smart Grids the Human Scale

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This research was conducted under the auspices of the Graduate School for Socio-Economic and Natural Sciences of the Environment (SENSE).

Smart Grids the Human Scale

Investigating householder participation in the decentralization, digitalization and decarbonization of energy grids in the Netherlands

Robin Smale

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List of abbreviations

DEH	Duurzame Energie Haaren
DSO	Distribution System Operator
ESCO	Energy Service Company
HEM	Home Energy Management
JEM2.0	Jouw Energie Moment 2.0, Dutch smart grid project
Solar PV	Solar photovoltaics
SPT	Social Practice Theory
SSmE	Samen Slim met Energie (Together Energy Smart), Dutch smart grid project
TSO	Transmission System Operator
STS	Science and Technology Studies

Chapter 1

Introduction

Chapter 1: Introduction

1.1 The social embedding of smart grids

Stable, affordable and sustainable electricity production, transportation and consumption are crucial to the functioning of any modern society. Nowadays, utility providers face technical, environmental, and societal challenges in securing the taken-for-granted services the energy grid is expected to provide to household. The electrification of daily life, especially in the sphere of mobility (EVs) and electrified heating, in combination with the rise of decentralized renewable generation (rooftop solar), places increasing pressure on the electricity distribution grid. This challenge goes together with an unprecedented pressure on the energy sector to reduce its climate impact in the next decades.

Smart grids are heralded as promising socio-technical innovation and a comprehensive solution for making the energy grid more flexible and green (Yu et al., 2011; Darby et al., 2013). A smart grid can be defined as "a socio-technical network characterised by the active management of both information and energy flows, in order to control practices of distributed generation, storage, consumption and flexible demand" (Wolsink, 2012, p. 824). Smart grids innovations presume the involvement of householders, who, by conserving, monitoring, and timing their consumption with the help of various smart technologies and information flows, contribute to the sustainability and stability of the electricity grid. To realize flexible grid management and decarbonization as key objectives of smart grids, domestic practices of (energy) consumption will undergo significant change. Without the engagement of householders these changes are unlikely to be achieved.

In light of these developments and the maturation of smart grid technologies, policy-makers, technology designers and infrastructure planners are in need for knowledge regarding the factors that determine the specific ways in which householders (co-) shape their everyday life involvement in smart grids (Verbong et al. 2013; Skjølsvold and Lindkvist, 2015; Geelen et al., 2016). In what – both individual and organized - ways, to what extent and with what kind of ideas, moods, values and emotions are householders gradually becoming engaged with the key objectives of smart grid developments? To answer this set of questions, communities of experts, including engineers, grid managers, (social-)psychologists and behavioural economists, have applied different perspectives and methods in the search for pathways towards the social embedding of smart grids in the everyday lives of situated households. So far, technology design, economic modelling and nudging individual behaviours have emerged as core features for analysing the role of householders in smart grids. As a result, the dominant perspective prevalent in government and grid operator circles can be characterized as technology-driven and based on the assumption of decision making by individual householders as rational-actors who should be nudged in the "right" direction (Christensen et al., 2013).

This dominant perspective generates insights which in turn inform smart grid policies, strategies, interventions and experiments (Verkade and Höffken, 2018) and technology development (Skjølsvold and Lindkvist, 2015) to a considerable extent. Research into the social acceptability of smart grid technologies such as smart meters, in-home displays, and battery storage, investigates householder attitudes (e.g. with respect to novelty and innovation) in order to align smart grid objectives and technologies to the values and preferences held by individual or groups of householders. From a behavioural economics standpoint, insights into the price sensitivity of householders with respect to variable energy tariffs inform demand-side-management modelling and planning. The nudging perspective identifies methods in which smart grid hardware and software can be used to steer and influence routinized behaviours within their domestic contexts, for example through timed notifications about energy use. In the Netherlands a number of smart grid pilot projects experiment with these insights and variables in real life contexts of (newly build and existing) homes that are furnished with smart grid information flows and technologies. Such projects typically attempt to engage householders via alluring financial incentives (such as variable energy tariffs or net metering), attractively designed energy monitoring technologies (such as in-home displays and apps), and the appeal to 'green' values as inherent elements of the modern household.

The approaches and experiments with householder involvement in smart grids have seen successes but have also demonstrated limitations. These include the disinterest of householders developing in the longer term (Hargreaves et al., 2013) and a mismatch occurring between the alternatives offered and trends among prosumers (Wallsten and Galis, 2019). At the same time as energy system actors are developing specific strategies for the inclusion of householders into smart grids, householders themselves start displaying their own agency by experimenting with new roles and responsibilities in energy systems that support their domestic practices. Emerging smart energy technologies such as in-home energy displays and home batteries are enabling householders to interact with their own energy use, with other householders and with the wider energy system in novel ways. For instance, some householders with an interest in autarky started to embrace smart energy technologies in order to go 'off-grid'. Domestic energy prosumers participating in energy (flexibility) markets started to look for ways to make the best out of their self-generated renewable energy through storage and the timing of their energy demand. Householders have also formed community- or network-based energy collectives, which exchange renewable energy among its members. Energy collectives (community-led sustainable energy initiatives and projects, Seyfang et al., 2014) vary greatly in terms of size, goal, organization, motivation, and actions. Coming to terms with these limitations and developments requires an investigation into the human scale of smart grids.

Searching the human scale

In his 1971 and 1983 books *Design For The Real World* and *Design At Human Scale*, Victor Papanek claimed that designers had lost sight of the real needs of human beings and outlined principles for morally and environmentally responsible design. He argued that the dominant assumptions about human needs and desires must be questioned critically, and that the *human scale* should be re-introduced into the design of everyday objects. Attention for the human scale demands the careful and critical examination of human behaviour in the real world, and encourages designers, planners and researchers to attempt to uncover the 'real needs' and desires of humans, or in the case of this thesis, householders as users and participants in low-carbon, smart grids. Recent use of the term in the Netherlands, equally relevant to smart grids, involves the critique of government bodies in operating in impersonal, bureaucratic, and technical modes. Re-introducing the human scale involves, amongst other, giving more space in government practices to tailor-made solutions, personal contact and empathy[1].

For the purposes of this thesis the 'human' part relates to householders' life world: their engagements, emotions, goals, and everyday practices associated with energy. 'Scale' is about how householders view and perform their role and relate energy use, generation, and management to sustainability, to other householders and to the wider energy system. 'Human scale' in the context of smart grids has to do with the ways in which householders are and feel engaged with, give context and meaning to their roles and practices in relation to wider societal issues such as sustainability. It is concerns householder agency in relation to an enormous and highly complex energy system and its powerful system-actors. This perspective broadens our view of householder involvement in energy transitions far beyond formal processes of participation.

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[1] As recommended in the parliamentary report 'Klem tussen balie en beleid', (Stuck between helpdesk and policy) by a temporary committee on government bodies, February 25 2021.

Observing the limitations of technology-driven and rational-actor based perspectives, researchers started to apply a different set of concepts to study the 'human scale' of smart grids. Within the social scientific literature on smart grids theories of social practice have attracted attention for their novel way of studying the human (agency oriented) approach to the sustainability transitions in the context of smart energy grids. Social practice theory places routinized behaviours at the centre of analysis. Adopting this approach, authors such as Naus (2017) and Hargreaves et al. (2015) have analysed how energy consumption and management are transformed in the context of smart grids, and how social and power relations (e.g. between family members and between householders and providers) are reconfigured in tandem. These studies have generated important insights into barriers and opportunities for householder participation, co-construction and shared decision-making in smart grids. However, understanding the human scale of smart grids requires a closer investigation of the character and trajectory of householder engagement with smart grids. Further research is required into the needs and desires which (de)motivate householder engagement with smart grids. An analysis of the human scale of smart grids must account for the collectively shared meanings, aspirations and emotional attachments of householders. For these reasons, this thesis dives more deeply into the normative and motivational dimensions of householder participation and agency in smart grids.

This is done on two levels. The first is the *situated, single household,* which is the site of home energy management (practices). At the household level, smart grid objectives and technologies, such as in-home energy displays and battery storage, align or clash with established domestic routines, preferences and goals. The second level encompasses the *wider socio-technical configurations* in which (collectives of) householders can participate in the context of smart grids. Novel social and technical organisational forms are enabled by key smart grid technologies (such as energy storage) and digital infrastructures (such as energy platforms). These socio-technical configurations transform and mediate roles and relations of householders with respect to neighbours and other prosumers, as well as with energy utilities, providers and markets. The question here is how these novel configurations, roles and relations accommodate and support the collectively shared meanings, aspirations and emotional attachments of householders. Moreover, (how) can householders co-create smart grid configurations which do so? By studying householders and emerging practices in real-life (experimental) settings, knowledge can be derived about types of energy grids and systems which are relevant and appealing to both householders and utilities and providers and constitutive of low-carbon energy futures.

Research aim and research questions

The following three main research questions underlie the proceeding chapters 2 to 5 and will be answered in concluding Chapter 6.

1. How do smart grid objectives and technologies interact with householder goals and preferences with respect to energy use and generation, and how does their implementation co-shape energy management practices, householder agency and power relations?
2. How do wider sociotechnical configurations of smart grids engage and empower (collectives of) householders, such as those involving energy storage and digital infrastructures? (How) can householder co-shape those wider configurations?
3. What are the implications of this analysis for stakeholder strategies and energy policies and governance concerning the co-construction of smart grids at human scales in the near future?

The thesis aims to enhance our understanding of emerging and transforming domestic energy practices enabled by smart grid innovations, and their consequences for sustainable grid management and the relationship between system actors, energy collectives, and households in Europe. The character of householder participation in smart grids will be assessed critically in terms of empowerment to self-organize or co-construct democratic, sustainable energy systems and sustainable lifestyles. Moreover, the thesis aims to generate insights and recommendations into how participation of householders in smart grids could be supported by governance strategies and policies from the side of both energy providers and (national and EU) government.

1.2 Theory: searching the human scale of smart grids beyond established framings

In order to answer the main research questions, a theoretical framework is required which conceptualizes the interaction between households and energy systems in the context of smart grids, both on the level of situated households and as part of wider socio-technical configurations.

1.2.1 Complexity of householder agency

As described in section 1.1, complexities with respect to householder agency in smart grids is found on two (equally important and interrelated) levels: (1) householders' (behavioural) response to smart grid objectives and technologies, and (2) householder agency with respect to reshaping relationships with utilities, energy markets and other households. To analyse these complexities, a social practices perspective is applied in this thesis.

Social practice theory, which has been developed over the last decades within the sociology of consumption, places shared and routinized types of behaviours at the centre of analysis (Warde, 2005). Social practices are understood as "temporally evolving, open-ended sets of doings and sayings" (Schatzki, 2002, p. 87), consisting of interconnected elements: know-how and embodied habits, institutionalized knowledge, engagements (including emotions), and technologies (Gram-Hansen, 2010). When applied to social practices of the production, consumption and management of domestic electricity in a domestic or decentralized setting, such practices may be understood as energy practices (Van Vliet, Naus, Smale, and Spaargaren, 2016). It is useful to distinguish between energy consuming (or consumption) practices – such as doing the laundry, watching television or cooking – and home energy management (HEM) practices (Naus 2017). What separates HEM practices from domestic consumption practices is "the fact that they are specifically focused on the management, steering or governance of domestic energy flows, technologies and infrastructures" (Naus, 2017, p. 125). These practices include energy monitoring, co/self-production of energy, energy sharing or trading, timing of demand, energy storage and energy conservation.

Viewed from a social practices perspective, the first level of householder agency in smart grids at which complexity has been signalled refers to the performance of energy (management) practices by householders in individual homes ('practices as performances'). As described in section 1.1., there are numerous factors which complicate householder 'enrolment' in and performance of emerging energy practices in smart grids. This has led Hargreaves et al. (2010) to argue that renewed attention for the moral economies of households is due: "The concept of 'moral economy' recognises that different households, even if they are demographically and technically comparable, have different histories and social practices through which they have developed agreed norms and values, habits and routines which are normally unquestioned." (p. 6112). Acknowledging this, the provisioning of (smart grid) technologies, information and objectives to households should be understood as triggering "a social process of questioning and renegotiating pre-existing and well-established household values and habits". Taking up the gauntlet, this thesis analyses householders as performers of energy (management) practices with particular attention paid to the teleo-affective, normative, and motivational dimensions which propel householder agency in the smart grid context.

The second level concerns the context of wider socio-technical configurations of smart grids. Here householder agency refers to (collectives of) householders being in the position to co-create and reshape the established roles, relations and objectives of prosumer and energy collectives in the current energy system by engaging in novel vertical (utilities, energy market actors) and horizontal collaborations (other households) (Naus et al., 2015). In this respect there are is a diversity of configurations emerging, with energy storage technology and (smart metering-enabled) digital energy infrastructures being notable building blocks through which households can connect to utilities, energy markets, and other households in novel ways. However, while householders will play a crucial role in realizing climate and energy goals in future energy systems (Naus, 2017), studies about how households would want to be engaged in and with wider socio-technical configurations of smart grids (e.g. energy storing and sharing communities, energy platforms) and how they view the different possibilities and risks of energy provisioning via emerging energy technologies are largely absent. Moreover, there is uncertainty regarding householder preferences with respect to what sustainability, social and economic issues they wish to address as well as whether (they believe) autonomy from the grid or further integration into (smart) energy grids and markets supports the realisation of (green, social, economic) objectives. To address these knowledge gaps, this thesis analyses householder agency in emerging socio-technical configurations of smart grids with specific focus on householder and community goals.

1.2.2 Power relations in novel socio-technical configurations

To understand how socio-technical configurations of smart grids (co-)shape householder participation, aside from normative and motivational aspects also the empowerment of householders in these configurations needs investigation. Power relations between householders and energy system actors shift as novel socio-technical configurations emerge in the context of smart grids. Researchers have employed different approaches and concepts for analysing those power dynamics in smart grids. The concept of affordance is used to analyse the enabling and disabling effects of various socio-technical configurations on householder agency (Hargreaves et al., 2013; Darby, 2010). Verkade and Höffken (2018) and Verkade et al. (2020) analyse smart grid design and development processes, focusing on how certain guiding logics and framings of householders lead to redistributions of power in smart grid configurations (or not).

Empowerment and home energy management

Smart energy technologies, such as in-home energy displays, home batteries and smart heat pumps, enable new forms of home energy management. However, there are indications that householders themselves have little influence on or understanding of their functioning. Technology-driven, automating solutions for home energy management may imply 'unwanted types of control' for householders (Hansen and Hauge, 2017; Hargreaves et al., 2015). Bulkeley et al. (2014) make use of the concept of 'governmentality' to expose the ways in which smart energy technologies attempt to steer domestic practices. Smart technologies also risk increasing energy consumption (Hargreaves, Wilson, and Hauxwell-Baldwin, 2018) and sustaining energy-intensive ways of life (Herrero, Nicholls, and Strengers, 2018). Finally, smart technologies bring the risk of locking householders into passive consumer roles (Strengers, 2013).

These studies have emphasized the risks of disempowering householders in smart grids. Acknowledging and building upon these insights, this thesis turns a corner. Smart energy technologies and the social relations surrounding them (socio-technical configurations) will be analysed for *empowerment*: how are or can householders be empowered to self-organize or co-construct sustainable lifestyles and energy systems? Viewed from a social practices perspective, empowerment points to householders as energy practitioners who are handed the 'tools' to actively and creatively re-shape energy practices. This goes beyond being the recipients of technologies, incentives or information. Technology-driven or financial incentive-driven socio-technical configurations of home energy management may attune householders to the needs of energy grids, but in what ways do they enable the realisation of self- or collectively defined (sustainability) goals and ambitions? Important in this respect are mediating technologies, such as home batteries, in-home energy displays, and smart heat pumps, which interconnect household and energy system and afford householders and energy system actors new roles, responsibilities and engagements.

The premise of access to the private sphere of the home inherent in smart grid technologies also gives rise to the question how trust between householders, utilities, and market actors is established and sustained. Evidence suggests householder trust and interest is easily lost in smart grid projects (Verkade and Höffken, 2018). Operating on the assumption that different socio-technical configurations of home energy management (re)distribute power and responsibilities (e.g. in daily operation and determining the overall objectives), the trust relations between providers and householders in this context warrants further analysis.

Empowerment and energy managing collectives

Zooming out from the power and trust relationships particular to configurations of home energy management in situated, single households, questions about empowerment should also be posed in the context of emerging energy managing *collectives*. Digital infrastructures – platforms being the prime example - and energy storage facilitate such collectives as they enable the exchange of electricity and information between householders, as well as between collectives of householders and utilities and energy markets. Energy managing collectives can be rooted in local communities or communities-of-interest forming networks, its members operating at a distance.

Empowerment in this context refers to the ability of these new collectives to (co-)create decentralized, democratic, sustainable and (socio-economically) just configurations of the energy system. Important in this respect is the space (bottom-up, community driven) collectives have (and demand) for experimentation and co-creation in smart grid (pilot) project which are typically utility- and/or market-led. This thesis explores the ability of novel energy managing collectives to articulate and realise collective goals vis-à-vis established and emerging energy system actors, objectives and requirements. The literature on (strategic) intermediaries (i.e. deliberative, goal oriented, hybrid organizations which 'constitute new forms of interdependencies and socio-technical assemblages', Marvin and Medd, 2004) may prove insightful in this respect.

1.2.3 Conceptual framework: household-grid interaction in the context of smart grids

Figure 1.1 illustrates the main concepts underlying the thesis and the relations between them. It constitutes the conceptual backdrop against which the questions about householder agency and empowerment will be investigated. Practices associated with (domestic) energy consumption and energy management are sited in and around homes, and embedded in clusters of household practices. Households are conceived as "hybrids of objects and people, which are implied in the (routine) performance of a series of interconnected practices reproduced in the domestic arena with the help of energy as a key resource" (Naus et al., 2014). Domestic energy practices are embedded in wider energy systems (systems of provision), which responds to energy practices which are consistently reconfigured by system actors, including utility providers, energy collectives, policy-makers, and others. In the context of smart grids, established energy consumption practices transform and novel energy management practices emerge due to changes in the system of provision, socio-technical configuration of the household, and the characteristics and agency of householders. Specifically, smart grids introduce new technologies, engagements, emotions, knowledge and know-how; these elements of social practices are co-produced, re-produced, and transformed in households and through systems of provision (Spaargaren, 2003).

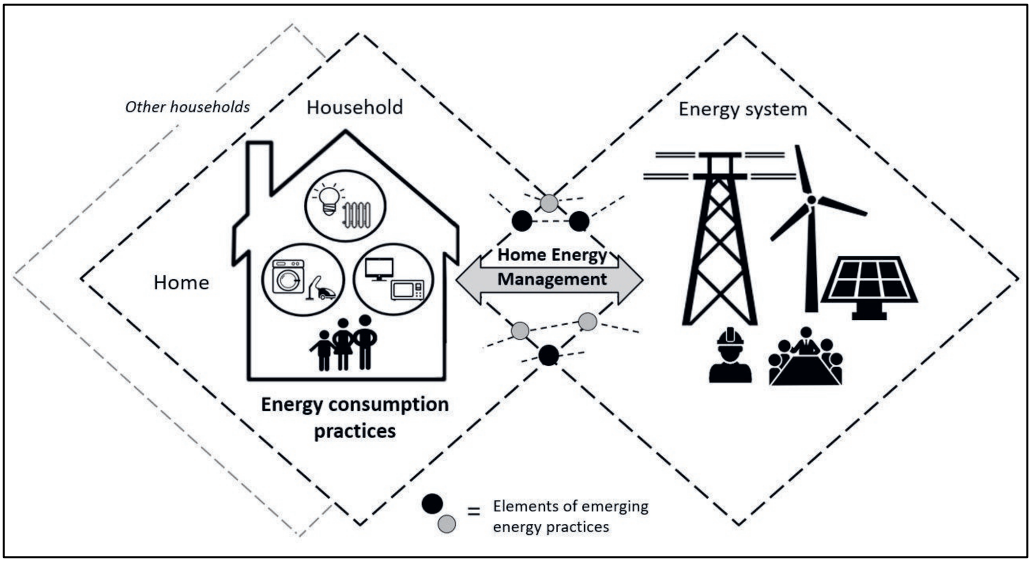

Figure 1.1. Conceptual framework: emerging home energy management (HEM) practices at the interface between the home and wider energy systems. Source: Adapted from Naus (2017, p. 125).

1.2.4 Sub-research questions

Analysing how smart grid objectives and technologies shape energy use, generation and management in domestic contexts first warrants a closer look at what is novel about smart grid development. Moreover, to understand how changes in domestic practices in smart grid contexts are accompanied by shifts in power and agency, it is useful to distinguish and analyse separately domestic energy consumption practices and home energy management practices. Finally, in order to analyse how householder engagement and empowerment are shaped in wider configurations of smart grids, the analytical focus shifts from situated, single households to configurations of energy storage and energy platforms. For these reasons, sub-research questions are posed in chapters 2, 3, 4 and 5. Sub-research questions 1 and 2 contribute to answering the first main research question and sub-questions 3 and 4 to the second research question respectively.

1. What shift in objectives of (home) energy management is implied by smart grid development, and how does such a shift interact with existing domestic energy consumption practices?
2. How do home energy management practices distribute power and responsibilities between smart grid technologies, (distanced, expert)

energy service providers and (lay) householders? How is trust between householders and providers established and sustained in this context?

3. How does the introduction of home batteries afford new roles and energy practices for householders?
4. How do householders view the social, environmental and economic opportunities and challenges of energy platforms, and how do they respond to the new roles and responsibilities for householders that energy platforms could bring along?

1.3 Methods

In order to investigate these research questions, methods were selected to match the level of the situated households as well as at the level of wider socio-technical configurations of smart grids respectively. In doing so, inspiration was drawn from the ‘zooming in and zooming out’ technique as outlined by Nicolini (2009). It involves “switching theoretical lenses and repositioning in the field, so that certain aspects of the practice are fore-grounded while others are bracketed” (pp. 1391). By doing so, a more complete understanding of social practice phenomena can be generated than through analysis using one particular theoretical lens or perspective.

For zooming in on the situated household level, a multiple case study design was used to facilitate in-depth analysis of energy consumption and management practices in the context of smart grids. Smart grid pilot projects were selected as the empirical setting: these experiments, where smart grid technologies and instruments are implemented and tested in real-life settings, serve as windows into potential smart grid futures. Qualitative research methods were applied. Drawing inspiration from ethnographic methodology, ‘show-and-tell’-style home tours were combined with ethnography-style observations. The aim in doing so is to foreground the real-life experiences of householders with energy use and management in the context of smart grids. Chapter 2 centres around energy consumption in the context of smart grid objectives and instruments. Chapter 3 shifts the analytical lens by focusing on key smart grid technologies. These technologies ((home batteries, in-home energy management displays, and smart heat pumps were selected) mediate the interaction between households and smart energy systems foregrounding the power and trust relations between householders and utilities, providers and experts which emerge as these technologies are implemented in real-life contexts and householders become enveloped in home energy management practices.

Next, in Chapters 4 and 5, the analysis zooms out in order to analyse the broader socio-technical configurations in which householders participate in smart grids. Energy storage and energy platforms were selected as case studies, due to their key function in interconnecting (individual) households to energy utilities and markets as well as to other households. Battery storage and digital infrastructures enable and organize the storage and exchange of electricity and (energy) data; as part of broader socio-technical configurations, they enable particular relations, roles, meanings and practices. By analysing different configurations of energy storage and energy platforms, this approach foregrounds emerging forms of (horizontal and vertical, (Naus, year)) collaboration which are characterized by varying types and degrees of (collective) engagement and empowerment.

To summarize, the empirical work for Chapters 2-5 consists of the following mix of qualitative methods:

- Semi-structured interviews
- 'Show-and-tell'-style home tours
- Ethnography-style observations
- Participatory workshops
- Group interview
- A small survey
- Participant observation

Below the research cases are described in more detail.

Research cases

Smart grid pilot projects

The research for chapters 2 and 3 was conducted with householders involved in two smart grid pilot projects: Jouw Energie Moment (Your Energy Moment, JEM) and Samen Slim met Energie (Together Smart with Energy, SsmE).

Table 1.1. Key characteristics of the smart grid trial Jouw Energie Moment (2012–2018).

	Phase 1 (March 2013–December 2015)	**Phase 2 (January 2017–March 2018)**
Main objective	Testing the potential of voluntary energy management for net balancing	Testing the potential of technology-assisted energy management for net balancing

Studied participant groups	Purpose-built all-electric smart home neighbourhood	Purpose-built all-electric smart home neighbourhood	Retrofitted homes
Energy technologies installed in participants' homes	In-home energy monitoring display Air-to-air heat pump with a 'smart' algorithm Smart laundry machine Dynamic energy pricing Photovoltaic (PV) panels	Home battery Online energy platform (webpage and app) Air-to-air heat pump with a 'smart' algorithm Smart laundry machine Dynamic energy pricing PV panels	Online energy platform (webpage and app) Air-to-air heat pump with a 'smart' algorithm Dynamic energy pricing PV panels
Number of participating households	39 (6 interviewed, one group interview with 7 participations)	39 (10 interviewed)	18 (4 interviewed)
Analysis in thesis chapter	Chapter 2	Chapter 3	

JEM, which ran in 2012–18, was initiated by a Dutch distribution system operator (ENEXIS) together with a consortium of energy service providers, technology and software companies, and knowledge institutes involved in smart grid development. This pilot project is a particularly relevant case study for two reasons: first, having participated in smart grid developments since 2012 and being familiar with at least two configurations of home energy management (phases 1 and 2, see Table 1.1), the smart home-dwelling householders in particular can be considered frontrunners and expert-practitioners from whose experiences with home energy management practices much may be learned. Second, a number of key aspects of smart grids are tested in conjunction: domestic batteries in combination with solar photovoltaics (PV), smart heat pumps, a time-of-use energy tariff and an online platform for energy management.

In the SSmE project, a digital energy platform was co-created by the project organisers (a grid operator, smart energy software developer, and energy technology providers) and the participants, who were all members of a medium-sized energy cooperative and solar panel owners. The purpose was to test new forms of cooperation between utility provider and organized households. Several smart grid features were tested, including voluntary time-shifting (without flexible energy tariffs), individual and collective monitoring of energy consumption and production (participants were given energy monitoring devices), information exchange, and energy-themed actions.

Energy storage
Chapter 4 features an in-depth case study of different forms of energy storage. Due to the variety of research material and differential access to energy storage cases, this chapter has an exploratory character. Real-world cases were used to conceptualize and identify the different forms of engagement that the use of home batteries may foster, rather than to systematically evaluate the extent to which new energy practices around storage already result in (new forms of) participation.

This chapter builds on empirical data that was collected at different moments and sites in the context of a research project on emerging energy practices in the smart grid (2014–2019). The data are qualitative and consists of interviews with different stakeholders in the energy system in the Netherlands, and to a lesser extent Germany and the United Kingdom. Interviews were conducted with providers of home battery systems and services, energy storage experts, NGO's and local governments involved in storage pilot projects. The bulk of the data comes from interviews and observations with householders who were involved in storage pilot projects, or who had installed home batteries themselves.

Energy platforms
Chapter 5 centres around participatory workshops conducted with two differing groups of householders involved in energy platform projects. The first group was engaged in a utility-led smart grid pilot project in an urban setting, the other was an aspiring energy community in a village setting. A participatory workshop methodology was selected because it can achieve a dual purpose: fulfilling participants' expectations that they might learn or achieve something related to their own interests on the one hand, and on the other, fulfilling a research purpose through the production of reliable data. By using this approach, the emerging diversity of energy platforms, with their different environmental, economic, and social characteristics, can be made understandable for (non-expert) householders. Making use of visualisations and an interactive format in order to convey complexities and consequences in bits, the method was designed to stimulate deliberation amongst householders while they navigate different energy platform scenarios involving a series of questions and challenges. In attempting to construct an immersive context for learning, deliberation and decision-making, this methodology is inspired by the emerging use of serious games in energy social science research (Wood et al., 2014).

1.4 Outline of the thesis

The thesis chapters are structured around the two-way interaction between households and energy systems in the context of smart grids. Chapters 2 and 3 focus on the situated, single household, whereas chapters 4 and 5 analyse wider socio-technical configurations of smart grids through case studies of energy storage and energy platforms. Chapters 2 and 3 address the first main research question. Chapters 4 and 5 address the second research question.

Chapter 2 analyses recent shifts in goals concerning domestic energy uses. In the smart grid transition, the balancing of (renewable) supply and demand in energy grids becomes the key priority of grid managers. Implications of grid balancing for domestic energy consumption and energy management are analysed.

Chapter 3 delves more deeply into the potential role of households as 'co-managers' of energy in (flexible and balanced) smart grids. Much remains uncertain about the social and power relations and practices emerging around novel smart grid technologies and their contribution to sustainability. Drawing on 'show-and-tell' home tours with householders in a smart grid trial, an analysis is presented of how home energy management (HEM) is performed in everyday life. The focus is on three technologies: monitoring technologies, smart heat pumps and home batteries.

Chapter 4 zooms in further on the themes of home energy management, power relations and emerging roles for householders, by investigating residential energy storage more closely. Drawing on literature that understands energy systems as sociotechnical configurations and the theory of 'material participation', the introduction of home batteries can be seen to afford new roles and energy practices for householders. Qualitative findings are presented from interviews with householders and other key stakeholders engaged in using or implementing battery storage at household and community level.

Having analysed the core instruments, technologies and strategies for (individual and collective) householder participation in smart grids, Chapter 5 investigates so-called 'energy platforms' and their potential for co-creation by (collectives of) householders. Energy platforms, comprising new business models and digital infrastructures, offer new ways for householders to trade or exchange energy with other households or with energy system actors, but also bring along challenges. Two serious-game style workshops were convened in which Dutch frontrunner householders assumed the role of platform members and were challenged to deliberate about different scenarios and issues.

Lastly, in the concluding Chapter 6 the main insights from the preceding chapters are synthesised and the main research questions are answered. In order to answer the third main research questions, the implications of the presented analysis are discussed in the context of broader societal developments, which provides context to recommendations for strategies and policies for householder and community engagement in and co-construction of 'human scale' smart grids.

Chapter 2

When social practices meet smart grids: Flexibility, grid management, and domestic consumption in The Netherlands

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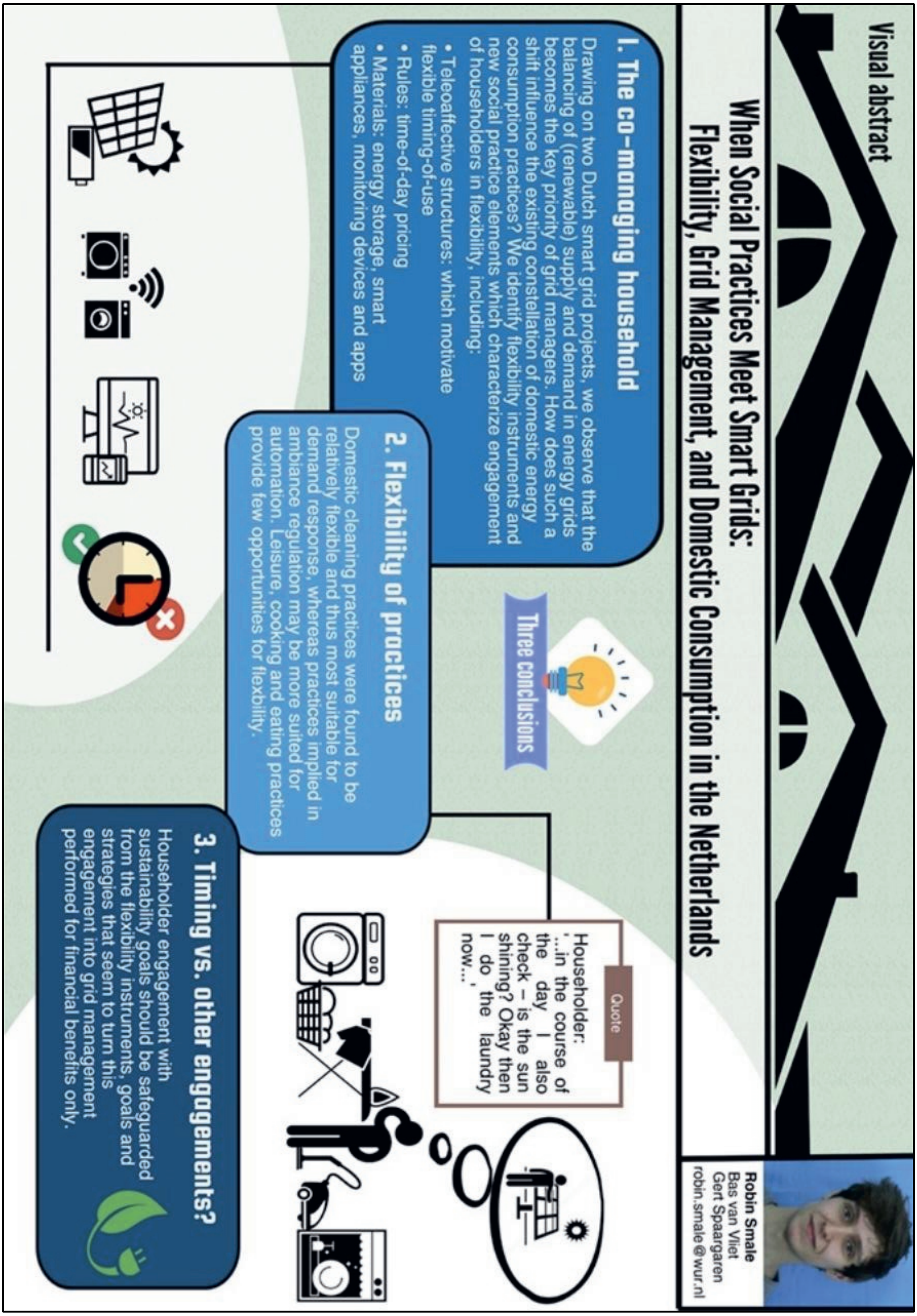
Chapter 2: When social practices meet smart grids: Flexibility, grid management, and domestic consumption in The Netherlands

Abstract

This article seeks to analyse recent shifts in goals concerning domestic energy uses. Drawing on two Dutch smart grid projects, we observe that in the smart grid transition the balancing of (renewable) supply and demand in energy grids becomes the key priority of grid managers. This shift becomes translated at the household level through so called 'teleoaffective structures' of energy practices which motivate and direct the behaviour of householders towards flexible timing-of-demand. New grid objectives are codified in the rules of social practice concerning the use of flexibility instruments (notably time-of-day pricing) and are materialized in monitoring devices, smart appliances, and energy storage. We investigated which domestic practices are most open for flexible timing-of-use. Cleaning practices were found to be most suitable for demand-side response, whereas practices implied in ambiance regulation, leisure, cooking and eating, align only with some flexibility instruments. Next, an analytical focus on linkages between social practices was used to specify opportunities and barriers to sustainable domestic energy consumption. In the concluding section, we argue that householder engagement with sustainability goals should be safeguarded from the flexibility instruments, goals and strategies that seem to turn this engagement into grid management performed for financial benefits only.



Visual abstract
When Social Practices Meet Smart Grids:
Flexibility, Grid Management, and Domestic Consumption in the Netherlands
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1. The co-managing household
Drawing on two Dutch smart grid projects, we observe that the balancing of (renewable) supply and demand in energy grids becomes the key priority of grid managers. How does such a shift influence the existing constellation of domestic energy consumption practices? We identify flexibility instruments and new social practice elements which characterize engagement of householders in flexibility, including:
• Teleoaffective structures: which motivate flexible timing-of-use
• Rules: time-of-day pricing
• Materials: energy storage, smart appliances, monitoring devices and apps
Three conclusions
2. Flexibility of practices
Domestic cleaning practices were found to be relatively flexible and thus most suitable for demand response, whereas practices implied in ambiance regulation may be more suited for automation. Leisure, cooking and eating practices provide few opportunities for flexbility.
Quote
Householder:
'...in the course of the day I also check – is the sun shining? Okay then I do the laundry now...'
3. Timing vs. other engagements?
Householder engagement with sustainability goals should be safeguarded from the flexibility instruments, goals and strategies that seem to turn this engagement into grid management performed for financial benefits only.

2.1 Introduction

In recent years, the smart grid has been embraced by grid managers, energy policy-makers, and energy market actors as a promising pathway for dealing with new grid challenges brought about by the introduction of renewable energy. Solar and wind power, both intermittent sources of energy, has to be integrated into existing, aging grid infrastructures (Verbong and Geels, 2010). This creates a need for real-time monitoring and management of energy flows, enabled by 'smart' energy technologies and techniques, at both the grid and household level. A smart grid can be defined as "a socio-technical network characterised by the active management of both information and energy flows, in order to control practices of distributed generation, storage, consumption and flexible demand" (Wolsink, 2012, p. 824).

Yet within most OECD countries, under the present conditions 'energy' does not play a central role in running most households (with the notable exception of householders in fuel poverty). Interactions and engagements with energy in the domestic sphere are limited to choosing an energy contract, paying the energy bill, being mindful of wasting energy, and at times making some energy efficiency improvements in and around the home. Energy consumption in particular has become a taken-for-granted and inconspicuous aspect of everyday life (Burgess and Nye, 2008). Consequently, householders are not (yet) the imagined energy 'co-managers', who engage with the technologies and behaviours that are relevant to the objectives of smart grids, like extensive energy monitoring, energy storage within or around the home, timing of demand, and the co-production of renewable energy. If these smart grid aspects are to be integrated into the household, this implies major changes in domestic everyday life.

To analyse changes that smart grids bring along for households, we use the theory of social practices as developed within the sociology of consumption over the last decades (Warde, 2014; Shove, 2003; Shove et al., 2013; Spaargaren et al. 2011). Practice theory is employed to analyse *energy practices* as the shared, routinized types of behaviours which involve "the production, distribution, storage, monitoring and use of domestic electricity in a domestic or decentralised setting" (Van Vliet et al., 2016). From a social practice perspective, the home is understood as a set of interdependent practices – for example, doing the laundry, showering, cooking, or watching TV – that fulfil specific domestic tasks (Shove, 2003; Gregson et al., 2007). To that effect, households can be understood as "hybrids of objects and people, which are implied in the (routine) performance of a series of interconnected practices reproduced in the domestic arena with the help of energy as a key resource" (Naus et al., 2014). Last but not least, scholars have shown the importance of considering the normative and emotional significance of the home when studying the impact of new energy policies and technologies. Aune (2007) illustrated how different ways in which householders relate to their homes – the home as *haven*, the home as *project*, and the home as *arena for activity* – reveal specific opportunities and obstacles for reducing energy demand. May (2011) argues that what happens in and around the home goes along with "a sense of personal control which contrasts with the more abstract ways in which individuals are controlled by the market and the state in modern societies" (p. 13).

New energy practices which 'emerge' in smart grid contexts have been described by several scholars (Christensen et al., 2013; Naus et al., 2014; Bulkeley et al., 2015). Emergence refers to both the birth of new practices (i.e. the monitoring of domestic energy flows, the utilization of new smart meters and smart appliances) and adaptations of existing practices (i.e. adapting the timing of laundry practices to moments of abundant solar energy supply) (Van Vliet et al., 2016). Strengers (2013) raises concerns associated with these practices and what they represent: an inadequate depiction of householders as resource optimizers, rooted in misunderstandings of householder agency; and a Foucauldian imposition of a 'smart management' discourse which does not reflect the diversity of competing visions of sustainable domestic energy. In a similar critical vein, Bulkeley et al.(2015) and Hargreaves (2012) make use of the concept of 'governmentality' to expose the ways in which smart energy technologies attempt to steer domestic practices. Smart grid imaginaries are mainly technological and economical in nature, argues Ballo (2016), which obstructs public debate and ultimately may undermine the legitimacy of a smart grid transition. Lastly, we take note of Throndsen's (2017) warning against the uncritical 'end-user engagement' paradigm, which ignores strategies for *non-participation* of end users in the smart grid, which he argues are both relevant and necessary; other avenues for household engagement in smart grids, for example in the design of algorithms, may in theory be more genuinely empowering and ultimately more sustainable than an active demand-response regime.

Sensitive to the concerns addressed by these authors, we hypothesize that the need for (localized) balancing of supply and demand in energy grids crucially shapes the character of emerging energy practices. Our objective in this paper is to arrive at a better understanding of the specific ways in which smart grids may contribute to or detract from environmentally sustainable and low-carbon energy consumption practices at the household level. Moreover, we assume that domestic energy consumption is not the result of rational, information- and cost-driven considerations made by householders, but results from a complex interplay between structure and agency. We hypothesize that householders co-construct and then draw upon a normative and intuitive frame of reference for the performance of energy consumption practices, one which we argue undergoes major changes in smart grid trials. Despite an expanding body of social scientific literature on smart grids, the normative implications of smart energy systems in relation to domestic life have not been explored systematically or in an integrated manner, theoretically nor empirically. So, our central research objective can be formulated as follows: What shifts in objectives of energy management are implied by smart grid development, and how does such a shift influence the existing constellation of domestic energy consumption practices?

The paper is built up as follows. Section two outlines a conceptual framework for the study of household energy consumption in a changing context. After introducing methods in section three, we apply this approach to two Dutch smart grid pilot projects in section four: Samen Slim met Energie (Together Smart with Energy, SsmE) and Jouw Energie Moment (Your Energy Moment, JEM). Section five relates the case study findings to literature and asks critical questions regarding sustainability.

2.2 Analysing domestic consumption with theories of social practices

In this section, we explore and operationalize the theoretical notion that domestic energy practices co-evolve with energy systems. In doing so, we assign a key role to normative and motivational structures, building on Schatzki's (2002) seminal work. The theoretical discussion starts an elaboration of what is meant by 'energy system', followed by an assessment of emerging objectives in the Dutch energy system. Then we discuss energy consumption and their social practice elements (Section 2.2). In Section 2.3 the concepts are applied to disentangle domestic practices, working with the hypothesis that smart grid objectives interact differently with various clusters of domestic practices. An analytical framework is presented visually at the end of Section 2.4.

2.2.1 New objectives in the Dutch energy system

In this paper, *energy system* refers broadly to the centralized and decentralized electricity provision infrastructures as well as the institutions, actors and markets directly engaged in the generation, provision and management of electricity flows. Any strict demarcation of 'an energy system' is problematic, because the boundary between energy provision and consumption has blurred, and actors are redefining their roles and responsibilities. A wide variety of professionals and end-users alike are engaged every day in the re-production of the energy system. However, by defining an energy system in contrast to the household, we emphasize the very different set of rationalities and normativities involved in energy consumption practices by householders versus the practices within the wider energy system. How and why new policy goals and objectives emerge in an energy system can be studied from a variety of perspectives. Ballo's (2015) concept of the 'techno-epistemic network' is particularly useful: "the members of a techno-epistemic network share a dedication and commitment for realizing a technoscientific innovation, related to a specific societal challenge" (p. 10). The changing practices of these actors in response to new grid challenges, while not the topic of this paper, are central to the construction of new imaginaries and objectives of future energy systems. Technology development and design processes are as much a situated practices as electricity use (Skjølsvold et al., 2017).

The actors engaged in smart grid development in the Netherlands arguably constitute a techno-epistemic network. This network can be characterized as led by distribution system operators (DSOs), in collaboration with both new and established smart energy technology and software companies. Dutch system operators state the following reasons for their support of and central role in the development of smart grids:

> *"They contribute to the integration of electricity production in all kinds of places in the grid. In principle, the directing and coordinating options make it possible to optimise energy use throughout the entire energy supply chain. Smart grids also make the energy user 'intelligent', because financial savings can be realised by flattening peaks in the power demand or at peak moments. Furthermore, they offer opportunities for new, energy-related services. And finally, the application of smart grids makes the energy system more 'dynamic' and they help to improve security of supply." (Netbeheer Nederland, 2012)*

Solar and wind are intermittent and inflexible power sources, whereas domestic electricity demand is highly synchronized around the work-day, work-week, and the seasons. While the Dutch electricity grid is reliable and stable, the proliferation of centralized and especially decentralized renewable energy generation will this balancing act ever more difficult. Decentralized renewable energy and synchronized demand put pressure on local and central grids, which, in combination with the gradual phasing out of feed-in tariffs and the development of smart energy innovations, give rise to the new central objective of low-voltage grid management: matching renewable energy supply to domestic energy demand, locally if possible. This coincides with the interest of the Netherlands' many renewable energy cooperatives (Schwenke, 2012), as well as PV-owning households, in optimising self-consumption to attain ever increasing levels of energy autonomy. The flexible matching of demand to supply, performed actively by the 'intelligent' energy users mentioned above, or automated, is typically referred to in short as *demand-side flexibility*. "Consumer flexibility" has become a key concept in smart grid imaginaries (Ballo, 2016). How this flexibility can and should be achieved – via technological means or via economic incentives in particular (Throndsen, 2017) – is still a matter of debate in the expert community.

A number of 'smart' techniques and technologies have been developed within the smart grid techno-epistemic network. Dutch smart grid trials experiment with dynamic tariff structures and smart appliances to provide more flexibility in energy production and consumption (Naus et al., 2014). Domestic energy storage can play a role in reducing grid imbalance by matching energy supply and demand within a home (Fares and Webber, 2017). We call such measures *flexibility instruments, goals and strategies* (or simply flexibility instruments). These also include 'flexibility products': "smart grid ready" devices which can automatically react to fluctuating energy prices by turning on and off, or by being remotely controlled (Schik and Gad, 2015). Demand-side flexibility may be achieved through automated demand-response via algorithmic control of appliances (bundled in flexibility contracts for example); or through active timing-of-demand by householders, with the aid of new tools for monitoring energy use, and programming or remote controlling appliances. Both are driven by time-of-use energy pricing. These incentives typically take the form of high tariffs at times of extra ordinary high demand (critical peak pricing); various time slots with pre-fixed tariffs (time-of-use pricing); and highly dynamic tariffs (real-time pricing) (Naus et al., 2014). Flexibility instruments play a key role in aligning domestic energy use with new system objectives. They assume an interconnecting function, effectively exposing households to both new system-needs and novel energy use strategies. Beyond a long established day/night tariff scheme, Dutch consumers are relatively unfamiliar with demand-side flexibility and grid imbalances in comparison to other countries such as Australia, or even nearby Belgium: there, summer peak demand[2] and

[2] See for example the 9 February 2017 power cut in Southern Australia, covered here in an article for The Conversation by H. Saddler:

security of supply in winter[3] respectively drive system operators to attempt to engage householders in demand timing and reduction.

In subsequent sections, we will illustrate how demand-side flexibility as emerging objective represents not only a shift in priority of the technical operation of the electricity grid, but becomes translated into everyday energy practices of households at a normative level. In 2009, Rohracher studied “the attempt of various non-profit organisations [...] to construct new markets for electricity from renewable energy carriers (‘green electricity’), by bringing actors together in new networks, establishing new ‘calculative practices’ for the evaluation of specific goods, and introducing ‘normalising practices’ to orient the market towards specific normative aims” (Rohracher, 2009). Similarly, we hypothesize that in current utility-led smart grid experiments in the Netherlands new goals of domestic energy use are constructed, centred around demand-side flexibility as a necessary attribute of low-carbon energy systems. In other words, when grid policy goals are translated to the lifeworld of homes via flexibility instruments, abstract system priorities become new ‘should’s’ and ‘ought’s’ of energy use.

2.2.2 Domestic energy consumption

To study how these new objectives co-shape domestic energy consumption in smart grids, we specify the energy practices of interest: energy consumption practices, which are defined as practices performed in or near the household that require the use of energy, such as cooking and showering.

Smart grid development introduces new material and non-material social practice elements into energy consumption practices. The works of Shove et al. (2012) have illustrated the importance of the material dimension in the co-shaping of practices, directing analysis to the circulation of objects and changes in consumption and provision infrastructures. Smart energy innovations, such as smart meters, home energy management systems (HEMS), and domestic energy storage constitute some of the key elements of the physical domestic energy infrastructure of smart grids. Next, we draw on Schatzki (2002) to conceptualize the less tangible, but equally important non-material social practice elements. Schatzki understands practices as bundles of human activities linked by practical understandings, rules and teleoaffective structures. *Practical understanding* involves three abilities:

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http://theconversation.com/why-did-energy-regulators-deliberately-turn-out-the-lights-in-south-australia-72729 (last accessed May 15, 2017)

[3] Via the websitehttps://offon.be/nl Belgian consumers can inform themselves of thegrid’s stability and energy saving measures they could take to contribute.

"knowing how to X, knowing how to identify X-ings, and knowing how to prompt as well as respond to X-ings (p. 78)." *Rules* are the principles, instructions, and formulations that practitioners adhere to or consider when they act or speak. *Teleoaffective structures* are defined as "a range of normativized and hierarchically ordered ends, projects, and tasks, to varying degrees allied with normativized emotions and even moods" (Schatzki, 2002, p. 80). Teleoaffective structures hold practices together; they organize meaning, motivation and engagement around domestic energy practices, encapsulating the notion that 'practices are guided by a direction toward an objective that has a substantial meaning for someone' (Gram-Hanssen, 2010).

Teleoaffective structure as concept paves the way for an interpretation of social practice theory in which emotion plays a more central role. Weenink and Spaargaren (2016) argue that practitioners are emotional agents, who are motivated to engage in or avoid certain practices because practices produce or take away 'emotional energy'. It is important to consider the ways in which the performance of (sustainable) energy practices can be inherently emotionally rewarding to (some) householders. Performance or non-performance of certain energy practices to some extent reflects the normative objectives of energy use held by householder-practitioners, and their emotional experiences of performing those practices. Based on the works of Shove (2003) and Van Vliet et al. (2005) on domestic practices, several established teleoaffectivities can be indicated: comfort, economy, autonomy, sustainability and safety (of supply). In practice, energy practices may be oriented towards and motivated by one or, more likely, a mix of these teleoaffectivities, varying from household to household. We identify these five teleoaffective structures as potential categories which could take a role in explaining why or why not householders feel attracted to certain (performances of) energy practices.

Theories of social practice are used by several social science authors to analyse the present development of energy practices in and around the home. In many cases, the focus is on the emergence and development of one or more specific, situated practices (Gram-Hansen (2010) on standby consumption; Van Dam et al. (2010) on energy monitoring). Hargreaves et al. (2010; 2013) studied in detail how householders monitor energy consumption with in-home displays, revealing a diverse range of responses related to age, gender, interactions between household members and many other factors. However, our aim is not to document the emergence or transformation of separate, singular energy practices in the context of new 'smart energy rationalities' (like investigating the ways in with (dish)washing is influenced by the smart grid). Instead, we address changes in the networks of social practices involved in domestic energy use holistically, focussing on the flexibility instruments that establish new linkages between households and energy systems. Flexibility instruments, goals and strategies are conceptualized as social practice elements which are initially designed by the system actors of the techno-epistemic network, and subsequently appropriated in unpredictable ways in everyday practice by householders. Next, combining the previous two sections, we consider in more detail how consumption practices interact with new smart grid objectives.

2.2.3 Timing and consumption practices

The emerging objective of supply-demand matching has implications for the temporal sequence of electricity-consuming practices in households. Energy consumption practices performed in the 17:00–21:00 evening time-slot contribute to peak energy demand, which is both most expensive and carbon-intensive system-wide. The intermittent and inflexible rhythm of renewable energy generation (solar and wind) shows a mismatch to the synchronized and consistent rhythm of domestic energy practices. But to what extent do householders have the ability and desire to structure their daily energy demand in coordination with renewable energy generation? Hargreaves et al. (2010) encountered resistance in their explorative study: "If the wind fails to blow, would households be willing to go to bed in the dark? Forego cooked breakfast and coffee? ... What would it take to persuade them they could or should do such things? We cannot provide answers to such questions but we can point to the strong resistance to such ideas from our early adopter households—households already engaged and interested in learning more about their energy consumption" (p. 6119).

Southerton (2006) has argued that 'sequences of performance [of practices] can be identified as recurrent and non-reflexive actions'; collective rhythms are, in other words, deeply structured by infrastructures and institutions, and are less so the product of individual timing strategies. At the household level, Southerton (2006) demonstrated that practices produce their own temporal demands, based upon the degree to which coordination or synchronisation with other people or practices is required. Kobus' (2016, p. 30) categorization of practices based on perceived time-criticality (the extent to which timing of a practice is considered important) is a useful starting point for identifying flexibility: some practices are time-critical, such as cooking or watching TV; other practices are not time-critical, such as doing the laundry; and yet other practices, like refrigeration, are continuous. The rhythm of a practice results from the interplay between different social practice elements. For example, the norm for showering has become a daily (morning or evening; or both) rhythm due to evolving norms of hygiene and comfort, as well as ease of access and affordability. The continuous rhythm of refrigeration is the result of practical considerations, normative food safety standards, and technical aspects of cooling infrastructure. Bearing in mind the constrained agency of householders to time everyday electricity-consuming activities, we now present an initial assessment of energy consumption practices based on characteristics relevant to the timing of demand.

The lighting, *heating and cooling of spaces* (or: ambiance practices) are crucial to a home, as it creates a comfortable and 'homely' environment for its residents. For some, 'good' lighting, cooling and heating habits imply frugality and care, i.e. avoiding wastefulness, both for environmental and financial reasons. This normative structure rewards practitioners with positive feelings of 'doing the right thing' for highly routinized actions such as switching off lights in unused rooms, and turning off the heater before leaving the house. Waste not, want not – energy efficiency can be a guiding normative orientation. Seasonality affects the daily rhythms of lighting and heating, which are otherwise highly inflexible: light and warmth are necessary for a home to be a home.

Secondly, practices implied in *cooking, eating and leisure activities* can be clustered together. The pursuit of comfort and relaxation are leading teleoaffective structures in these practices. Food and entertainment practices also play an important role in shaping and maintaining social bonds between members of a household. That makes the timing of food and entertainment practices – for example, at what times people eat together – a matter of (often complex) coordination between household members first; energy considerations likely take a back-seat. Electricity-intensive forms of entertainment like watching TV and video gaming are two more examples of inflexible practices during which people relax and are typically less reflexive of energy issues.

Thirdly, we distinguish a category of activities most commonly associated with 'running a household': *domestic cleaning practices*. Such practices are guided by a social practice rule (when the house is dirty, it should be cleaned), which in practice is mixed with other considerations (a house is cleaned when its residents have time, or when the maid arrives, or when guests are expected, for example). 'Good' performances of domestic cleaning practices involve a certain frequency, care, thoroughness, and to a lesser extent, frugality. 'Cleanliness' practices vary in rhythm, ranging from daily, to weekly to monthly; social interaction is a key factor in the timing of cleanliness performances (Jack, 2016). The performance of a domestic cleaning practice, such as laundering, is itself relatively flexible in time

(Kobus, 2016); it is more so the outcome of cleanliness practices which is time-critical (e.g. a clean house before guests arrive). Table 2.1 summarises the distinctions made above. In Section 4.1, we discuss what challenges and opportunities these clusters of practices present to smart energy systems in relation to demand-side flexibility. The theoretical discussion will be continued and substantiated with empirical insights obtained in two smart grid pilot projects in the Netherlands.

Table 2.1. Clustering of domestic energy consumption practices based rhythmic and other timing-relevant characteristics (assessment made by authors).

Cluster of practices	Appliances involved	Timing-relevant characteristics
Lighting, heating and cooling spaces	Lighting, radiators, heat pumps, air-conditioning, other	• Daily and seasonal rhythm; some daily planning • Light and warmth are requisite; timing is inflexible • Frugality and care (conserving energy)
Cooking/eating and leisure activities	ICT, Audio/video, kitchen appliances, electric cooking, other	• Comfort and control over timing is important • Time-critical, daily rhythm • Less reflexive practices in relation to energy use
Domestic cleaning practices	Dishwasher, washing machine, tumble dryer, vacuum cleaning, ironing	• Frequency, care, thoroughness, frugality • Non-time-critical, daily to weekly rhythm • Some level of (weekly) planning

2.2.4 Analytical framework

In the sections above we discussed the energy (provision) system, in which new objectives emerge, and households, in which energy consumption practices are performed. We propose that through smart grid development, households and energy systems become more deeply interlocked. Figure 2.1 visualizes the dynamic relationship between both. The conceptual framework is used in Section 4 to investigate how the prioritization of demand-side flexibility co-shapes energy practices and householder engagement in smart grids. First, the methods used to inform the Dutch case study are presented below.

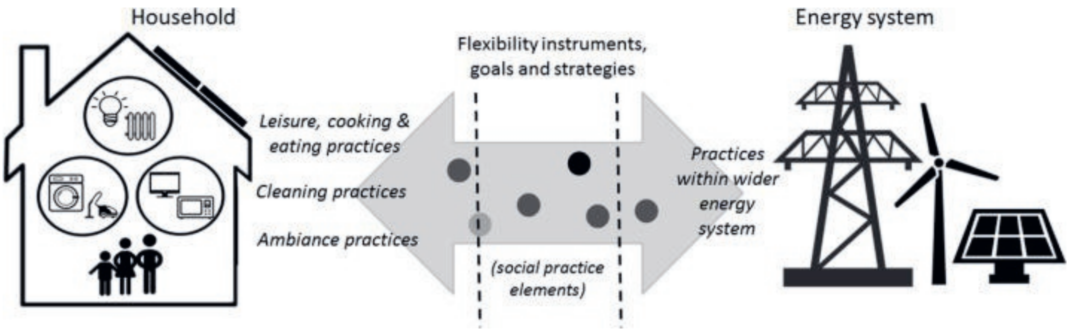

Figure 2.1. Analytical framework: Three clusters of energy consumption practices are performed in households. Their social practice elements are in part (co-)shaped by new objectives in the energy system, and by householders themselves, constituting new linkages between both. This process is mediated in smart grids through flexibility instruments.

2.3. Methods

The concepts introduced above are applied in a case study of two Dutch smart grid pilot projects. Explorative, semi-structured interviews of around 60 min were conducted and recorded, with three householders taking part in the Samen Slim Met Energie pilot project (SsmE, *Together Smart With Energy*) in Haaren, The Netherlands; and with three householders taking part in pilot project *Jouw Energie Moment* (JEM, *Your Energy Moment*) in Zwolle and Breda, The Netherlands. In addition, a small survey among 9 SsmE householders was conducted, and SsmE and JEM project documents were reviewed. A two-hour, semi-structured group interview session was held in September 2015 with 7 SsmE householders (all senior, male members of the local energy cooperative), to gather experiences of participants and to discuss trends and preferences regarding the changing role of householders in the sustainable energy transition. The researcher attended 7 meetings of the SsmE project organization team, functioning as participant observant from an early phase in the project. The interview recordings were transcribed, and along with the notes taken at project meetings were then coded and analysed by identifying key topics, words and phrases, with reference to the conceptual framework.

In the SsmE project, a digital energy platform was co-created by the project partners and participants, all members of a medium-sized energy cooperative and solar panel owners, and the project organizers, with the purpose of testing new forms of cooperation between utility provider and organized households. Several smart grid features were tested, including voluntary time-shifting (without flexible energy tariffs), individual and collective monitoring of energy consumption and production (participants were given energy monitoring devices), information exchange, and energy-themed actions.

The JEM project tested the effects of time-of-use tariffs on time-shifting among around 250 participants, half of whom live in newly built detached houses, and the other half in apartments. All participants received a "smart"[4]; laundry machine, and a monitoring device and app. Domestic energy storage was not part of the studied pilot projects, but its role in demand-side flexibility is considered based on literature. Both smart grid pilot projects are initiated by utility provider Enexis (a distribution system operator or DSO), and ran from 2014 to 2016. It should be noted that in the SsmE pilot project, most feedback to the organizers and researchers was provided by men; in JEM, the active participants were younger and more mixed. Qualitative insights from both pilot projects are presented to first explore time-shifting of energy consumption practices (Section 4.1) and secondly, to explore how differences between households factor into responses to flexibility instruments (Section 4.2); finally, the case study findings are compared to literature and interpreted from an international perspective (Section 4.3).

2.4. Demand-side flexibility: a Dutch case study

2.4.1 Time-shifting energy consumption practices

Smart grid technologies offer new ways to generate the demand-side flexibility sought after by grid operators, so expensive and carbon-intensive peak demand may be lowered. A practices perspective on demand-side flexibility is presented below to develop a deeper understanding of potential matches and mismatches between flexibility instruments and the various practices which make up daily life. In Table 2.1, domestic energy practices were clustered. The three clusters – heating and lighting spaces, leisure and cooking/eating, and domestic cleaning activities – are related in Table 2.2 to demand-side flexibility.

[4] A smart laundry machine is Wi-Fi-connected can be programmed to use energy data for pre-planned or automatic use, and can be remotely controlled and monitored.

Table 2.2. Clusters of domestic energy practices, demand-side flexibility potential and possible flexibility instruments and strategies (author's assessment, based on the two Dutch smart grid case studies 'JEM' and 'SsmE').

Cluster of practices	**Flexibility potential**	**Possible instruments and strategies for flexibility**
Lighting and heating spaces	Medium	• Automated demand response via direct remote control, flexibility contracts
Cooking/eating and leisure	Low	• Smart refrigeration
Domestic cleaning practices	High	• Dynamic energy pricing incentives

The *lighting, heating and cooling of spaces* is the largest contributor to domestic energy consumption. In the JEM pilot project, homes were fitted with an electrical heat pump and floor heating. The householder participants themselves had requested 'smarting' of their heat pumps, to aid them in their efforts to time-shift demand in coordination with the dynamic energy tariff. Several months after installation, 34 out of 38 households had not switched off the 'smart' functionality of their heat pumps, citing cost-saving without loss of comfort as their main motivation (Kobus et al., 2014). Smart heat pump floor heating systems certainly afford householders the opportunity to micromanage their heating-related demand – with thermostats in most rooms, setting temperatures per room is possible in the JEM trial –, yet householders in the JEM trial nonetheless requested smart functionality to support time-shifting. In the SsmE pilot project, a small survey among 9 participants also indicated that householders see little possibility to be actively flexible in lighting and heating. The potential for active demand-response to price signals of these practices appears to be limited. Greater flexibility gains may be generated outside of continuous incentivized household participation (Enexis, 2016); (smart) heat pumps can be set to prioritize operation for hours when electricity costs are lower, or reducing demand during peak demand on the basis of price signals and forecasts (Hedegaard and Balyk, 2013). Householders may in the near future have the opportunity to sign up for a discounted energy contract which includes a flexibility clause, essentially authorizing grid operators to remotely and directly manage demand (see e.g. Schik and Gas, 2015), for example by fluctuating 'smart' electric boiler temperatures (appliances such as fridges and freezers may be 'smarted' and linked up as well, e.g. via smart plugs). Such arrangements would generate flexibility without the need for active time-shifting by householders (Ea EnergiAnalyse, 2015).

However, not all group discussants were convinced of the primacy of the time-shifting problem over other sustainability issues. SsmE participant Mr. Wellink for example, prioritizes the purchasing of energy efficient appliances and lighting, over smart appliances and gadgetry for the purposes of flexibility:

> *'I believe that it is important that when you buy appliances, that they are as energy efficient as possible.'*

The practices that make up *leisure activities as well as cooking and eating* represent few opportunities for time-shifting. Half of the small survey respondents indicated flexibility in charging ICT; since laptops, phones and tablets have energy storage of their own, their use is mostly independent from the charging. The same applies to cooking: most respondents indicate a preference for not shifting the time of use of their oven, microwave, and electric stove. This is an indication that householders consider control over the timing of their cooking and eating practices as important and are probably less likely to respond to price incentives. The interviews support the notion that the family coordination required in households with children during 'family peak' periods reduces the ability of those households to time-shift energy demand (Nicholls and Strengers, 2015). In general, it appears to be important for residents to be able to ignore the price incentive at certain moments or in certain situations. Mrs. De Jong, participant in JEM, indicated that she did not experience constraints on her autonomy, as she would ignore the timing of use advice occasionally:

> *'The system does not limit you; you can choose if you want to take part or not, making use of cheaper moments. But you can also say: "that doesn't work for me today." I feel no constraints by the system.'*

> *'It totally doesn't feel like a command, "now you have to use energy at the right times", not at all. I do that completely voluntarily. But in the back of my head, we maintain that when we need to do our laundry, we do it. So, we keep that flexibility.'*

Cooking, eating and leisure practices contribute especially to the evening peak energy demand. The expensive and carbon-intensive electricity required for these inflexible practices may instead be suitably provided through domestic energy storage charged with cheap solar power during the day. The consistent energy demand of refrigeration (freezers, fridges), however, does provide opportunities for flexible demand-response. Smart freezers and fridges will be able to respond automatically to price signals and make small and safe adjustments to the cooling temperature.

Domestic cleaning practices appear to offer the best entry points for householder involvement in energy supply-demand matching, probably due to the absence of time-criticality (in comparison to dinner times, for example) in combination with the relatively infrequency and high energy-intensiveness of such practices. All survey respondents reported that the use of their laundry, tumble-drying and dishwashing machines is (in theory) flexible, an indication supported by other studies (Linear consortium, 2014). Vacuum cleaning and clothes ironing were considered somewhat, but less flexible. In the Your Energy Moment pilot project, participants mostly time-shifted the use of their washing machines, tumble driers, and dish washers, from the evening peak to other times of the day (Kobus, 2016). Interesting to note is that although the participants all received smart laundry machines which could automatize the time-shifting, a majority (around 80%) of the 250 project participants did not use the function and still preferred to operate the laundry machine manually. Mrs. De Jong reflected on her laundry practice as follows:

> *'In the mornings, I like to check the display to see at what times the cheaper energy tariff will apply – usually that is until 20:00, then I know that I should finish washing and drying clothes before then.'*

> *'But in the course of the day I also check – is the sun shining? Okay then I do the laundry now, now the sun shines. Then it [the tariff] automatically goes down. … That is the fun of the whole project'*

After a brief learning phase at the start of the pilot, in which she and her husband explored the functionalities of the energy management device, energy rhythmicity was internalized in the washing practice of Mrs. De Jong with relative ease. In subsequent performances of the practice, she relied on her intuition, visual cues, and past experience to time her laundry practice. Of the 20% of participants who did use the 'energy computer', 90% programmed their laundry machine to switch on when electricity is at its cheapest; the remaining 10% chose the 'use (own) sustainable energy' mode. Ultimately, adding up all demand-matching efforts, 35%

of the energy used in Mrs. De Jong's residential block could (virtually) be provided by the residents' own solar panels.

The willingness to time shift certain practices, as displayed in the JEM pilot project, illustrates that a well-implemented timing-of-demand scheme can mobilize practitioners to take up and internalize new elements into established energy practices. Mr. Leenders reflected:

> *'After a while I wasn't concerned with it [the home energy management device]. It is a variable tariff, it changes every 15 minutes, but still – you learn the patterns.'*

Mr. Leenders (participant in JEM) took the new energy context into account when purchasing a dish washer:

> *'We bought a dish washer specifically with delayed-use functionality, so that it can operate in the night. That is how I adapted because of the pilot.'*

In time, residents may achieve a certain level of energy literacy at which point timing-of-demand advice and active monitoring is no longer deemed necessary. Mr. Dijkema (participant in SsmE):

> *'Now, when the sun shines, I can predict reasonably well how much power my solar panels are generating. And when the children are home and the laundry machine is running, I can estimate our energy consumption. So, you gradually check [the digital energy platform] less and less over time.'*

2.4.2 Flexibility in relation to established engagement with energy

How does 'flexibility' as emerging teleoaffectivity interact with other teleoaffective structures associated with energy use, including comfort, economy, autonomy, sustainability and safety? Continuous engagement with energy for the purpose of demand-shifting may not be expected in households for whom comfort is their primary motivator in their interaction with energy. If little comfort is sacrificed, households motivated primarily by cost-saving may be expected to be open to flexibility contracts and automated demand response; especially if little effort on behalf of the residents is required, the financial benefits are clearly communicated, and if safety of supply is not in danger. In the group interview, Mr. Dijkema related flexibility in energy use to loss of comfort:

> Mr. Dijkema*: 'I think a likely scenario is that a comfort level, with a price, will be implemented; do I want to pay for it or not, otherwise you have just a little less comfort. Then you will not quite be able to switch on that deep-fryer, or lights. And then you pay for a higher comfort level, ICT will calculate that and arrange that you pay a bit more for it.'*

The households participating in SsmE own solar panels and are motivated by a desire to become self-sufficient and autonomous; therefore, there was the expectation that they would be interested in optimizing self-consumption through timing-of-use. However, demand-side flexibility schemes seem to create new types of grid dependency (whether it be flexibility contracts, automated demand response, or market-based dynamic energy pricing incentives). A utility-driven regime of active supply-demand matching seemed unappealing to group discussant Mr. Veenstra:

> Mr. Veenstra: *'People should not be steered, machines should. Because as a person in your home you should not look all the time if it's cheap or expensive, that should be automatic.'*

The SsmE pilot simulated a decentralized, (semi-)autonomous grid context. The pilot project organizers attempted to engage residents in timing-of-use with a narrative of 'using the energy we produce ourselves'. The hypothesis was that if a convincing and clear connection between time-shifting and energy autonomy is formulated, the members of the energy cooperative would become engaged in matching their demand to local energy supply. This communication strategy was adopted by the SsmE pilot project team (SsmE meeting, 2016). To test if households could be collectively persuaded (without financial reward) to shift demand towards 'energy autonomy' (demand matching own renewable energy generation), the utility provider and leaders of the energy cooperative (called *DEH)* organized a campaign as part of the SsmE project: the "week of *DEH* energy". Despite extensive communication towards the participants about the DEH-energy week and the things households could do to take part, no effect was measured on the energy consumption curve (Enexis, 2016). The campaign week engaged few households to go beyond their regular efforts; only 5 of the most engaged participants indicated that they paid more attention to energy that week.

The desire for energy autonomy alone did not motivate even these few highly energy-literate households to align their demand with renewable energy supply (group interview SsmE, 2015).

The discussion members – all frontrunners of the energy cooperative – had clearly formulated own ideas regarding sustainable energy provision and consumption, which became apparent during the discussion. Some of them indicated that they believed that their established practices were already as 'good' as they could be; others challenged the superiority of the demand shifting approach over investing in renewable energy generation and energy efficiency measures. Ms. Spoel, JEM participant, does not believe her time-shifting efforts make her household 'greener' on the whole:

'If I am honest, to me that [grid balancing to cope with renewable energy transition] is mostly a technical story.'… 'Honestly, we are not greener than before.'

If a persuasive 'grid balancing facilitates green energy transition' narrative is lacking, these residents may be expected to be less inclined to actively time-shift their energy consumption purely for (minor) financial gain. They may prefer instead to stick to established forms of 'green engagement' with energy (frugal use, green energy contracts, replacing energy inefficient appliances, etc.). Flexibility, in other words, as emerging normative orientation, practical sensibility or 'project', competes with established teleo-affective structures which already motivate householders to engage with energy in a variety of ways.

2.5 Discussion

2.5.1 Case study in context

Interpreted in social practice terms, the ways in which flexibility instruments attempt to establish a shift in goals of energy use become apparent. Time-shifting represents a new avenue for engagement with energy at home, and a new overarching goal-orientation and source of positive feelings derived from 'doing things right'. Flexible energy pricing introduces a new (or old) principle into pre-existing practice rules: the notion that timing of energy consumption is relevant and valuable. The new 'rules' are intertwined with new practical understandings (e.g. how to incorporate a visual cue, the shining sun, into the performance of laundry practices) and teleoaffectivities. Functioning as a kind of 'moral economic signal' (Nyborg and Røpke, 2013), the time-of-use tariff rewards and motivates householders to mind the timing of their energy consumption practices, and is made meaningful through design (e.g. happy or sad emoticons displayed on in-home displays). The 'teleos' or goal of demand-side flexibility is linked discursively (in instructions) and intuitively (in design) to facilitating the renewable energy transition. In the two case studies presented above we have attempted to showcase how and to what extent, among two particular household groups, flexibility indeed became part of domestic energy practices; certain practice-specific dynamics (Section 4.1) and established teleo-affective structures of energy use (Section 4.2) were found to be important factors in *why* flexibility is achieved or not.

The case study findings match past studies in several ways: Nyborg and Røpke's (2013) assessment of the Danish 'eFlex project' also showed that active time-shifting by householders mostly boiled down to postponing laundry and dishwashing (typically to night-time); further demand-side flexibility was generated mostly through technology ('smart' appliances, power nodes, and heat pumps) instead of active participation, which decreased over time. Householders often disengage with smart energy technologies in the longer term (Hargreaves et al., 2013); the same occurred in the case study, but flexibility did remain part of practices such dishwashing and laundry. Reviewing reports from the Danish Smart Grid Network, Schick and Gad (2015) conclude householders are severely constrained in their ability to become the 'flexible electricity consumers' imagined the techno-epistemic smart grid network; the flexibility householders can realistically generate by active timing-of-use of appliances is too small to be relevant for Danish grid operators. It seems fair to conclude that the 'temporal demands' (Southerton, 2012) of domestic (energy) practices themselves greatly complicate attempts to introduce flexibility in energy demand.

While we argue that the two analysed pilot projects are reflective of smart grid development in the Netherlands (in being DSO-led and demand-side flexibility focused), empirically, we only scratched the surface. More research is needed to assess how the interaction between household and smart grid plays out in various (international) contexts; which energy practices settle, and to what extent flexibility, sustainability and other goals are achieved. This small case study could only uncover some of the dynamics involved. Thankfully, a growing body of research of smart grid-type projects across Europe is revealing more, and emphasizing other aspects at play when households are fitted with smart energy technologies for the purpose of generating demand-side flexibility. Barnicoat and Danson (2015) indicate difficulties specific to engaging older householders in timing-of-use. Nicholls and Strengers (2015) reveal how the coordination of practices between family members in time and space constrains demand-side flexibility during the 'evening peak', a dynamic also picked up by Nyborg and Røpke

(2013). Skjølsvold et al. (2017) emphasize internal household dynamics between men and women: drawing on two Norwegian smart grid demonstration projects, feedback was found to 'trigger' learning amongst eager men while alienating or excluding women. These age, family and gender related dynamics should also be considered key factors in the ability of householders to be flexible in energy demand. The different perspectives taken by these studies in different empirical contexts together contribute to a more empirically and theoretically grounded understanding of how, what, and why energy practices emerge in smart grids, including opportunities and limitations for flexible domestic energy demand.

2.5.2 Developing low-carbon energy consumption practices

To what extent does the shift in objectives towards flexibility, as implemented in the two studied smart grid trials, constitute a step towards more sustainable energy consumption practices?

In the JEM pilot project, the time-shifting of laundering and dishwashing had very limited impact on the aggregate consumer demand curve (Kobus, 2016). Trends towards the further electrification of daily life, especially in the sphere of mobility (EVs) and electrified heating, however, ensure that demand-side flexibility will remain high on the agenda of grid operators in the years to come. Potential benefits of engaging households in timing-of-demand, beyond the immediate peak-shaving achieved, include enhancing understanding among consumers of what drives energy demand and supply, and greater familiarity with automated demand response. For example, the time-shifting of cleaning practices, as most applicable 'entry point', generates know-how and affinity, which may transfer to other energy practices that could play a role in (local) supply-demand matching. Responding to new electricity price incentives is a skilled activity; evidence suggests that feedback is a key factor in achieving energy conservation at peak times and overall, as it enables householders to embark upon a learning process and pick up new skills (Jessoe and Rapson, 2014). The Danish eFlex project successfully developed householders' interest in flexible timing-of-use, while also boosting energy savings (Nyborg and Røpke, 2013).

Still we argue that flexibility instruments risk 'overriding' the sustainability frame-of-reference of energy practices. Flexibility instruments should not only appeal to rational decision-making and calculation, but should also be energizing, motivating and intuitive – particularly considering that the financial rewards for active engagement in demand shifting may be marginal. If such instruments align with the realities of everyday domestic life (practice-specific), and attune to the normative orientations which motivate households to engage with energy, they may be more effective in transforming established domestic energy practices. To illustrate, time-shifting may appear less of a daunting task to residents if the 'story' accompanying flexibility instruments focuses on (and exemplifies) domestic cleaning practices. A balance should be sought between orchestrating demand-side flexibility and maintaining other forms of green engagement with energy – energy conservation in particular. While domestic batteries contribute flexibility to the electricity grid, "home energy storage would not automatically reduce emissions or energy consumption unless it directly enables renewable energy" (Fares and Webber, 2017), due to storage inefficiencies and operation of the device. Smart energy practices draw upon new meanings, objects, rationalities and teleoaffectivities which are emerging in smart grids; in this unpredictable and complex process of emergence, it is important to preserve a sustainability frame-of-reference so that a range of sustainable energy consumption behaviours will still feel good, logical, intuitive, and rewarding. This makes it a matter of concern that "many actors consider the smart grid path as a way to develop new business and growth opportunities for the ICT sector and that they emphasise comfort and convenience for the 'users of the system"' (Nyborg and Røpke, 2013, p. 668); smart energy technologies may end up failing to reducing energy consumption by creating unforeseen energy practices (Geels and Smit, 2000).

An additional concern is social sustainability. Ballo (2015) argues that the concept "consumer flexibility" entails commodification of individual behaviour in households. Householders 'offer flexibility' to system operators in exchange for economic benefits. "However," Ballo continues, "this is not necessarily a fair trade; different households will have various financial situations, and financial incentives and price tariffs as a means to achieve desired behaviour change will hit some households harder than others" (p. 15). Considering that "an incentive not reacted upon inverts to a penalty" (Throndsen, 2017), financially vulnerable households may end up feeling forced to adapt.

Finally, demand-side flexibility as emerging objective represents a particular vision of sustainable domestic energy which is not uncontested. The 'co-managing householder' ideal is met with a diversity of end-user engagements with energy. For example, smart home advocates and 'off-gridders' are motivated by alternative visions of sustainable energy consumption and provision, both of which problematize the lifestyle championed by others. Strengers (2015) reflects: "[these competing visions and lifestyles] remind us that what is considered sustainable and pleasurable, and how these ideals are pursued, is a highly contentious and ongoing project." For these reasons, we believe that it is important to evaluate critically the specific ways in which prioritization of demand-side flexibility conflicts with other forms of sustainable householder participation in smart grids.

2.6 Conclusion

This article investigated recent shifts in goals concerning domestic energy uses. We posed the question: What shifts in objectives of energy management are implied by smart grid development, and how does such a shift influence the existing constellation of domestic energy consumption practices? For that purpose, a conceptual framework was developed which addresses how domestic energy consumption practices and practices within the wider energy system are interlinked and co-evolving. We studied two DSO-led smart grid trials involving householders in southern Netherlands.

The case study and literature review lead us to conclude that smart grid development constitutes a shift in objectives towards the balancing of (renewable) supply and demand in energy grids. Flexibility instruments are key components of smart grids which organize and mediate the deepening interlinkage between energy use in households and grid management. The return of rhythm in domestic energy practices is characterized by a teleoaffective structure which introduces the principle of 'timing' and motivates time-shifting of demand, codified in new practice rules as flexibility instruments (notably time-of-day pricing), and materialized in domestic energy storage, real-time monitoring devices, smart plugs/power nodes, and smart appliances. The interviewed householders typically make sense of the imperative of demand timing by adopting new practical understandings such as 'sun shining at midday means my electricity is cheap and green, so I can use the laundry machine now'.

To reveal the flexibility potential of domestic energy consumption, practices were clustered into ambiance practices, cooking/eating and leisure practices, and domestic cleaning practices. These three clusters were found to show different openness to new rhythms, and interact with flexibility instruments in different ways. Ambiance practices do not suit active demand response, yet flexibility may feasibly be generated through automated demand response and flexibility contracts. Cooking/eating and leisure practices are inflexible, with resistance to time-shifting to be expected. Domestic cleaning practices are distinct, energy intensive, and typically consciously timed activities, and therefore constitute the most appropriate entry point for demand-response in the household.

We then explored how timing-of-demand relates to established ways of engaging with energy at home. Flexibility appears to compete with established teleo-affective structures (autonomy, sustainability) which already motivate householders to engage with energy in a variety of ways. The case study findings suggest that in pilot projects, communication with householders about time-shifting of energy demand may be more successful if the renewable energy transition context, from which the need for flexibility stems, is emphasized. More generally, if smart grids are to actively engage a broad audience of householders, smart grid innovations should enable and incentivize householders to engage in a plurality of sustainable energy behaviours, ranging from daily energy conservation, to energy efficiency upgrades and investment in renewable energy, to active and automated supply-demand matching.

Yet, there are apparent limitations to demand-side flexibility: householders are severely constrained in their ability to time-shift energy consumption practices (see e.g. Schick and Gad (2015); Nicholls and Strengers (2015). Flexible energy consumption represents *sustainable* energy consumption only to the extent to which 'flexibilization' helps relieve grid constraints on the growth of renewable energy, and reduces the need for carbon-intensive back-up generation. The question remains to what extent sustainable energy practices should take the shape of demand-response, which is only one of many ways of generating system flexibility, in addition to other valuable forms of householder participation potentially enhanced by smart grids. Low-carbon engagements with energy in the household should be safeguarded from flexibility instruments that seem to reduce this engagement with sustainability goals into grid management practices performed for financial benefits only.

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Chapter 3

Householders co-managing energy systems: space for collaboration?

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Chapter 3: Householders co-managing energy systems: space for collaboration?

Abstract

The potential role of households as 'co-managers' of energy in smart grids is widely discussed in the social science literature. Much remains uncertain about the social relations and practices emerging around novel smart grid technologies and their contribution to sustainability. Drawing on 14 'show-and-tell' home tours with householders in a smart grid trial, an analysis is presented of how home energy management (HEM) is performed in everyday life. The focus is on three technologies: monitoring technologies, smart heat pumps and home batteries. How and why householders do (not) engage with energy management during the pilot project is described. When householders participate in HEM practices, they gain energy management understandings and an awareness of smart grid objectives. Since HEM practices are shared between householders and actors from the energy provision system, they display particular ways of distributing responsibilities, power and agency over technologies, experts and householders. The time and space granted to these three smart grid technologies are shown to depend on the trust relationships between householders and the more or less absent providers of technologies and services. These insights emphasize the need to develop smart grid solutions reflexively with respect to the different spaces and practices in households in which they operate.

Householders Co-managing Energy Systems: Space For Collaboration?

Graphical abstract

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September 2018

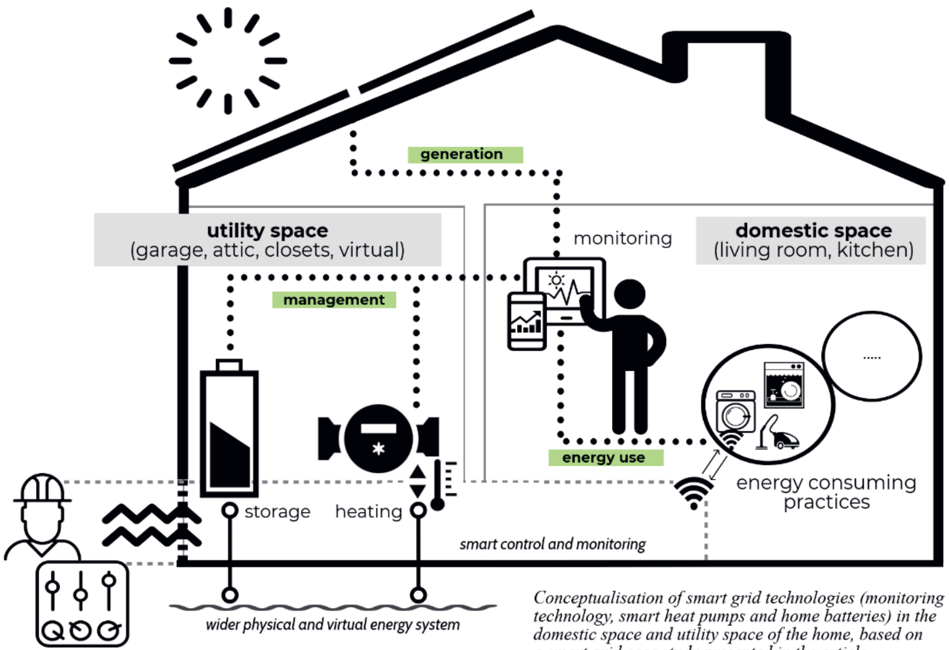
Highlights

1. When performing Home Energy Management (HEM) practices, **householders learn** about new energy management skills and objectives.

2. HEM-practices display ways of **distributing responsibilities**, **power** and **agency** over technologies, providers and householders.

3. Connecting homes to smart grids entails an **expanding utility space** in households.

4. The time and space granted to the three smart grid technologies in homes are shown to depend on the **trust relationships** between householders and – more or less absent - providers of technologies and services.



Conceptualisation of smart grid technologies (monitoring technology, smart heat pumps and home batteries) in the domestic space and utility space of the home, based on a smart grid case study presented in the article.

3.1 Introduction

Smart grid trials experiment with new forms of collaboration between householders and energy service providers for the purpose of better aligning renewable energy generation and demand (Goulden et al., 2014; Naus, 2017). Decentralization, decarbonization and digitalization are supposed to work together in a transition towards a smarter and more sustainable energy system in which households play a bigger role in managing electricity supply and demand. Energy utilities and market actors are exploring new technological applications and business models, which range from better information provision to technologies that offer householders greater control over appliances and domestic energy flows.

From a householder's perspective, smart grids imply a deepening of the relationship with energy as part of daily life. Householders in smart grids would not only be consumers and producers of electricity (also known as prosumers; typically households with rooftop solar panels or a stake in wind turbines) but also gain a role in the *management* of electricity supply and demand. Their main contributions in this respect are to realize a better matching of energy use with the availability of self- or locally generated, low-carbon energy and to take part in the trading of surplus energy (Geelen et al., 2013). Variable energy tariffs, remote control of appliances, home batteries, connected heating systems and smart charging of electric vehicles are all strategies that are being explored in smart grid pilot projects. This wide range of technical solutions encompasses a diversity of potential new roles for householders (*e.g.* as energy trader or sharer, as storage provider) and new everyday practices related to home energy management (HEM).

However, much remains uncertain about these new householder roles and practices, and various concerns have been raised. Numerous studies demonstrate that householders are limited in their ability to time-shift many of their energy-consuming practices, with the exception of more flexible practices such as laundry and dishwashing (Klaassen et al., 2016; Nicholls and Strengers, 2015; Powells, et al.,2014; Smale, et al., 2017). The need for family coordination and moments of relaxation or 'switching off', as well as the technologies in our homes, age and gender (Palm et al., 2018), all factor into the socio-temporal coordination and socio-material structuration of everyday practices (Shove, 2009), which limits demand-side flexibility of energy use. Technology-driven, automating solutions for HEM in smart grids also face challenges. Technology-centred solutions may imply 'unwanted types of control' for householders (Hansen and Hauge, 2017; Hargreaves et al., 2015), drawing attention to the trust relationship between households, utilities and market actors in smart grids. Evidence suggests householder trust and interest is easily lost in smart grid projects (Verkade and

Höffken, 2018). Smart technologies also risk increasing energy consumption (Hargreaves, et al., 2018) and sustaining energy-intensive ways of life (Herrero et al., 2018); locking householders into passive consumer roles (Strengers, 2013).

To summarize, both dominant visions of smart grid users are problematic: the fully integrated, 'automaton' smart grid participant, as well as the passive participant serviced by automating technology (Goulden et al., 2018). It remains uncertain how HEM can become a feature of more sustainable energy systems and domestic lifestyles in ways that are actively supported, enacted and appreciated by householders.

The present authors hypothesize that the specific ways in which energy management powers and responsibilities become distributed across households, smart grid technologies and experts will have consequences for whether or not smart grid pilot projects manage to achieve their goals. Among these goals are: realizing higher levels of sustainability, reliability and affordability in the energy system; stimulating demand response and reduction together with households; and generating trust in providers of energy services and technologies. To examine this hypothesis, an in-depth case study is explored: a smart grid project in the Netherlands, and an analysis is undertaken of how (smart) energy management is being performed within a number of selected households. The research questions addressed are as follows:

- How do HEM practices distribute power and responsibilities for their performance across (smart grid) technologies, (distanced, expert) energy service providers and (lay) domestic actors/householders?
- How is trust between householders and providers established and sustained in the context of HEM practices?

The paper is structured as follows. The next two sections provide the conceptual framework and the methods used to organize the empirical research. The focus is on social practices developing around three key smart grid technologies: monitoring technology, smart heat pumps and home batteries. The fourth section presents the results of the empirical research among a group of householders who took part in a smart grid pilot project involving these technologies. This shows that the social practices developing around the three selected smart grid technologies are 'split' between householders, technologies and experts in different ways, with varying and important consequences for householder engagement. The forms of householder (non)-engagement and the character and fragility of emerging trust relationships between householders and providers are presented and discussed in the fifth section. The final section discusses the key findings in the broader perspective of householders (co-)managing domestic energy systems.

3.2 Home energy management (HEM) in smart grids

Building on Naus (2017), this section considers a social practice approach to HEM. Novel energy management or smart grid technologies enable and co-shape new energy practices (Herrero et al., 2018). Through a social practices lens, key challenges surrounding the social embedding of smart heat pumps, home batteries and monitoring technology come into focus. By examining these three distinctive smart grid technologies, a better understanding can be generated of how such technologies co-shape roles for householders, and how they affect social relations and routines in different ways. Furthermore, inspiration is drawn from the work of Anthony Giddens on expert systems (Giddens, 1990) to discuss in more detail the role of trust between householders and providers of smart grid technologies.

3.2.1 HEM: a social practice approach

Social practice theory, which has been developed over the last decades within the sociology of consumption, places shared, routinized types of behaviours at the centre of analysis (Warde, 2005). When applied to social practices of the production, consumption and management of domestic electricity in a domestic or decentralized setting, such practices may be understood as *energy practices* (Van Vliet et al., 2016). It is useful to distinguish between energy *consuming* (or consumption) practices – such as doing the laundry, watching television or cooking – and HEM practices (Naus, 2017). What separates HEM practices from domestic consumption practices is 'the fact that they are specifically focused on the management, steering or governance of domestic energy flows, technologies and infrastructures' (p. 125). These practices include energy monitoring, co/self-production of energy, energy sharing or trading, timing of demand, energy storage and energy conservation.

HEM practices are constituted by different social practice elements, which, for the purposes of the present analysis, we hold to include general and practical understandings, rules and teleo-affective structures (Schatzki, 2002), as well as technologies (Gram-Hanssen, 2011). Teleo-affective structures hold practices together by organizing meaning, motivation and engagement around domestic energy practices. These elements embody and invoke novel energy management objectives in everyday domestic consumption practices, co-shaping new normative sensibilities of 'how to do things right' with energy in the home (Smale et al., 2017). When new understandings interact with established teleo-affectivities surrounding domestic energy (such as conserving energy), (some) domestic consumption practices can become imbued with energy management teleo-affectivities, reframing them as energy-consuming practices (Smale et al., 2017). Moreover, HEM practices interconnect domestic consumption practices and systemic practices in ways that *distribute* energy management activities, technologies, understandings, teleo-affectivities and responsibilities between households, system actors (experts, providers) and smart grid technologies. Therefore, it is appropriate to place HEM practices 'in the middle' between households and the energy system, as depicted in Figure 3.1. By doing so, it is possible to separate households from energy systems, despite (domestic energy) infrastructure being an integral element of energy practices. This approach can be analytically productive as this production–consumption divide mirrors the still dominant demand-management paradigm in the energy sector (Strengers, 2011), and allows for 'zooming in' on the specific ways householders encounter energy systems in daily life. The matter of the blurring of production and consumption boundaries is considered further below in the analysis and discussion sections.

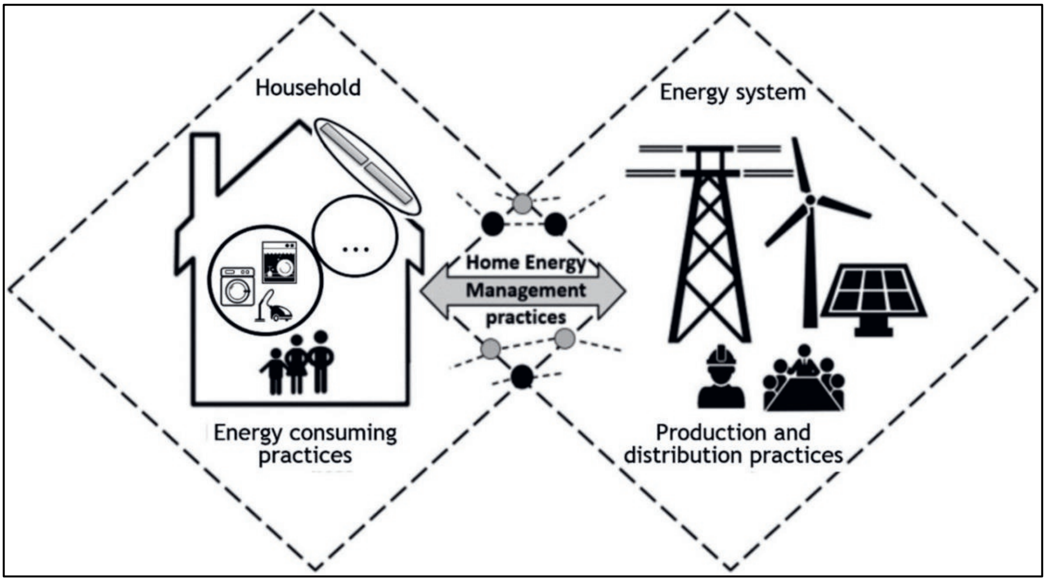


Figure 3.1. Conceptual framework: emerging home energy management (HEM) practices at the interface between the home and wider energy systems. Source: Adapted from Naus (2017, p. 125).

3.2.2 Zooming in on monitoring, heating and storing energy in smart homes

This section considers three smart grid technologies that feature in the case study. These technologies are widely seen as components of smart homes (SH) in decentralized, low-carbon energy systems (Darby, 2010): low-temperature, connected heating systems (smart heat pumps); domestic energy storage (home batteries); and enhanced energy feedback (in-home displays (IHDs) and online platforms).

Their functions in the smart grid vision can be described as follows: smart heating systems automatically shift (a portion of) the electricity demand for heating to those times of the day and night when (green) electricity is abundant and cheap. Storing electricity in domestic batteries bridges part of the gap between the daily availability of renewable energy and peak electricity demand. Enhanced energy feedback equips householders with: “the information they need to help reduce their overall energy consumption, shift it away from periods of peak demand, and/or respond flexibly to periods of ‘over’ supply” (Buchanan, et al., 2015, p. 89).

Together, these technologies are thought to facilitate the renewable energy transition by enhancing the flexibility of electricity demand by users and domestic devices, and by increasing local storage capacity. However, challenges emerge when feedback devices, domestic energy storage and smart heat pumps become enveloped in domestic practices.

3.2.3 Social embedding of energy monitoring, heating and storing energy in smart homes

Over a decade of research has tackled the various challenges of energy monitoring technology. It has become apparent ‘that the information [IHDs] provide needs to be clear, transparent and flexible […] in order that it can be easily related to everyday practices and contextualised’ (Hargreaves et al., 2010, p. 6118). Monitoring can be performed as a practice in its own right, but other HEM practices (such as smart heating and storing energy) also presume some form of monitoring. Householders accomplish, handle and use new information flows in relation to existing (sets of) domestic consumption practices (Naus, 2017). Enhanced energy monitoring is only effective, in other words, when meaningfully interwoven into everyday domestic practices.

This contrasts with the way in which smart-controlled heat pumps take energy management responsibility out of the hands of householders. Smart heat pumps present householders with a new form of outside intervention in domestic practices. In response, householders often develop coping strategies to deal with the different heating and cooling dynamics of heat pumps, which so far has resulted in less energy demand reduction or time-shifting than expected (Nyborg and Røpke, 2013). Householders do not use their heat pumps as intended and actually 'tamper with their pumps in "innovative" ways' (Shick and Gad, 2015, p. 55; see also Nyborg, 2015). The professional practices of supply-side actors (e.g. advice, provision and installation) co-shape the residential comfort, know-how and use, as well as the material integration of heat pumps into homes (Gram-Hanssen et al., 2017).

Home batteries, increasingly part of the SH vision, seem to offer householders little to no room for interaction. Here too the professional practices of supply-side actors crucially determine the operation of batteries; at the time of installation, householder preferences can be translated into the algorithm governing the battery's charge and discharge strategy. Yet, home batteries appear to be more socio-technically open-ended when compared with heat pumps: energy storage has the potential to generate different kinds of energy practices, for example, the trading or sharing of energy between (distanced) householders or within a community, or collaborating with utilities or energy market actors to provide net-balancing services (Kloppenburg et al., 2019).

The social relations and practices surrounding each of these technologies differ significantly. All three (attempt to) govern domestic energy flows in particular ways and to achieve specific energy management objectives. Monitoring technology aims to support HEM by becoming integrated with and interwoven into everyday domestic practices, whereas smart heat pumps and (potentially) home batteries effectively seek to relieve householders of 'energy management duties' by connecting HEM with some form of remote, external control. The issue of *trust* is brought to the fore by the fact that external actors acquire remote access (via information and communication technology - ICT) to the home on which smart technologies depend.

3.2.4 Trust in HEM practices

'Considering the notion of "home" and its characteristics, access to the private sphere is based on trust', argue Hansen and Hauge (2017, p. 120). Often, however, arguments about trust and engaging the public are used to suggest better communication strategies that ultimately aim at 'acceptance' (*e.g.* Park et al., 2014): a kind of idealized, disengaged end-goal in the relationship between householders and energy systems. In contrast, De Wilde and Spaargaren (2018) emphasize that trust between householders and energy system actors involves continuous work and affirmation. To better conceptualize emerging trust relations, it is productive to view smart grid technologies as extensions of an emerging *expert system* (Giddens, 1990) – the 'smart grid' – extending into the sphere of the home. Giddens identifies three factors that are important when lay people make judgements about the trustworthiness of expert systems: (1) trust in the people running the abstract system; (2) trust in the sciences, principles and technologies being operated in the abstract system; and (3) the past performance of the system in terms of failures, breakdowns and scandals. These factors are highly relevant for our analysis of trust. As an expert system, the 'smart grid' features an ongoing relationship between lay people and expert operating at a distance from the home. These experts select and shape the understandings, and teleo-affectivities that govern householder participant in the abstract system, as well as the technologies that mediate these on to householders. In smart grid pilot projects, objectives are derived from the system rationality of grid management (which may (not) align with domestic practices; Smale et al., 2017). Importantly, the social relations and practices of monitoring technology, smart heat pumps and domestic energy storage differ significantly. Smart heat pumps, for example, operate through remote control by an expert system and work best with no householder interference, whereas IHDs are intended to empower householders to take ownership over their energy affairs. Depending on how energy storage is configured in practice, householders may be recruited by utilities or market actors as 'distributed energy resources' (Pallesen and Jacobsen, 2018), or, at the other end of the spectrum, they may use energy storage to achieve self-determined goals such as energy self-sufficiency or autonomy. These technologies embody different visions of 'smart grid users', and are consequently likely to spark very different trust dynamics. These we intend to tease out in our analysis.

3.3 Case study

Smart grid pilot Jouw Energy Moment (Your Energy Moment, or JEM), which ran in 2012–18, was initiated by a Dutch distribution system operator together with a consortium of energy service providers, technology and software companies, and knowledge institutes involved in smart grid development. The research presented in this paper was conducted in the second phase of the pilot project, with a majority of participants 'carried over' from the first phase. The two phases are briefly described below.

3.3.1 JEM: voluntary and technology-assisted energy management

The goal of the first phase of the JEM was to see if and how householders may be recruited into demand-side management. In other words, if householders could be motivated to seek out 'their energy moment' in the day, so that more renewable energy is used locally when it is available. For this purpose, householders were provided with an in-home energy monitoring display, a smart laundry machine and a time-of-use tariff. In terms of engaging householders in timing of use, the project was considered a success, with some 'peak-shaving' being achieved; however, taken as a whole, much community management and customer service was required to elicit minor benefits to grid management (Klaassen et al., 2016).

Phase 2 of the JEM comprised three participant groups in two towns in Noord-Brabant, the Netherlands: 39 households in a new build all-electric SH neighbourhood in Teteringen (purpose built for the smart grid trial); and 18 households residing in retrofitted homes (RH) in the town of Etten-Leur. The SH households all participated in phase 1 of the project and opted in for phase 2, whereas the 18 RH households only joined the trial at this stage. Instead of voluntary time-shifting of demand, the objective of phase 2 was to test the potential of smart grid technologies in achieving flexibility. Each SH household was fitted with an air-to-air smart heat pump as well as 10 solar panels on average; in phase 2, these homes were provided with a home battery and an online energy monitoring platform (a website and app). The SH householders all came to live in the all-electric neighbourhood knowing about its special status as smart grid trial, and agreed to participate in it upon moving in. The RH participant group, recruited for phase 2, received the same online platform but did not receive a domestic battery. The platform provides insight in current and past electricity consumption, solar energy generation, the variable energy tariff and displays some information about the battery (percentage full/empty and 'mode': charging, neutral or discharging). Table 3.1 provides an overview of the smart grid trial's two phases and the two studied research groups.

Table 3.1: Key characteristics of the smart grid trial Jouw Energie Moment (2012–2018).

	Phase 1 (March 2013–December 2015)	**Phase 2 (January 2017–March 2018)**

Main objective	Testing the potential of voluntary energy management for net balancing	Testing the potential of technology-assisted energy management for net balancing	
Studied participant groups	Purpose-built all-electric smart home (SH) neighbourhood	Purpose-built all-electric SH neighbourhood	Retrofitted homes (RH)
Energy technologies installed in participants' homes	In-home energy monitoring display Air-to-air heat pump with a 'smart' algorithm Smart laundry machine Dynamic energy pricing Photovoltaic (PV) panels	Home battery Online energy platform (webpage and app) Air-to-air heat pump with a 'smart' algorithm Smart laundry machine Dynamic energy pricing PV panels	Online energy platform (webpage and app) Air-to-air heat pump with a 'smart' algorithm Dynamic energy pricing PV panels
Number of participating households	39	39 (10 interviewed)	18 (four interviewed)

This pilot project is a particularly relevant case study for two reasons: first, having participated in smart grid developments since 2012 and being familiar with at least two configurations of HEM (phases 1 and 2), the SH householders in particular can be considered frontrunners and expert-practitioners from whose experiences with HEM practices much may be learned. Second, a number of key aspects of smart grids are tested in conjunction: domestic batteries in combination with solar photovoltaics (PV), smart heat pumps, a time-of-use energy tariff and an online platform for energy management. However, these specific frontrunner qualities also limit the applicability of the findings to different configurations of smart grids and SH. The authors compared the insights derived from the SH residents with those from the RH residents in order to ascertain how their different prosumer 'histories' and HEM configurations influence their participation in the smart grid project.

3.4 Methods

Interviews were conducted with 14 householders between March and July 2017. Participants were recruited through the pilot's newsletter and via email. Ten interviews were conducted with SH residents and four interviews with RH participants, after which a point of saturation was reached at which additional interviews yielded little additional insight. Equal numbers of men and women were interviewed; in about half the interviews spouses were present.

The interviews lasted between 40 and 75 min. Each visit had a brief 'show-and-tell' around the home, focusing on the heating system, the solar panels, the home battery and the smart laundry machine; as well as a 'digital tour' of the online platform. Interviewees were asked to describe how they use and feel about these technologies in broad terms in order to allow them to use their own words to describe how HEM works out in everyday life. After the show-and-tell, the interviews were continued in a semi-structured manner usually at the kitchen table. The topics addressed were timing of demand, energy saving, energy monitoring, energy generation and storing energy in the domestic battery (where applicable), as well as a general reflection on the pilot project. The show-and-tell and sit-down parts of the interview were both recorded, transcribed and anonymized. The interviews were coded according to the different HEM practices (time-of-use, generating, storing energy, etc.) described during different parts of the interview. The emerging findings were validated through comparison with a broad survey issued by the trial's research team, through discussion with the project organizers (some of whom also interacted with the participants), and by having the participating households respond to the findings at the closing session of the smart grid trial. Pseudonyms are used in the results section to protect the interviewees' anonymity, with 'SH' or 'RH' added to the name to indicate from which participant group the quotation was derived. The householders in this part of this study approved their participation in research activities and the use of (anonymized) data as a condition for their participation in the pilot project. Additionally, all participants provided verbal consent for the interviews to be recorded and used anonymously for scientific publications.

3.5 Results: HEM practices in the pilot project

3.5.1 Uncertain spaces in smart homes

The show-and-tell '*home tour*' involved the householders guiding the researcher around the places in their home where (new) energy technology was installed. This method delivered several insights which standard (sit-down) interviews alone would not have done. Conversing at the heat pump, the home battery and the solar panels revealed, first, that householders rarely visited these spaces in the house to control or monitor these technologies. The (large) heat pump installation was usually stowed away and hard to reach (Figure 3.2). While the home battery typically had a visible position on the wall in the garage (or in a few cases on an outside wall of the house), it offers no information display or any control functions; only a slight buzzing informed householders of its operation (Figure 3.3). The solar panels, situated on the roof of a shed behind the house, could usually be viewed from inside the home. More information about these three technologies could be obtained through the monitoring platform, on which householders relied to check if the technologies were still working as expected. The conversation adjacent the technologies often faltered quickly as the householders ran out of things to say (neither the home battery nor the heat pump displayed information to talk about), or the conversation was taking place in an awkward place (*e.g.* in a less-than-tidy garage, or while peeking in a storage closet). Intervening with the smart heat pump itself by unplugging it was very much discouraged for example, as one householder described:

> *It [the smart heat pump] requires little looking after. Apart from the switch between winter and summer, then I adjust the settings, and if the weather is very changeable, then I might switch off the cooling every now and then. But I should not do that too often, because then I get told off by the engineer – he can see that.*
>
> *(Mrs V (RH))*

Seated in the living room or at the kitchen table appeared to be a more natural space in which to discuss HEM. At the request of the researcher, householders gave a '*digital tour*' of the online platform and how they used it (on either phone, tablet or computer; Figure 3.4). Whereas the tone of the conversation about the technologies was uncertain and somewhat distanced (the householders did not touch the technologies during the tours), the conversation with 'app in hand' displayed a degree of confidence and mastery of the various functions, and a pride in the results achieved (e.g. while going over energy generation or consumption data).

Figure 3.2. A heat pump installed in a garage. Photo: authors.

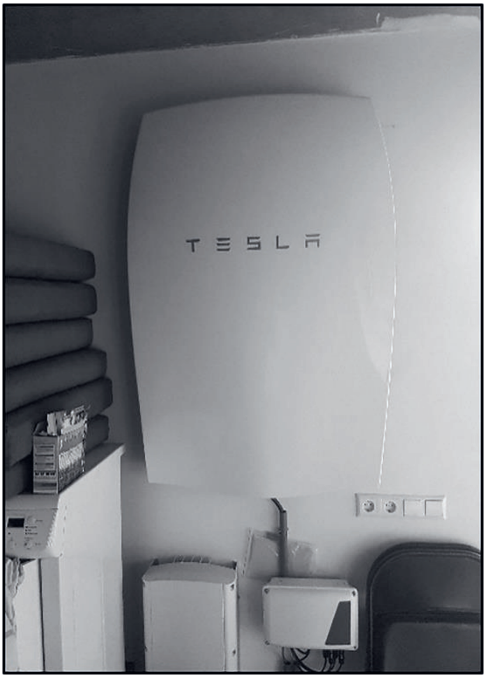


Figure 3.3. A home battery installed in a garage. Photo: authors.

Figure 3.4. Screenshot of the landing page of the energy interface provided to householders, featuring a price curve and information on the home battery.

3.5.2 Monitoring: enabler of HEM practices

Householders interacted with their IHD regularly and often cited the information it provided as instructive in 'taking action':

I used to use the screen on the wall up like a hundred times a day […] 'look, now the sun is shining – now I can switch on the dishwasher, or do the laundry'.

(Mrs M (SH))

If you have more insight in how your tariffs fluctuate, then with that insight you can act more consciously with energy, and that can be useful.

(Mr J (SH))

Monitoring practices were often performed in the living room with IHD, upon going to bed, after waking up, when leaving the house or returning home. However, this established monitoring practice broke down when the IHD was replaced with the online platform. A 'breakdown' of the monitoring practice triggered householders to make insightful reflections on what had made it all work before:

Personally I think it is a pretty big loss. Although we have that app of course, it does take more effort to use the app. Before you would come home, tap the screen […] so yes, personally, I do a bit less with it now. A bit of a shame.

(Mr D (SH))

When it [the IHD] was on the wall, it was a physical reminder. Generation and consumption, and what the heat pump is doing in relation to total usage. And very simply: the weather report. It was very pleasant.

(Mr W (SH))

The IHD also allowed for more family interaction around it than the online platform.

Generally, the SH householders were more attached to the teleo-affective structures of the HEM as defined by the pilot project than the RH group. This reflects the bigger commitment these householders made when joining the pilot project (moving to the new SH and 'rebooting' their domestic practices instead of upgrading existing houses and apartments with enhanced energy monitoring), as well as their homes being fitted with solar panels. Optimizing self-consumption of solar power was often mentioned as a reason for maintaining the effort of checking energy prices and timing activities. However, the introduction of the online platform was disruptive to many of the householders accustomed to the IHD:

> *So that functionality is lost completely. Everyone is just 'doing stuff' again. And all those people I've spoken to, they said, we are just doing stuff again. Using our feeling – 'this was how it was, around this expensive [...]'.*
>
> *(Mrs H (SH))*

This quotation also illustrates how participants felt that before the reconfiguration their actions contributed to a cohesive project, guided and affirmed by appropriate energy feedback. Understanding and being able to easily monitor the 'bigger picture' of HEM was crucial:

> *I no longer have an idea of what does what. And whether or not it is delivering us any benefits. We lost the overview somewhat, in part because the display is no longer working.*
>
> *(Mr P (SH))*

3.5.3 Smart heat pump: 'You are not supposed to touch anything'

The interactivity of the smart heat pumps was of an altogether different calibre than the that of other heating systems to which the householders were previously accustomed (gas-based central heating being the most common in the Netherlands). The heat pump system featured thermostats in most rooms of the home, offering householders the opportunity to adjust heating preferences per room (which many actively did). The IHDs and online platform provided householders with some insight into current and past electricity demand for heating. Most householders were pleased with the smart heat pump with respect to the savings it helps them achieve, and the stable temperature the system provides. However, with the smart algorithm governing the heat pump's operation, householders were critical of the slowness and unresponsiveness of the system. Several householders described issues operating the heat pump in different weather conditions:

> *I am pleased with the user-friendliness. It does not take much looking after. However, there are certain temperatures, for*

example when it is 15°C outside [...] then you cannot completely heat your home. For those time you would need additional heating.

(Mrs B (SH))

It takes a lot of getting used to. It took me 2 years to sort it out the way I want it. [...] I called the housing association and they were like, 'you are not supposed to touch anything'. [...] So then I called the heat pump installer. They were happy to come by. That man explained it to me fully, how the system actually works. I also went online to find out what a heat pump actually does.

(Mrs V (RH))

3.5.4 Energy storage: a black box

The home batteries offered no options to householders to manipulate their operation; the charging and discharging is determined entirely by algorithm. The householders did not express a desire to interact with their home battery on a daily basis, but did indicate that information provision about their home battery was lacking. The online platform displayed under a separate tab the 'status' of the battery (charging, discharging or neutral), as well as how full the battery is (as a percentage). This information did not help householders guide or reflect on their energy use; in fact, it left many householders confused as the battery would often switch 'mode' rapidly:

Charging, discharging, charging, discharging. [...] I just do not get it at all. Currently the price [of electricity] is dropping. So it should be charging [...] right?

(Mrs H (SH))

In addition, the 'percentage full' indicator provided little insight to the householders, who, contrary to what they expected, barely saw this figure move in the course of the day in spite of their generation and consumption:

Researcher: What can you tell me about how the battery works?

Mr S (SH): You tell me! [Shows energy platform on tablet.] Look, I hope that it is charging now. Because the solar panels

> *[…] that my battery is charging now, and then at 17:00 tonight, at the time when I think a peak takes place [it discharges] – but I cannot see that currently. That it discharges, for my house. I don't get that impression.*

Overall, the householders were ambivalent about their home batteries. They valued the way they imagined that the battery was boosting their ability to optimally use their self-generated solar power – to become more self-sufficient and sustainable, individually and locally. However, householders were uncertain about whether or not and to what extent this was the way their batteries were functioning.

3.6 Analysis

The HEM practices in the case study became a part of the daily life of many householders but were also revealed to be fragile and dependent on trust relations.

3.6.1 Distributing energy management between domestic space and utility space

Monitoring technology initially facilitated householders in building understandings about energy management, and engaged them with teleo-affective structures such as reducing energy consumption, increasing energy efficiency and maximizing (self-)consumption of solar power. The case study also showed that the home battery and smart heat pump allocate energy management powers and responsibilities to actors in the energy system. These technologies became part of an expanding *utility space* rather than becoming embedded in the *domestic space* of households (Figure 3.5). The householders reflected critically on the HEM practices which consequently emerged.

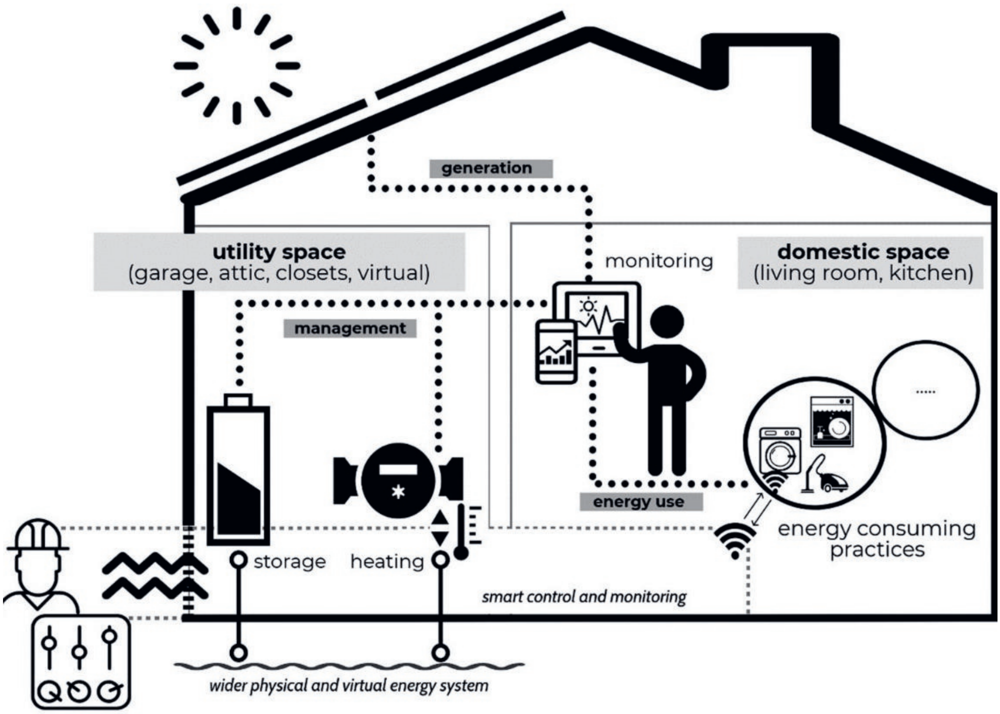


Figure 3.5. Conceptualization of smart grid technologies in the domestic space and utility space of the home, based on the Jouw Energie Moment (JEM) case study. The home battery and smart heat pump occupy spaces in the home, which are hard to access for householders; remote control by outside parties ensures their contribution to energy management. Monitoring technology, on the other hand, brings forward 'energy' as a resource to be managed (by saving, timing, etc.) in certain domestic practices.

First, the discontinuation of HEM practices was generally the direct result of householders' dissatisfaction with the new online platform, which took away the familiarized 'nexus' of energy management that linked various (parts of) practices together under a shared logic and objective. After replacing the IHD with the online platform, householders were generally less motivated to monitor and time-shift energy use, often continuing with some of their HEM practices out of habit albeit with less conviction and clarity of purpose than before. Many householders were confused, for instance, about how their time-shifting efforts related to their home battery's operation. Householders lamented the lack of feedback about the home battery. The change in the monitoring practice significantly reduced the presence of 'energy management', as concept, project and practice, in the domestic space.

Second, the case study homes were fitted with home batteries and smart heat pumps that functioned as *utility technologies*: technologies that deliver direct benefit to grid management and are controlled in some way (at a distance) by utilities and other providing parties. Integrating what used to be public utility infrastructures for generation, distribution and monitoring of electricity into SH may be effective and desirable for achieving energy goals. But there were complications: householders do not necessarily develop the required energy management understandings or automatically attach to the underlying complex principles and objectives of net balance. The heating practices of smart heat pumps featured algorithmic control and experts monitoring and intervening at a distance, while offering householders little opportunity to interact with and learn from their devices. The social practice rule of these utility technologies in the case study was 'do not to intervene'. The key insight in this respect is that smart grid technologies entail different mixes of outsider access, algorithmic control and householder empowerment to perform energy management actively, which may not align with the householders' needs.

3.6.2 Householder trust in smart grids

As energy management powers and responsibilities are (re-)distributed, often out of householders' hands, new trust relationships between householders and providers of smart technologies and services become instrumental. Below the three key factors which Giddens has argued determine trust of lay people in expert systems are applied to the case study: (1) trust in the people running the system; (2) the past performance of the system in terms of failures, breakdowns and scandals; and (3) trust in the sciences, principles and technologies that are being operated in the abstract system.

To start, participants did not appear to distrust the people running the pilot project. Several interviewees described their face-to-face interactions with the installer and the mechanic to install or fix issues with the IHD or smart heat pump as key moments in which insights were derived, and significant improvements were made to thermal comfort. This matches Gram-Hanssen et al.'s (2017) finding regarding the importance of face-to-face interactions in the professional practices of heat pump installers. However, with little face-to-face interactions occurring between householders and project representatives overall, the trust relationship on a day-to-day was mediated by the monitoring technology. The changing of the monitoring technology was a modest 'scandal' in the project after which the established HEM practices largely broke down. A main theme that emerged during the home tours and interviews was householders recollecting the past performance of the system ('how well it worked before'). Householders tended to resort to discussing complaints and solutions with neighbours and circulated advice from a neighbour known to be an energy expert.

Importantly, the objectives of the pilot project had changed in the second phase in a way that many householders felt left them peripheral to the mission and disengaged. They generally appreciated a teleo-affective structure of becoming 'as self-sufficiently green as possible' with the help of their solar panels, home battery, smart heat pumps and own actions to reduce consumption and time-shift energy use. Yet, little was done to connect the trial with established teleo-affective structures (such as saving energy) or novel ones (such as becoming self-sufficient), via, for example, the information presented on the monitoring tool. The prospective of minimizing one's negative impact on electricity grids proved not to be an attractive proposition for many participants. Instead, prosumers may be more tempted if the overall sustainability principles and rationales behind HEM practices and their technologies are better elaborated. If smart grid technologies are fixed on objectives that do not connect to the aspirations of households, the trust relationship between householders and providers may break down.

A potential supplement to trust-building could be an accountability system built on transparency, and informed and independent judgement (O'Neill, 2014). In such a system, householders would be able to 'check' their providers on, for example, the operation of their batteries and smart heat pumps. However, considering the highly complex dynamics of electricity grids and markets, which frequently vexed even the smart grid trial organizers, as well as the knowledge disparity between householders and energy professionals, it is difficult to imagine what 'intelligent accountability' (O'Neill, 2014, p. 180) in HEM would look like.

3.7 Discussion and conclusions

The aim of this paper was to come to a better understanding of how so-called HEM practices distribute responsibilities and power for their performance across smart grid technologies, energy service providers and experts, and householders. The case study, which consisted of 14 interviews and show-and-tell home tours with householders participating in a smart grid pilot project situated in the Netherlands, generated several findings in that respect.

First, it was found the studied smart grid technologies (monitoring technology, energy storage and smart heat pumps) become part of HEM practices with differing characteristics in terms of householder agency, responsibility and engagement. Monitoring technology proved to be the key element, interconnecting numerous

HEM practices that bring energy forward in everyday life as a resource to be managed. Householders' continued use of IHDs ingrained new teleo-affective structures, competences and meanings concerning 'proper' (timing-sensitive) energy use in domestic practices. This aligns with studies that have noted that: "[IHDs] can increase the visibility and salience of energy consumption and related behaviours, contribute to householder knowledge about their energy consumption, and prompt behaviour change and consumption reduction" (Burchell et al., 2016, p. 179).

With respect to two key constraints of energy monitoring technology identified in past studies – different levels of engagement between householders (Hargreaves et al., 2010) and disengagement over time (Hargreaves et al., 2013) – the case study emphasizes the value of presence in domestic space. The IHD (much more so than the online application) became an integral part of the living space of householders; once the displays were replaced, many householders disengaged with the HEM entirely. The IHD's ease of access and use by different household members led to exchanges about the HEM, evening out levels of engagement. With respect to prolonged use, the case study supports Hargreaves et al.'s (2010) argument that the communication strategy for IHDs should be flexible in response to varied and changing householder needs; in the case study, for example, the potential of strengthening the prosumer participants' engagement through community action (Burchell et al., 2016) or self-sufficiency frames remained untapped.

Smart-controlled heat pumps, on the other hand, which allow direct access by distanced experts to the practice of heating the home, ended up restricting the agency; many householders reported living with a smart heat pump as a challenge and adapted in varying ways. Furthermore, the case study supports the finding that a 'hands off' socio-technical configuration of smart heat pumps leaves potential energy savings unrealized (Guerra-Santin and Itard, 2010) while risking householder frustration with smart controls (Hargreaves et al., 2015), because householders are not provided with an informational and motivational framework to reduce their use and create more comfort in coordination with the demand–response algorithm.

While a 'black box' to the participants, they were generally content with housing the energy storage device as to their (incomplete) understanding it served to boost their own efforts to optimally use their solar PV generated electricity. The smart heat pumps and home batteries were both stowed away in hard-to-reach places and offered householders little information or ways of interacting. They functioned as *utility technologies* that become part of an enlarged *utility space* within households, leading us to consider more closely how trust is established and sustained between householders and energy management providers.

It turned out that while some trust-building happened during face-to-face interactions with householders and the installers and the pilot project's 'fixers' – key moments for successful socio-technical embedding (Gram-Hanssen et al., 2017) – after installation householders could only resort to the digital monitoring technology of the smart heat pumps and home batteries present in their homes. Moreover, when the smart grid trial's objective shifted from engaging householders in time-shifting energy demand to net-balancing with smart technologies, the monitoring practice built on the IHD largely fell apart and householders gradually disengaged from energy management.

These insights suggest a need to identify how and where householders gain as well as give up control in HEM practices. Providers of smart grid technologies and services could then better match various socio-technical configurations of HEM that operate on different distributions of control and insight to appropriate lifestyle groups (such as prosumer householders). This requires a more differentiated and reflexive approach to the type of users and practices being created, instead of aiming for either full engagement or disengagement (Goulden et al., 2018). Maintaining the trust and engagement of householders in smart grid projects demand ongoing trust-building work similar to low-carbon retrofitting (De Wilde and Spaargaren, 2018), as well as technological design which is sensitive to established social practices and motivational frameworks. In this respect, the research presented here reaffirms the importance of having a 'consistent and open communication practice with users about project progress and expectations' (Verkade and Höffken, 2018, p. 7).

Energy utilities and market actors are exploring novel smart grid solutions in different spaces and practice in the home to facilitate the transition to low-carbon energy systems. In this effort, the old boundaries of utility closets no longer apply. The ICT component of smart grid technologies shrinks the distance between households and electricity grids. For example, when energy market-driven algorithms are introduced into heating practices. Since the rise of prosumers, utilities have been developing strategies that regard householders as co-producers of value: this has increasingly blurred the line between production and consumption in electricity grids (Marvin et al., 1999). Smart grid development follows these developments, promising sustainability benefits through enhanced collaboration between utilities, householders and energy market actors, towards creating low-carbon electricity systems (Darby et al., 2013; Stephens et al., 2013).

However, to realize these benefits, further research is required into what would constitute a *supportive* utility space in the context of HEM, rather than an invasive one, and how such space may be accommodated in homes both materially and virtually in order to achieve comfort, and energy and climate goals. This paper presents an illustrative example of how smart grid technologies reshape and introduce new practices characterized by varied power relations between householders and the – more-or-less absent – providers of technologies and services.

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Chapter 4

Technologies of engagement: how battery storage technologies shape householder participation in energy transitions

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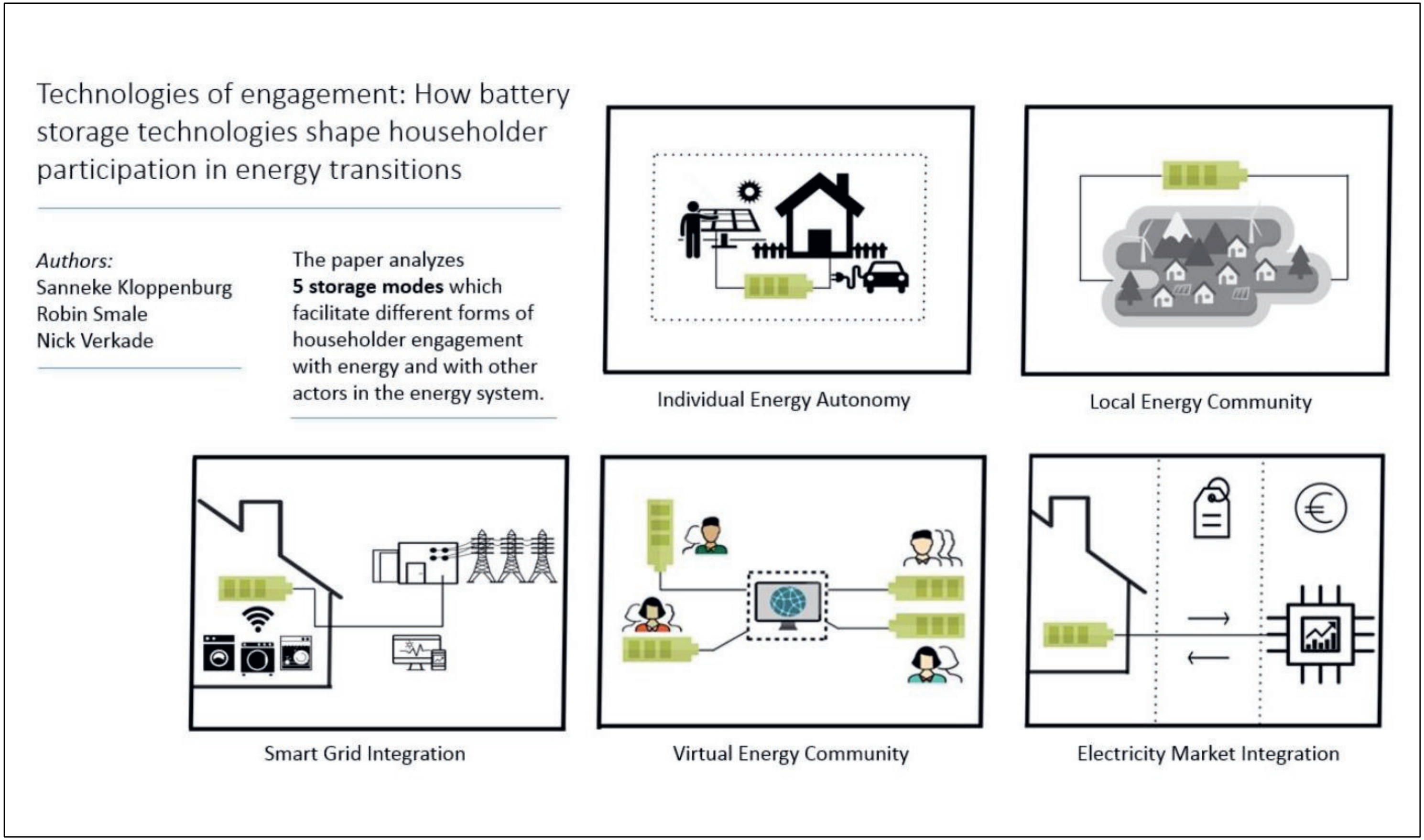
Chapter 4: Technologies of engagement: how battery storage technologies shape householder participation in energy transitions

Abstract

The transition to a low-carbon energy system goes along with changing roles for citizens in energy production and consumption. In this paper we focus on how residential energy storage technologies can enable householders to contribute to the energy transition. Drawing on literature that understands energy systems as sociotechnical configurations and the theory of 'material participation', we examine how the introduction of home batteries affords new roles and energy practices for householders. We present qualitative findings from interviews with householders and other key stakeholders engaged in using or implementing battery storage at household and community level. Our results point to five emerging storage modes in which householders can play a role: individual energy autonomy; local energy community; smart grid integration; virtual energy community; and electricity market integration. We argue that for householders, these storage modes facilitate new energy practices such as providing grid services, trading, self-consumption, and sharing of energy. Several of the storage modes enable the formation of prosumer collectives and change relationships with other actors in the energy system. We conclude by discussing how householders also face new dependencies on information technologies and intermediary actors to organize the multi-directional energy flows which battery systems unleash. With energy storage projects currently being provider-driven, we argue that more space should be given to experimentation with (mixed modes of) energy storage that both empower householders and communities in the pursuit of their own sustainability aspirations and serve the needs of emerging renewable energy-based energy systems.


Technologies of engagement: How battery storage technologies shape householder participation in energy transitions
Authors:
Sanneke Kloppenburg
Robin Smale
Nick Verkade
The paper analyzes 5 storage modes which facilitate different forms of householder engagement with energy and with other actors in the energy system.
Individual Energy Autonomy
Local Energy Community
Smart Grid Integration
Virtual Energy Community
Electricity Market Integration

4.1 Introduction

In Europe and elsewhere, there is an increase in renewable energy generation at domestic and community level. By installing solar panels, more and more householders are becoming prosumers and take responsibility for the decarbonization of the electricity system. However, for the grid, the uptake of solar poses challenges to the balancing of supply and demand of electricity and to grid management. Solar panels only generate energy during day time, whereas a peak in domestic electricity consumption takes place in the evening. Moreover, there are seasonal differences in the hours of day light and in weather conditions. Storage of renewable energy near to their decentralized sources, at the domestic or local level, is increasingly seen as a solution to this problem. Rapid developments in battery technologies have even led some to claim that we are at the brink of a 'storage revolution' (Crabtree, 2015) that may change the way householders and institutional actors engage with energy in fundamental ways. In addition to promises about the potential of storage for decarbonization and decentralization of the energy system, storage features in discourses about the empowerment of householders and communities to take more control over their energy use and become more independent from energy suppliers (Koirala et al., 2018; Ruotsalainen et al., 2017).

Despite the view of storage as a potential enabler of the energy transition, not much is known about the role that householders play, or are imagined to play, in energy systems that include distributed storage (Devine-Wright et al., 2017). Yet, home batteries open up a range of possible roles and practices for householders. They enable householders to store their energy for use at a later time, but are also an important element in enabling new energy practices such as sharing and trading energy. These new energy practices place householders in a different relationship with the energy system and its key actors, such as energy suppliers. For example, the use of residential energy storage can help householders to become (more) autonomous in their energy supply, but domestic storage may also be used for Demand Response to help stabilize the grid (Parra and Patel, 2019).

In this article our aim is to explore potential ways in which home batteries can enable householders to become engaged in the transition towards low-carbon energy systems. Departing from the idea that energy systems are socio-technical configurations, we identify different ways in which householders and communities can become involved in low-carbon energy systems with storage. We link this idea of socio-technical configurations, or storage modes, to theories of 'material participation' (Marres, 2016; Ryghaug et al., 2018) that argue that through everyday interactions with (energy) technologies, people can express concerns and ‘intervene’ in the energy system. Our theoretical argument then is that the ways in which householders (are enabled to) engage with energy storage technologies in an everyday, practical sense at the same time shape their participation in wider energy systems and their transitions.

In the following sections, we first explain our approach to energy storage as a technology of engagement, and the way we conducted our research. Next, we distinguish five different socio-technical configurations -or storage modes- in which householders can play a role. We identify how each mode affords specific energy practices for householders, such as storing, trading, or exchanging energy, and how the performance of these practices implies a particular distribution of tasks and responsibilities between householders and others energy system actors. In discussing the wider potential implications of these new types of engagements, we reflect on how energy storage may foster new collective energy practices and engagements that challenge our traditional understanding of energy communities, but also how these new energy practices often imply automation and reliance on intermediaries.

4.2 Renewable Energy Technologies as Technologies of Engagement

Literature in science and technology studies (STS) views technologies not just as material objects, but argues that the social and the technical are co-dependent and co-evolving (Geels, 2005). This field stresses that technology and its social context mutually shape each other. Societal values such as sustainability, and ideas about the roles of users shape the technology, and at the same time technologies are constitutive of the social, in the sense that they actively shape their own context of use. Renewable energy technologies too have been approached as configurations of the technical and the social (Walker and Cass, 2017; Juntunen and Hyysalo, 2015; Rutherford and Coutard, 2014). Walker and Cass (2017) use of the term ‘mode’ to understand renewable energy technologies as configurations of technology and social organization. By social organization they refer to the ways technology is ‘utilized and given purpose and meaning’. They distinguish for example the traditional ‘public utility mode’ from modes that have emerged more recently, such as a the ‘private supplier’, ‘community’ and ‘household mode’. Walker and Cass seek to understand how different modes embed within them different roles for publics in renewable energy deployment. They characterize these roles in terms of people’s spatial proximity to the technology and their level of awareness and active engagement with renewable energy. For example, what they call the ‘captive consumer’ role entails a consumer who is distanced from the sources of renewable energy generation and consumes green energy passively. In an ‘energy producer’ role, on the other hand, people own and operate their own green energy generation technologies, for example via solar panels on their roofs, and are necessarily active and aware (Walker and Cass, 2017). This approach thus recognizes the variety of roles and engagements of publics that emerge in relation to different renewable energy configurations.

While Walker and Cass discuss a wide range of technologies, from micro to macro scale, other studies have characterized and categorized different sociotechnical configurations around one particular technology. For community energy storage, Koirala et al. (2018) have identified three configurations, namely shared residential energy storage, shared local energy storage, and shared virtual energy storage. This allows them to analyze the various ways in which local communities can use energy storage. Parra et al. (2017) describe four categories defined by scale and application: single home storage, community storage, grid storage, and bulk storage. We take a different approach in basing our categorization of different storage modes on the question of how householders can become involved in and use energy storage.

4.2.1 Storage Modes and New energy Practices for Householders

Rather than understanding engagement in terms of general ‘roles’ for ‘publics‘ or positioning ourselves in emerging research on public perceptions of energy storage (Ambrosio-Albalá, 2019; Thomas et al., 2019), our aim is to examine what these ‘publics’, as householders who have installed energy storage devices, can do. In other words, we unpack the roles and forms of engagement by focusing on the (new) *energy practices* that become possible in different storage modes. Here we build on the work of Noortje Marres (2016), who calls for an appreciation of everyday material practices as forms of participation. She views people’s everyday use of energy technologies such as smart meters, as possibilities for public engagements in environmental issues. As she argues, everyday material actions can enable ‘practical or physical interventions in current states of affair’ (Marres, 2016). Such an understanding of ‘material participation’ acknowledges the ways in which people are engaged in sustainable energy transitions through their everyday practices with household and energy devices.

Building on Marres’ work, Throndsen and Ryghaug (2015) apply the concept of material participation to assess the character of householder engagement in the case of smart grids. They conclude that householders, as ‘material publics’, articulate widely ranging (and politically engaged) smart grid enactments. Ryghaug et al. (2018) argue the introduction of novel energy technologies in householders' everyday lives, such as solar panels, the electric car, and the smart meter, may create new forms of (materially based) energy citizenship. They give the example of the smart meter that through near real-time measurement and visualization of energy consumption makes energy visible in the household. This may result in the articulation of the issue of energy efficiency, and new forms of (practical) participation such as time-shifting of energy consumption, or replacing existing electric appliances with more efficient ones. The theory of material participation thereby challenges the dominant but narrow understanding of participation as involvement in decision-making. Instead, participation also takes the form of households interacting with energy systems through their everyday use of energy technologies in domestic settings, because in these everyday practices, issues around sustainability and climate change are articulated, and energy decisions are taken (Ryghaug et al.. 2018).

We draw upon the theory of material participation to explore how interactions with home batteries can engage people in the energy systems in different ways. For example, through installing a home battery, people can express their concern for climate change. At the same time, the use of batteries can also make them aware of new issues, such as the rhythms of domestic energy production and consumption and the systemic problem of grid balance. Finally, batteries also enable people to intervene in energy systems in a very concrete and physical sense, because batteries allow the redirecting of energy flows between the household and the wider grid. These examples illustrate energy storage devices as 'objects of participation and engagement' (Ryghaug et al., 2018) in energy systems. Conceptualizing residential energy storage as a technology of engagement thereby allows us to examine not only how different modes imply different roles and energy practices for householders, but also how each mode at the same time shapes householders' participation in the transition to low-carbon energy systems in distinct ways.

In analyzing which different storage modes are emerging and what forms of engagement they imply, we follow a four-step approach (see Figure 4.1). Our first step is to examine how storage is viewed as a 'solution' to a particular problem, and whose problem this is (or is made to be). Different problematizations of electricity production and consumption entail specific ways of thinking about storage in home batteries as a solution. Some storage rationalities are more directly linked with householders experiences and practices as solar PV owners, while others start from the problems grid operators face in the context of a changing energy system. Starting from these diverse problem-solution sets we then describe the variety of (new) roles and energy practices for householders that are made available. Next, we analyze the distribution of tasks in these practices. It is important to discuss not only the (new) practices that emerge for householders, but also how and with whom these practices are being carried out, as some of these activities and choices may be delegated to technologies or providers and intermediaries. Finally, we examine the storage modes in relation to the wider energy system (outer circle of the figure). Everyday material practices of storing energy in household batteries enable interventions in the direction and management of (green) energy flows within household and between households, but also in the wider energy infrastructures. As such, these practices represent a rather 'direct' form of engaging with, and potentially reshaping the energy system. Our approach therefore also pays attention to the potential implications on the relationships between householders, providers, and technologies in low-carbon energy systems.

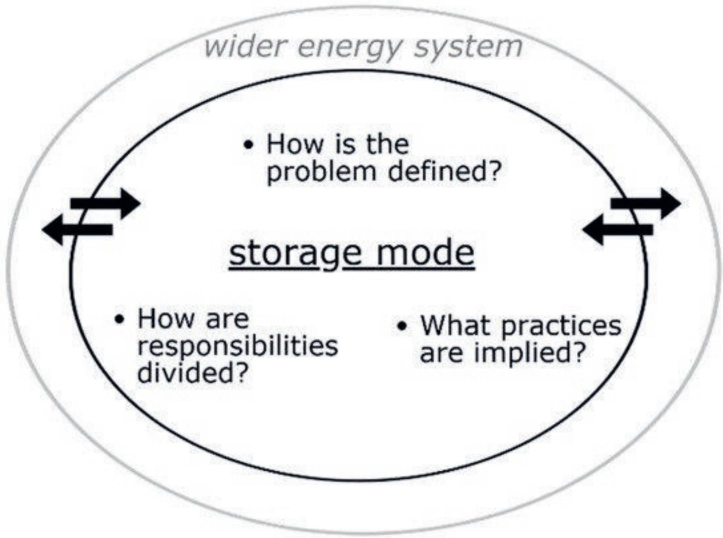


Figure 4.1. Analytical framework for identifying and analyzing storage modes.

4.3 Materials and Methods

This paper builds on empirical data that was collected at different moments and sites in the context of a research project on emerging energy practices in the smart grid (2014–2019). The data are qualitative and consists of interviews with different stakeholders in the energy system in the Netherlands, and to a lesser extent Germany and the United Kingdom. We conducted 14 interviews with providers of home battery systems and services, energy storage experts, NGO's and local governments involved in storage pilot projects. The bulk of the data, however, comes from interviews and observations with householders who were involved in storage pilot projects, or who had installed home batteries themselves. In the fall of 2016, 6 interviews were held with householders in Germany who had installed batteries for individual self-consumption, of which a few also participated in a virtual energy community called SonnenCommunity. In the Netherlands we conducted longer term fieldwork in the context of two demonstration projects. Here 14 interviews were held with householders engaged in the pilot project Jouw Energie Moment ('Your Energy Moment') in which home batteries were used for grid balancing. Furthermore, 30 interviews were conducted in the City-zen pilot project, where householders with batteries engaged in wholesale energy trading. A shortcoming is that we were unable to conduct interviews with local communities who owned and operated storage collectively, because there are relatively few real-world examples of this (but see the Feldheim case reported in (Koirala et al., 2018). To gather information about community-owned storage, we therefore relied on interviews with storage providers and document study. Due to the variety of research material and differential access to cases, this research has an exploratory character. Hence, we use the real-world cases to conceptualize and identify the different forms of engagement that the use of home batteries may foster, rather than to systematically evaluate the extent to which new energy practices around storage already result in (new forms of) participation.

4.4 Results

Below we draw out five different socio-technical configurations around home batteries: individual energy autonomy; local energy community; smart grid integration; virtual energy community; and smart grid integration.

4.4.1 Mode 1: Individual Energy Autonomy

In the first mode, Individual energy autonomy (Figure 4.2), individual households deploy domestic energy storage for the purposes of using (more) self-generated solar energy. The rationality of this mode is optimizing self-consumption of electricity produced by PV panels. Self-consumption itself is a gratifying project for many PV panel owners. As one of the interviewed householders put it, 'I can use the energy, it gives a good feeling to me. To produce it and to use it'. Beyond this, two main motivations are at play here: (long-term) economic reasoning, and desire for autonomy or self-sufficiency. Self-consumption of solar power with domestic storage emerges as an alternative 'business model' for PV owners, as there is a common expectation that in the near future feeding back electricity into the grid will become less financially attractive. Secondly, domestic batteries appeal to householders who wish to become more energy autonomous, and less dependent on subsidies and energy providers. Here, different levels of energy autonomy may be pursued, ranging from going off-grid, to being self-sufficient during a black-out (back-up power), to remaining connected to the grid but relying on it as little as possible. As one of the householders argued: ‘Somewhere the subsidies will stop and then you have a big advantage when owning a battery, then you are independent’.

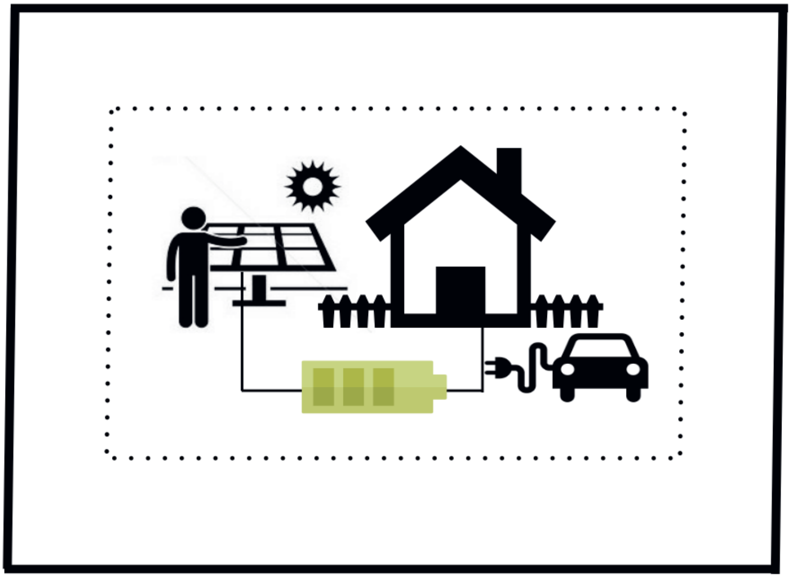


Figure 4.2. Individual energy autonomy.

Home batteries for self-consumption often come along with an app or display on the device itself which enables householders to develop monitoring practices. One of the householders described it as a ‘little pleasure’ when he uses his app and sees ‘that the sun shines and that you can see the battery charging’. Several respondents planned energy-intensive activities, like laundering and dishwashing, in such a way that solar (battery) power is used.

Domestic batteries used for the purpose of enhancing self-consumption place ownership in the hands of householders. However, this does not mean that individual householders can operate their batteries directly. The battery installer can translate the wishes of the householder into the learning algorithms which subsequently govern operation of the battery. As one householder put it: ‘With the installer you can configure the battery and optimize everything so that it is attuned to the household. What could the customer do herself? Not so much.'

4.4.2 Mode 2: Local Energy Community

In the local energy community mode (Figure 3), both problem and solution are defined at the community level or within a local area. Local communities cannot always use their locally produced energy within the community itself. For distribution system operators (DSOs), the renewable energy generated by 'green communities' places local pressure on the distribution grid. To both communities and DSOs, an attractive solution is optimizing the local use of locally produced renewable energy. In terms of infrastructures, this mode can either consist of a local community connected to a larger 'neighborhood battery' or be formed by connecting distributed domestic batteries in a local setting. This mode comprises a range of variants from fully self-sufficient off-grid communities to local communities who are sharing energy via the public grid.

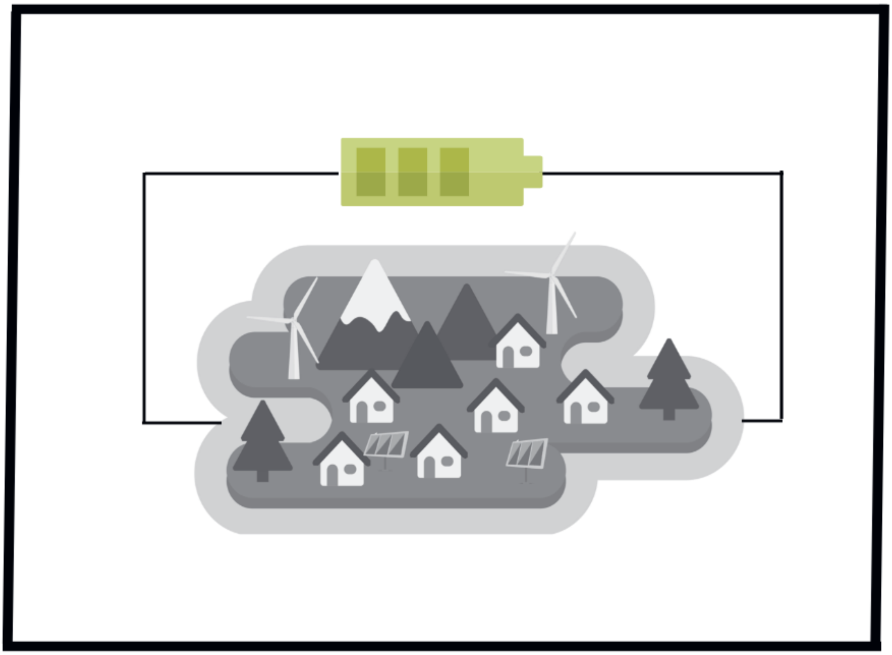


Figure 4.3. Local energy community.

In the local energy community mode, householders become prosumers who not only generate and consume individually, but also for and from the community's pool of energy. This allows for engaging with energy as a 'common good', or a 'common pool resource' (Wolsink, 2012). Managing the 'common energy pool' at the community level implies new practices which include the monitoring of not only individual but also community-wide demand and generation; timing-of-demand to match local renewable energy availability (in storage); and energy sharing or peer-to-peer trading between community members.

Theoretically, local energy community storage can be organized in various ways. The local energy community may consist of a pre-existing energy cooperative that decides to add storage to its local renewable energy generation. In the pilot projects we studied, however, the batteries were owned, operated and controlled by other parties than the community itself, requiring little involvement of communities and households. Community energy storage with batteries in its present phase is still experimental, taking place in pilots and living labs. One of the reasons for the absence of 'commercial' variants of this mode are the regulatory barriers to peer-to-peer trading within a community, and to energy collectives becoming their own supplier (Parra et al., 2017). In the Netherlands and the United Kingdom, however, regulatory sandboxes are now in place that enable the first communities to experiment with peer-to-peer supply (Lammers and Diestelmeier, 2017). In conclusion, community energy storage in principle offers a range of possibilities to organize energy supply and demand at decentral level. Different forms of (community) co-ownership of storage technologies (and generation units) can be imagined, as well as partnerships between energy suppliers and cooperatives; for example, energy suppliers could partner with cooperatives to supply the deficit at moments when the community's energy demand is higher than supply.

4.4.3 Mode 3: Smart Grid Integration

The smart grid integration (Figure 4.4) mode centers on the increasing problems grid management faces with the ongoing growth of renewable generation at the domestic scale. Grid assets at this scale are not necessarily suited for greater and volatile flows to and from the household. This can be accommodated by making more intelligent use of the grid assets and domestic devices in place with the help of IT, which is the 'hype' (Verbong et al., 2013) called the smart grid. In the smart grid, the demand of households is no longer something that is simply predicted and accommodated by the grid; demand becomes something to be managed and steered at level of the individual household. The flexibility of domestic energy usage becomes an asset to be maximally unlocked and used towards efficient grid management. Domestic energy storage capacity is an ideal flexibility tool from the point of view of the DSO: storage can buffer peaks and troughs in domestic energy demand without requiring the involvement of householders or interfering in their energy use. The rationale of this mode is therefore to align the workings of the batteries (and other household appliances) with the needs of the grid.

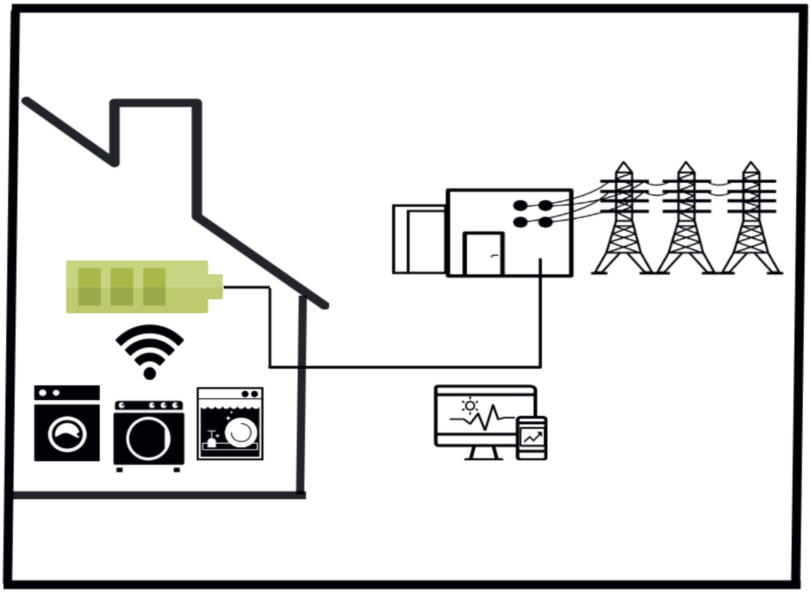


Figure 4.4. Smart grid integration.

Within the smart grid, householders are assigned a role as (active or passive) micro-managers with some responsibility to manage the impact they have on the grid. While they might actively shift some energy usage in reaction to more variable grid tariffs, the smart home with battery storage can also automate some of these decisions. Householders thus 'share' their batteries with the grid, allowing external control of the (dis)charging the battery.

As a result of automation and external control batteries may end up as black boxes, obfuscating the flows of renewable energy in the home and thereby creating a number of new uncertainties for householders. In smart grid pilot project Jouw Energie Moment, many participants critiqued the unintuitive information they were provided with: 'The only thing we pick up on with respect to that battery, is when it is 'humming', which means it is doing something.' The batteries would seemingly switch randomly switch between charging, discharging and neutral, never reaching full charge. Another householder stated: 'I just have no clue of what does what. And whether or not the battery is providing us any benefits.' In this respect, many householders stated that 'naturally, one would preferably want to be self-sufficient'. However, they were unclear if the batteries were contributing to this objective.

Since DSOs are barred from fulfilling "market-able" roles, the batteries are most likely controlled by an intermediate market actor like an aggregator. Domestic storage and other 'smart appliances' in the home thus become tools for grid supporting services. If householder insight into the functioning of home batteries (and other smart energy technologies) is insufficient, householders may come to see them as external or even invasive tools for solving others' problems (Smale et al., 2019): 'At the moment it feels as if I help to solve a logistical problem for the project. I have found space in my home for someone else's experiments. But if I benefit... how can I see that? In effect I can't. I only see a big battery and hear a humming sound.'

4.4.4 Mode 4: Virtual Energy Community

The fourth mode –virtual energy community (Figure 4.5)- has parallels with the local energy community mode. The situation in which householders possess a battery system to increase their individual self-sufficiency while still relying on conventional energy suppliers to cover additional needs is seen as unsatisfactory. The rationale therefore is to link householders and optimize the use of self-produced energy within the community. While in the local energy community mode members live in the same local area, the virtual community members consist of geographically dispersed households. The members' energy devices (including solar panels, storage devices) are connected via smart meter technologies to a digital platform that allows for the monitoring and exchange of surplus energy. The first real world applications are now emerging (e.g., SonnenCommunity, Schwarmdirigent). One of these virtual energy communities, established by a battery storage provider, is presented as 'a community of [battery owners] who are committed to a cleaner and fairer energy future'. The same provider states that 'as a [member of our community], you don't need your conventional energy provider anymore—ou are independent' (Sonnen, 2017). In these framings, householders become not only prosumers in a virtual energy community, but also 'part of the energy future'. The goal of the virtual energy community is to meet the energy demand of the community with energy that is generated by the community itself.

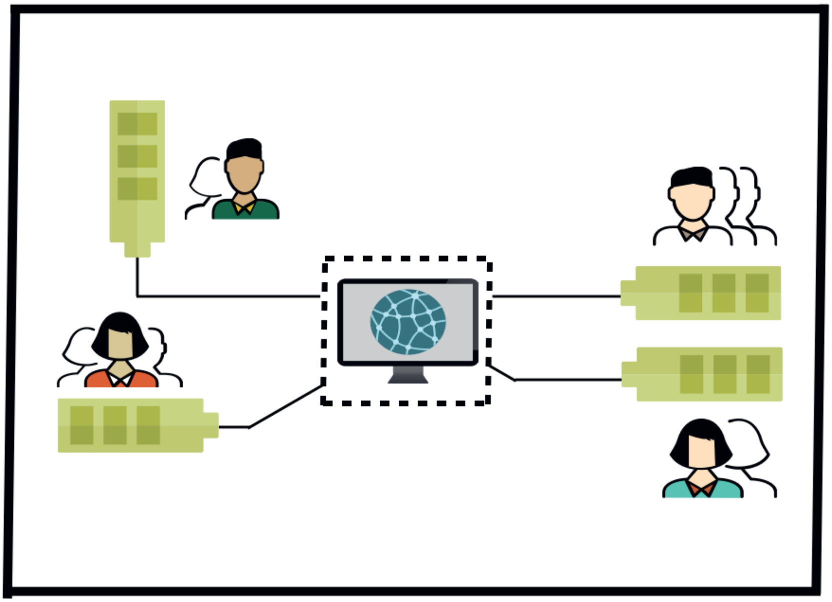


Figure 4.5. Virtual energy community.

In this mode, ownership of the battery is with the individual householders, but the solar surplus that is produced when the batteries are full and/or the stored energy is 'shared' with others. It is important to note here that the sharing or exchanging of energy is virtual: The network does not consist of separate cables between members, but of a digital platform that enables virtual exchange via the existing grid. The meaning of 'sharing' therefore is complex. As one interviewed virtual community member put it: 'the idea is good. With [my friends] I spoke about it, they are part of it. Then I said, when there's sun at your place, I'm using your power. It's certainly a good idea, as the solar power that is stored, that is too much, can also be used on a place where it rains. But it's all virtual, it's not physical. The energy does not move from one place to the other, but okay, it doesn't matter'.

In the examples we studied, households were not actively engaged in energy exchange in the sense that they needed to decide on when and with whom to enter transactions; the process was managed by a third party—the aggregator—and often highly automatized. It is the responsibility of the aggregator to make sure that the demand within the virtual community matches the supply, so choices and decisions about the distribution of energy are made by this intermediary actor. The exchange of energy is not disclosed or made actionable to householders in the sense that they get insight in for example the current availability of community energy or get rewarded or sanctioned for their energy behavior. What is requested from households is to provide access to their energy data: the energy production, consumption and storage practices of members are monitored, and together with weather forecasts, used to make predictions of supply and demand in the community.

4.4.5 Mode 5: Electricity Market Integration

In the fifth and final mode, electricity market integration (Figure 4.6), the problem is defined in economic terms: due to competition on free electricity markets and growing renewable energy generation, electricity markets have become increasingly volatile. Batteries allow people to exploit this volatility, because the electricity flow can be temporarily halted, captured, and released again at a later point in time. The rationale of this mode is to align the workings of the batteries with energy market demands in order to create financial benefits for battery owners. In our research, we did not find any commercial variants of this mode yet, but there are examples of trials such as the Dutch pilot project City-zen. The households with batteries do not trade individually because the capacity an individual household can have available is too small. Instead, the participating households are aggregated to form a collective of householders. The aggregator in the Dutch project uses a Virtual Power Plant as the underlying technical infrastructure and explained that 'with all 50 participants, we want to create a large community. This community will be seen as one energy producing or consuming unit' (Greenspread, 2019). In the project, the batteries loaded from the grid when prices were low and exported the electricity to the grid when prices were high. Energy thereby became a (tradeable) commodity and householders were ascribed a role as an economic actor who 'acts' according to market rhythms and logics. In the City-zen project, it appeared that for many householders this role as a market actor was at tension with their initial motivation to acquire solar panels for environmental reasons. As one householder explained: 'I didn't first go green with these things to now only think about money!'

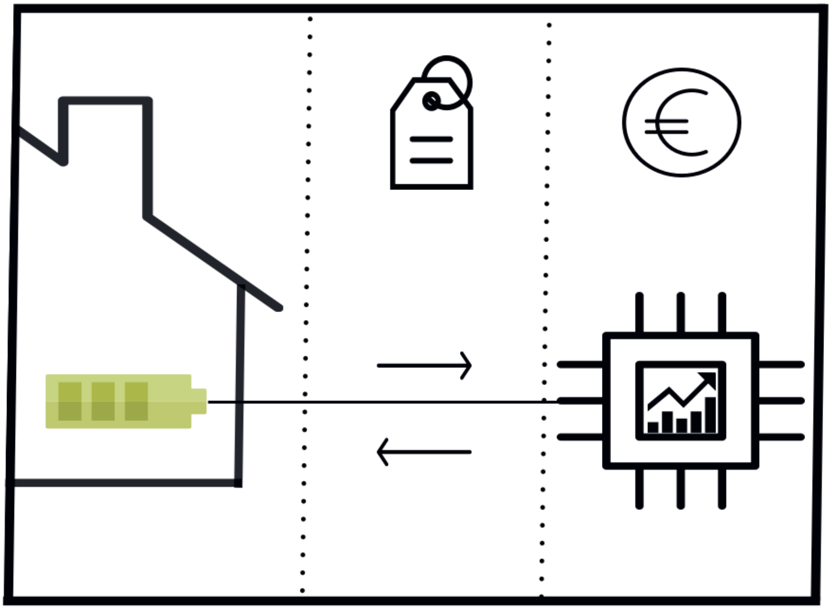


Figure 4.6. Electricity Market Integration.

In theory, in this mode the batteries could be owned by householders as well as third parties. The householders provide (stored) energy, their energy data, as well as the control over the charging and discharging of the battery to an intermediary party in exchange for a monetary reward. The intermediary acts as an aggregator of a group of households and trades on their behalf, by using historical and real-time energy consumption and production data from households in order to make accurate predictions of the amount of energy each household has available for trading. Householders thus engage in trading but this activity does not require specific skills or competences from them, nor does it require or stimulate them to actively adjust their energy consumption practices.

4.5 Discussion

4.5.1 Comparing the Five Storage Modes

Our identification of storage modes shows that a variety of different combinations of home battery storage technology and social organization is currently emerging. In addition to the already more established individual energy autonomy mode, providers are developing new modes that enable energy sharing and providing energy services to the energy system. The five modes we have distinguished differently engage householders in energy production and consumption through storage, in terms of the practices householders are enabled to engage in, and with regard to their relations with the conventional energy system and other householders (see Table 4.1).

Table 4.1. Five modes of energy storage, including the real-world examples in which fieldwork was conducted.

Storage Mode	Householder Engagement			Real-World Example
Modes	**Energy Practices**	**Relation to Conventional Energy System**	**Engagement Level**	**Title**
Individual energy autonomy	Self-consumption	Autonomous	Individual	Sonnenbatterie (DE)
Local energy community	Self-consumption and sharing	Autonomous	Collective	project ERIC * (UK), SWELL * (UK)
Smart grid integration	Providing grid services (and possibly self-consumption)	Integrated	Individual /collective	Jouw Energie Moment (NL)
Virtual energy community	Self-consumption and sharing	Autonomous /Integrated	Collective	SonnenCommunity (DE)
Market integration	Trading (and possibly self-consumption)	Integrated	Individual /collective	City-zen (NL)

*: no interviews with householders.

First, each mode affords particular energy practices for householders to engage in. In the individual energy autonomy mode, householders engage in self-consumption of stored energy within their household. In the other four modes, self-consumption is complemented with energy sharing, providing grid services, and trading.

Second, the modes entail particular relationships of householders to the conventional energy system. In the individual energy autonomy and local energy community modes, the aim is to increase self-sufficiency at household or community level, and in the ultimate case create a local microgrid. This idea of storage facilitating greater energy autonomy is opposite to the logic of integration that underpins the smart grid and market integration modes. In the latter modes, householders provide energy and services to actors within the energy system and thereby engage in the management of the energy system. The virtual energy community mode is less straightforward to characterize, as it fosters both autonomy and integration. While virtual energy communities may aim at autonomy from conventional energy suppliers, their geographically distributed character means that they need to rely on the public grid for sharing energy.

Third, the five storage modes also imply different types of relationships with other householders. The individual energy autonomy mode is the only mode in which householders do not engage with other householders. The two community modes (mode 2 and 4) connect householders based on shared local identity or values, in order to exchange energy among each other. The market and grid modes, on the other hand, may also aggregate individual households, but these ‘collectives’ engage in energy transactions with market and grid actors. For householders it may feel as if they participate on an individual basis, while in fact an aggregator treats multiple households as a pool in order to enable their participation in grid management and energy markets (Rathnayaka et al., 2014).

In the remainder of this paper, we want to draw out two important potential implications of these storage modes. Rather than discussing the implications of each mode separately, we reflect on two overarching effects that we consider to bring the most fundamental changes to how people can take part in the energy transition. First, some of the modes enable householders to engage in energy production, consumption and storage via *new collectivities* that challenge our traditional understanding of energy communities. Second, in all of the modes, a large part of the organizational ‘work’ around storage is performed by *intermediaries and smart technologies*, which challenges the idea of empowerment of prosumers and communities.

4.5.2 New Collective Material Practices

The individual energy autonomy mode is the only mode in which householders produce, store and consume energy within the bounded spaces of their own home. The other four modes comprise material practices which enable householders to form larger collectives and share their hardware and/or energy with others. Such material practices allow householders to go beyond optimizing self-consumption and exchange energy with other households or start transacting with the market or the grid. Existing local energy communities can add batteries to their renewable generation to boost local energy autonomy, but batteries can also enable the formation of new collectives of prosumers. These new collectives are a result of technical infrastructures that interconnect multiple households with batteries. Since aggregation does not require geographical proximity of the households, such new collectives can have members nation-wide as the example of the SonnenCommunity showed. The storage modes that afford collective material practices thereby bring along a range of questions about the character, aims and ideologies of these practices, and how they may and may not differ from the well-known local renewable energy generating communities.

In the literature, a common way to describe renewable energy communities is as 'those projects where communities (of place or interest) exhibit a high degree of ownership and control in renewable energy production as well as benefiting collectively from the outcomes' (Barbour et al., 2018). Such communities for example consist of local energy cooperatives that develop collective energy practices (Seyfang et al., 2013), such as collectively generating solar energy for local use. The aggregation of domestic batteries in particular affords new communities of interest, with new collective practices, to be formed. While the SonnenCommunity is an example of the creation of a community of like-minded users aiming at autonomy from conventional suppliers, other prosumer collectives may align their collective practices with market or grid rationalities. So just like local communities, the new collectives may be oriented towards social goals (e.g., autonomy), sustainability (green energy), and economic goals (profit seeking). An important difference is that the prosumer collectives that are now emerging are often not initiated bottom-up by citizens, but by grid operators, energy suppliers, and start-ups which have the expertise to build and manage the complex underlying technical infrastructure.

How householders can engage these new collectives may differ widely. There are prosumer collectives in which householders participate without being aware of the other 'members', for example when householders are aggregated to provide grid services. In other collectives the connections with other households are made visible in particular ways. For the SonnenCommunity, for example, the provider visualizes the location of community members on a map and shows which type of energy they generate for the community (solar, biogas). In some peer-to-peer exchange platforms consumers can even choose the peer they want to buy energy from. Emerging prosumer collectives thus shape new collectives which can take very different forms: from the aggregation of householders in collectives that remain invisible and anonymous, to a community of interest with 'members' or 'peers'. An important remaining question, however, is how inclusive these new collectives are for different types of households including lower-income households or tenants. As Ryghaug et al. (2018) also argue for the case of electric vehicles and solar panels, the costs of these storage devices may mean that material participation via batteries is not equally accessible to all groups in society.

4.5.3 The Growing Power of Aggregators and Algorithms in New Material Energy Practices

Even though storage devices are located in households or communities, the role of householders in energy storage cannot simply be characterized as the active and aware prosumer. Most of the 'work' around energy storage is carried out by or on behalf of professionals, such as the installation and maintenance of the battery system, the monitoring and management of the battery charging strategy, and the managing of aggregated batteries. The emerging material practices surrounding storage are organized by intermediaries (Verkade and Höffken, 2019) as well as by information technologies.

Intermediary organizations, such as aggregators and green energy suppliers, play a key role in facilitating what householders can do with storage, as well as how, and with whom. Intermediaries are new players in the energy system, who act as a mediator or broker between householders and energy providers. They collectivize householders' energy consumption and production practices and enable and manage their participation in local and national energy systems. In the case of energy exchange among householders, intermediaries may arrange the balancing of supply and demand in the community. Intermediaries thus broaden the options for householders to enter into transactions with other householders and the energy system: transactions that are either too complex, or otherwise inaccessible to (individual) households. For geographical and virtual energy communities who want to become (more) self-sufficient, increased autonomy may thus go along with new forms of dependence on intermediaries who arrange the management and operation of energy exchange. There are concerns about the extent to which householders are able to access the full market potential of their batteries, as business models offered by intermediaries may distribute burdens and revenues unfavorably (Hodson et al., 2013). Material participation by householders through the purchase of storage batteries is, in other words, not synonymous with householder empowerment.

Information technologies too are a major factor in the management and control of (networked) households with batteries. Smart metering technologies monitor householders' energy consumption, production and storage practices. Hence, it is through these technologies that the householders' energy behavior becomes visible and gets embedded in battery management. Battery charging and discharging strategies often rely on algorithms that predict a household's energy behavior based on its historical energy production and consumption data. In addition, algorithms instruct the direction of energy flows (e.g., discharge to the household, or to the grid). Algorithms may also prioritize certain types of energy (green energy, cheap energy) in the way the battery systems work. In other words, they decide which energy is allowed to flow where and when. Householders choose these 'settings' when they buy a particular storage product or service, and may fine-tune them when the battery is installed. After that, the charging and discharging processes are often automated and users have little possibilities to change settings. Information technologies thus appear as a key factor in enabling connections between local or geographically distributed households and connections with wider infrastructures such as electricity markets. In shaping which transactions can take place, how, and between which entities, digital platforms (Burlinson and Giulietti, 2018) are becoming a new underlying structure for organizing energy production and consumption at decentral level, with as yet unknown implications for power relations in the energy system (Gillespie, 2010).

4.6 Conclusions

In this paper, we discussed energy storage as a 'technology of engagement' to better understand how householders and communities through their interactions with storage technologies engage in energy transitions. Drawing on Walker and Cass, we developed the concept of 'storage mode' to examine how battery technologies can be part of diverse sociotechnical configurations. We identified the emergence of five different storage modes, which demonstrates that renewable energy storage can entail a wide variety of relationships and interactions between householders and other energy system actors. To further unpack the various roles and engagements for householders, we examined the problem definitions, practices and task divisions in the modes. Our approach highlights that people can relate to renewable energy technologies not just as supporters or protestors or users, but through a diversity of roles that actively integrate them in the wider energy system (see also Throndsen and Ryghaug, 2015): as co-manager or market actor, and as communities or individuals organizing energy production and consumption at decentral scale. As a technology of engagement, energy storage thus allows householders to interact with and shape the energy system in new ways. Most of the storage modes allow prosumers with battery systems to generate not only use value (by self-consumption of stored energy), but also exchange value (by sharing and trading energy and providing grid services) (Kloppenburg and Boekelo, 2019). Energy storage thereby leads to more options for prosumers about what they want to do with their self-generated energy and with whom.

When storage affords energy practices in which self-produced energy gets exchange value, an important question is how prosumers will relate to this. Two diverging storylines now get connected to this exchange value: the first presents self-produced energy as a potential source of revenue for householders (energy as commodity), and the second emphasizes the sharing of surplus energy with other households (energy as (common pool) resource). Future social scientific research could follow up on these storylines and analyze the "moral economies" -or in other words moral and ethical questions about the production, distribution and exchange of energy- that emerge around this newly unlocked exchange value.

In examining the ways in which the new energy practices are organized in storage modes, our framework challenges the notion of active and aware citizens owning and operating their own household or community batteries. On the one hand, energy storage enables householders to become more autonomous from conventional suppliers and to enter new exchange relationships with other householders and the energy system. On the other hand, they face new dependencies on intermediaries and opaque information technologies. As long as householders believe that aggregators and algorithms act in their interest, they may not consider this a problem. Our analysis showed, however, similar to Parra et al. (2017), that the real-world applications of energy storage are still very much provider-driven. For existing community groups, it is difficult to initiate storage projects because in most countries legal limitations and complexities block communities from supplying their own energy to its members, or to organize the distribution of energy. In this context of provider-driven storage products and services, the question for householders is if they trust it is their aspirations and interests that are taken into account.

It is with regard to this potential for alternative forms of organizing energy production and consumption that we can identify policy implications. To foster storage modes that take into account a wider range of (future) interests and aspirations of householders and communities, and enable diverse forms of energy citizenship, governments could develop policies to actively support experimentation with social organization. An example of this is the Dutch

'Experimentenregeling' which provides energy cooperatives regulatory lenience to experiment with generating, supplying and distributing energy in their own local network. At the same time, studies have shown that such community-based models face difficulties due to financial, legal, social and technical restrictions and complexities surrounding energy storage and engaging with governance circles (Koirala et al., 2018; Lammers and Diestelmeier, 2017). Beyond regulatory leniency, two other requirements for enabling experimentation include elimination of some of the financial risks and uncertainties in order to embolden communities as initiators of pilot projects, and secondly, professional facilitation of householders and communities to enable them to articulate their interests and ambitions vis-à-vis intermediaries. The emergence of prosumer platforms too offers opportunities for co-creation by citizens. Prosumer platforms could be developed or adapted together with local or virtual energy communities to ensure that energy exchange takes place based on valuations of energy and distribution of benefits and costs that the community favors. Opening up spaces for communities to initiate and develop energy storage projects may prevent that some emerging modes become marginalized too soon, and prevent lock-in situations in which existing power relations between providers and householders are reproduced. Recognizing that energy storage (as technology of engagement) offers prosumers enticing—and sometimes conflicting—perspectives on greater energy autonomy and self-sufficiency as well as on greater systems integration, it is important to provide space for experimentation with (mixed modes of) energy storage that both empower householders and communities in the pursuit of their own sustainability aspirations and serve the needs of emerging renewable energy-based energy systems. Providers and policy makers need to recognize that the 'storage revolution' should not just be seen in technical or economic terms, but also as an experiment with multiple new ways of relating to energy and new forms of social organization of energy production and consumption.

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Conflicts of Interest

The authors declare no conflict of interest. The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, or in the decision to publish the results.

Chapter 5

Platforms in power: householder perspectives on the social, environmental and economic challenges of energy platforms

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Chapter 5: Platforms in power: householder perspectives on the social, environmental and economic challenges of energy platforms

Abstract

New business models and digital infrastructures, in the form of 'energy platforms', are emerging as part of a transition towards decarbonised, decentralised, and digitised energy systems. These energy platforms offer new ways for householders to trade or exchange energy with other households or with energy system actors, but also bring along challenges. This paper examines how householders engage with potential environmental, social, and economic opportunities and risks of energy platforms. We convened two serious-game style workshops in which Dutch frontrunner householders assumed the role of platform members and were challenged to deliberate about different scenarios and issues. The workshop results, while explorative in nature, are indicative of a willingness to pursue energy system integration rather than autarky or grid defection. The idea of energy platforms as vehicles for energy justice appealed less to the householders, although the participants were moderately interested in sharing surplus renewable energy. Finally, environmental motivations were of key importance in householders' evaluation of different platform types. This shows that in the role of energy platform members, householders can engage with both the community and the grid in new and different ways, leading to a diversity of possible outcomes for householder engagement.

5.1 Introduction

With the emergence of new renewable energy technologies at a household level, such as solar panels, smart meters, and home batteries, householders have taken on new roles in the energy system. As prosumers, they have installed solar panels and started producing their own green energy, thereby taking responsibility for the decarbonisation of the electricity system. Households can also engage in energy generation collectively, for example in local energy initiatives (Van der Schoor and Scholtens, 2015). With the roll-out of smart meters and the introduction of smart grids, households have started to monitor their household energy consumption and production, and responding to this information by shifting their energy use in time, or taking energy-saving measures. Their involvement in so-called demand response programs makes them co-managers of the grid (Smale et al., 2017). Recently, the term 'prosumager' (Schill et al., 2019; Sioshansi, 2019) has been coined to refer to grid-connected households who have, next to solar panels, also installed residential batteries.

In addition to these renewable technologies at a household level, at a more general level, new business models and digital infrastructures in the form of 'energy platforms' are emerging as part of a transition towards decarbonised, decentralised, and digitised energy systems. In this paper we define energy platforms as digital technology-based, decentralised platforms in which (groups of) householders manage the generation, consumption, storage and exchange renewable electricity between their members and the wider electricity grid. Energy platforms can perform a variety of functions within energy systems: aggregating distributed energy resources and integrating them into the wider grid, providing grid balancing flexibility, boosting self-consumption of renewable energy, facilitating peer-to-peer and local energy exchange, and organizing trading of energy on markets (Morstyn et al., 2018).

There are a myriad of positive expectations about the benefits energy platforms can bring to both energy systems and householders, ranging from reducing overall costs and CO_2 emissions by better integrating and coordinating distributed energy resources (Koirala et al., 2018), democratising access to renewable energy (Kloppenburg and Boekelo, 2019), to eliminating reliance on established energy actors or central intermediaries (Mengelkamp et al., 2018). At the same time, there are concerns that 'platformisation' produces uncertainties and privatises energy provisioning, which may hinder the transition towards sustainable energy systems (Kloppenburg and Boekelo, 2019). These concerns echo the now widespread critiques of what has been called the 'platform society' (Van Dijck et al., 2016) and 'platform capitalism' (Langley and Layshon, 2017). These critiques revolve around platform accessibility and exclusion, exploitation of participants, and the potentially surreptitious role of algorithms, among others. Moreover, the deployment and operation of renewable energy assets in energy platforms is characterised by trade-offs and different (environmental and economic) outcomes. For instance, McKenna et al. (2017) highlight a tension between economic gains and environmental gains with respect to energy storage technology, a key component of (real and imagined) energy platforms: "the scenarios in which storage is operated for economic gains increase emissions, whereas those that decrease emissions are unlikely to be economically favourable" (p. 601).

The opportunities and risks posed by energy platform development warrants a closer look at what participation in energy platforms can mean for the roles and energy practices of householders in the (future) energy system. Still, while householders will play a crucial role in realizing climate and energy goals in future energy systems (Naus, 2017), studies about how households would want to be engaged in and with platforms, and how they view the different possibilities and risks of energy provisioning via these emerging energy technologies are largely absent.

The aim of this paper is to provide a householder perspective on the emergence of energy platforms. Our main research question is: how do householders view the social, environmental and economic opportunities and challenges of energy platforms, and how do they respond to the new roles and responsibilities for householders that energy platforms could bring along? Since energy platforms can take many forms, from boosting self-consumption of green energy, to energy trading and providing grid balancing services, our goal was to understand how householders view different alternatives. To do this, we draw on our findings from two serious game-style workshops in which we confronted householders with different future scenarios of 'platformised' energy provisioning.

In the next section, we place the rise of energy platforms in the broader context of the emergence of new roles and responsibilities for households in low-carbon energy systems. In the methodology section, we provide a typology of energy platforms and describe how we conducted the workshops. Section 4 presents the results of the workshops. Finally, we reflect on what the new role of prosumers as platform members might imply for energy justice and citizenship in decentralised energy systems.

5.2 Energy Platforms: New Roles and Responsibilities for Prosumer Households

The role of households in the energy transition, and in particular, their engagement with renewable energy technologies in or close to their homes, has received a lot of attention in the energy social sciences. The introduction of solar panels, smart meters, and home batteries has led scholars to analyse how householders have taken on new roles as prosumers: individually, or as energy collectives and cooperatives (community energy), and more recently as co-managers of energy in so-called smart grids. As the number of prosumers increases, the electric utility sector is expected to undergo significant changes, offering new possibilities for the greening of the system as well as many unknowns and risks that need to be identified and managed (Parag and Sovacool, 2016).

5.2.1 Prosumers as Energy Community Members

Prosumers can pool resources and start a local energy initiative (Van der Schoor and Scholtens, 2015). In the literature, such grassroots innovations are seen to be challenging the existing governance of the energy system. Community energy has broadly been characterised as civil society activity 'tackling a wide range of sustainable energy and related issues' (Seyfang et al., 2013). Community energy initiatives can be understood as "diverse–explicit and implicit, more or less conscious–forms of political engagement" (Martiskainen et al., 2018). Jenkins et al. (2016) describe how energy communities engage with different dimensions of energy justice, such as distributional energy justice (referring to divisions of costs and benefits) and procedural justice (power dynamics in decision-making). Community energy is viewed as a key component of 'energy democracy', a vision and movement which advocates redistributing power to the people through renewable transformation, for example by establishing community ownership of renewable energy assets and "locally-focused decision making reflecting local priorities" (Stephens, 2019). Research has shown that a mix of gain and normative considerations, and, to a lesser extent, hedonistic motivations (such as having fun and community cohesion), play a role in householders deciding to engage with community energy (Dóci and Vasileiadou, 2015).

Scholars have also identified various risks associated with the proliferation of community energy. There are concerns, for example, that affluent communities who pursue renewable energy self-sufficiency and autonomy may not contribute equitably to the societal costs of energy grid maintenance (sometimes referred to as 'islanding', or less neutrally, as 'utility death spiral' (Kloppenburg and Boekelo, 2019). Moreover, energy communities tend to be socio-economically homogenous, not reaching those at risk of energy poverty, in this and other ways, community energy has "the potential to reproduce, or even exacerbate, existing socio-economic and spatial inequalities" (Johnson and Hall, 2014; p. 149). More generally, the emphasis on self-reliant communities and a diminished role for the state (as observed in UK discourse on community energy) reveals a politics of localism which neglects social justice considerations (Catney et al., 2014).

5.2.2 Prosumers as Co-Managers of Energy

Studies on households and smart grids have examined how with the introduction of smart grids, households are imagined to get a more active role in the energy system through monitoring their household energy consumption and production, and responding to this information by shifting their energy use in time, or taking energy-saving measures [2]. Home energy management by prosumers (who then become 'prosumer-managers' or "prosumagers" Schill et al., 2019; Sioshansi, 2019), in the forms of both everyday behavioural adjustments and automated digital energy technologies (such as storage devices and smart heating systems), is considered crucial to the success of smart grids (Naus, 2017; Smale et al., 2018).

However, a growing number of practice-theory informed studies on smart grid pilot projects has shown that in such projects, the images of householders as rational decision-makers held by designers and providers often do not fit with the ways in which people use energy as part of everyday domestic practices (Hargreaves et al., 2018; Strengers, 2014). This literature has also pointed out that despite the rhetoric of 'active users', many smart grid projects are steered by a provider-driven logic, with users experiencing a lack of control (Smale et al., 2018; Verkade and Höffken, 2018). There are concerns that smart energy technologies "may reinforce unsustainable energy consumption patterns in the residential sector, are not easily accessible by vulnerable consumers, and do little to help the 'energy poor' secure adequate and affordable access to energy at home" (Herrero et al., 2018). Moreover, the assumption that prosumers will be motivated to act as co-managers out of financial considerations is problematic, as rewards are likely to be very small (Kowalski and Matusiak, 2019). A stronger motivator for ongoing engagement with energy management appears to be optimally using self-generated renewable energy (for example by shifting energy use) (Smale et al., 2017).

5.2.3 Prosumers as Energy Platform Members

With the rise of energy platforms, a novel role for householders in energy systems is emerging. The energy platform member is both connected to a community and to energy systems, and, hence, combines aspects of the community prosumer and the grid-connected prosumer roles. Energy platforms are thought to represent a profound break from previous generations socio-technical configurations of energy systems (Kloppenburg and Boekelo, 2019). They vary greatly in terms of their socio-technical characteristics and range from commercial networks of electricity-trading prosumers spread across the country, to local initiatives where residents collaborate with energy utilities and/or market actors to better manage the generation, distribution, and consumption of locally generated renewable energy in order to achieve costs and emissions reductions. Typically, an intermediary party acts as "supervisory third-party in charge of interfacing with the market and system operator and of guaranteeing the collective common agreements" (Moret and Pinson, 2018). The intermediary role can be played by established energy sector actors, for example, utilities such as distribution system operators (DSOs) or energy companies, as well as new entrants such as aggregators. Energy platforms referred to by Koirala et al. (2016) as 'integrated community energy systems', "are emerging as a modern development to re-organise local energy systems allowing simultaneous integration of distributed energy resources and engagement of local communities" (p. 981). However, much remains unknown about the potential value that these systems can provide to local communities and to the wider energy system (idem.).

We propose, as the main theoretical argument of this paper, that energy platforms establish and significantly reconfigure three key relationships: (1) prosumers' relations with the wider energy system, (2) relations between platform members, and (3) relations with non-members. Similar to the energy co-manager and the community member models of householder participation, this reconfiguration opens up a range of (social, environmental, and economic) opportunities as well as risks for householders and communities. With respect to prosumer relations with the wider grid, energy platforms can be aimed at grid integration or local self-sufficiency. The first version works towards a deepening entwinement of households with national energy markets, the latter can potentially result in grid defection. Similarly, relations between platform members may be characterised by individual or by collective approaches to goal-setting, decision-making, monitoring and sharing of data, and the provisioning of (financial) incentives. Moreover, energy platforms can be organised as geographically dispersed peer-to-peer networks of more or less anonymous prosumers, but can also be rooted in local frontrunner networks or communities. Social cohesion between platform members, feelings of responsibility towards non-members (and associated with that, opportunities for enhancing energy justice or alleviating energy poverty) are likely to differ greatly between community, (commercial) grid-integration and peer-to-peer models of energy platforms. To conclude, energy platforms as socio-technical innovation appear to be highly open-ended and flexible entities which deserve closer analysis with respect to the opportunities and risks for householders and communities.

5.3 Methodology

To investigate the main research question, we conducted two iterations of a serious game-style workshop with householders involved in energy platform projects. Below we provide an outline of the workshop, including the typology of three energy platforms upon which the workshop is based, and a description of the two participant groups. We selected a participatory workshop methodology because it can achieve a dual purpose (Ørngreen and Levinsen, 2017): fulfilling participants' expectations that they might learn or achieve something related to their own interests on the one hand, and on the other, fulfilling a research purpose through the production of reliable data. By using this approach, the emerging diversity of energy platforms, with their different environmental, economic, and social characteristics, can be made understandable for (non-expert) householders. The use of visualisations and an interactive format, designed to convey complexities and consequences in bits (mini-assignments), contributes to this. The method employed in this paper was designed to stimulate deliberation amongst householders while they navigate different energy platform scenarios involving a series of questions and challenges. In attempting to construct an immersive context for learning, deliberation and decision-making, this methodology is inspired by the emerging use of serious games in energy social science research (Wood et al., 2014).

5.3.1 Three Platform Types

While at first sight energy platforms seem to contribute to the energy transition, they may, in fact, do so in widely different ways. For the workshop, we drew up three distinctive platform types, each of which performs a different function in relation to the wider grid: commercial platforms, balancing platforms and climate platforms.

Commercial Platform:

In commercial platforms, platform members engage in energy trading on (national) energy markets. Renewable electricity generated by the platform members is stored in in-home batteries and sold to the grid at optimal times. The sustainability objective is to increase the overall share of renewable energy on the grid. Commercial platforms generate a flow of (financial) benefits to platform members.

Platform members can choose to distribute those benefits in different ways. Individual returns may be coupled, for example, with some form of benefits sharing, to alleviate energy poverty or to support local facilities, like sports clubs. In this way, platform members are challenged to weigh individual economic returns against (collective) environmental and social objectives.

Balancing Platform:

In balancing platforms, platform members provide grid balancing services to the wider grid. Householders are engaged and financially rewarded as co-managers of energy systems. The sustainability objective is to increase the resilience and flexibility of the grid infrastructure. By aligning with energy system needs, households become further integrated into energy systems (instead of becoming more autonomous/autarkic). In this way, platform members are provided with new opportunities to take responsibility for the wider energy infrastructure. On the other hand, balancing platforms may also create new dependencies where platform members become reliant on the intermediary actors which organise the grid balancing services.

Climate Platform:

In climate platforms, platform members engage in self-consumption of (locally or self-generated) renewable energy and/or in local energy exchange. The sustainability objective is to achieve CO_2-reductions through local renewable energy generation, energy-saving, and self-sufficiency. The climate platform provides members with the opportunity to achieve ‘climate neutrality’ at the individual household level or at a more collective (platform) level, through individual engagement or collective action to reduce the CO_2-footprint. In addition, the focus on CO_2 reduction challenges platform members to consider to what extent non-energy related practices (such as food consumption and everyday mobility) should be included in the platform.

Each of the three platform types thus enables householders to become involved in new energy practices: energy trading, providing grid balancing services, self-consumption and local energy exchange. In addition, each platform type has embedded in its workings particular economic, social, and environmental opportunities and challenges (see Table 5.1). For example, the balancing platform can contribute to the resilience and sustainability of public electricity infrastructure, whereas commercial platforms can increase pressure on (local) electricity grids. Moreover, within one platform type, tensions can emerge between social, economic, and environmental objectives. In the workshop, householders were confronted with the three platform types, the new roles and practices these platforms would afford them, and the key opportunities and challenges of the platform types.

Table 5.1. Overview of key features of three socio-technical configurations of energy platforms.

	Energy Practice	***Key Opportunities and Challenges***
A: Commercial platform	Energy trading on (national) energy markets	• relative importance of quick economic returns vs. environmental(/social) objectives • optimal economic returns for individual households versus benefits sharing • individual householder engagement or local community engagement
B: Balancing platform	Providing grid balancing services	• integration into and responsibility for wider infrastructure (vs. autarky) • reliance on intermediary actors
C: Climate platform	Enabling self-consumption and/or local energy exchange	• individual householder engagement or collective action to reduce CO_2-footprint • energy-focus versus broadened platform to target CO_2-reduction in non-energy related practices

5.3.2 Outline of the Workshop

The workshop consists of two phases, each 45 min long. The objective of the first phase was to enable discussion among householders about social, environmental, and economic aspects of energy platforms. Dual statements were developed to structure the discussion, each statement reflecting different values with respect to social, environmental, and economic aspects of energy platforms. To illustrate, one set of dual statements concerned the distribution of economic gains: (1) “It is more than reasonable to aim for a quick return on my investment” (reflecting individualist/economistic values), and (2), “I want to use my assets to achieve broader sustainability or community benefits” (reflecting ‘green’ or community values). After discussing the statements, the participants were asked to declare their preferred statement, first individually and then as a group. The series of dual statements took the shape of a decision-tree, physically depicted on the floor in which the workshop was conducted. After a series of three to five group choices, this leads the participants to their preferred energy platform (platform type A, B, or C) depicted on a large poster (Figure 5.1). As an example, if participants consistently picked 'economic' statements over socially or environmentally motivated ones, they would arrive at the commercial platform and be confronted with the (environmental, social, and economic) qualities of that platform type. The small sample size and frontrunner characteristics of the participants did not allow for a representative assessment of the relative popularity of different platform types, and therefore participants' preferences for the platform types are not presented quantitatively in the Results section. Instead, the participants' deliberations generated by the workshops constitute the primary research data.

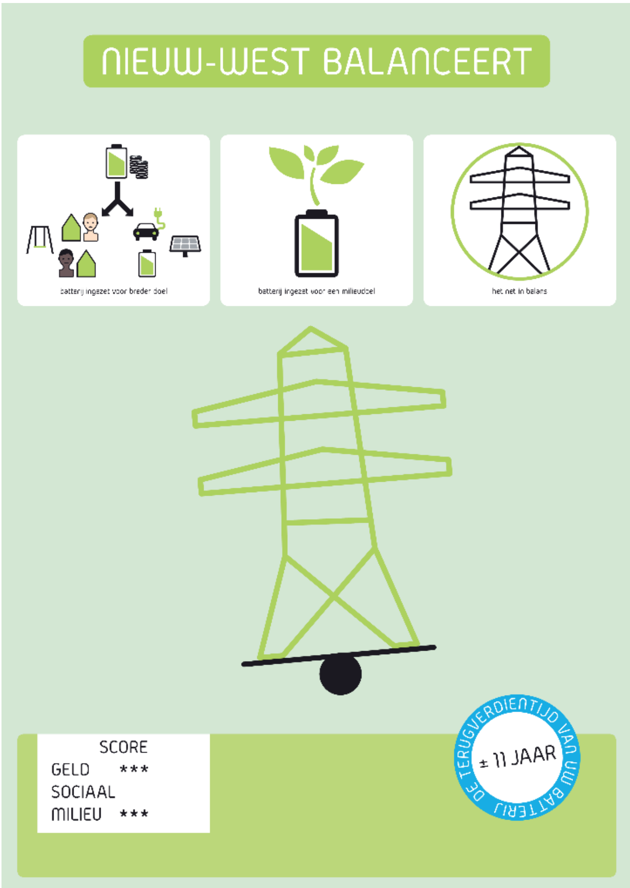

Figure 5.1. Example of a poster used during the workshop, depicting a grid-balancing platform. Translation of the workshop materials is provided in the Supplementary Materials.

The goal of the second phase of the workshop was for householders to develop a more in-depth familiarity with different platform scenario's, and to engage them in the discussion about potential issues as members of future energy platforms. This part of the workshop was structured around an introductory text and a visual depiction of a dilemma or 'challenge' for the participants to debate and solve, as members of the platform in question. Three challenges were developed, each tied to the commercial platform, the balancing platform, and climate platform, respectively. The first concerned the distribution of benefits in energy platforms in relation to socio-economic justice and equity. The second revolved around the trust relationship between platform members and potential intermediary partners. Finally, the third challenge concerned operationalising the climate objective, specifically with respect to the in- or exclusion of non-energy domains (food, everyday mobility, air travel) and the selection of instruments (information provision, gamification, financial incentives).

The role of the researchers during the workshop was to: (1) explain the assignments during the workshop, (2) to moderate and record the discussions, requesting input from all participants and when necessary providing extra context or explanation, and (3) to keep track of the time and, if necessary, nudging participants on to the next question or issue. The recordings of the workshops were transcribed and anonymised. The workshop transcriptions were colour-coded per theme (environmental, social, economic) and subsequently analysed for reference to previously identified tensions (Table 5.2). References to and discussions about these tensions were then grouped per platform type, enabling the integration of results into the narrative-style format which is presented in the Results section. Pseudonyms have been used section to protect participants' anonymity.

Table 5.2. Analytical framework used to analyze the workshop transcriptions.

Theme	*Tensions*	*Indicative Keywords*
Environmental	• Energy self-sufficiency vs. system-efficiency • Indicators of sustainability (at different scales) • Narrow vs. broad approach to CO_2-reduction • Climate objectives vs. household needs	Climate change, self-reliance, autarky, Paris accords, comfort, grey and green electricity, CO_2-neutral, grid balance, flexibility, responsibility
Social	• Individual vs. collective approaches	Engagement, participation, fun, decision-making, power

Theme	*Tensions*	*Indicative Keywords*
	• Householder empowerment vs. intermediaries and algorithms • Trust and intermediaries • Social cohesion	relations, democratic, community, peer-to-peer
Economic	• Inclusion and exclusion • Responsibility for societal costs • Distributional effects	Costs, benefits, fairness, inequity, members and non-members, solidarity, sharing, trading, business model, incentives

5.3.3 Description of the Participant Groups

Two participant groups were selected for the workshops. The two groups were selected based on their involvement in two energy platform demonstration projects, both of which featured battery storage and some degree of householder engagement (i.e., not a purely technical pilot). Both groups consisted of frontrunner householders with experience with renewable energy generation (all participants owned solar panels) as well as some familiarity with energy platforms. In this way, the participants would be able to rely on their knowledge and past experience to reflect critically on different energy platforms and their issues. The two, small-scale demonstration projects out of which the participants were recruited were primarily technical in nature and made no particular attempts at demographic representativeness. As a result, the participant groups' characteristics mirrored those generally attributed to 'energy frontrunners', with an overrepresentation of older, male, affluent, well-educated householders. Detailed demographic data on the participants was not collected or used in analysis due to the limited representativeness of this participant group and the explorative nature of the study.

Workshop 1 involved 35 participants in the 'CityZen VPP', a demonstration project of a Virtual Power Plant (VPP) in a neighbourhood in Amsterdam. In this VPP project, the householders' renewable energy resources (solar panels and batteries) were pooled and used to test out different functions, including providing grid balancing services and trading energy on energy markets. The workshop was conducted at the end of the pilot phase of the VPP. Therefore, the participants had first-hand experience with home batteries and smart energy services prior to the workshop. The general attitude in the participant group at the time of the workshop was that the innovation is laudable but information provision about battery functionalities, the broader objectives and results of the pilot, and the value for the participants could be improved.

Workshop 2 was conducted with 24 participants of the project 'cVPP Loenen'. Relative to the urban and dispersed CityZen participant group, these householders formed a more tightly-knit community, situated in a semi-urban village. As members of a local renewable energy cooperative, they declared their interest in establishing a community-based virtual power plant (cVPP). The idea was to develop the cVPP together with the community, with the householders co-determining the objectives and practices of the platform. Adding to this participatory approach, the workshop presented in this paper was organised at the start of the householders' involvement in the initiative. As such, these householders did not yet have the first-hand experience with home batteries, energy platforms or smart energy services.

5.4 Results: Discussion with Householders in Two Workshops

This section reports on the general themes which emerged in householders' discussions during workshops, in which the participants were confronted with three diverse socio-technical configurations of energy platforms: commercial, balancing, and climate platforms.

5.4.1 'Commercial' Energy Platform

The commercial platform scenario confronted participants with the concept of individual households acting as traders on (national) energy markets to sell their renewable energy, to generate income for themselves or the community. By presenting participants with different forms of benefits-sharing, the scenario challenged householders to discuss their economic self-interest (operationalised as the 'pay-back time' on the home battery) in relation to environmental and social objectives. This triggered debate about what constitutes fair and just social and economic relationships among energy platform members, and between members and non-members (the local community and beyond it).

During the discussions, the participants articulated their (moral) engagement with their 'green energy'. Many were critical of profit-based energy trading and instead were enthusiastic about self-sufficiency or sharing green energy with others.

> *Mr. Visser: 'For me, part of the returns should go to cover the costs of exploitation, to expand and reinvest in renewable energy assets, or even to provide my neighbours with power in the future.'*

When confronted with the notion that charging batteries with fossil fuel-based 'grey' electricity at night (when electricity demand and thus prices are low) may be profitable or contribute to grid balance, the participants were equally critical:

> *Mrs. Smit: 'I didn't quite understand when you said that batteries might be charged with grey electricity at night, wind turbines produce electricity at night, right?'*

> *Mr. Martel, in response: 'Yea, it should be possible to choose to only allow your battery to be charged with green energy at night...'*

> *Mr. Hendriks: 'I would want to be able to check if the electricity being purchased [by the intermediary] is green and self-generated'.*

The participants generally did not evaluate the economic performance of different energy platform configurations purely as rational economic decision-makers. Instead, they drew frequently upon a range of moral frames, such as responsibility towards future generations. Some householders explicitly adopted a long term, (environmental) ethics/morally motivated perspective with respect to their investment in renewable energy technologies, even when confronted with slower returns on investment:

> *Mrs. Jacobs: 'I have read the Club of Rome report, I know what is coming towards us... If I know [our community] as well as I think I do, we are in it not for our own profits but for the common good.'*

> *Mr. Visser: 'That dot on the horizon, for my children and the children of my children, that is why I decided to place solar panels on my roof'.*

Other householders, on the other hand, emphasised that a sound economic model would be crucial for recruiting a critical mass of participants to kick-off energy platforms and ensure their longevity.

> *Mrs. Van Beek: 'Emphasizing economic returns is not greedy behaviour–a return on investment is the only way to get a project like this off the ground.'*

Next, the participants reflected on how platform benefits and costs should be distributed. The participants discussed and expressed a preference for different ways of reinvesting (part of) the profits generated by the energy platform. These included: (1) paying out all the financial gains to the members, in accordance with their relative contribution, (2) collectively re-investing in additional renewable energy resources, (3) redistributing platform benefits to (certain) members and/or non-members, (4) investing in exclusive (e.g., a shared 'energy platform e-bike') or non-exclusive neighbourhood facilities (e.g., a playground), or (5) a mix of these options.

Confronted with this task, participants argued option 1 (paying out to members) was the most motivating and fair to the platform members. They tended not to view energy platforms as vehicles for social or energy justice. The participants drew boundaries between platform members and non-members when they were debating how to distribute and reinvest profits. Instead of assuming broad socio-economic responsibility, the participants identified a number of 'thematic' (energy-related) opportunities for benefits-sharing or synergies with the wider community. Householders who are not able to invest in, for example, solar panels, due to lack of suitable roof space or insufficient capital, could benefit from roof sharing projects or 'revolving' renewable energy investment funds.

> *Mr. De Jonge: 'We can also consider 'lease' constructions, for people who do not have a roof and those who have many panels, saying: 'I have 15 panels, you can lease 3'. Then you do end up with a form of collectivity'.*

Some participants also suggested that benefits for the wider community could be achieved through support for local associations and facilities, such as a swimming pool, sports club, or community farm, for example by co-financing rooftop solar PV, by sharing expertise, or by offering energy contracts at a reduced fee.

The discussions in both workshops revealed a critical attitude towards assuming socio-economic responsibilities within an imagined community energy platform. Wholesale redistribution of benefits was seen as unfair and unmotivating. Instead, participants expressed enthusiasm for concrete, 'thematic' energy-related projects and schemes through which to engage and share benefits with the wider community (ranging from non-member residents to local clubs and facilities).

5.4.2 'Balancing' Energy Platform

The 'grid-balancing' energy platform scenario confronted participants with possible consequences of decentralised renewable energy generation for the electricity grid (imbalance, curtailment, societal costs of infrastructure reinforcement), challenging the participants to reconsider their households' and the platform's relationship to the wider energy system and to intermediary actors. In the discussions which followed, several participants stated that solely pursuing self-sufficiency or autonomy, as a platform, a community, or as individual households, would likely introduce "inefficiencies". Moreover, they considered a resilient energy grid as a "boundary condition" for any energy platform's success:

Mrs. Veenstra: 'You need the grid. Your goal can be to reduce CO_2 as much as possible, but you cannot simply make that step without ensuring a stable energy grid. That is a precondition'.

Mr. Scholten: 'So you say that you also carry responsibility for the grid, to keep it into account?'

Mr. Bosch, in response: 'Yes, I think so. Otherwise, you start introducing inefficiencies. That would be a shame.'

Many participants stated being keenly aware of the different kinds of resources required to establish and run an energy platform (including knowledge, capital, access to energy markets, and technology), as well as of their own lack of insight into the overall energy system needs. This led several participants to wonder if a 'hybrid energy platform' would be possible:

Mrs. Hermans: '[We need] a type of hybrid. You cannot go off the grid anyway, so you have to take it into account. We don't have to start trading, but we can see how we can all reduce and how we can relieve the grid'.

In such a 'hybrid' platform, householders would team up with electricity distribution system operators (DSOs) or other energy sector actors to form an energy platform which combines grid balancing functions with other sustainability objectives, such as renewable self-sufficiency. In these discussions, there was a willingness to think along with the wider energy system. Participants were keen to debate energy platforms which prevent grid problems rather than exacerbate them. Notably, one participant felt more empowered to contribute to grid balance than to tackle fossil-fuel dependence:

Mr. Sanders: 'Look, we ourselves do not control getting rid of our dependence on fossil fuels, that is much more with companies. Large companies, that is where the problem lies. I believe we are much better off if we, together, ensure that there is a stable energy grid.'

However, some participants were sceptical about contributing to grid balance, with some arguing that this type of entwinement with the energy system would lead to new dependencies:

Mr. Verbeek, in response: 'I believe balancing the grid is not something we should do. It is not an option for me, because then before you know it we are once again in bed with the big energy companies who will be involved in that'.

Moreover, simply providing grid balancing services for a financial return did not match the idealistic motivations of many participants. To them, a precondition for engaging with the needs of the wider grid was that measures taken by the platform should contribute to its own central objective: to become energy neutral and accelerate the sustainable energy transition. Next, the researchers asked the participants which type of actor they would consider trustworthy, why, and under which conditions, to collaborate with a platform in order to provide balancing services to the grid. The participants discussed a number of aspects (desired qualities of the intermediary, preconditions for the contract) which would contribute to the trust relationship:

Mr. Timmermans: 'I would take as a precondition that there is no commercial interest involved, that it won't be about making a profit or something like that as in the case with energy companies. I think that when it comes to knowledge and structure, they [grid operators] are most suited to deal with the power fluctuations. If you can combine that with a progressive and innovative start-up, then that would be excellent indeed. But the grid operator is my first choice.'

Some householders argued that established actors in the energy sector (energy companies, grid operators) should be preferred because of their capabilities (knowledge, experience, capital, etc.). Overall, the participants were sceptical of commercial interests and emphasised the importance of control (checks and balances), transparency, and participation in decision-making. Moreover, they emphasised the importance of the trust-building role of authentic local 'advocates' and contact persons towards (potential) members:

> *Mrs. Vink: 'I think that the added value of active community involvement is simply that you earn the trust of the people in the village who joined. It would be best if as cooperative you form a trustworthy point of contact towards the community. From there, you outsource to another party. I don't think that we should have a company from 'outside' tell our story.'*

5.4.3 'Climate' Energy Platform

The 'climate' energy platform scenario challenged participants to consider different ways in which energy platforms may achieve climate objectives (operationalised as CO_2-emissions reduction). Participants were triggered to discuss their preferences for individual or collective approaches to goal-setting, monitoring, and providing incentives (financial rewards, gamification), as well as to consider if and under which circumstances the energy platform could achieve climate benefits in non-energy lifestyle domains (food consumption, daily mobility, and vacationing).

With respect to an individual or collective approach to the 'climate' energy platform, the participants generally agreed amongst each other that a collective strategy was undesirable. Collective approaches to monitoring and providing incentives were viewed particularly unfavourably. The participants' main arguments for this were the possibility of 'invasive social control' and the risk of making unfair comparisons between incomparable households–especially if such comparisons would be attached to financial consequences or if they would lead to naming and shaming.

> *Mr. Dijkstra: 'This [a collective approach to monitoring] gives me the image of 'big brother is watching you'. But, big brother is sitting right next to me! And as much as I find him a nice guy, the idea that he knows what is up or where I might be, that is not for me.'*

Participants were generally more positive about collective goal-setting. Still, several participants argued that those collective objectives should be made meaningful and actionable in the context of the individual households which make up the platform:

Mrs. Vermeulen: 'A collective objective can only be articulated individually. Otherwise, nothing will happen'.

Mr. De Bruin: 'In the end, you yourself inhabit the home in which energy is used. So if the VPP helps me to reduce my energy bill, to use energy more sustainably, then perhaps it will automatically trigger the interest of those around me.'

Some participants strongly preferred an "own energy affairs in order first" approach:

Mrs. Postma: '[I think] all have the same ideology, which is that "I want to do something, I want to do something primarily for my own house". And secondly, whatever [resources] might be left is saved and tagged for later investments'.

With respect to expanding the 'mandate' of a climate-energy platform into non-energy domains, participants were generally sceptical. The main argument for retaining a renewable energy focus was the likely ineffectiveness and unpopularity of any attempts to set objects for, monitor, or reward non-energy lifestyle aspects in a platform initiated by householders who "came together on the topic of renewable energy". Moreover, the participants in both workshops considered sustainable vacationing (flying less) an individual responsibility and not a lifestyle change a climate-energy platform should set targets for, monitor or reward. However, the energy community participants, in particular, did see some potential for an energy platform committed to climate objectives to facilitate and stimulate more sustainable daily mobility and food consumption, especially if multiple problems experienced by the community could be addressed in conjunction. For example, this group concluded, the platform could play a role in helping senior residents remain mobile by sponsoring a locally operated electric mini-van, or by collaborating with community-oriented farms (e.g., local organic produce offered at a discount to platform members). While the participants identified a few such specific, positive ways in which the platform could 'move into' domains other than energy, the ultimate consensus in both workshop groups was that an energy platform is not an appropriate vehicle for "broad" climate change action unrelated to the theme of energy.

5.5 Discussion and Conclusions

The main argument presented of this paper is that energy platforms reconfigure several key relations: householder relations with energy systems (infrastructure and intermediary actors), relations between platform members, and relations with non-members. How householders come to relate to energy systems, to fellow platform members, and to non-member as energy platforms, has important social, environmental, and economic implications. Therefore, the aim of this paper was to explore and analyse how householders deliberate about social, environmental and economic opportunities and challenges in the context of different socio-technical configurations of energy platforms. To achieve this objective, two workshops were held in which frontrunner (prosumer) householders were challenged to think, discuss and make choices as platform members. This methodology yielded a number of insights.

The first concerns platform members' relations with other members and with non-members. Energy platforms enable new forms of trading and sharing of energy. As such, energy platforms present opportunities to enhance energy justice, as well as risks of exacerbating energy poverty due in part to the capital- and knowledge-intensive barrier to entry. In the two workshops, participants acknowledged these opportunities and risks and were moderately interested in for example sharing surplus renewable energy. However, they generally argued that energy platforms were not appropriate for vehicles of social justice. Participants were moreover wary of scenario's in which neighbour platform members would be able to monitor and compare each other's performance ('Big Neighbour'). Furthermore, the (potentially) limited socio-economic diversity of platform members was considered natural and unavoidable, indicating that the participants were not strongly triggered by distributive or recognition justice issues in the context of energy platforms (Jenkins et al., 2016).

Secondly, with respect to householder relations to energy systems, the two workshops showed that the prospective platform members were to some extent aware of and cared about the effects of their platform on the grid. The extent to which participants would be willing to actively take responsibility for these effects differed, with some participants referring to negative perceptions of intermediary actors or pointing to the perceived (in)commensurability of grid-integration and autonomy objectives. The nuanced positions most participations took with respect to pursuing either energy independence or system integration necessitates distinguishing between autarky and autonomy ambitions. Autarky can be defined as independence from energy supply, whereas autonomy refers to the ability to self-determine one's energy provision. Both individual autarky and autonomy have been shown to be strong motivators for the adoption of energy storage technology (Ecker et al., 2018). The workshop discussions centred not around platform autarky, but on different ways, energy platforms can interact with the wider grid for mutual benefit, and how in that interaction the platform members can set terms and conditions (fairness in decision-making, or procedural energy justice (Jenkins et al., 2016)). The question became how energy platforms can operate as autonomous actors vis-a-vis or in collaboration with established energy sector parties to determine platform relations and ambitions, as well as how environmental, social, and economic tensions and dilemma's should be addressed.

Householders in their (imagined) role as platform member thus appeared to be open to engaging with the energy system. While other studies have shown that energy storage technology in individual households can facilitate autarchy and disengagement of householders with energy management (Smale et al., 2018), our workshop findings indicate that storage in the context of energy platforms can also serve as a building block for public participation and engagement in wider energy systems. This is also important because grid-connected energy platforms which optimise self-consumption of renewable energy in coordination with the wider grid have been shown to outperform grid-defected platforms cost-wise. Moreover, such grid-connected platforms are considered as 'beneficial to the alternative of solely being supplied from the grid both in terms of total energy costs and CO_2 emissions' [6]. Importantly, the willingness of both participant groups to engage with the wider energy system rather than pursue self-sufficiency must be understood in the context of their participation in demonstration projects, which were designed specifically to experiment with householder collaboration and integration in smart energy systems, in the process of which householders learned about energy system needs.

Thirdly, for most participants, sustainability was the primary motivator in making choices and discussing alternative scenarios. Even when the participants chose the scenario of energy trading on energy markets to optimise economic returns, they strongly preferred not to trade in non-renewable energy. At the same time, they expressed themselves negatively about incorporating substantive connections to other lifestyle consumption domains in energy platforms, such as food or mobility. This broadening of energy platforms to become 'sustainability platforms' is in principle made possible by ongoing platformisation (various recent technological applications enable cross-domain valuation and exchange). It will be interesting to monitor if such integration will yet occur overtime.

A final, general observation concerns how the particular backgrounds of the participating householders shaped their deliberations and preferences with respect to energy platforms. They frequently referred to and applied their past experiences and motivations for engaging with sustainable energy as well as with their local community during the discussions. In the two workshops analysed in this paper, this meant that one participation group responded more positively to energy platforms catered towards individual households, whereas the participant group with an energy community background expressed preference for additional 'green' investments in the neighbourhood and for platforms structured as cooperatives (rather than, for example, commercial- or utility-led platforms). Moreover, one participant group was at the start and the other was at the end of their involvement in a VPP project: this difference in an experience enabled the latter group to formulate more precise desires and priorities, surrounding, for instance, transparency of battery operation. This implies that yet other groups of participants will likely yield different outcomes of the deliberation.

In conclusion, the workshop showed that-with facilitation-prosumers are very well able to articulate their concerns, motivations and values with respect to different ways of organising and operating energy platforms. With households and their renewable energy resources representing the crucial 'nodes' of emerging platform networks, prosumer householders are an (if not the most) important factor in energy platforms. There is a clear need for householders to be involved in discussions about how platforms should work and what their role in platforms could be. Such discussions need to cover issues such as responsibility for public energy infrastructure, climate change, the (re)distribution of costs and benefits, decision-making, and inclusion and exclusion. These are all issues which connect individual households and their everyday energy consumption, generation and management to general public issues (Throndsen and Ryghaug, 2015). The new role of energy platform member presents prosumer householders with opportunities and risks ones associated with both energy co-manager and community modes of participation in energy systems, leading to a diversity of possible outcomes for householder engagement. How energy platforms members intend to employ their renewable energy to achieve which energy and climate goals, and what type of relationships they wish to form with fellow platform members and non-members, and with actors in the wider grid, has important implications for the transition towards decarbonised, decentralised, and digitised energy systems.

Supplementary Materials

The following are available online at https://www.mdpi.com/2071-1050/12/2/692/s1, Table S1: Example of a 'play-through' of the decision-tree assignment. Bolded text means that statement was chosen over the other; in this fictional case, the outcome is platform A1.

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Conflicts of Interest
The authors declare no conflict of interest.

Chapter 6

Conclusion & discussion

Chapter 6: Conclusion and discussion

6.1 Introduction

While there is much debate about different energy transition pathways, speeds, and technologies, the necessity of renewable energy transitions is not in serious question in European policy-making circles. There is a strong, widespread consensus around the need to tackle climate change by reducing greenhouse gas emissions. At the same time, societal resistance against energy transitions appears to be growing and hardening when projects become concrete or hit close to home. This applies to energy transitions both in local environments (land-based wind and solar projects) and in homes. In the Netherlands and other EU countries, plans for windmills and solar parks lead to heated local protest. In the Netherlands, the transition away from natural-gas based heating towards climate-neutral housing is equally faced with resistance. There is every reason [references] to expect that smart grid development, which implies major changes in domestic every life, will similarly face similar societal resistance. Resistance against government energy policies which are frequently perceived to be top-down places centre stage the question of how to involve and include citizens in energy transitions. Participation processes are seen as crucial in this respect. Yet there is a growing understanding that localized, procedural forms of public involvement are not sufficient in generating public support for energy transitions (Solman et al., 2021). Of equal importance is the co-construction of (smart) energy systems by householders, intermediary and energy system actors on an everyday life, ongoing basis, and the dimensions, aspects and qualities of such systems.

In this respect a recurring theme in societal debates about energy transitions revolves around a certain, multifaceted quality said to be lacking: the human scale. For example, citizens are faced with ever larger windmills and green pastures are sometimes filled with densely packed solar panels, creating outsized techno-landscapes. Conversely there are positive examples of a human scale in the renewable energy transition: such as local residents using a mobile app to stop a nearby windmill rotating when shadows impact their wellbeing, or scaled-down solar parks being made accessible to the public. These examples hint at possible aspects that contribute to or detract from a 'human scale-ness' in energy transitions. They include the practices, engagements, agency and power householders have in low-carbon energy systems. For the purposes of this thesis the 'human' part is argued to relate primarily to householders' life world: their engagements, emotions, goals, and everyday practices associated with their everyday energy practices. 'Scale' is about how householders view and perform these practices and about how they relate their energy use, generation, and management to sustainability, to other householders and to the wider energy system. 'Human scale' in the context of smart grids has to do with the ways in which householders are and feel engaged with, give context and meaning to their roles and energy practices in relation to others and to wider societal issues such as sustainability. It is also about householder agency and power in relation to enormous and highly complex energy systems which stretch out over wide geographical scale and scope. This 'human scale approach' broadens our view of householder involvement in energy transitions and go far beyond formal processes of participation[5], so I would argue.

Smart grids are heralded as promising socio-technical innovation and a comprehensive solution for making the energy grid more flexible and green (Yu et al., 2011; Darby et al., 2013). Householder participation in smart grids is viewed as crucial to smart grids' success. Smart grid innovations presume the involvement of householders, who, by conserving, monitoring, and timing their consumption with the help of various smart technologies and information flows, contribute to the sustainability and stability of the electricity grid. Smart grids provide a novel framework or context for householder agency, i.e. for householders to do, feel, and relate to energy in new and different ways. In this respect and from a householders' perspective, smart grids open up a new world of householder agency and engagement. However, previous research has identified a variety of limitations and obstacles in involving householders in smart grids, such as disengagement in the longer term (Hargreaves et al., 2013). Other social scientific studies have pointed to how smart grids constrain householder agency and engagement by subjugating householders under a kind of 'smart grid regime'. When householders are addressed primarily as co-managers of energy grids this contributes to a narrow view of householder agency in smart grids in which householders are merely 'efficient micro-resource managers' (Strengers, 2014). In doing so, smart grid development risks of increasing energy consumption (Hargreaves et al., 2018) and sustaining energy-intensive ways of life (Herrero et al., 2018). The picture painted by these studies is that of householders caught in a net of disciplining

[5] A more definitive operationalization of human scale in the context of smart grids, based on the insights from the research, is provided in the recommendation section 6.4.

energy (micro)management, distracted or blocked from affecting substantive changes towards sustainable energy practices.

These insights into householder participation in smart grids formed a valuable vantage point for further analysis into the constraining and empowering aspects of smart grids. The analytical point of departure of this thesis was that smart grid innovations both enable and constrain householder agency in new ways, leading to the emergence of new energy practices and generating new forms of engagement. The thesis aimed to contribute to the ongoing social scientific debates about householder participation in smart grids by analysing how that participation (acknowledging its constraining dimension) is accompanied by forms of empowerment, such as countervailing power, co-construction, and other emerging forms of householder agency. Its (normative) premise was that by adopting a householders' perspective and a 'human-scale'-approach, sensitized to householders' life world, insights could be generated which contribute towards strategies and policies which can help achieve sustainable two-way interaction between householders and low-carbon energy systems in smart grids. The thesis investigated how emerging practices relate to sustainable grid management and to the evolving (power) relationship between system actors, energy collectives, and households in Europe. Householder participation in smart grids was analysed using a mix of qualitative research methods. It involved a dual focus on *householder engagement* and *householder empowerment.* The research covered several emerging energy (management) practices (including flexible timing-of-demand, energy monitoring, storing energy and trading or sharing energy), as well as a variety of socio-technical configurations of smart grids emerging in Europe.

The research was guided by the following research questions:

1. How do smart grid objectives and technologies interact with householder goals and preferences with respect to energy use and generation, and how does their implementation co-shape energy management practices, householder agency and power relations?
2. How do wider socio-technical configurations of smart grids engage and empower (collectives of) householders, such as those involving energy storage and digital infrastructures? (How) can householder co-shape those wider configuration?
3. What are the implications of this analysis for (strategies and policies) for co-construction of smart grids at human scales?

Section 6.2 synthesizes the chapter results in order to provide integrated answers to questions 1 and 2. The third research question is answered in sections 6.3 and

6.4. Section 6.3 discusses the research findings in the context of broader societal developments. Section 6.4 outlines policy recommendations based on the presented analysis and several suggestions for future research are made.

6.2 Synthesis of results

6.2.1 Opportunities and limitations for sustainable energy practices

Chapters 2 and 3 zoomed in on situated households in order to analyse the changes smart grids bring about in the domestic sphere. Smart grids are associated with novel energy technologies (e.g. monitoring technologies, energy storage) as well as new objectives and rationalities concerning sustainable energy use, generation and management. These different aspects of smart grids imply new roles and energy-related behaviours for householders. However, households are no tabula rasa: smart grids interact with pre-existing features of domestic life (e.g. family dynamics, rhythms of energy demand, standards of comfort and convenience) and the agency and attributes of householders (such as their energy literacy).

This interaction was analysed using a social practices approach. Viewed from a social practices perspective, smart grids introduce new elements into existing energy practices related to consumption and generation. They also provide the building blocks for new practices which emerge out of the two-way interaction between households and energy systems in the context of smart grids. These new practices are defined as home energy management (HEM) practices: practices which are "specifically focused on the management, steering or governance of domestic energy flows, technologies and infrastructures" (Naus, p. 125). Such practices include energy monitoring, co/self-production of energy, energy sharing or trading, timing of demand, energy storage and energy conservation. Of particular interest for the analysis were the objectives and teleo-affective structures associated with energy practices in the context of smart grids and their interaction with householders' sensibilities and aspirations.

Moreover, a variety of energy system actors are involved in smart grid development: established actors such as energy utilities as well as new market actors, including smart energy technology and service providers. Smart grids also imply new relations amongst householders themselves. The ICT-aspect of smart grids, which enables householders and system actors to interact at a distance in novel ways, is particularly relevant in this respect. Therefore the home energy management practices emerging from this interaction were also investigated in terms of shifting power relations and new roles for householders in relation to those of other householders and of energy systems actors.

Chapter 2 demonstrated that in the smart grid transition the balancing of (renewable) supply and demand in energy grids has become key priority of grid managers. This shift has been translated to the household level through altering teleoaffective structures of energy practices, which motivate and direct the behaviour of householders towards flexible timing-of-demand. New grid objectives are codified in the rules of social practice concerning the use of flexibility instruments (notably time-of-day pricing) and are materialized in monitoring devices, smart appliances, and energy storage facilities. 'Flexibility', as a teleo-affectivity, places emphasis on the *timing* of energy use where previously timing was of little importance to householders relative to other sustainability priorities. In this respect it constitutes an addition to established teleo-affectivities and understandings associated with sustainable energy practices, which centre around minimising energy consumption and maximising renewable energy generation (mostly) irrespective of timing. In some respects the flexibility objective turns previously held notions upside-down: for example when householders are incentivized to consume (more) during episodes of negative energy pricing.

The research also analysed how householders bring flexible timing-of-demand into practice. Cleaning practices were found to be most suitable for flexible timing, with householders reporting that they find aligning the use of cleaning appliances (laundry machine, dryer, dish washer, vacuum cleaner) with renewable energy availability and/or price incentives both motivating and feasible. However, practices implied in ambiance regulation, leisure, cooking and eating are generally not suitable for flexible timing by householders; energy demand implied in their performance can only be made flexible through other flexibility instruments such as energy storage. These insights speak to householders' preference to remain autonomous (and flexible) in making choices with respect to timing of energy use in most domains of domestic life.

Chapter 4 analysed how the implementation of smart grid objectives and technologies co-shape energy management practices. These novel HEM practices imply new householder roles and power relations. The research showed that when householders participate in HEM practices (as 'co-managers', mediated by key smart energy technologies), they gain energy management understandings and an awareness of smart grid objectives. Moreover, HEM practices are characterized by ICT which enables ongoing and distanced interaction between householders and energy systems. In this respect HEM practices are shared between householders and actors from the energy provision system: they display particular ways of distributing responsibilities and agency over technologies, experts and householders. The analysis showed that ICT- centric configurations of HEM place householders in control of some aspects of home energy management (e.g. via greater access to information). In other aspects, householders rescind control to the energy system, as in the case of smart heat pumps controlled by algorithms. These dynamics represent shifts in power relations between householders and system actors which in turn hold implications for trust relations. Successful implementation of smart grid technologies relies on establishing and maintaining the trust relationships between householders and the more or less absent providers of technologies and services.

Two main conclusions can be drawn from these research findings.

The first conclusion is that HEM-practices are characterised by alignments and clashes between the ‘life world’ of householders and the ‘system world’ of smart grids. Different energy consuming practices show different levels of fit with smart grid instruments used so far. The underlying causes could be family interactions, rhythms of relaxation and ‘home management’, expectations related to comfort, cleanliness and convenience (Shove, 2003), and the frequency and duration of energy consuming practices. Interactions between the life world of householders and the system world of smart grids can lead to either adoption, reinterpretation, or rejection of smart grid objectives and technologies by householders.

Moreover, while householders understood the smart grid objective of adding flexibility to the energy system, it is nonetheless an abstract notion detached from their world of experience as prosumer-householders. In other words, flexibility did not constitute a motivating frame of reference for sustainable householder agency in its own right. Instead, householders in general interpreted their time-shifting activities as optimising the use of their renewable energy or cast it in the light of reducing CO_2 emissions to combat climate change. In other words, householders drew upon sustainability teleo-affectivities. Teleo-affective structures associated with sustainability range from combating climate change by reducing CO_2 emissions, to self-, local, or collective sufficiency, to collaboratively generating, storing and exchanging renewable energy, to the improving the manageability of renewable energy based grids. These teleo-affectivities are related but distinct in the emotions and aspirations they attach to home energy management practices. To unlock the potential for engaging householders in home energy management practices, the imperatives of smart grids should be operationalized in (sustainability) terms that are meaningful and motivating to householders.

Additionally, smart grid instruments should focus on the particular domestic practices which are amenable to energy management.

The second conclusion is that smart grids both enable and constrain sustainable householder agency in new and specific ways. HEM-practices involve redistributions of responsibilities for energy management between householders and system actors. These redistributions of responsibility also imply shifts in power relations between household and energy system. In terms of enabling, smart grids empower householders to articulate and employ new and relevant low-carbon lifestyle ambitions by performing HEM practices. Smart grids facilitate the ecological modernization of energy practices by re-aligning householder understandings and teleo-affectivities with modern renewable energy system characteristics (decentralized, decarbonized, digitalized) and requirements of flexibility. By performing HEM practices such as energy trading, timing of demand, and energy storage, householders can contribute to the sustainability of the wider energy system while pursuing objectives meaningful to them, such as self- or local renewable energy sufficiency. As a result, householder engagements with respect to energy are expanded beyond the scope of situated, single households to include interactions with energy grids and with other householders.

In terms of constraining householder agency, particular (ICT-centric) configurations of HEM also introduce new forms of control of households by system actors. The digital nature of smart energy technologies means that those power relations between householders and system actors are immediate, continuous, and distanced. Moreover, algorithmically controlled smart energy technologies (e.g. battery storage, smart heat pumps) can operate in an opaque and (for householders) difficult to grasp manner. The tendency is to limit, discourage or disable tinkering or adjustment of settings by householders, which limits householder agency. Limiting householder control over smart energy technologies increases their reliability in generating flexibility for the energy grid, while also placing system actors and intermediaries in greater control. Socio-technical configurations of HEM also have distinctly physical and spatial qualities – literally and metaphorically taking up room in the home, they transform functionality and householder agency with respect to particular domestic spaces (e.g. the utility closet). The span of control which householders and system actors are afforded respectively in particular configurations of HEM calls attention to trust relations. The importance of trust is compounded by the real and perceived distance between system actors and householders as enabled by digitalisation. Power and trust dynamics play out as householders perform, adopt, adjust or reject novel HEM-practices.

With respect to the enabling and constraining of householder agency, it is useful to envision the extremes which in real life smart grid projects were shown to occur in variously mixed forms. On the one end, householder agency is constrained via hyper-integration and colonisation of domestic space and subjugation under energy system requirements, for example through commodification and gamification - in the vein of Jeremy Rifkin's The Age of Access (2000). On the other end, the redistribution of power and responsibilities involves a radical subversion of established roles and power relations resulting in a partial break-away of homes and districts from the conventional centralised energy system, an example being the Buiksloterham area in Amsterdam (Jansen et al., 2017). The case studies of smart homes, energy storage and energy platforms showed how power relations and the roles and agency of household and system actors in domestic spaces shift in mixed, nuanced and diverging ways; smart grids both enable and constrain householder agency by introducing new forms of control over and monitoring of flows of energy and energy data.

6.2.2 Variation in householder engagement and empowerment in wider smart grid configurations

The previous section concluded that HEM practices afford both householders and system actors new forms of agency and control, and that the performance of HEM practices reveals particular alignments and mismatches between the lifeworld of householders and the system imperatives of smart grids. Zooming out from HEM practices as they are performed in households, the second part of the research (as reported in chapters 4 and 5) addressed the question how wider socio-technical configurations of smart grids engage and empower (collectives of) householders.

These wider socio-technical configurations (were theorized to) organize particular forms of engagement and specific roles and practices for householders and system actors in distinct types, modes or configurations (e.g. energy storing and sharing communities, energy platforms). These configurations both enable and constrain householder agency in specific ways. The role of intermediary actors, such as providers of digital energy infrastructures and battery storage systems, in organising socio-technical configurations is of particular interest in this respect. Moreover, the research explored householder preferences with respect to what sustainability, social and economic issues they wish to address as participants in these wider configurations; as well as whether (they believe) autonomy from the grid or further integration into (smart) energy grids and markets supports the realisation of (green, social, economic) objectives. These aspects were analysed by applying a mix of methods in case studies of energy storage and energy platforms.

Chapter 4 proposed that energy storage technologies, as 'technologies of engagement, shape householder participation in wider energy systems and their transformations. Five emerging storage modes were identified in which householders can play a role. These storage modes were labelled as: individual energy autonomy; local energy community; smart grid integration; virtual energy community; and electricity market integration. For householders, these storage modes facilitate new energy practices such as providing grid services, trading, self-consumption, and sharing of energy. Associated with these practices are different householders engagements and meanings (e.g. energy as common pool resource, or as tradable commodity). Several of the storage modes enable the formation of prosumer collectives and change relationships with other actors in the energy system. At the same time, modes of energy storage imply shifts in power relations: householders face new dependencies on information technologies and intermediary actors to organize the multi-directional energy flows which battery systems unleash.

Chapter 5 demonstrated that energy platforms, similar to configurations of energy storage, offer new ways for householders to trade or exchange energy with other households or with energy system actors. At the same time this means householders become part of wider systems which structure householder agency and engagement. Acknowledging the two sides to empowerment in energy storage and platforms (enabling and constraining householder agency), participatory workshops were performed as an experiment to include groups of end-users in the co-construction of (smart) energy systems and energy production, storage and use as well as matters of accessibility, exclusion, distributive justice, and sustainability. During the participatory workshops, householders discovered and interacted with a variety of issues related to energy platforms such as energy system integration versus autarky or 'grid defection' (households or neighbourhoods physically disconnecting from wider energy infrastructures); as well as practices associated with energy justice such as energy sharing. Householders articulated a variety of goals and aspirations, some matching grid flexibility objectives more than others. In spite of differences in knowledge, resources and power between householders, intermediaries and established energy actors, the experiment indicated that - when provided with space and facilitation - collectives of householders are able to co-shape energy platforms or modes of energy storage based on self- or co-defined objectives and teleo-affectivities. Environmental motivations were of key importance in householders' deliberations of different platform types. In the role of energy platform members, householders can engage with both the community and the grid in new and different ways, leading to a diversity of possible outcomes for householder engagement. However, the experiment also showed that no clear pathway towards defining appropriate boundaries and levels of scale for energy managing collectives can yet be discerned.

Several conclusions can be drawn from these research findings with respect to householder engagement and empowerment in wider configurations of smart grids.

The first is that socio-technical configurations of smart grids featuring energy storage and digital infrastructures enable exchange, trade and storage of energy and entail diverse and not yet crystallized roles and engagements for householders or communities. They provide individual householders, collectives of householders, utilities and market actors the means to pursue a variety of energy and sustainability objectives, which was previously not possible. Householders can form novel vertical and horizontal collaborations in pursuit of sustainability goals, at the scope of household or community level, the grid, or the energy market at large.

The second conclusion is that energy storage is paradoxical with respect to empowerment. The analysis problematizes the widely shared association and teleo-affectivity that energy storage empowers (collectives of) prosumers to 'break away from the grid'. In fact, the configurations of energy storage householders face in real-life (experimental) settings also empower system actors to get involved in residential energy flows. What results is a dynamic field of experimentation in which different interests and goals mix and mingle. In this experimental context, energy platforms are discussed in terms of democratising access to renewable energy (Kloppenburg and Boekelo, 2019) and to eliminating reliance on established energy actors or central intermediaries (Mengelkamp et al., 2018). However, considering the (legal) limitations and complexities communities face in initiating and organizing energy storage and exchange, novel intermediary actors are positioned to play a decisive role in the organisation of particular configurations for the foreseeable future. The research found that a large part of the organizational or mediating 'work' around energy storage and energy platforms is performed by intermediaries with the help of digital technologies; it is unlikely that (collectives of) householders will perform this work independently. This brings the key role of intermediary actors as mediators between householders and system actors in novel energy systems to the forefront. These insights about the dual enabling and constraining dimensions of emerging energy configurations mirror debates about digital platforms[6].

6.3 Discussion: human scale smart grids in reflexive modernity

The search for the human scale in smart grids sparked an investigation into emerging energy practices, householder roles, power, and forms of engagement and agency in the (co-)management and (co-)construction of smart energy systems. The previous section brought together findings and insights from the four research chapters in order to answer the main research questions. The conclusions can be summarized as follows.

Smart grid development at the level of situated households is characterised by alignments and clashes between the 'life world' of householders and the 'system world' of smart grids. Smart grids involve new technologies and objectives which bring about the emergence of novel home energy management (HEM) practices and transform established energy practices and their associated teleo-affective structures, understandings and engagements. HEM-practices also involve redistributions of power and responsibilities for energy management between householders and system actors and hence have implications for trust relations. Moreover, wider socio-technical configurations of smart grids organize particular forms of householders engagement and distribute specific roles and (HEM) practices for householders and system actors in distinct configurations. The case studies of energy storage and energy platforms uncovered a wide variety of configurations currently emerging, involving a diversity of practices, engagements, objectives and scales. Importantly, configurations of smart grids enable and constrain householder agency in particular ways. Understanding that smart grid development is in 'flux' (a stage of experimentation and uncertainty), the research concluded with an experiment in co-constructing the boundaries of emerging socio-technical configurations together with frontrunner householders.

[6] Platforms are associated with expectations of democratization, greater connectivity, and bottom-up organisation and empowerment, however analyses of 'platform society' (Van Dijck et al., 2018) or 'platform capitalism' (Langley and Leyshon, 2017) have pointed to issues related to accessibility, exclusion, privatisation, and the potentially surreptitious role of algorithms, among others. In this respect, Fraanje and Spaargaren (2019) identify two diverging trajectories: one that sticks to the social aspects of connecting people through sharing things, and another that heads towards impersonal forms of collaborative consumption.

These research findings reveal smart energy systems to be deeply connected to characteristics of late- or reflexive modernity, as described by Anthony Giddens (1990), and Ulrich Beck (1992) in particular. This phase of modernity is characterised by space and time distanciation (6.3.1) and reflexivity (6.3.2). Space and time distanciation refers to the stretching of social systems across space and time as enabled by new kinds of technology. In the case of smart grids, smart energy technologies enable interactions between householders and other actors in energy systems to occur at a distance. Understanding how 'distancing' leads to processes of social disembedding and new forms of social integration gives context to the research findings about the interplay between the domestic world of householders and the system world of smart grids. Reflexivity is another core facet of smart grids: smart grids can be viewed as socio-technical innovations aimed at managing inherent uncertainties of decarbonized, decentralized, and digitized energy systems. A final piece of the puzzle in grasping householder engagement and empowerment in smart grids lies in understanding smart grid development – also in terms of governance - as a reflexive societal project.

In section 6.1, 'human scale' was related to householders' life-world and lived experience (as participants in smart grids, performers of HEM practices, etc.) as well as to the contexts, scales and social, power, trust relations in which householders interact with energy. This section proposes that space-time distanciation and reflexivity are concepts that contribute to defining pathways towards *smart grids at human scales*. Discussing the research insights in this light provides inspiration for the recommendation section (6.4).

6.3.1 Smart grids and space-time distanciation

Time and space distanciation is visible in energy configurations of current modernity. Novel digital energy technologies interconnect households with the wider energy system (utilities, markets) in profound and wide-reaching ways, such as in networks of energy and data exchanging between households (platforms, storage). Since smart grids champion householders as collaborators in energy management, householders are faced with the implications of time and space distanciation. In conditions of time and space distanciation, the interactions between situated (lay) householders and distanced (expert) energy system actors take place over greater spans of space and time. Co-presence is often made obsolescent and irrelevant as a result, which holds serious implications for trust relations in which face-to-face contacts and co-present forms of interaction typically play an important role. Two examples of this changing relationships include i) energy monitoring and iii) the storage of energy.

Smart meters afford system actors the ability to continuously monitor energy flows at a distance. This removes the need for the annual visit of the meter inspector, one of the few moments during which householders have face-to-face contact with a professional representing the energy system. At the same time, smart metering also makes energy systems more transparent by enabling householders greater insight into their energy. Another example from this research of a shift in relations brought about by remote monitoring involves the householder who switched off her smart heat pump and was then surprised by a phone call from a technician requesting to switch it back on. Digital energy storage technology is a third example. Rather than energy storage - storing energy in the form of wood, coal, etc. in a physical location- being a practice performed by and for the individual householders, the research presented in chapter 4 demonstrated how modern energy storage integrates householders into larger (e.g. flexibility providing) collectivities irrespective of geographical boundaries. These examples illustrate the ways in which smart grid technologies transform relations between householders and providers of energy technologies, grid operators and energy market actors. Smart energy technologies enable face-to-face interactions between householders and system actors to be replaced by remote access and monitoring, challenging previously established trust relations as noted in chapter 3.

Smart grid technologies also impact horizontal relations, meaning the relations householders have to other householders (Naus et al. 2015). The rise of decentralised energy generation and the 'prosumer' has seen many energy communities springing up, which vary widely in terms of ambitions and practices but are generally rooted in a particular geographically bounded community. When energy consuming and producing householders – prosumers –start exchanging, trading or storing energy in collectives, enabled by energy storage and digital infrastructures, they can form geographically dispersed networks in which social relations are stretched across time and space. Chapters 4 and 5 showed that localized and distanced energy (managing) collectives support diverging householder engagements and meanings with respect to energy use and management. Moreover, 'spatially distanced' energy managing collectives are organised in networks and platforms and lose some of their bottom-up characteristics as they come to rely on (technological) intermediaries. In this respect it is relevant to note that in societal debates digital platforms are particularly distrusted forms of space-time distanciation, as platforms (such as Uber) can use their powerful monopolistic position vis-à-vis platform users to advance their own interests at the costs of users. Under conditions of digitally enabled space-time distanciation, digital platforms have proven to be powerful tools for interconnecting and providing services to users. However, intermediaries can attain dominant positions by setting the conditions for in- and exclusion. Chapter 5 showed householders to be sensitive to these new dependencies, preferring certain forms of collaboration with particular (trusted) actors.

Smart grids as new forms of system integration and social disembedding

The preceding section discussed how smart grids co-shape energy systems characterized by 'distanced' horizontal relations (between householders, e.g. in platforms) and vertical relations (between householders and energy system actors, such as utilities). The examples showcase outcomes of smart grid development in terms of new forms of *system integration.* System integration is defined as the reciprocity or interaction between actors or collectives across extended time-space, outside conditions of co-presence (Giddens, 1984). Tele-communications play a key role in system integration: smart phones, the internet, and ICT in general facilitate system integration by enabling people to interact with different kinds of abstract systems (e.g. banking) without meeting system representatives (e.g. finance professionals) face-to-face.

In the course of system integration some of the historically established and reproduced frames of reference which shape householder roles and energy practices are transformed or fall away. These are processes of *social disembedding*. By social disembedding Giddens means “the "lifting out" of social relations from local contexts of interaction and their restructuring across indefinite spans of time-space” (Giddens 1990, p. 21). Local contexts and co-presence of actors are replaced by standardised, abstract, and "empty" dimensions. These dimensions rationalise and coordinate activities between actors or collectives, across extended time-space. Smart grid development brings about social dis- and re-embedding. As shown in chapter 2, established understandings, competences, and teleo-affectivities which guide domestic energy practices are replaced and altered. Relationships among householders and between householders and system actors are transformed as well. In smart grids households become nodes in wider networks for exchanging, sharing, storing energy collectively. Collectives of householders interact as 'blocks' with the wider grid at scale.

Social integration and social re-embedding

The reproduction of socio-technical energy systems is also accompanied by processes of *social integration and social re-embedding.* Social integration refers to situations where actors are physically 'co-present' (Giddens, 1984). Examples from research chapters 2 and 3 show how system integration may be followed by new forms of social integration. When instances of co-presence fell away, and other forms of social interaction which contribute mutual trust and shared expectations between householders and energy suppliers were replaced by distanced interactions, householders actively sought out contexts for social integrations or expressed missing opportunities for face-to-face contact. For example, as reported in chapter 3, householders in the smart grid pilot neighbourhood sought out 'energy literate' neighbours who could explain issues related to home energy management or to relay messages to the project managers on their behalf. Moreover, the smart grid project was a frequent topic of discussion among neighbours, with householders exchanging tips and advice face-to-face.

System integration and the social disembedding of domestic energy practices may similarly be accompanied by forms of *social re-embedding*. Householders re-contextualise energy use, generation and management in interesting ways. Research in chapter 2 illustrated how in a smart grid pilot context householders did not respond to the (rational) incentives provided by in-home energy displays but instead coordinated their high-energy-use practices with self-generated renewable energy availability via intuitive understandings and visual clues (e.g. a sunny day means a good time to use the laundry machine). New meanings, goals and emotions fill (teleo-affective) "voids" created by social disembedding, and complement the 'empty', abstract, and standardized dimensions in coordinating and motivating the performance of new (HEM) practices.

To summarize, smart grids facilitate time-and-space distanciation, enabling system integration and social disembedding in turn. These processes are accompanied by new forms of social integration and social re-embedding. Placing the research findings in the context of these dual processes contributes to formulating recommendations on smart grid governance, which is done in Section 6.4.

6.3.2 Smart grids and the reflexivity of modernity

Similar to how space-time distanciation gives context to the interplay between household and energy system in smart grids, the concept of reflexivity can contribute to a deeper understanding of how smart grids bring about the variation in forms of householder engagement and empowerment described in section 6.2. Reflexivity departs from the understanding that uncertainties are at the core of societal risks (Beck and Ritter, 1992). Renewable energy-based systems are wrought with uncertainties, risks and challenges. More technology or knowledge alone no longer offer the solutions to these risks. Instead, smart grids aim to manage uncertainties through digitisation and decentralisation, improving coordination across the grid. This understanding of uncertainty and risk and the flexible, information-based approach for coping with uncertainties and risks are what characterise smart grid development as a reflexive societal project. In smart grids, the feedback loops of information about the (renewable energy-based) system and the steering and reforming of that system take on instantaneous and multiscale characteristics. Digital information about flows of energy, energy demand, energy markets, and weather patterns is shared instantly across the entire system. Decentralized renewable energy generation and demand side management emerge as cornerstones of future low-carbon energy systems: both entail novel roles, practices and responsibilities for householders.

Because a significant role is attributed to householders in smart grids, the reflexivity of smart grids reverberates in the home energy management practices which emerge in the context of smart grid development (chapters 2 and 3). Moreover, the decentralizing tendency of smart grids opens up smart grid development to co-construction processes (chapter 5) which are in essence exercises in reflexive governance, so we will argue.

Reflexivity and home energy management

In reflexive modernisation, "social practices are constantly examined and reformed in the light of incoming information about those very practices, thus constitutively altering their character" (Giddens, 1990, p.38-39). Likewise, smart grids confront householders with uncertainties, unforeseen consequences, and novel dilemmas associated with their energy use and decentralized generation such as intermittency and timing of energy delivery and use. The confrontation stimulates reflection on questions such as: What constitutes environmentally friendly energy behaviour in a renewable energy dominated grid? Through the implementation of smart metering and monitoring technologies, domestic energy practices are brought under scrutiny and are reformed in light of (digital) information about those practices and the wider energy system. This confrontation and scrutiny could in principle challenge previously held beliefs, sometimes in rather radical ways (i.e. negative energy pricing at times of renewable energy abundance; local solution not representing the best possible option, etc). The research presented in this thesis indicates that meaningful reflexivity on the part of householders involves critically recasting energy use, generation and management in light of broader sustainability goals (such as combating climate change, renewable self-sufficiency, and local energy neutrality). As a result, the character of energy practices – their understandings, skills, and teleo-affectivities involved – may be altered. An important insight from the research is that the forms of householder engagement emerging in the context of smart grids are not simpel or simply pre-decided, defined and imposed top-down. Smart energy technologies, such as storage batteries and energy platforms, not just enable (and constrain) particular forms of householder engagement. They also, and more importantly so, tend to widen the horizon of thinking about what it is that householders engage with in the first place: householders engage and co-shape energy systems with yet unforeseen possibilities and outcomes. Becoming engaged in home energy management practices means engaging in the co-constructing of reflexive modernity.

Reflexive co-construction of smart grids

The decentralizing tendencies of smart grids also open up opportunities for householders to reflexively co-create new kinds of energy collectives and relations between householders, energy utilities and markets. Smart grids broaden the scope of householders-as-energy- prosumers; there are new questions to answer and challenges and dilemmas to face that pertain to householders' own practices, relations, goals and understandings. How does our energy use and generation impact the wider energy system, both positively and negatively? How can our household, energy community, platforms or network make more optimal use of our renewable energy, or contribute to flexible, affordable, sustainable energy grids? Should our renewable energy be stored, traded, shared, and at what scale, with whom, and under which conditions? And what kind of technologies and collaborations are involved in these activities? The participatory workshops (Chapter 5) were an experiment with tackling such questions and defining energy system boundaries in the age of reflexive modernity. Such co-creative design approaches proved to be a valuable tool for engaging householders in smart grids. Beyond shaping householder engagements, the co-construction of smart grid configurations by practitioners through co-creative design can also empower (collectives of) householders vis-à-vis system actors and (novel) intermediaries in particular. Such methods can lead to co-decision-making (e.g. about objectives, technologies, incentives) or forms of co-ownership of smart grids assets such as batteries. The opening up of energy systems to reflexive co-creation facilitates a range of outcomes in terms of householder empowerment. These types of co-creation and co-construction of smart grids bring together perspectives and frames of different stakeholders in an effort to bridge differences and overcome tunnel vision, and controversies; in this respect these efforts are essentially exercises in reflexive governance. Reflexivity is an essential governance capability for dealing with wicked problems where multiple frames and perspectives are at play, and the problem is unstructured (Termeer et al., 2015).

The investigation into the human scale of smart grids has involved a theoretical and empirical deep-dive into householder participation in decentralizing, digitalizing and decarbonizing energy grids. The research generated insights about emerging energy practices and the wider socio-technical systems they are embedded in, investigating the shifting roles of householders and system actors and householder engagements implied in these developments, and discussed the implications of these transformations for power and trust relations and smart grid governance. In order to summarize the preceding synthesis of results and discussion sections, Table 6.1 provides an overview of the research findings and the research questions and research chapters they relate to. The research findings provide the frame of reference for the ensuing Recommendations section chapter 6.4.

Table 6.1: Summary of research findings.

Research findings	**Research question**	**Research chapter**
1. Smart grids introduce new elements, including technologies, understandings, and teleo-affectivities, into domestic practices in the interest of balancing (renewable) energy supply and demand.	1	2
2. Certain domains of domestic life are more amenable to flexible timing-of-demand (cleaning practices) than others (practices involving leisure, ambiance regulation, cooking and eating).	1	2
3. When householders participate in HEM practices, they acquire new (energy management) understandings and skills while also confronting practical obstacles and new meanings associated with energy use.	1	2 and 3
4. HEM practices display particular ways of distributing responsibilities, forms of power and agency over technologies, energy system actors and householders.	1	3
5. HEM practices depend on trust relations between householders and more-or-less absent providers of technologies and services.	1	3
6. Financial incentive-centred and 'black box'-style configurations of home energy management risk disengaging and/or disempowering householders.	1	2 and 3

7. Energy systems involving battery storage and energy platforms display variation in terms of objectives, practices, and roles for householders.	2	4 and 5
8. As participants in energy platforms and energy systems involving storage, householders can interact and engage with other householders and the wider grid in new and different ways. They also face new dependencies on intermediary actors.	2	4 and 5
9. Particular HEM practices and wider configurations of smart grids can match or mismatch to householders' capabilities, skills, and (sustainability) goals and aspirations.	1 and 2	2, 3, 4 and 5
10. Involving householders in co-creation of smart energy systems and in deliberations about their societal effects opens up smart grid development to new and greater forms of householder engagement and empowerment.	2	5
11. Smart grid governance in reflexive modernity benefits from lessons learned from real-life experimentation and co-creation with practitioners.	3	2, 3, 4 and 5

6.4 Recommendations

The research findings presented in 6.2 in combination with the discussion of those findings in 6.3 provide building blocks for bringing the human scale into smart grids. When householders adopt and perform home energy management practices and become part of wider (socio-technical) systems through smart energy technologies, they participate in a complex, emerging socio-technological systems characterized by planning, rationality, and abstraction. The boundaries of these systems are undefined and comprise different co-existing configurations (e.g. different energy storage modes). Householders are empowered to form new productive relations with other householder, both localized and at a distance, as well as with utilities and energy markets. They are empowered to pursue new or pre-existing (sustainability) objectives meaningful to them. However they also face dependencies on novel intermediaries and established energy system actors and markets (and their objectives and methods) when doing so. The smart grid promises engagement but also risks in some sense the alienation of its participants because of the distanciation of social (energy) relations and the limited number of co-present interactions. Householder disengagement is furthermore connected to emerging power imbalances and mismatches between householder goals, emotions and skills on the one hand and smart grid rationalities and affordances on the other.

From these insights several key factors can be derived which signify what 'human scale' means in the context of smart grids. These include:

- understanding the (domestic, life-world) context of home energy management and attuning smart grid configurations to sustainability aspirations of householders;
- confronting social dis-embedding and re-embedding with sensitivity towards the novel social relations which are emerging around energy production, distribution, storage and use
- dealing with uncertainties and giving space to learning, co-creation and ongoing social science research on the issue;
- preventing skewed power relations between providers and intermediaries on the one hand and householders on the other;
- empowering householders to perform new practices and form new collaborations while avoiding the reduction and disciplining of householders into 'energy managing robots';
- fleshing out smart grids into particular configurations which are understandable and motivating to householders.

These insights and factors point to a number of building blocks of strategies and policies for co-constructing 'smart grids the human scale'. The recommendations are directed towards (public, semi-public, and market) actors involved in organising smart grid (pilot) projects in real life settings as well as actors involved in smart grid policy-making and developing strategies for smart grid technology implementation. Among these actors are incumbents - energy utilities (distribution system operators), government agencies, and established energy market actors – as well as new intermediaries such as developers of digital infrastructures and platforms for smart grids. The recommendations may also be of use to energy cooperatives and other types of energy collectives and citizen initiatives interested in expanding their activities into smart grid 'territory' such as collectively storing, exchanging, and monitoring of energy.

6.4.1 Reflexive governance of smart grids

Experimentation with smart grids in real life contexts has shown that 1) engaging householders in sustainable home energy management is fraught with complexities and limitations, as well as opportunities, and 2) that wider configurations of smart grids display great diversity (in objectives, organisational forms, methods, engagement) and come along with unsettled boundaries and under or ill-defined (power) relations between actors. Therefore it is recommended that governance actors pursue a reflexive governance strategy with respect to ‘rolling out’ or scaling up smart grid projects as part of the ongoing energy transitions in Europe. Reflexive governance “refers to governance that is concerned with itself by means of the self-critical scrutiny of current governance, including its achievements and unintended negative effects” (Böstrom et al., 2017). Termeer et al. (2015) argue that reflexivity is one of four essential governance capabilities (next to resilience, responsiveness and revitalisation) for dealing with wicked problems. Smart grid development involves domains of wicked problems in the sense that multiple frames and perspectives are at play, and the problem remains unstructured. Reflexivity, defined as the capability to appreciate and deal with unstructured problems and multiple realities, this is crucial if tunnel vision and seemingly intractable controversies are to be overcome; in the case of smart grids, the often perceived as insurmountable differences in interest and capabilities between householders and energy system actors come to mind.

The various socio-technical configurations of smart grids currently emerging - the demand-side management programmes, the energy managing collectives connected through energy storage and digital platforms and networks - offer (groups and organized collectives of) prosumers enticing and sometimes conflicting perspectives on greater energy autonomy and self-sufficiency as well as on greater systems integration. To foster smart grid configurations that take into account a wider range of (future) interests and aspirations of householders and communities, and enable diverse forms of energy citizenship, governance actors in governmental and commercial organizations could develop policies to actively support experimentation with different forms of home energy management and with social organization of energy managing collectives. Moreover, reflexive governance would involve professional facilitation of householders and communities to enable them to articulate their interests and ambitions vis-à-vis powerful established energy system actors and novel intermediaries such as aggregators. There is a clear need for householders to be involved in discussions about the objectives and methods of home energy management in households as well as about how energy managing collectives should work and what their role could be. Such discussions need to cover issues related to the interaction between grid and household in the context of HEM-practices (power, control, trust, sustainability objectives), as well as broader themes such as responsibility for public energy infrastructure, climate change, the (re)distribution of costs and benefits, decision-making, and inclusion and exclusion.

It is worthwhile to operationalize this general call for greater reflexivity in smart grid governance (both on the side of system actors and householders). Research on reflexivity points out the "importance of developing meeting points, social arenas, and organizational forms that enable time and space for deliberations between various groups, sectors, and networks, which can in turn facilitate interframe reflexivity and mutual learning" (Böstrom et al., 2017). It is with respect to specifying these meeting points and organisational forms for enabling time and space for deliberations between householders, energy utilities, providers and market actors, that an emerging intermediary field of activity, strategy and policy instruments comes into focus (as a main recommendation of this thesis): smart grid mediation.

Smart grid mediation comprises of activities, procedures, rules of practice, as well as policy instruments (such as certification), performed by a novel intermediary role and/or instituted by different institutions or entities. Smart grid mediation is located at the intersection of householder and smart grid, as observed in the context of smart grid pilots. The importance of smart grid mediation is evident from insights derived from the qualitative research methods applied in this thesis. The studied householders lacked and thus greatly valued face-to-face contact with someone thought of as independent during the home tours and sit-down interviews, to share and reflect on positive and negative experiences and to pass along suggestions for improvement. Householders also valued the opportunity to discuss and exchange with neighbours during the participatory workshops. These interactive moments stimulated a renewed reflexivity on the part of householders who typically at that point had established a 'new normal' after adapting their domestic practices to smart grid instruments. Smart grid mediation is imagined to operate in the context of smart grid projects initiated from the side of either householders or energy system actors (utilities, market actors, energy communities or other types of energy collectives), likely on the level of a neighbourhood, housing block, or village. Intermediaries operating in this field work to establish and maintain trust relations between householders and energy system actors in the context of smart grids. They do so by striking a balance between 'proximity' and 'distance': engaging in face-to-face, tailor-made interaction on the one hand and operating at scale and within energy system-technical boundaries on the other. In doing so smart grid mediation reduces the real and imagined distance between system actors and householders, facilitating co-design and co-decision-making, and stimulate reflexivity among all actors involved.

The mission of smart grid mediation is two-fold:

- Facilitating the co-shaping by householders and governance/system actors of energy management practices which are both effective for sustainability and grid management and meaningful, motivating and realistic for householders as performers of energy management;
- Facilitating householder participation in the co-creative design of energy managing collectives, with respect to these collectives' objectives, rules, and instruments as well as to dilemma's and opportunities related to sustainability, social, and economic aspects.

This dual mission can be specified further into a set of activities and sub-goals (Table 6.2).

Table 6.2: Sub-goals, activities and tool-kit of smart grid mediation during co-design, implementation, and evaluation phases.

Phase and tool-kit	**Sub-goals**	**Activity**
Co-design phase Co-design methods, which can include but is not limited to: - Participatory workshops - Serious games - Focus groups - Surveys	*Sub-goal 1:* Providing context	• Introducing householders to smart grid objectives, technologies, and the role of householders in smart grids with emphasis on renewable energy transition context • Naming the shared and diverging interests of energy utilities, market actors and (new) intermediaries involved in smart grids vis-à-vis householders
	Sub-goal 2: Establishing shared goals	• Mapping householder diversity of life phases and aspirations related to dwelling and sustainability • Mapping the needs and requirements for a (local) sustainable energy system from a systems perspective • Building a shared vision (an energy self-sufficient local community, a network of energy traders, etc.)
	Sub-goal 3: Mapping capabilities	• Mapping levels of energy literacy • Mapping flexible-energy-use capabilities and preferences of householders
	Sub-goal 4:	Providing overview of:

	Outlining smart grid alternatives	• HEM-practices: energy monitoring, co/self-production, storing, timing of demand, energy trading and sharing, energy saving • Smart grid technologies and instruments • Different configurations of HEM, including passive / active, different scales
	Sub-goal 5: Deliberating about opportunities, dilemma's, and trade-offs	Facilitating a structured debate about the alternatives in relation to: • Climate, energy, grid, social and economic issues • Trust, control, forms of collaboration
	Sub-goal 6: Matching alternatives to goals and capabilities	Facilitating collaborative decision-making resulting in a particular configuration or mix of configurations: • what set of householder, community and energy system objectives are pursued • which HEM-practices will be enabled and what are expectations with respect to their performance by householders (incl. flexible energy use, energy saving, monitoring) • what smart energy technologies and other instruments will be implemented and under which conditions
Implementation phase Home visits, scheduled and 'upon request'	*Sub-goal 7:* Training householders and informing system actors	• Providing instructions to householders about how to interact with and how to tweak, tinker and counteract smart energy technologies and instruments • Providing the utilities, intermediaries, providers with ongoing 'from the field' feedback and insight

	Sub-goal 8: Maintaining trust relations	• Ongoing face-to-face contact with householders as information provider, instructor, and messenger
	Sub-goal 9: Recalibrating configurations	• Suggesting changes to the configurations to system actors based on feedback from the householders or community
Evaluation phase Roundtables	*Sub-goal 10:* (institutional) reflexivity	• Compiling lessons learned together with householders, energy utilities, market actors and intermediaries

Rather than suggesting that the listed activities and tool-kit are requirements for success in smart grid implementation, this exercise in delineating an emerging intermediary field is intended to urge and inspire actors involved in smart grids to engage householders more broadly and deeply in co-design of smart grid projects. Different types of actors, both experts and professionals from within the energy field as well as householder collectives, could perform smart grid mediation at this intermediary level. Structured and ongoing interaction between (collectives of) householders and energy utilities, markets actors, and intermediaries can contribute to more human scale smart grids which bring together the interests, needs aspirations of householders and system actors in motivating, meaningful, and ‘system-smart’ collaborations.

6.4.2 Suggestions for future research

Three promising lines of research inquiry can be suggested at this point.

The first concerns the continuance of research into smart grid pilot projects involving householders. While the potential contribution of households to smart grids and flexibility in particular remains subject of debate, and while discussion surrounding the role of energy utilities in smart grid pilot projects has led to a slow down on experimentation, the research conducted as part of this thesis showcases on the one hand the value of real-life experimentation with emerging smart energy systems and on the other hand, the value of such experiments for research into important aspects of future low-carbon energy systems including householder empowerment and engagement. Moreover, since smart grid projects tend to be conducted among a relatively small slice of society – front-runner householders, typically prosumers and home-owners - there is much potential for broadening the research population, notably to lower income groups and home renters. Analysis of smart grid dimensions such as home energy management among a greater diversity of societal groups could yield a deeper and broader understanding of householder empowerment and engagement in smart grids.

A second potential line of enquiry could investigate more deeply the role of intermediary actors in smart grid development and mediation. Further research could build upon recommendations outlined in the previous section to analyse how intermediary actors perform practices associated with smart grid mediation, how these practices are part of wider emerging socio-technical systems, as well as the outcomes of mediation for householder empowerment and engagement. Such research could connect insights into dynamics surrounding home energy management to understandings of reflexive modernity to further develop participatory and reflexive approaches to organising and scaling up smart grid projects.

Lastly, It is also promising to expand the research into wide array of energy platforms and other types energy managing collectives currently emerging with quantitative research methodology. Such research could for example operationalizing analytical dimensions (such as empowerment, engagement, proximity and distance) brought forward in this thesis into quantifiable indicators and subsequently score and rank real-life cases on the basis of these indicators. Combining qualitative with quantitative research could provide a better overview and greater insight into the overall character and trajectory of the transition towards smart energy systems as well as to emerging niches within that wider transition.

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Summary

Smart grids are heralded as promising socio-technical innovation and a comprehensive solution for making the energy grid more flexible and green. Smart grids innovations presume the involvement of householders, who, by conserving, monitoring, and timing their consumption with the help of various smart technologies and information flows, contribute to the sustainability and stability of the electricity grid. In this context, grid operator, energy producing companies, governments and other actors are redefining their relationships to each other and to citizens. These actors have to face the desires, values and actions of citizens. Meeting this challenge requires a closer investigation of the character and trajectory of householder engagement with smart grids. Further research is required into the needs and desires which (de)motivate householder engagement with smart grids. An analysis of the human scale of smart grids must account for the collectively shared meanings, aspirations and emotional attachments of householders. For these reasons, this thesis dives more deeply into the normative and motivational dimensions of householder participation and agency in smart grids.

The thesis aims to enhance our understanding of emerging and transforming domestic energy practices enabled by smart grid innovations, and their consequences for sustainable grid management and the relationship between system actors, energy collectives, and households in Europe. The character of householder participation in smart grids is assessed critically in terms of empowerment to self-organize or co-construct democratic, sustainable energy systems and sustainable lifestyles. The term 'human scale' is introduced as means of broadening our view of householder involvement in energy transitions far beyond formal processes of participation. Moreover, the thesis aims to generate insights and recommendations into how participation of householders in smart grids could be supported by governance strategies and policies from the side of both energy providers and (national and EU) government. To achieve these aims, three main research questions were posed:

- How do smart grid objectives and technologies interact with householder goals and preferences with respect to energy use and generation, and how does their implementation co-shape energy management practices, householder agency and power relations?
- How do wider sociotechnical configurations of smart grids engage and empower (collectives of) householders, such as those involving energy

storage and digital infrastructures? (How) can householder co-shape those wider configurations?

- What are the implications of this analysis for stakeholder strategies and energy policies and governance concerning the co-construction of smart grids at human scales in the near future?

In order to answer the main research questions, a theoretical framework is applied which conceptualizes the interaction between households and energy systems in the context of smart grids. Social practice theory is used to identify two levels of analysis. The first is the *situated, single household,* which is the site of home energy management (practices). The second level encompasses the *wider socio-technical configurations* in which (collectives of) householders can participate in the context of smart grids. The *engagement* and *empowerment* of householders is investigated in relation to home energy management and in relation to energy managing collectives. A conceptual framework is presented which places emerging home energy management (HEM) practices at the interface between the home and wider energy systems.

Methods were selected to match the level of the situated households as well as at the level of wider socio-technical configurations of smart grids respectively. The empirical work consists of a mix of qualitative methods, including semi-structured interviews, 'show-and-tell'-style home tours, ethnography-style observations, participatory workshops, and participant observation.

Research chapter 1 analyses recent shifts in goals concerning domestic energy uses. Drawing on two Dutch smart grid projects, it is observed that in the smart grid transition the balancing of (renewable) supply and demand in energy grids becomes the key priority of grid managers. This shift becomes translated at the household level through so called 'teleoaffective structures' of energy practices which motivate and direct the behaviour of householders towards flexible timing-of-demand. New grid objectives are codified in the rules of social practice concerning the use of flexibility instruments (notably time-of-day pricing) and are materialized in monitoring devices, smart appliances, and energy storage. Domestic practices were analysed for amenability to flexible timing-of-use. Cleaning practices were found to be most suitable for demand-side response, whereas practices implied in ambiance regulation, leisure, cooking and eating, align only with some flexibility instruments. Next, an analytical focus on linkages between social practices was used to specify opportunities and barriers to sustainable domestic energy consumption. In the concluding section, the argument is made that householder engagement with sustainability goals should be safeguarded from the flexibility instruments, goals and strategies that seem to turn this engagement into grid management performed for financial benefits only.

Research chapter 2 investigated the potential role of households as 'co-managers' of energy in smart grids. Drawing on 14 'show-and-tell' home tours with householders in a smart grid trial, an analysis is presented of how home energy management (HEM) is performed in everyday life. The focus is on three technologies: monitoring technologies, smart heat pumps and home batteries. How and why householders do (not) engage with energy management during the pilot project is described. When householders participate in HEM practices, they gain energy management understandings and an awareness of smart grid objectives. Since HEM practices are shared between householders and actors from the energy provision system, they display particular ways of distributing responsibilities, power and agency over technologies, experts and householders. The time and space granted to these three smart grid technologies are shown to depend on the trust relationships between householders and the more or less absent providers of technologies and services. These insights emphasize the need to develop smart grid solutions reflexively with respect to the different spaces and practices in households in which they operate.

Research chapter 3 presents an analysis about how the introduction of home batteries affords new roles and energy practices for householders. Qualitative research involving interviews with householders and other key stakeholders engaged in using or implementing battery storage at household and community level point to five emerging storage modes in which householders can play a role: individual energy autonomy; local energy community; smart grid integration; virtual energy community; and electricity market integration. For householders these storage modes facilitate new energy practices such as providing grid services, trading, self-consumption, and sharing of energy. Several of the storage modes enable the formation of prosumer collectives and change relationships with other actors in the energy system. The analysis is followed by a discussion about how householders also face new dependencies on information technologies and intermediary actors to organize the multi-directional energy flows which battery systems unleash. With energy storage projects currently being provider-driven, the argument is made that more space should be given to experimentation with (mixed modes of) energy storage that both empower householders and communities in the pursuit of their own sustainability aspirations and serve the needs of emerging renewable energy-based energy systems.

Research chapter 4 examined new business models and digital infrastructures in the form of 'energy platforms'. These energy platforms offer new ways for householders to trade or exchange energy with other households or with energy system actors, but also bring along challenges. This research chapter examines how householders engage with potential environmental, social, and economic opportunities and risks of energy platforms. Two serious-game style workshops were convened in which Dutch frontrunner householders assumed the role of platform members and were challenged to deliberate about different scenarios and issues. The workshop results, while explorative in nature, are indicative of a willingness to pursue energy system integration rather than autarky or grid defection. The idea of energy platforms as vehicles for energy justice appealed less to the householders, although the participants were moderately interested in sharing surplus renewable energy. Finally, environmental motivations were of key importance in householders' evaluation of different platform types. This shows that in the role of energy platform members, householders can engage with both the community and the grid in new and different ways, leading to a diversity of possible outcomes for householder engagement.

Four main conclusions are drawn from these research findings. The first conclusion is that HEM-practices are characterised by alignments and clashes between the 'life world' of householders and the 'system world' of smart grids. Interactions between the life world of householders and the system world of smart grids can lead to either adoption, reinterpretation, or rejection of smart grid objectives and technologies by householders. The second conclusion is that smart grids both enable and constrain householder agency by introducing new forms of control over and monitoring of flows of energy and energy data. In terms of enabling, smart grids empower householders to articulate and employ new and relevant low-carbon lifestyle ambitions by performing HEM-practices. In terms of constraining householder agency, particular (ICT-centric) configurations of HEM also introduce new forms of control over households by system actors. The third conclusion is that socio-technical configurations of smart grids featuring energy storage and digital infrastructures enable exchange, trade and storage of energy and entail diverse and not yet crystallized roles and engagements for householders or communities. The fourth conclusion is that energy storage is paradoxical with respect to empowerment and socio-technically flexible, with the emergence of energy storage resulting in a dynamic field of experimentation in which different interests and goals mix and mingle.

In the discussion section, the research conclusions are discussed with reference to two features of modernity: space-time distanciation and reflexivity. Understanding how 'distancing' leads to processes of social disembedding and new forms of social integration gives context to the research findings about the interplay between the domestic world of householders and the system world of smart grids. The smart grid promises engagement but also risks in some sense the alienation of its participants because of the distanciation of social (energy) relations and the limited number of co-present interactions. Moreover, the findings indicate that meaningful reflexivity on the part of householders involves critically recasting energy use, generation and management in light of broader sustainability goals (such as combating climate change, renewable self-sufficiency, and local energy neutrality). The decentralizing tendencies of smart grids also open up opportunities for householders to reflexively co-create new kinds of energy collectives and relations between householders, energy utilities and markets.

Based on the conclusions and discussion, recommendations are formulated. These centre around the importance of understanding the (domestic, life-world) context of home energy management and attuning smart grid configurations to sustainability aspirations of householders; dealing with uncertainties and giving space to learning, co-creation and ongoing social science research on the issue; and minding (skewed) power relations between providers and intermediaries on the one hand and householders on the other. These insights and factors point to building blocks of strategies and policies for co-constructing 'smart grids the human scale'.

Considering the emerging, complex and uncertain nature of householder participation of householders in smart grids, characterized by diversity (in objectives, organisational forms, methods, engagement), unsettled relational boundaries not yet crystalized power relations between actors, it is recommended that governance actors pursue a reflexive governance strategy with respect to scaling up smart grid projects. To foster smart grid configurations that take into account a wider range of (future) interests and aspirations of householders and communities, and enable diverse forms of energy citizenship, governance actors in governmental and commercial organizations could develop policies to actively support experimentation with different forms of home energy management and with social organization of energy managing collectives. Moreover, reflexive governance would involve professional facilitation of householders and communities to enable them to articulate their interests and ambitions vis-à-vis powerful established energy system actors and novel intermediaries such as aggregators. An emerging field of smart grid mediation is described, which comprises of activities, procedures, rules of practice, as well as policy instruments, performed by a novel intermediary role and/or instituted by different institutions or entities. Structured and ongoing interaction between (collectives of) householders and energy utilities, markets actors, and intermediaries can contribute to more human scale smart grids which bring together the interests, needs aspirations of householders and system actors in motivating, meaningful, and 'system-smart' collaborations.

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Continuing in Dutch

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Overview of publications

Thesis chapters

- When social practices meet smart grids: Flexibility, grid management, and domestic consumption in The Netherlands, R Smale, B van Vliet, G Spaargaren, Energy research and social science 34, 132-140
- Householders co-managing energy systems: space for collaboration?, R Smale, G Spaargaren, B van Vliet, Building Research and Information 47 (5), 585-597
- Technologies of engagement: how battery storage technologies shape householder participation in energy transitions, S Kloppenburg, R Smale, N Verkade, Energies 12 (22), 4384
- Platforms in Power: Householder Perspectives on the Social, Environmental and Economic Challenges of Energy Platforms, R Smale, S Kloppenburg, Sustainability 12 (2), 692

Additional academic publications

- 2019 Emerging e-practices, information flows and the home: A sociological research agenda on smart energy systems, BJM Van Vliet, J Naus, R Smale, G Spaargaren, Smart Grids from a Global Perspective, 217-233

Conference contributions

- Presentation at ESA Prague: "Emerging energy practices in smart energy systems: a moral economy approach", preliminary findings (26 August 2015)
- Presentation at 'The First Asian Energy Conference: Smart Grids, Sustainability Transition, and Innovation in Governance' in Hong Kong: "Smart grids, information flows, and emerging energy practices: the Dutch experiences and implications for China" (2 November 2015)
- Seminar presentation at the Asian Energy Studies Centre: "Energy consumption in perspective" (5 November 2015)
- Presentation at conference 'Disclosing Sustainability: The Transformative Power of Transparency', Wageningen, the Netherlands: "Household participation in the Smart Grid: Transparency and Equity" (24 June 2016)
- Presentation at the 3rd Energy & Society conference, 'Transforming Energy for Society', Leipzig, Germany: "Inclusive Householder Participation in the

Smart Grid: a Case Study of Demand-Side Flexibility and Domestic Energy Storage in Practice (in NL & UK) (13 September 2016)

Additional non-academic publications

- 2020 Flexibeler energieverbruik van huishoudens, R Smale, N Verkade, D Geelen, J Kohlmann, Energie+, 4-7
- 2018 Platform stimuleert vraagverschuiving coöperatieleden, M van Huijkelom, R Smale, N Verkade, H Slootweg, Energie+, 20-22, 2015

About the author

Robin Smale was born on August 1st 1991 in Coevorden, the Netherlands. Growing up in the Drenthe as the son of two high school teachers, he is an eager learner with broad interests. Picking up an interest in geography and the environment at a young age, it took a few years of interdisciplinary study at Wageningen University to discover and then grow an ongoing fascination with the social sciences of the environment. He received a Master Degree in Environmental Policy in 2014 at Wageningen University and then commenced a PhD project at the Environmental Policy Group.

Since 2019, he is employed as policy officer Climate and Sustainability with the municipality of Wageningen. In this role, he works to further the renewable energy transition locally. Engaging with stakeholders ranging from local businesses, nature and landscape organisations, citizens and activists, he has developed affinity with a wide variety of sustainability subjects, ranging from sustainable mobility to participation in and spatial quality of renewable energy projects such as solar parks.

Research school education certificate

Netherlands Research School for the
Socio-Economic and Natural Sciences of the Environment

D I P L O M A

for specialised PhD training

The Netherlands research school for the
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(SENSE) declares that

Robin Smale

born on 30th August 1991 in Hardenberg, The Netherlands

has successfully fulfilled all requirements of the
educational PhD programme of SENSE.

Wageningen, 2nd December 2021

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KONINKLIJKE NEDERLANDSE
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The SENSE Research School declares that **Robin Smale** has successfully fulfilled all requirements of the educational PhD programme of SENSE with a work load of 35.6 EC, including the following activities:

SENSE PhD Courses

- Environmental research in context (2015)
- Research in context activity: 'Publishing article on householders' role in flexible, green grids in Dutch newspaper NRC' (2021)

Other PhD and Advanced MSc Courses

- DEMAND Centre Summer School, Lancaster University (2015)
- Summer School 'Making Everyday Futures', Eindhoven University of Technology (2017)

Management and Didactic Skills Training

- Co-organiser PhD Study Trips visiting academic & policy institutions in Germany (2016), Switserland and China (2018)
- Co-organiser of scientific conference 'Disclosing Sustainability: The Transformative Power of Transparency?' (2016)
- Lead organiser of two PhD Writing Retreats with the Wageningen School of Sustainability Governance (2017-2018)
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- Supervising two MSc students with thesis (2016-2017)
- Teaching in the BSc courses 'Theories and Themes: Sociology' (2015, 2016) & Sustainability Transitions: Concepts, Issues and Indicators (2015, 2018)
- Teaching in the MSc course 'Governance for Sustainable Cities' (2018)

Oral Presentations

- *Smart grids, information flows, and emerging energy practices: the Dutch experiences and implications for China*. The First Asian Energy Conference: Smart Grids, Sustainability Transition, and Innovation in Governance, 2 November 2015, Hong Kong, Hong Kong
- *Inclusive Householder Participation in the Smart Grid: a Case Study of Demand-Side Flexibility and Domestic Energy Storage in Practice (in NL & UK)*. 3rd Energy & Society conference Transforming Energy for Society, 12-14 September 2016, Leipzig, Germany
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