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Smart energy prosumers in Norway: Critical reflections on implications for participation and everyday life

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A B S T R A C T

As evidenced by the EU's 2016 political ambition to empower energy consumers by allowing them to become prosumers, smart energy technologies are expected to contribute to energy savings as well as healthier and more comfortable lives. Norway is a vanguard country in implementing smart energy technologies, and a growing literature of social science and humanities research has investigated how such technology impacts everyday life. Taking stock with this literature and comparing two Norwegian high-tech demonstration cases, where local production and smarter consumption is enabled through novel technologies, the research objective of this paper was to analyse the ways in which smart energy technologies affect users, and the extent to which users can influence the role of smart energy technological arrangements in their everyday lives. Results indicated that there is a divergence between the intentions and the effects of the introduced technologies. For instance, smart technologies and prosuming affected the way people organised their everyday lives by demanding more work of participants. We conclude with recommendations for practitioners relating to consumer participation and energy prosuming, advising a focus on broader implications in addition to smart technological fixes.

1. Introduction

In 2016 the EU introduced a high-level policy ambition to provide 'Clean Energy for All Europeans' (Europa.eu, 2016). Enabled through smart energy technologies, this policy package rests on an idea of a specific type of consumer empowerment that gives consumers the ability to generate power for own use or to share, store, or sell back to the market — in other words, to become energy prosumers. Furthermore, it states that by taking control of their consumption through smart technologies, people are better equipped to make informed choices about how to use energy, ultimately improving energy efficiency.

Norway is an energy rich, relatively egalitarian and politically stable country where most people have few concerns with regards to covering basic energy needs. As a consequence of government subsidies, by 2019 Norway had the most electric vehicles (EVs) per capita (Regjeringen.no, 2019) and was one of a handful countries globally that had rolled out smart metres to almost all of its citizens (Iot-analytics.com, 2019; Nymaler.no, 2019). This makes Norway an ideal country to test energy solutions of the future and to gain an understanding about the wider sociotechnical implications of these solutions.

Since 2015, the idea of the prosumer gained a foothold in the Norwegian discourse (Throndsen et al., 2017). In Norway, being an energy rich nation where hydropower is used for space and water heating, cooking and most other general electricity use, domestic energy efficiency policy has historically been dominated by making energy efficiency efforts profitable (Ryghaug and Sørensen, 2009). Although some buildings have been equipped with PV panels or solar collectors, the fact that end users were able to facilitate load-shifting and could sell electricity to the grid, i.e., engaging in prosuming, has not been featured much in the domestic energy efficiency dialogue (e.g., Korsnes, 2017). With the recent re-introduction of the term 'prosumer' and the availability of smart metres, the provision of flexibility for grid and market purposes has been included within the purview of everyday energy users. The increased interest in prosuming may also be connected to the rapid increase in the use of EVs in Norway, which has prompted concerns about their strain on the electricity grid (Skjølsvold et al., 2019). EVs have, therefore, become an integrated part of prosumer discussions, as they can be considered both a challenge due to higher loads when charging, but also a solution due to their batteries and

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load-shifting abilities (e.g. charging at night, consumer savings, etc.) (ibid).

In the concerted efforts by government and the energy sector, not only in Norway, a wide variety of arguments is used to advocate for making systems 'smart': resource, energy and time efficiency are prominent examples, as are ideas of security (e.g. Gram-Hanssen and Darby, 2018), health benefits (e.g. Wilson et al., 2015), and comfort and independence (e.g. Nicholls et al., 2020). Ideas about smart living are intertwined with expectations among advocates of smart energy technology that people will accept, adapt, extend or even co-create new technological systems as a natural part of their everyday life. Within this range of expectations, people are simultaneously thought of in two different ways (Strengers, 2013). On the one hand, they are considered passive and need not do anything new or differently in their smart homes because the energy use can be automated and programmed to make smart consumption decisions (ibid.). On the other hand, end users are considered to be self-informed, empowered and actively engaged as co-creators of future solutions (Prahalad and Ramaswamy, 2004). However, Lennon et al. (2019, p. 185) summarises findings by social sciences and humanities (SSH) made in efforts to tackle the question of user engagement by positing that 'current energy systems are structured in a way that provides little agency to the majority of citizens'.

As visions both for 'passive' and 'active' end users in the energy system of the future are plausible, this poses a question of how users will adapt to the one or the other, and what the significance of different strategies employed in implementation work, if any, might be for such outcomes. Thus, the fundamental questions addressed in this paper are: how does smart energy technology implementation affect the everyday lives of end users, and what agency do people have in influencing smart energy technology arrangements as they are implemented?

In order to answer these questions, we set out to compare results from studies of two microgeneration and smart energy demonstration sites in Norway, both of which were conducted by way of interviews with end users and participants. The two cases were investigated as part of two separate research projects (detailed in section 3), and they were purposefully selected and compared, as they represent two somewhat different approaches to sustainability in Norway: Evenstad focused on zero-emission neighbourhoods and Hvaler on renewable energy generation and consumption. We found that in many cases the new technology, rather than seamlessly optimising demand response and prosumer activity, users often made additional considerations and effort. In light of these findings, this paper emphasises the continued relevance of addressing visions for end users in the energy system of the future.

The next section introduces previous and recent work on smart energy technology as they relate to end users in the everyday setting, with a particular focus on Norway. The section then elaborates on the concept of the energy prosumer, and the potential analytical affordances it might provide. Thereafter, section three introduces the two cases, their selection, and our respondents, and summarises our methodological approach. Section four provides results from our interviews and focus group that highlight user experiences with smart energy technology. Section five summarises, compares and discusses findings. Finally, section six provides some conclusions.

2. Smart energy technologies and the energy prosumer

This section presents a brief introduction to sociotechnical perspectives on smart energy technologies and energy prosumers, with a particular emphasis on Norway and the relevance to this study. The aim is not to provide an exhaustive literature review, but rather to highlight some key points of relevance to the present analysis.

2.1. Smart energy technologies and Norway

There has been a massive amount of work globally to align interests and support platforms and standards that coordinate technological development relating to smart energy technologies (Berker and Throndsen, 2017). In this sense, the smart energy technology project is 'deeply rooted in seductive and normative visions of the future where digital technology stands as the primary driver for change' (Luque-Ayala and Marvin, 2015, p. 2105). Given this strong technological enthusiasm associated with smart energy technologies, there is a need for critically examining the co-production at play when technologies and people bond. On one hand, smart grid demonstration pilots generally aim to show how smart energy technologies can be a solution to the presumed lack of consumer rationality exhibited in the energy market (Throndsen, 2017). Recent SSH research on people who live in smart homes on the other hand, tend to focus on the broader implications of smart energy (or smart home) technologies for how we organise our everyday lives and society (e.g. Hargreaves and Wilson, 2017). It seeks to ask more fundamental questions about the smartness of these new technologies (e.g. Wilhite and Diamond, 2017), whether there is evidence that smart technologies generate energy savings (e.g. Hargreaves et al., 2018), or question the social value of ever larger quantities of metering data (Kragh-Furbo and Walker, 2018). Even admitting that pricing schemes impact energy decisions, the SSH literature dispels the idea that there is any kind of direct causality between price and behaviour, and that e.g., local context and material surroundings strongly intercede (Christensen et al., 2020).

A growing SSH literature has focused on the development of smart energy technology in Norway. Some of the early research by Throndsen (2013) illustrated the structural and regulatory struggles that were faced in implementing smart grids after Norway decided to achieve full coverage of smart metres by 2017 (later changed to 2019). Throndsen (2013, p. 1) emphasized that stakeholders, especially network operators, were 'not convinced by the largely abstract rationales for smartness presented to them' and questioned what the improvement would in fact entail for household end users. Shortly thereafter, Ballo (2015) illustrated the performativity of the smart grid discourse in Norway, underlining that the implementation of smart grids in Norway was not heavily grounded in concerns connected to 'prosuming' or a logic of environment friendliness. Rather, smart grid discussions were grounded in market logics and 'ideas of technology providing control over uncertainties caused by nature, as well as providing "intelligence", and solving potentially challenging social issues' (Ballo, 2015, p. 18).

Several other studies have been conducted pointing out that the smart grid development in Norway has been a top-down initiative with economic incentives and techno-centrism as a main focus and with a large variety of interpretations of core concepts such as users, flexibility, peak-demand shaving and shifting (e.g. Skjølsvold & Ryghaug, 2015; Throndsen & Ryghaug, 2015; Throndsen, 2017). This variety of interpretations has made it more difficult to achieve some of the anticipated advantages, such as energy efficiency (Winther and Wilhite, 2015). In other words, a systematic lack of understanding of user-perspectives and implications for different user groups in Norwegian smart energy technology projects persists. Even as end users are routinely lauded as the indispensable actor in energy grids of the future, continued inquiry into the implementation sites of this technology is thus still strongly warranted. Before moving on to the cases and methods, a quick outline of the concept of the prosumer is provided in the following, final part of this section.

2.2. The energy prosumer

The term prosumer, a combination of the two words producer and consumer, was introduced by Toffler (1980). The term has recently been used to understand energy demand in the context of an increase in microgeneration technologies of renewable energy combined with an increasing interest in smart technologies (e.g. Juntunen, 2014; Ellsworth-Krebs and Reid, 2016). The typical energy prosumer has PV panels on the rooftop of a house as well as smart metres and home energy management systems. Parag and Sovacool (2016, p.1) define energy prosuming as ‘when energy customers actively manage their own consumption and production of energy’. Using this definition, energy prosuming could also mean producing your own heat, for instance, with a combined heat and power boiler, or through chopping, stacking and burning firewood to heat up your house. What is more, it could also include actions such as wearing a sweater, cooking your own meal or growing your own vegetables, given that all these include forms of energy consumption and production. Hence, to make it useful for the analysis of this paper, we need to specify the term prosumer a little bit.

For starters, *electricity* prosuming can include forms of heating since heating is becoming increasingly electrified with the use of heat pumps and similar technologies. This is particularly relevant for Norway, where most of the heating happens through electric radiators; however, firewood use, which represented 12 percent of household energy use in 2017, is significant as well (Energifaktanorge.no, 2019). Since electricity in Norway supports such a wide swath of services—lighting, heating and cooking, to mention just a few (e.g. Wilhite et al., 1996)—there is not necessarily a direct connection between how power is used and how it is produced. Compared with, for example wood heating, which requires either buying or chopping, stacking and drying wood repeatedly, a PV panel, which is installed once with a 20-year lifetime, requires less recurring work. This begs the question of what types of work are included in the production part of prosumption, and what parts of the value chain are taken over by prosumer activities. In her classic book, *More Work for Mother* (1983), Ruth S. Cowan showed how new needs, services and interdependencies were created as domestic automation tools, such as the washing machine or the microwave oven, were introduced into the home. An example relating to energy is the preparation of firewood, which some consider inconvenient. Nevertheless, what is considered inconvenient is constantly changing and depends on the context. As pointed out by Rinkinen (2019 Kindle loc. 1753), the ‘inconvenience of living with the temporal demands of wood heating can be defined in other ways, especially if this method of warming the home is culturally accepted and if it is taken to be normal’. In other words, what could be a daunting or even impossible task (i.e., chopping wood) for some is entirely normal or even a leisure activity for others. Such aspects make the prosumer term more complex when talking about electricity or heating, leading to repercussions for how we understand impacts on a wide range of issues relating to everyday life, inclusion and justice, such as age, class and gender (Standal et al., 2020). Thus, prosumer activities impact daily routines and activities and may deepen, reinforce or challenge already existing patterns of social division and domestic work depending on how the prosumer is conceptualised and implemented.

To summarise, nuancing our understanding of prosuming could potentially assist in studying broader issues that go beyond the smart energy technologies themselves. This provides an opportunity to take a closer look at the services these technologies provide, the needs they potentially address and the impacts they have on the organisation of everyday life. Taking these considerations into account, this paper studies microgeneration and smart energy technologies’ effects on everyday life, not only necessarily because they assist in producing and consuming, but because of a wide range of impacts such as the timing, feeling or meaning of these technologies that reconfigure the everyday (Strengers, 2016).

3. Introduction of cases, data and methods

The two cases presented here (see Table 1) were purposefully sampled to highlight two different types of smart energy technology ambitions in Norway. Purposeful sampling is often used to ‘select information rich cases that best provide insight into the research questions’ (Emmel, 2013, p.33). As such, the case sampling was not driven by theory, but rather by practical and pragmatic considerations, which would enable a comparative analysis relevant to the research questions set out.

3.1. Campus Evenstad

Campus Evenstad houses the Department of Applied Ecology and Agriculture at the Inland Norway University of Applied Sciences and has about 60 employees and 220 students. The campus is relatively isolated, located in mid-Norway about 40 km away from the nearest larger town (of 2000 inhabitants) and 100 km away from the nearest city (of 30,000 inhabitants). Campus Evenstad serves as one of eight pilots of the Norwegian Research Centre on Zero Emission Neighbourhoods in Smart Cities (ZEN). The technologies included at the campus are: a zero-emission building (ZEB) with the highest ambition level, 60 kW of grid-connected rooftop PV panels, a wood chip based combined heat and power (CHP) plant (40 kW power, 100 kW heat), a district heating system, 100 m^2 of thermic solar collectors and the five largest batteries in Norway (as of 2019) with grid-connection (204 kWh energy and 120 kW power). At the end of 2019 Vehicle-to-Grid was implemented, making use of the battery capacities of electric vehicles to balance the grid.

As Europe has a vision to become 100% powered by renewables, Campus Evenstad aims to make a significant contribution towards making this goal a reality. The campus aims to demonstrate flexible energy use in practice and to develop new solutions for energy use management. Therefore, a smart energy management system has been implemented to reduce the peaks in energy consumption and thereby the load on the grid. The aim is also to increase the amount of self-produced energy and optimize the interplay between different electricity (photovoltaics, CHP, grid) and heat (CHP, solar collectors, bio-based and electric boilers) sources (for more info see Backe et al., 2019).

In total ten interviews were conducted in May and June 2017: nine at the campus, including the dean and vice-dean, two of the technical staff taking care of day-to-day operation, employees, researchers and PhD students. One interview was conducted over phone with the project engineer from the construction company responsible for the construction of the ZEB. Interviews were selected based on availability, and relevant interviewees were identified mainly through the ‘snowball’ sampling method. Interview questions centred around experiences with working at the campus, particularly how the new zero-emission technologies were experienced, how this impacted everyday work routines, and expectations about what a zero-emission campus would look like in their opinion. We also conducted one focus group interview with five bachelor students living at the campus. The focus group was held with residents of the campus because it was thought to elicit more dynamic responses compared with interviews regarding how

Table 1
Overview of technologies and research data in Campus Evenstad and Hvaler.

	Campus Evenstad	Hvaler
Type	Campus	Municipality
Population	Ca. 300	5000
Types of technologies	- a zero-emission building (ZEB) - rooftop PV panels (60 kW) - combined heat and power plant (40 kW power, 100 kW heat) - district heating - solar collectors (100 m^2) - five grid-connected batteries (204 kWh energy and 120 kW power)	- rooftop PV on about 100 houses, 3–5 kW - smart metres - visualisation - EVs - power demand tariff
Number of interviews	10 (see appendix A)	17 (see appendix B)
Other data	Focus group with five students Local stay at the campus	

it was experienced to live at the campus. Thus, the topic of that focus group was aiming to provide information about everyday life issues experienced by the students. Interviews lasted between 35 and 90 min, and the focus group lasted 90 min. One of the authors lived at the campus for about a week in total, conducting participatory observation during this time. See appendix A for overview of interviews and focus group.

3.2. Hvaler municipality

The second case in this paper presents findings from a study of the smart technology demonstration activities of Smart Energi Hvaler (SEH) which was a joint venture by Smart Energy Markets (a research organization), Fredrikstad Energi (the local ESCO/DSO), and the Hvaler municipality. Operating on the island municipality of Hvaler, SEH showcased a demonstration project on residential PV systems in combination with prosumer market models and novel consumption monitoring and control systems. It was a testbed for the first power tariff in Norway, charging customers not for energy demand, but power load demands. Hvaler is a small archipelago in the Oslo Fjord on the border with Sweden that includes five islands covering 86 km^2 with a total of 4000 vacation homes with 30,000 seasonal visitors, 5000 permanent residents in 2700 domiciles and some commercial properties. A focus at the demonstration site was to explore the effects in the home and in the grid of smart metering with solar photovoltaic (PV) panels with the aim of giving the users the means of becoming prosumers. At the time of interview, households had lived with these technologies for 1–2 years, however the functionality for automated demand response on household appliances like water heaters, floor heating and stove was still not fully operational at the time of study.

The study was undertaken with two rounds of interviews, one in spring 2017 and one in fall 2017. SEH had at this point rolled out PV to about 100 houses, and access to 28 potential respondents was provided by SHE, ultimately providing this study with 17 interviews—15 with households conducted in the home and three with two experts (one was interviewed twice) working within the SEH framework. There were 22 respondents in total, as in some interviews more than one householder was present. The goal of the interviews was to assess to what extent novel energy technologies and price regimes had changed everyday life in terms of electricity use, such as changes in practices and habits. Questions probed matters of everyday life and electricity consumption (i.e., describe a typical day), processes and motivation (i.e., details about joining the project and installing technology), and finally, experiences (how new technology affects consumption behaviour).

The data was gathered as part of the ERA-Net MATCH (Markets, Actors, Technologies) project and with the help of Smart Energy Markets, which provided access to household participants and experts. Because interviews were usually conducted in the home with one or more household dwellers, they provided some insight into the actual setups in the households, which were varied. The interviews were transcribed verbatim.

We coded the transcribed material using NVivo qualitative data analysis software. Using a constructivist inspired grounded theory approach (Charmaz, 2006), we compiled codes inductively based on their appearance in the material and relevance to the research questions. Thus, the coding was based on existing ideas for analysis and the development of matters of concern throughout the data collection and analysis phase. The analysis was shaped by experiences made during the fieldwork that functioned as ‘sites of conversation’ about the collected data (Clarke, 2005, p.202). In the end, this study has multiple sources of evidence, mainly from interviews and documents as well as some observation. This procedure of triangulation is employed in order to reduce the likelihood of misinterpreting the case study (Stake, 1994). Essentially, triangulation means studying the same phenomenon from multiple sources, so that the validity of a case study increases (Yin, 2009, p. 116).

In brief, the codes from Evenstad related to automation, energy use, the ZEB, the role of the environment and self-sufficiency. The codes from Hvaler were related to electric vehicle (EV), motivation and participation (in demo), process and red tape, equipment and learning, and wish-list of participants. The most extensive topic, that of flexibility, garnered sub-categories automation, metering, consumption and control, load shifting, prices and tariffs, and power and peak load. In Appendix C, we provide a table of the codes from Evenstad and Hvaler, the number of interviews in which the codes were sourced and the total number of instances for each code. The tables represent the final data selection upon which the analysis in the paper is based.

4. Local energy experiences at campus Evenstad and Hvaler

4.1. Prosumers at Campus Evenstad

Campus Evenstad has been part of two national research centres: the research centre on zero emission buildings (2009–2017) and the research centre on zero emission neighbourhoods (2017–2025). As part of the first centre, construction of the ZEB was finished in 2016. Participation in the second centre aims to include the whole campus with local energy microgeneration technologies as well as smart and flexible energy systems. The fact that Campus Evenstad is a relatively isolated community was an important reason that local Campus stakeholders were interested in these technological solutions in the first place. The difficulty of such remoteness was compounded because there were frequent power outages in the area. As pointed out by one of the PhD students:

> Yes, there’s a lot of power outages. Sometimes they are quite long, like ten hours or so. You survive, of course, but you start thinking a bit about your freezer. That’s how it is here in the

> countryside. Large distances, and somewhere a tree has fallen on the power grid. (PhD student 1)

One bottleneck to increased local energy production was that the two local technical staff were already overworked due to problems with the new combined heat and power (CHP) system. The system heats wood chips to form wood gas, which fuels an internal combustion engine that runs a power generator. Heat from the process is recovered into water, which is then circulated at the local district heating system. The local employees were part of choosing this system, which gave them more ownership in the technology and made them very set on making this relatively new technology work. The problem involved difficulties in feeding the machine the correct type of woodchips. One initial problem was that the wood chips had to be very dry for the system to work. The local supplier had dried it to the required dryness—below 15 percent—but over the winter, this had changed:

> The [CHP] oven is very picky. A colleague said that it only takes ‘champagne chips’, and we pay champagne prices for it as well (laughter). It was estimated that we needed 900 m^3 of woodchips, so the guy who is delivering them just dried 900 [m^3] last autumn, and he had them at about 13–14 percent dryness and put them under roof. But as the winter passed the temperature went up and down, and then the wood chips became more and more moist. So, after Christmas it was at 17, 18 or 19 percent and then we got problems. (Technical staff 1)

As we see, the woodchip-based technology came with some unexpected infrastructure issues that needed some time to adapt to. Another issue was that the local technical staff had to show up at odd times in weekends and holidays to refill the system woodchips because it worked best if it could run constantly without interruption. Combined with the other technical issues, the local staff were worn out:

> We are at a point now where we simply need more staff. We have reached a point of saturation, and we cannot get anymore tasks pushed on us now. Then it will have to come at the expense of something else, and that’s not desirable. (Technical staff 2)

This extra demand in effort relates to the point made by Rinkinen (2019), that taking over a larger part of the supply chain—as prosumers often do—implies more work. This work does not necessarily have to be a burden, but it needs to be taken into account in assessments of how new local microgeneration technologies should and could be operated.

Getting used to new technical systems can certainly feel like a burden. Another example of this occurred when the local technical staff were demonstrating how the smart energy system of the brand new zero emission building worked. One of the classrooms, in which students were undergoing an exam, showed a reading of 30 °C while the set temperature was 21 °C. Clearly, something was wrong. Soon enough, a call was received from a disgruntled teacher that the automated windows did not open. To solve the issue, the technical staff had to improvise by cutting the power to the windows and open them manually. In other words, they had to resort to the regular (unsmart) manual way of opening up the window.

Although the local technical staff were overworked, they had hopes of solutions. Keeping in mind that the average temperature from November 2018 to April 2019 was −4.5 °C, with temperatures as low as −30 °C in January/February, energy security was a very important consideration for the local staff, especially when it came to heating. A frequently mentioned solution to the issue of unstable electricity supply was the batteries that were going to come to the campus. Because the pumps for the local district heating system were depending on electricity to circulate the heated water, the batteries were considered useful should there be a power outage in winter. Reducing peak loads with batteries was also an existing ambition, including plans to use the local electric vehicle batteries (V2G) as a way to flatten loads. In 2007, at the time when the campus had installed rooftop PV, several of the local employees decided to get their own EV. As local charging infrastructure improved, more people decided to get EVs, including the university, which acquired one for its staff – making V2G a relevant solution for the campus. Nevertheless, whether these solutions actually led to reduced work for the two technical staff is doubtful as they were the two only people locally with the technical competence to help out should there be any issues, e.g., with charging or connecting.

4.2. The role of environmentalism

The students and staff at Campus Evenstad consider themselves above average when it comes to environmental consciousness, given that their area of study is applied ecology. Many of the interviewees mentioned the various things they did for the environment, not only driving an EV, but also local farming, hunting, heating with firewood, and reducing meat consumption. As one of the university employees said: ‘If you are interested in asphalt and latte and those things, then this would perhaps not be your first place to apply to’.

When asked about self-sufficiency and prosuming, several interviewees mentioned that it was not only about being self-sufficient in energy. They were expecting the zero-emission neighbourhood project to also include local food production and reusing local resources such as waste handling and recycling. The university dean put it this way:

> We might become self-sufficient in energy, and that should be possible to achieve with respect to food as well. Organic, self-produced vegetables for instance. It would be great if we could become a model, self-sufficient organic campus.

This was not only voiced with respect to food, but also in reusing local resources. One of the researchers said that:

> It should be possible to reuse the rainwater here somehow, and it was disappointing that the ZEB house did not include that. They even have a fireplace where the heat is led straight out, so they could have reused more of the resources. (Researcher)

Thus, people working and living at the campus were concerned about not wasting energy and resources, but they were also disappointed that the project owners had a too narrow understanding of environment and energy saving. During a presentation round of the local technical system, one employee expressed that he was expecting the zero-emission neighbourhood project to also consider reusing local sewage, for instance to produce biogas or heating. In general, we observed that the local staff and students were thinking much broader in terms of local sustainability than a narrow focus on prosuming electricity or heat:

> Since it is difficult to change behaviour, I think that you need to change the rules of the game instead of just informing people what they should do to reach the climate goals. So, I think we need to do something more drastic than what is done today. (PhD student 2)

This quote summarises the experience at Campus Evenstad as a relatively environmentally conscious campus, where staff and students appear to agree about the direction they want to go. As we have seen, this includes a much broader understanding of prosuming than only solar panels on a rooftop or an ambitious zero emission building, and as such, they represent a different kind of prosumer than the passive, automated kind.

4.3. Prosumers in hvaler

In a Norwegian context, Hvaler is an ideal location to implement solar PV because it is one of the places with the most days of sunlight. However, there are also some concrete challenges that has made Hvaler attractive as a demonstration site for distributed microgeneration in the form of solar PV. The island only has a single power line connecting it to the mainland. This means that, much like in Evenstad, if it were interrupted, any part of the community downstream from the breaking point will be without power until the situation is resolved. Throughout the years, this has been happening frequently enough to make security of supply a contentious issue. Power fluctuations pertaining to grid balancing issues has also been a problem, and many incidents of ruined home appliances on the customer side were reported. These events led to a local citizen's action group to demand, among other initiatives, the commissioning of an underwater cable to service the islands (they have since claimed a victory for their struggle).

These developments had made an issue of security of supply that would normally not figure very prominently on the mainland (see e.g. Skjølsvold et al., 2020). In short, these problems are island-problems—although they are comparable to the Evenstad case because of Evenstad's relatively secluded location. Demand side management is therefore relatively more relevant in Hvaler, as it has presented one solution that may increase grid robustness without resorting to costly grid expansion. Any such grid expansion is also controversial in terms of natural interference, as large parts of Hvaler have status as national park.

Due to this contentious nature of the energy supply on Hvaler, engaging and recruiting households to the demonstration project was not difficult. One respondent provided a representative statement when asked why they joined the project, which did incur a substantial (though rebated) installation cost for the PV rig:

> I thought that this would not make sense. The subsidies were very small. If I wait five years, it will be cheaper than if I participate in this with Hvaler now. But *then* I thought: OK, I can afford it. Someone is taking an initiative here, moving to the forefront, so I thought: someone needs to be bothered. (Interview 3)

Several respondents expressed similar sentiments: a feeling of being innovative in the face of climate challenges, local grid congestion, and expensive grid investment—the cost of which ultimately is transferred to consumers over their grid tariff. This, however, is not to say people were motivated to become prosumers for the money:

> Of course, we knew it would not be economically justifiable, that's not why we did it. […] the motivation was to test it. Just be in on the project, test it and see if we can make it work. Not really anything more than that. Money-wise it's probably better to put it in the bank. (Interview 1)

This interest in 'testing it' was a prevalent consideration, and that 'being in on the project' was considered the 'right thing to do'. The concept of short-travelled electricity appears to have a special meaning in Hvaler, partly due to the history of interrupted power supply, but also because it was desirable to avoid more overhead cables. Having to have more cables "crisscrossing the landscape" was considered highly controversial by almost everyone living there. Being able to do something about this at the individual level provided a social marker signifying one's dedication to solving common issues in the small community, with literally physical evidence on the roof to prove it.

Some respondents indicated that being a prosumer and dealing hands-on with the aspect of resource management was fun:

> 'It's enjoyable when you can turn on the dishwasher and turn on the washing machine and see that we don't take a single kilowatt from the grid. We are producing ourselves. That's fun!' (Interview 4).

This particular household had produced 5500 kWh in total that year, consuming 3000 of these themselves. This was in combination with managing to reduce consumption overall from 27,000 to 15,000 kWh. According to these respondents the reduction was attributable to increased awareness induced by the monitoring equipment, which would present an image of a sad smiley-emoticon if the power consumption was high (Interview 4).

4.4. Power demand tariff experiments

Challenges were experienced with acting in accordance with the day/night cycle and attempting to avoid peak loads. Since respondents also had been subjected to a power-based grid tariff, the majority of them were well aware of the idea of load shifting in order to reduce peak loads. Under this pricing model, the monthly electricity tariff was made out of the average of the three largest power demand peaks created each month, rather than according to accumulated kWh consumption. For this reason, interviewees attempted to spread consumption out over the day, rather than bunching electricity use together and creating a demand peak that would increase the monthly average. One interviewee provided an example of this:

> Well, these days it's peak shaving, and that power tariff impacts a lot. To get that peak down is something we're working on, so that the electric car does not charge at the same time as the water heater. And the floor heating. So, we get them all to not run at the same time. Because each of them pulls 2,000 W. And then you reach 6,000 W like *that*. (Interview 2)

In the above case, the final number on the bill would be influenced by the amount of kW the peak consisted of. A 6 kW peak would present a multiplier of 6. Conversely, keeping the load at 2 kW by spacing out the chores would represent a multiplier of 2. This was considered significant, and many reported it having an impact on household routine. Often people would manage to avoid peaking their consumption by implementing small changes in household routines:

> I wait with putting on the tumble dryer if the washing machine is also running. And if the dishwasher also is running then we maybe wait until one of the other two are done. So, they are not all three running at the same time. (Interview 15)

Thus, respondents engaged in experimental behaviour aimed at avoiding concurrent running of electrical appliances. This would often entail making changes to a whole array of household routines like washing clothes and doing dishes, heating and showering, and charging electric vehicles. Respondents said that they were not much aided by the solar panels in avoiding peaks, but that it “contributed to guiding” when they should use electricity:

> In the summer when we have full production from the solar panel installation, then we run the dishwasher in the daytime. Because then we use the energy from the solar panels for our own consumption. Then we don’t have to buy it. (Interview 6)

The power tariff affected the way in which it felt reasonable to prosume and load-shift. A feature of the demand tariff structure implied that the user, within a billing cycle, got *three strikes, then they’re out*:

> On a regular day it’s no problem. But if one day you have to make dinner, it’s cold outside, the tenant comes home, and there are four snow suits full of mud [referencing children]. Then it goes to pot. (Interview 1)

In other words, the power-tariff as it was structured in this case could then have the opposite of its intended effect, since, as one interviewee said:

> ‘Then you can just use as much as you want, because if you hit that snag there’s nothing more to think about’ (Interview 9).

This made some respond with despondency to the demand tariff. They felt the whole deal was a backwards step for society and were not happy with being punished with high demand peaks due to events that were ‘outside of my control’, such as forgetting to turn off a switch: ‘I do the same today as my mother did. Fly around and turn off switches to keep the meter under the red line’ (Interview 4).

In the case of these last respondents, it seems apparent that this particular kind of tariff structure was demanding and required a far more complicated smartness than the one implemented to avoid needing to implement extra measures. A weakness of this study is of course the fact that automated demand response was still being developed at this point and having it in place could have automated away some challenges like avoiding concurrent running of several appliances, which here had to be solved manually. At any rate, the power tariff and solar PV combined with monitoring equipment served as teachers for existing consumption patterns and guides for load shifting (as evidenced in interview 4 the sad smiley) as well as the more abstract phenomenon of grid congestion issues. Even so, being armed with this knowledge did not make life easier, quite the contrary.

5. Comparing and discussing Evenstad and Hvaler

Taking a step back and looking at the two cases in comparison (see Table 2), we can summarise some more general findings seen in light of the theoretical discussion on smart energy technologies and the energy prosumer. Different types of smart energy technologies were implemented in each case with a goal of reducing emissions and increasing energy security and independence. Implementation of these were, in both cases, related to an interest in becoming more energy self-sufficient.

The Evenstad case shows that local staff felt overworked by the various energy solutions that were implemented to make the campus more energy independent. It also shows an interest in wider self-sufficiency initiatives beyond heat and electricity, namely growing food locally and reusing water and sewage, which had not even been contemplated on the side of technology developers. The Hvaler case shows that people were interested in contributing to development projects thought to solve local problems. Being a prosumer was experienced as being fun and rewarding in terms of giving back to society and the local community, but also somewhat in terms of economy. Hvaler’s power tariff had some unintended consequences. Even though it effected mutability into cemented daily routines, its strict intolerance of high loads combined with the contingencies of everyday life made it difficult to cope with and less meaningful. Given that the Hvaler case was part of a trial, these experiences now serve practitioners with an example of how not to implement power tariffs.

The two cases highlight some important discussions that need be taken into account for future pilots to be successful. For instance, it is clear that the local inhabitants not only accepted but supported the intentions behind the projects. This is in line with energy transition research showing that the NIMBY-explanation is unconvincing (e.g., Ryghaug et al., 2018). In the Evenstad case, inhabitants wanted to go further than the ambitions of the project to become a ‘model eco-campus’, and in the Hvaler case, local inhabitants showed they were willing to put resources and effort into a project that was aligned with collective ideas in the local community (i.e. security of supply and avoiding cables in nature). The idea of ‘active’ consumers in this sense will likely produce varied results for different kinds of households. More information requiring manual efforts for timely load shifting does not make a happy prosumer and does not imply the best way achieving short more robust grids. What is more, given the wide variety and difference between households, interest in and capability to shift load away from peak hours and thus provide flexibility can have negative implications for inequality and energy justice (Throndsen & Ryghaug, 2015; Skjølsvold et al., 2019). As we were able to note, Hvaler inhabitants participating and investing in PV were generally more economically resourceful and at later stages in life. This aligns with critique presented by Levenda (2019, p. 575) pointing out that experimental projects often apply only to ‘“early adopters” and those with enough wealth (…)’, or to those who possess enough ‘flexibility capital’ (Powells and Fell, 2019). Being a functional part of the energy grids of the future should perhaps not be so materially contingent.

The local interest in participating in sustainability-oriented projects shown in both cases demonstrates that (lack of) engagement and participation are not necessarily the barriers hindering the successful implementation sustainable solutions in Norway. Rather, we could say that local inhabitants are supportive and want to contribute, but this engagement is not catered to by the relatively narrow, technical, efficiency optimised scopes of many smart technology development projects. In the Evenstad case, for instance, the local participants had imagined an eco-system consisting of reusing rainwater, growing local vegetables and reusing sewage for local heat production. None of these aspects were of any interest to the academic and industry partners of the zero-emission neighbourhoods research centre that initiated the project with Campus Evenstad, who had entirely different solutions in mind. In the Hvaler case, the local inhabitants were eager to pay back to society through investing in relatively expensive solar panels on their roofs but were less happy with the added costs of manual efforts that were imposed due to events outside of their control. Additionally, people at the Evenstad campus were made to feel somewhat estranged by the technical system, in particular by such experiences as having to shut it down in order to accomplish the simple task of opening a window for overheated students during an exam. Such obvious absurdities implies that the ways in which people or users are supposed to be engaged and to participate are preconfigured and may leave little room for broader interests

Table 2
Comparing central findings of Evenstad and Hvaler.

Evenstad	Hvaler
Power outages, remoteness, energy security	Power outages, remoteness, energy security
- Need for demand response	- Need for demand response
Wood chips-challenge:	- Hvaler is a nature reserve
- Keeping chips dry is hard	- Environmental concerns
- Users take on added responsibility	- Highly motivated solution adopters
- More staff needed	- Willingness to contribute
- New tech demands more work	- Individual tech investments pose as solutions to community challenges
Windows challenge:	'Being a prosumer is fun!'
- Also more work	Power tariffs demand work and cautious consumption behavior to avoid concurrent electricity use:
Batteries	
- Seen as solution, but might also in the end entail more work	- Making new routines to avoid peaks
Environment	- Routines collapsing in times of high demand and intensity of activities
- Not latte drinkers	- If at first you have three peaks and a high average, there is no longer an incentive to conform
- Highly motivated ecologists	
- Disappointed in ZEB, too narrow focus	- Monitors provided actionable feedback, but smartness was insufficiently developed to allow passive consumption posture
- Missing non-tech focus	
- e.g. reuse rainwater and heat	
Overall:	
- Too narrow, individualistic focus	
- Solutions did not offer a way to fulfill local visions	
- Users want to be active and participate, this is negated by technologies based on passive user ideals	

beyond smart optimization and economically optimize system perspective.

The ways in which participants in both the Evenstad and the Hvaler cases reacted to their technological arrangements can be taken as interest in reshaping the system. They not only install solar panels on their roofs and attempted to use energy wisely, but they *did more work* in order to achieve something that could be of use to researchers and to themselves. The important question is: will the feedback that these users give, which goes beyond the efficiency and optimization-focus of the providers, ever influence the way future prosuming, sustainability and zero-emission arrangements will look? Networks that keep smart energy technological arrangements in place are strong, and reports pointing out the potential adverse effects of not fully taking the perspective of users into account lack impact. In other words, there appears to be a limitation in the scope of the perceived solutions to techno-economically framed problems that only includes a certain range of options (e.g., Lennon et al., 2019).

More generally we can say that successful participation depends highly on the criteria by which success is judged; i.e. it depends on what the pilot projects want to achieve. In this sense, rolling out a new smart energy technology for testing can be a success in itself, making the act of 'demonstration' more important than the act of testing (Korsnes, 2017). This may, in turn, have a strong effect on engaging citizens, e.g., through media attention, which in turn affects the collective image and attractiveness of these technological arrangements (e.g. Berker and Throndsen, 2017). Another aspect of this is the internal logic that is created relating to the way in which energy efficiency is defined, and what is and is not relevant when talking about actually reducing energy use (Shove, 2018). Thus, system boundaries of what is taken into account in terms of energy use and environmental sustainability can limit the types of solutions offered and the ways in which we can achieve actual reductions in resource and energy use.

6. Conclusions

In response to our research questions on how smart energy technology implementation affects end users' everyday lives, what role people have in influencing smart energy technology arrangements, and how people can participate and be engaged, we make the following conclusions.

The first relates to the concept of the energy prosumer. Although rooftop solar PV often generate a reduction in energy bought for families, the concept of 'prosumer' is not often needed to describe that type of transaction. To make the concept more useful and avoid tokenism, we need to broaden the idea of simultaneous energy production and consumption. This broadening relates particularly, perhaps, to the core finding of this paper that participants struggled to realise benefits from some selected measures, such as the power demand tariff and automated, smart, zero-emission buildings. The *extra work* required to make such technological solutions deliver made it challenging to gauge the purpose of the intended benefits. A 'good' energy prosumer who cannot afford or does not need rooftop PV may as well be wearing another layer of clothes indoors or heating with firewood. However, incorporating this way of thinking about prosumers requires the concept to be lifted out of the strictly technical sphere it resides in its current iteration.

The second relates to smart technology arrangements and participation. Contrary to prevalent views of passive, uninformed users, we found that users are not unwilling to engage or participate. Sometimes users do not even mind spending extra time, money and effort to make new technological arrangements work. However, getting 'forced' into uncomfortable situations can make people question the whole arrangement (e.g., Korsnes et al., 2018). Some research presents the usage of microgeneration technologies such as solar PV as de facto enactments and reinforcements of energy citizenship through material agency (Ryghaug et al., 2018). Households with rooftop PV and smart energy technologies are distinct participants in energy transitions through their active engagement with these futuristic technological arrangements (Skjølsvold et al., 2018). Nevertheless, as we highlight in this paper, there is an imbalance in the range of available options to households, which strongly affects the direction toward novelty and weakens the impact of the selected technological home arrangements. A narrow interpretation of what is sustainable offers fewer chances for people to participate and engage in sustainability transitions successfully.

Admittedly, the energy sector is typically responsible for implementing smart technology interventions and therefore delineates energy systems and everyday lives according to their interests and understandings. For the environmentally concerned, engaged users in our data, a sustainable lifestyle is much more than energy. In general, the transition we seek could become more engaging with a broader approach. Rather than expecting that the energy tech sector will solve all our transition challenges for us, we could ask ourselves whether the future, smart everyday life has to include a Tesla, a smart metre and a rooftop PV panel, or if it can somehow look different? If participation is measured only as a function of making a variety of smart technology solutions work, its extent and impact is likely to remain low.

Norway is a wealthy and relatively egalitarian social democracy with a high per capita electricity use. Although most of its wealth comes from oil and gas, Norway is busy testing microgeneration and intelligent energy technology solutions for the future. Studies from other European countries show that justice and equity issues concerning energy prosumerism are increasing (Wittmayer, 2021). The increase of energy prosumerism seen in Poland recently has been connected to regulatory simplifications, a concern for the environment, and a desire to reduce energy prices (Kuchmacz and Mika, 2018). As argued by Kotilainen (2020), energy prosumerism can contribute to environmental, social and economic sustainability. Nevertheless, there are still widespread issues connected to social impacts and control arising from smart energy technology home solutions, as pointed out by Nicholls et al. (2020, p. 181): 'We are lacking ongoing in-depth analysis that seriously considers the negative potential social impacts of smart home technologies (…) and treats them as socio-technical issues in need of socially-informed solutions'. This paper is providing an empirically informed analysis of precisely such issues.

As with any case study, this study is limited by its focus on two Norwegian cases. Nevertheless, by looking at the impact of novel energy technology solutions on ordinary, everyday life, we believe lessons can be learned in Norway that are useful elsewhere. A fundamental question we believe needs to be addressed in future research and practice is how to broaden the idea of what is smart to encompass fair and sustainable sociotechnical home arrangements? In answering this question, we believe that a central task is to challenge visions of users dominated by a purely techno-economic efficiency paradigm. This is especially important if we want to achieve real participatory and co-produced solutions for the sustainability challenges we currently face.

CRediT authorship contribution statement

Marius Korsnes: Case 1, Data collection, analysis, writing. **William Throndsen:** Case 2, Data collection, analysis, writing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Interviews and focus groups case 1, Evenstad.

No	Background	Date	Time	Place	Type	# of people
1	Project manager, contracting company	16.05.2017	45 min	Telefon	Interview	1
2	Dean and vice-dean, Campus Evenstad	06.06.2017	60 min	Evenstad	Interview	2
3	Technical staff 1	06.06.2017	90 min	Evenstad	Interview and tour of campus	1
4	Researcher	06.06.2017	60 min	Evenstad	Interview	1
5	Technical staff 2	07.06.2017	60 min	Evenstad	Interview	1
6	Employee	07.06.2017	40 min	Evenstad	Interview	1
7	Professor	07.06.2017	60 min	Evenstad	Interview	1
8	PhD-student 1	08.06.2017	35 min	Evenstad	Interview	1
9	Postdoc	08.06.2017	45 min	Evenstad	Interview	1
10	PhD-student 2	08.06.2017	50 min	Evenstad	Interview	1
	Bachelor students at Campus Evenstad	07.06.2017	90 min	Evenstad	Focus group	5

Appendix B. Interviews case 2, Hvaler municipality.

Int. no.	Background	Date	Time (m)	Place	Type	# of people
1	Resident	15.02.2017	60	Residence	Interview	1
2	Resident	16.02.2017	60	Residence	Interview	1
3	Resident	17.02.2017	60	Residence	Interview	4
4	Resident	20.02.2017	60	Residence	Interview	1
5	Resident	20.02.2017	60	Residence	Interview	1
6	Resident	20.02.2017	60	Residence	Interview	2
7	Resident	21.02.2017	60	Residence	Interview	2
8	Expert 1	21.02.2017	60	Fredrikstad	Interview	1
9	Expert 2	08.05.2016	50	Telephone	Interview	1
10	Resident	09.11.2017	60	Residence	Interview	1
11	Resident	09.11.2017	60	Residence	Interview	1
12	Resident	09.11.2017	60	Residence	Interview	1
13	Resident	10.11.2017	30	Telephone	Interview	1
14	Expert 1	10.11.2017	60	Residence	Interview	1
15	Resident	13.11.2017	60	Residence	Interview	2
16	Resident	13.11.2017	60	Residence	Interview	1
17	Resident	08.11.2017	60	Residence	Interview	1

Appendix C. Codes from Campus Evenstad and Hvaler

Campus Evenstad		
Code	Number of interviews	Number of codes
Air quality	10	16
Automation	6	9
Energy use	1	1
Environment	8	27
Food production	1	2
Home office	1	1
Including users	4	7
Power outage	2	2
Self sufficiency	8	21
Social meeting places	1	1
Solar energy	8	24
The CHP oven	2	6
The Zero Emission Building (ZEB)		
- Automated blinds	6	8
- Issues with layout	3	4
- Light	2	2
- Noise cancelling	5	10
- Office doors	7	16
- Open-plan offices	3	10
- Regulating heat	10	29
More work	2	4
Hvaler Code	Number of interviews	Number of codes
EV	6	19
Flexibility	3	5
- Automation	3	4
- - Metering	4	11
- Consumption and control	7	25
- Load shifting	6	26
- Prices and tariffs	5	27
- - Power and peak load	3	3
Motivation and participation	7	21
Process and red tape	1	4
Equipment and learning	6	27
Wish-list	3	10

References

Ballo, I.F., 2015. Imagining energy futures: sociotechnical imaginaries of the future Smart Grid in Norway. Energy Research & Social Science 9, 9–20.

Backe, S., Sørensen, Å.L., Pinel, D., Clauß, J., Lausselet, C., Woods, R., 2019. Consequences of Local Energy Supply in Norway. A Case Study on the ZEN Pilot Project Campus Evenstad. ZEN REPORT No. 17 – 2019. Online – URL. https://fmezen.no/wp-content/uploads/2019/08/ZEn-Report-no-17-ny.pdf. (Accessed 3 July 2020).

Berker, T., Throndsen, W., 2017. Planning story lines in smart grid road maps (2010–2014): three types of maps for coordinated time travel. J. Environ. Pol. Plann. 19 (2), 214–228.

Charmaz, K., 2006. Constructing Grounded Theory: A Practical Guide through Qualitative Analysis. Sage Publications, Thousand Oaks, London, New Delhi.

Christensen, T.H., Friis, F., Bettin, S., Throndsen, W., Ornetzeder, M., Skjølsvold, T.M., Ryghaug, M., 2020. The role of competences, engagement, and devices in configuring the impact of prices in energy demand response: findings from three smart energy pilots with households. Energy Pol. 137, 111142.

Clarke, A.E., 2005. Situational Analysis: Grounded Theory after the Postmodern Turn. Sage Publications, Thousand Oaks, London, New Delhi.

Cowan, R.S., 1983. More Work for Mother. Basic Books.

Ellsworth-Krebs, K., Reid, L., 2016. Conceptualising energy prosumption: exploring energy production, consumption and microgeneration in Scotland, UK. Environ. Plann.: Economy and Space 48 (10), 1988–2005.

Emmel, N., 2013. Purposeful sampling. In: Sampling and Choosing Cases in Qualitative Research: A Realist Approach. SAGE Publications Ltd, pp. 33–44.

Energifaktanorgeno, 2019. Energibruken I Ulike Sektorer. Online – URL. https://energifaktanorge.no/norsk-energibruk/energibruken-i-ulike-sektorer/. (Accessed 20 October 2019).

Europaeu, 2016. Commission Proposes New Rules for Consumer Centred Clean Energy Transition online – URL. https://ec.europa.eu/energy/news/commission-proposes-new-rules-consumer-centred-clean-energy-transition_en.

Gram-Hanssen, K., Darby, S.J., 2018. "Home is where the smart is"? Evaluating smart home research and approaches against the concept of home. Energy Research & Social Science 37, 94–101.

Hargreaves, T., Wilson, C., 2017. Smart Homes and Their Users. Springer International Publishing.

Hargreaves, T., Wilson, C., Hauxwell-Baldwin, R., 2018. Learning to live in a smart home. Build. Res. Inf. 46 (1), 127–139.

Iot-analyticscom, 2019. Smart Meter Market 2019: Global Penetration Reached 14% – North America, Europe Ahead. Online – URL. https://iot-analytics.com/smart-meter-market-2019-global-penetration-reached-14-percent/. (Accessed 3 July 2020).

Juntunen, J., 2014. *Prosuming Energy – User Innovation and New Energy Communities In Renewable Micro Generation.* PhD Dissertation. Aalto University.

Korsnes, M., 2017. Householders as co-producers: lessons learned from trondheim's living lab. eceee Summer Study proceedings 831–839.

Korsnes, M., Berker, T., Woods, R., 2018. Domestication, acceptance and zero emission ambitions: insights from a mixed method, experimental research design in a Norwegian Living Lab. Energy Research & Social Science 39, 226–233.

Kotilainen, K., 2020. Energy prosumers' role in the sustainable energy system. In: Leal Filho, W., Azul, A., Brandli, L., Özuyar, P., Wall, T. (Eds.), Affordable and Clean Energy. Encyclopedia of the UN Sustainable Development Goals. Springer, Cham.

Kragh-Furbo, M., Walker, G., 2018. Electricity as (big) data: metering, spatiotemporal granularity and value. Big Data & Society 5 (1), 1–12.

Kuchmacz, J., Mika, Ł., 2018. Description of development of prosumer energy sector in Poland. Polityka Energetyczna 21.

Lennon, B., Dunphy, N., Gaffney, C., Revez, A., Mullally, G., O'Connor, P., 2019. Citizen or consumer? Reconsidering energy citizenship. J. Environ. Pol. Plann. 22 (2), 184–197.

Levenda, A.M., 2019. Thinking critically about smart city experimentation: entrepreneurialism and responsibilization in urban living labs. Local Environ. 24 (7), 565–579.

Luque-Ayala, A., Marvin, S., 2015. Developing a critical understanding of smart urbanism? Urban Stud. 52 (12), 2105–2116.

Nymalerno, 2019. Bytte av strømmålere har vært en suksess. Online – URL. https://www.nymaler.no/aktuelt/nyheter-2019/bytte-av-strommalere-har-vart-en-suksess/. (Accessed 3 July 2020).
Nicholls, L., Strengers, Y., Sadowski, J., 2020. Social impacts and control in the smart home. Nature Energy 5 (3), 180–182.
Parag, Y., Sovacool, B.K., 2016. Electricity market design for the prosumer era. Nature Energy 1 (4), 1–6.
Powells, G., Fell, M.J., 2019. Flexibility capital and flexibility justice in smart energy systems. Energy Research & Social Science 54, 56–59.
Prahalad, C.K., Ramaswamy, V., 2004. Co-creation experiences: the next practice in value creation. J. Interact. Market. 18 (3), 5–14.
Regjeringenno, 2019. Norway is electric. Online – URL. https://www.regjeringen.no/en/topics/transport-and-communications/veg/faktaartikler-vei-og-ts/norway-is-electric/id2677481/. (Accessed 3 July 2020).
Rinkinen, J., 2019. Chopping, stacking and burning wood: rhythms and variations in provision. In: Shove, E., Trentmann, F. (Eds.), Infrastructures in Practice, Kindle Edition. Taylor and Francis.
Ryghaug, M., Sørensen, K.H., 2009. How energy efficiency fails in the building industry. Energy Pol. 37 (3), 984–991.
Ryghaug, M., Skjølsvold, T.M., Heidenreich, S., 2018. Creating energy citizenship through material participation. Soc. Stud. Sci. 48 (2), 283–303.
Shove, E., 2018. What is wrong with energy efficiency? Build. Res. Inf. 46 (7), 779–789.
Skjølsvold, T.M., Ryghaug, M., 2015. Embedding smart energy technology in built environments: a comparative study of four smart grid demonstration projects. Indoor Built Environ. 24 (7), 878–890. https://doi.org/10.1016/j.futures.2014.08.001.
Skjølsvold, T.M., Throndsen, W., Ryghaug, M., Fjellså, I.F., Koksvik, G.H., 2018. Orchestrating households as collectives of participation in the distributed energy transition: new empirical and conceptual insights. Energy research & social science 46, 252–261.
Skjølsvold, T.M., Fjellså, I.F., Ryghaug, M., 2019. Det fleksible mennesket 2.0: om sosiale relasjoner i fremtidens digitale elektrisitetssystem. Norsk sosiologisk tidsskrift 3, 03.
Skjølsvold, T.M., Ryghaug, M., Throndsen, W., 2020. European island imaginaries: examining the actors, innovations, and renewable energy transitions of 8 islands. Energy Research & Social Science 65, 101491.
Stake, R.E., 1994. Chapter 14. Case studies. In: Denzin, N.K., Lincoln, Y.S. (Eds.), Handbook of Qualitative Research. Sage Publications, Thousand Oaks, California.
Standal, K., Talevi, M., Westskog, H., 2020. Engaging men and women in energy production in Norway and the United Kingdom: the significance of social practices and gender relations. Energy Research & Social Science 60, 101338.
Strengers, Y., 2013. Smart Energy Technologies in Everyday Life: Smart Utopia? Springer.
Strengers, Y., 2016. Envisioning the smart home: reimagining a smart energy future. In: Pink, S., Ardèvol, E., Lanzeni, D. (Eds.), Digital Materialities: Design and Anthropology. Bloomsbury, London, New York.
Throndsen, W., 2013. Constructing the Norwegian smart grids: to fix what is not broken? eceee Summer Study proceedings.
Throndsen, W., 2017. What do experts talk about when they talk about users? Expectations and imagined users in the smart grid. Energy Efficiency 10 (2), 283–297.
Throndsen, W., Ryghaug, M., 2015. Material participation and the smart grid: exploring different modes of articulation. Energy Research & Social Science 9, 157–165.
Throndsen, W., Skjølsvold, T.M., Ryghaug, M., Christensen, T.H., 2017. From consumer to prosumer. Enrolling users into a Norwegian PV pilot. eceee Summer Study proceedings.
Toffler, A., 1980. The Third Wave. Bantam books, New York.
Wilhite, H., Nakagami, H., Masuda, T., Yamaga, Y., Haneda, H., 1996. A cross-cultural analysis of household energy use behaviour in Japan and Norway. Energy Pol. 24 (9), 795–803.
Wilhite, H., Diamond, R., 2017. Do smart homes know what people want and allow them to realize it. eceee Summer Study proceedings.
Wilson, C., Hargreaves, T., Hauxwell-Baldwin, R., 2015. Smart homes and their users: a systematic analysis and key challenges. Personal Ubiquitous Comput. 19 (2), 463–476.
Winther, T., Wilhite, H., 2015. An analysis of the household energy rebound effect from a practice perspective: spatial and temporal dimensions. Energy Efficiency 8 (3), 595–607.
Wittmayer, J.M., Avelino, F., Pel, B., Campos, I., 2021. Contributing to sustainable and just energy systems? The mainstreaming of renewable energy prosumerism within and across institutional logics. Energy Pol. 149, 112053.
Yin, R.K., 2009. Case Study Research: Design and Methods, fourth ed. Sage Publications, Thousand Oaks, California.