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# Like having an electric car on the roof: Domesticating PV solar panels in Norway

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## Introduction

Worldwide, the number of end-users who produce electricity is rapidly increasing. The term 'prosumer'[1] is often used to denote end-users who both produce and consume electricity. Following innovations in policy, technology, regulations, tariffing and subsidy schemes as well as consumers' increasing drive for self-production, solar panels (PV – photovoltaic) connected to the grid have entered the electricity systems in many countries. In the UK, approximately half a million homes have solar panels installed, as have almost a million homes in Germany (Inderberg, Tews, & Turner, 2016). This development paves the way for a global transition of power production, challenging traditional centralised power systems with a bottom-up feed-in of electricity to the grid (Schleicher-Tappeser, 2012).

Norway is an exceptional case in several ways. In Norwegian energy policy, reportedly because electricity production is mainly based on hydropower (96%), solar power does not form a significant part of the future national energy mix for electricity. Furthermore, due to abundant access to relatively cheap electricity, Norwegian households consume more electricity (7600 kWh per year per capita) than what is common in other countries. An important current trend is the rapid uptake of electric vehicles (EV) in Norway, which is estimated to constitute 45% of total sales of all new cars in 2018 (Nordic EV Barometer, 2018). In the sector of holiday cottages, Norwegians have been using low voltage solar systems for many years (Throndsen, Skjølsvold, Koksvik, & Ryghaug, 2017), but the market for PV technology connected to the grid has been almost non-existent. Before 2011 there were no officially registered prosumers in Norway. Hafslund Nett, the distribution system operator (DSO) in the Oslo region, claims to have been the first grid company in 2011 to have connected a prosumer (Hafslund Nett, 2018). Since then, and despite almost non-existent policy and support systems until recently, the market has grown considerably. From 2015, when our research was initiated, to 2016, the number of households with grid connected PVs grew from 150 to 200 to approximately 700 (Inderberg et al., 2016), and growth is continuing.

In this paper we analyse why households, in the particular case of Norway, decide to engage as prosumers and how PV panels and associated monitoring devices are integrated into people's daily practices and potentially affect their energy use. Studying prosumer practices in a context with few incentives from authorities gives the opportunity to investigate prosuming as a demand driven phenomenon, which can reveal people's own drives for becoming prosumers. As noted below, a number of studies have focused on the role of prosumers in other countries, but apart from one study on prospective users (Throndsen, Skjølsvold, Ryghaug, & Christensen, 2017), this is, to our knowledge, the first empirical study in Norway on this group of pioneers and early adopters.[2]

Prosumer regulations in Norway have changed over the years. From 2010, the regulator of the power system[3] allowed for prosuming activities through a general exemption from the regulatory requirements. Under this arrangement, prosumers were loosely defined as customers who produce some electricity, where the 'annual sum demand of electricity is larger than its generation, and that the household in periods generates more than it uses' (Norwegian Water Resources and Energy Directorate, 2015, found in Inderberg et al., 2016: 57). Given this exemption, prosumers no longer needed to register legally as power plants and comply with requirements for power producers (THEMA Consulting Group, 2015). This did not provide formalised prosumer rights, and the grid company retained the right to decide whether to accept the prosumer or not. The material for our study was collected in this phase.

A full prosumer regulation entered into force in January 2017. A new legal definition defines the prosumer as an end-user with production and consumption connected to the grid, and where the electricity fed into the grid should at no point exceed 100 kW (NVE, 2016). The

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[1] We follow Norwegian regulations and use the term 'prosumers' to denote end-users with an annual production of electricity that is normally not higher than their own consumption, but who in shorter periods have a surplus of electricity that can be fed into the grid.

[2] This research derives from the project 'Power from the people? Driving forces and hindrances' funded by the Research Council of Norway, project no. 243947/E20.

[3] The Norwegian Water Resources and Energy Directorate – NVE. www.nve.no/english/

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DSOs are obliged to connect these customers to the grid. The electricity exported must be bought by an energy supplier chosen by the prosumer and not by the DSO. Further, the smart meters to be rolled out in Norway (by 1.1.2019) are equipped to meter both consumption and production of electricity, and it is expected that these meters will facilitate the process of becoming a prosumer.

Both the general exemption (2011–16) and the prosumer regulation (2017–) financially encourage self-consumption. When the prosumers buy from the grid they pay a grid tariff, comprised of an energy part (cost per kWh) and taxes. When they feed into the grid, they get paid the energy part agreed upon with an energy supplier. Prosumers are exempted from paying a feed-in tariff for the electricity delivered to the grid. This implies that self-consumption of the electricity produced by their PV system is usually more beneficial to prosumers than feeding it into the grid (depending on the price paid by the energy supplier).

In this study we draw on material from 29 in-depth interviews with prosumers located across Norway in 2015 and 2016. As we discuss below, the analysis is informed by consumption and domestication theory, with particular attention to issues of identity creation when analysing why and how people acquire and deal with the solar technology in everyday life. Our findings show that there are different types of prosumers in Norway, whose motivations and interactions with solar technology vary considerably. Further, the technology is attractive to different groups through its ability to fit with different types of identities. This signifies that solar panels have the potential to spread to a variety of energy customer groups.

## Previous studies and framework for analyses

### *Prosumers in the literature*

Prosumer research has largely focused upon the perspectives of 'traditional actors' in the energy system (Hansen & Hauge, 2017), i.e. grid operators and policy makers, thus covering technical aspects (e.g. Oliveira, Antonio, Burani, & Udaeta, 2017 and Kästel & Gilroy-Scott, 2015) and management schemes (e.g. Parag & Sovacool, 2016; Kaufmann, Kuenzel, & Loock, 2013, and Schleicher-Tappeser, 2012). Although not abundant, there are studies that focus on prosumers themselves, addressing their motivation for investing in PVs, experiences with prosuming and how micro-generation affects prosumers and their energy practices, investment behaviour, competencies and perceptions (e.g. Juntunen, 2014; Bergman & Eyre, 2011; Hansen & Hauge, 2017). In this paper, we focus primarily on studies that have looked at prosumers, including their characteristics and motivations.

Working from a socio-technical system perspective, Bergman and Eyre (2011) show that microgeneration, such as production of electricity from PV, may have 'soft benefits' which might play a substantial role in emission reduction. For example, prosuming might lead people to gain increased awareness and understanding of their energy use. Experience with microgeneration might also empower people to be more involved in energy debates and increase their responsibility for developing low-carbon energy systems. This implies that people have the possibility to take a more active role in a decentralised energy system, influencing the way the energy system is designed and managed. Hansen and Hauge (2017), drawing on practice theory, elaborate on this topic by studying Danish prosumers. They focus on how households changed their energy practices upon becoming prosumers (equipped with PVs, heat pumps, electric vehicles etc.). In line with Turner's (2015) study from the UK, they found that depending on shifting times of electricity production from their PV, many prosumers would reschedule the time when they used their washing machines, dishwashers and tumble driers, and some would use their vacuum cleaner and charge their electric car (Electric Vehicle – EV) when the sun was shining. In line with the findings of Bergman and Eyre (2011), Hansen and Hauge (2017)also indicate that this interaction influenced the skills and competencies of the prosumers. Gradually they became skilled practitioners who developed clearer expectations of the energy companies.

A related question deriving from practice theory is whether household production of electricity leads prosumers to become more active or passive with regard to energy consumption (Strengers, 2013). Electricity is often characterised as a largely invisible good, which means that it tends to escape human consciousness and reflexivity (Lindén, Carlsson-Kanyama, & Eriksson, 2006; Pedersen, 2000; Wilhite, 2008). Strengers suggests that electricity production through PVs might have the potential to transform energy consumers into active prosumers who are engaged in monitoring and managing their own consumption. Although these perspectives rest on the assumption that consumers think and act as a rational 'resource man' (Strengers, 2013:137), they entail the important possibility that prosuming may lead households to have increased interest and competence in – and agency for modifying – their energy use. Bahaj and James (2007), positioned in engineering studies, also argue that the visibility of PV systems enhances prosumers' understanding of energy use. Moreover, a study by Pierce and Paulos (2010:121), who used an integrated design perspective on energy and materiality, found that when people were presented with different models of microgeneration systems, they tended to express pleasure at the thought of generating electricity, sometimes comparing (the idea of) this with doing gardening or cooking. The authors conclude that microgeneration may lead to a new type of energy engagement. Several studies underline that the possibility of activating households regarding their own energy management rests on an important assumption: that they get regular feedback on the amount of electricity produced and consumed (Caird & Roy, 2010). Hence, feedback technology is regarded as a crucial link between the PV systems and the households to facilitate prosumers' active engagement (Bergman & Eyre, 2011).

In contrast to these findings on increased awareness, prosuming might also pacify households if management of the energy is taken over by demand management systems and 'plug-and play' solutions (Strengers 2013:137). Instead of empowering households to take control of their energy consumption, such solutions might ascribe them to playing a passive role, with possible negative impacts from a sustainability energy perspective. Many PV systems run without any interference from household members, which may imply that the household does not interact with the system at all (Abi-Ghanem & Haggett, 2010).

Several studies suggest that there are links between prosuming, awareness and electricity consumption. On the one hand, prosuming practices might lead households towards seeing electricity as a scarce resource, with their increased awareness leading to reduced electricity consumption, as noted in a study anchored in behavioural change (Keirstead, 2007). However, self-production of electricity might also lead to viewing electricity as an abundant resource (Abi-Ghanem & Haggett, 2010), implying that households increase their consumption when becoming prosumers.

Strengers (2013) put forward the argument that narrowly seeing prosuming practices as an issue of creating passive or active prosumers does not bring insight into how prosumers engage with their energy production possibilities, and also limits the scope for understanding the implications of different micro-generation possibilities. Sources of power production have specific material qualities that interact with and contribute to forming energy practices. For instance, solar power and wind power produce electricity under different weather conditions and hence might influence practices differently. Solar power is produced when the sun shines and might thus lead households to shift energy consumption towards peak hours for solar radiation (Pierce and Paulos, 2010). However, how this might influence the total use of electricity, could vary. From the perspective of Strengers (2013), the degree of success through prosuming in terms of sustainability hinges on the ability of the technologies to make 'energies that matter' as a 'material element of practice' (Strengers, 2013:152).

We sympathise with this stance of literature regarding technologies as forming part of meaningful social practices and the need to understand to what extent and how technologies matter to the users in everyday life. Prosuming also forms part of wider social practices. The present study explores potential shifts in electricity consumption among Norwegian prosumers while paying attention to the way material elements and existing social practices come into play and potentially become modified. We also examine people's motivations for becoming prosumers, how they introduce and integrate the PV technology and monitoring devices in their homes, and how they experience their new role. In short, we examine how Norwegian prosumers make use of PV technology to signal identity. For these purposes we draw on the approach referred to as domestication theory.

### *Domestication as an approach to understanding the uptake, use and effects of PV*

When a household decides to become a producer of electricity in a context where this step represents a pioneering activity, consumption theory may enhance our understanding of why they decide to do so. Mika Pantzar (1997) refers to new objects either as those 'replacing former objects', such as a light bulb replacing kerosene light, or 'novelties', which represent objects with a new type of function. When the television set was introduced in Norway, this object was a novelty and hence an 'object of desire' (Pantzar, 1997) to which early adopters were attracted. Such acquisition is associated with social esteem (see also Shove, 2003). Pantzar accounts for the way the status of a given novelty, such as a television set, tends to change over time. When first introduced and promoted in the market, they are objects of desire, which may also be socially risky. Then they become relatively common objects where acquisition can be legitimised by referring to functionality (I need a television set to watch the news). Finally, objects reach the state of being 'normal', where mass consumption comes in and when it may be socially risky not to possess a given item.

Considered in this perspective, solar panels in Norwegian homes may hypothetically represent novelties, i.e. objects of desire. The key aspect would be that solar panels are perceived as a new object acquired to signal a given identity. An alternative possibility could be that prosumers simply consider solar power production as a replacement of parts of their electricity purchasing. In that case, the social significance would be less important, while one may presume economic viability to be their key concern. A third possibility, linked with the first option, could be that people's rationale is linked to altruistic motives that go beyond social esteem and the functional rationale of replacement. In that case, behaviour psychology might point to biospheric and altruistic motives that create a personal norm through beliefs about consequences of certain behaviour, which activates interest in investing in solar PV (Stern, 2000).

To help structure the analysis of people's acquisition, social display and use of solar technology, we draw on the cluster of approaches referred to as domestication theory. This commonly includes four interlinked steps (Silverstone, Hirsch, & Morely, 1992). Firstly, objects are *appropriated* through negotiation processes between different household members, leading to acquisition. The second step is denoted as *objectification*, in the sense that attention is paid to the way technologies become spatially located and integrated in the household. Thirdly, there is the process of *incorporation* in which the object is temporally incorporated, integrated and used in everyday life, potentially modifying former routines. Fourthly, if the object reaches the stage of *conversion*, this signals that the technology has the status of reflecting the identity, aspirations and cultural values of households (Silverstone 2006: 236–9).

In the analysis, we scrutinise the appropriation process by looking at people's stated motivations for becoming prosumers, including the extent to which various family members played an active part in the acquisition. Because solar panels in Norway are placed on pitched roofs and are thereby socially visible (cf. Henning's (2000) study of solar collectors in Sweden), we might expect that some people obtain them to socially express values. Such display would concern processes of objectification, which is of key interest in the work to be presented.[4] Hence, Pantzar's notion of 'objects of desire' may yield validity, also if the underlying desirable values are modesty, altruism or environmentalism. We then note how the solar panels and monitoring technology became incorporated into daily routines both spatially and temporally. Here we look at the way people interact with the new technology (including metering and billing procedures) on the one hand, and potential shifts in their daily energy use on the other. Finally, we discuss the social drives for and implications of becoming prosumers in the Norwegian context. Hence, we seek to understand how householders draw on their role as prosumers to create who they are. We conclude by discussing these emerging results and the implications for the status of prosumers in Norway and for sustainability.

## Method

The empirical material was collected through 29 in-depth interviews with prosumers (householders) in Norway.

### *Cases and informants*

All our informants were self-tenants and kept PV systems connected to the grid. With one exception (a family living in a semi-detached house) they lived in detached houses. We obtained a geographical spread across Norway because we expected local regulations and regulatory bodies (municipalities, grid companies) to play a role in the process of obtaining PV and because of the occurrence of different solar radiation intensities throughout Norway. In Arendal, Kirkenes and Hurdal (Fig. 1), we included 17 prosumers who had moved into ready-made houses equipped with solar panels (PVs). In addition we recruited 12 'individual prosumers', primarily in or around Oslo, Bergen and Trondheim, who had acquired PVs themselves.

The interviewees in Arendal and Kirkenes were conducted with people living in ready-made houses referred to as 'smart houses'. In Arendal, we included households in Skarpnes Housing Cooperative, which had been built following the so-called 'passive house standard' with heat pumps for production of space heat and hot water.[5] The PV systems in Skarpnes come with a web-based solution for monitoring production (Sunny Portal), and one of the interviewed households was using an app for this purpose. The housing construction in Kirkenes is ready-made, module-based environmentally friendly houses referred to as 'Shelter'. Here, the informants in Kirkenes did not have a separate display, but an inverter which displays the production level in real time.

Also in Hurdal ecovillage,[6] the houses are of the type Shelter. The inhabitants have the opportunity to observe the production of electricity in real time through a small display on the inverter placed in a storage/washing room inside the house. As we elaborate elsewhere (Westskog, Winther, & Aasen, 2018), environmental concern had been the residents' main rationale for moving to Hurdal ecovillage.

The individual prosumers live in various types of detached houses and they had all been in charge of the installation of the PV equipment themselves. Most of them had thoroughly researched the PV market, found the type that suited them best, ordered and had the equipment installed (either by themselves or with the help of professionals or friends). They had also contacted the grid company (DSO) to become a prosumer, to have the possibility to deliver electricity to the grid. Table 1 shows an overview of the profiles of the interviewees and the type of PV monitoring equipment installed in their homes.

[4] For purposes of text efficiency, we do not treat objectification as a separate step when we present the findings.

[5] The developer had initially planned to include PV in a number of units (17 detached houses and several semi-detached houses and flats). However, due to limited response when putting these properties on the market, only five houses were equipped with PVs and three of these households agreed to be interviewed.

[6] Ecovillages are intentional communities whose goal is to become more socially, economically and ecologically sustainable Kozeny's (1995). Hurdal ecovillage is a part of this movement, and is located in Akershus County in Norway.

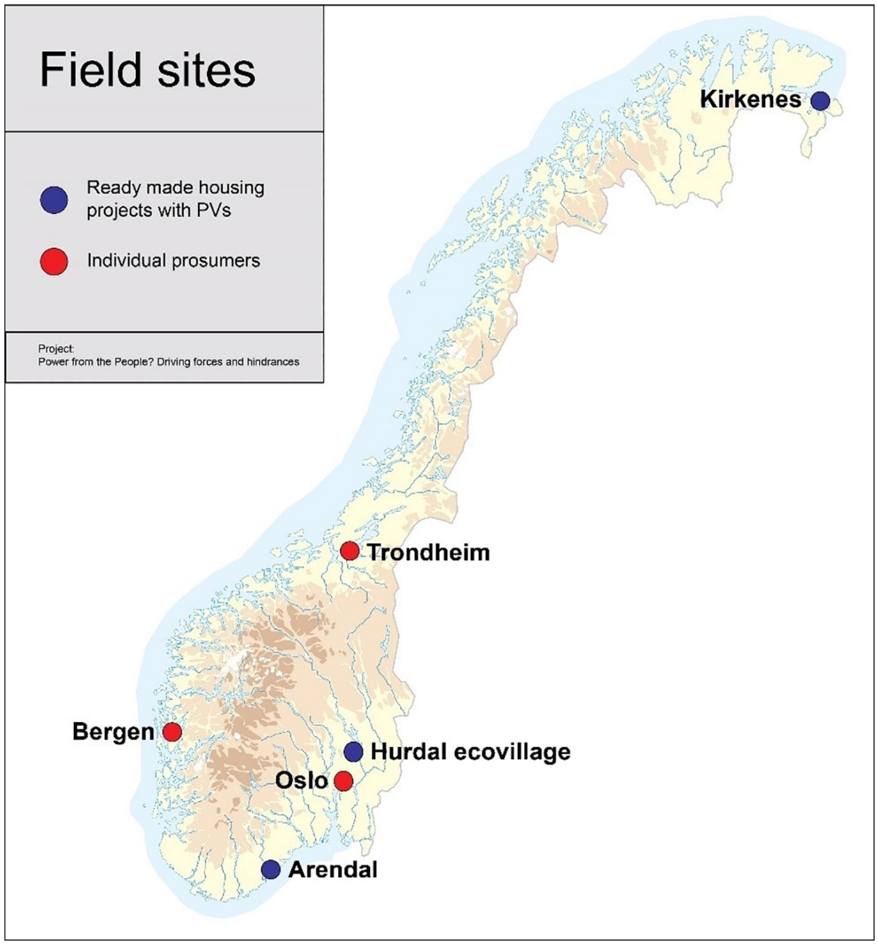


**Fig. 1.** Map of Norway and the selected field sites.

*Recruitment*

In Kirkenes we contacted the developer and were given names of the four owners of houses with PVs. We contacted them and two responded positively for an interview. One tenant in Kirkenes had rented out his house. We contacted the tenants, but they did not respond.

To recruit informants in Skarpnes we collaborated with SINTEF Building and Infrastructure[7] who were already involved in the housing development project. As it turned out, SINTEF needed to collect qualitative data from the households with PV, so we decided to conduct joint interviews for our two projects. SINTEF recruited three of the five households with PV in Skarpnes.[8]

We approached the inhabitants in Hurdal ecovillage through the communication advisor in a firm responsible for the development of the village. We provided her with an introductory letter and contact e-mail, giving necessary details about the interview process and the topics we would cover (see below), which she distributed to all households in the village. Eleven of the households in the village were recruited in this way. In addition, one household was spontaneously recruited when we visited the village.

There are few individual prosumers in Norway, and there is no overview of them from the grid companies or other actors. Hence, we used a snowballing technique in the recruitment process. First, we managed to identify some of them from newspaper articles where they shared experiences as prosumers. Everyone we contacted agreed to be interviewed, which signals their personal interest in the topic. They also provided us with contact details for other prosumers, mostly in their own region.

*Interviews and strategy for analysing the material*

Most of the interviews (25 of 29) took place in people's homes. Two interviews were conducted via phone due to difficulties in finding a suitable time for visiting, one took place in a public space (shopping mall) after a request from the informant, and one was conducted in the informant's office. The interviews lasted approximately one and a half hours. In most of the houses we visited, we also got a chance to see the indoor equipment connected to the solar panels (inverter, displays and computer programs).

The interviews were semi-structured which allowed the respondents to bring up various issues of concern. Generally, after introducing ourselves and the project, we provided information about how the data would be collected, stored and used, and we asked if we could record the interview, which most informants agreed to.[9] All participants received information about the project, including their right to withdraw and how we would manage anonymity. The interview guide covered six topics:

1) The process that the household had gone through to acquire the PV or move into the house with PV. We also asked about the possibilities for the informants to follow their electricity production from the PV on displays, computer programs or the inverter itself.

[7] SINTEF is a Norwegian applied research institute.

[8] The collaborating researcher at SINTEF was Judith Thomsen, and the results from the SINTEF study on temperatures, humidity and comfort have been published (SINTEF, 2017).

[9] Not recorded: One interviewee was unwilling, one interview took place in a noisy environment, and in three cases (including on the phone) we had technical difficulties audio-recording. We took detailed notes from all interviews.

**Table 1**
Overview of the 29 interviews.

| Number of interview[a] | Age group | Gender of interviewee(s) | Type of production monitoring technology |
|---|---|---|---|
| H1 | 30–45 | F | Display (real time) on inverter |
| H2 | 20–30 | F | Display not working |
| H3 | 20–30 | F + M | Display (real time) on inverter |
| H4 | 30–45 | F | Display (real time) on inverter |
| H5 | 30–45 | F | Display (real time) on inverter |
| H6 | 30–45 | F | Display (real time) on inverter |
| H7 | 30–45 | F + M | Display (real time) on inverter |
| H8 | 30–45 | F | Display (real time) on inverter |
| H9 | 30–45 | F | Display (real time) on inverter |
| H10 | 20–30/30–45 | F + M | Display (real time) on inverter |
| H11 | 20–30 | M | Display (real time) on inverter |
| H12 | 45–60 | M | Display (real time) on inverter |
| S1 | 30–45 | M | Web solution |
| S2 | 30–45 | F + M | Web solution, app |
| S3 | 30–45 | F + M | Web solution |
| K1 | 30–40 | F + M | Display (real time) on inverter |
| K2 | 20–30 | F | Web solution |
| I1 | 30–45 | M | Web solution |
| I2 | 45–60 | M | Advanced display |
| I3 | 30–45 | M | Advanced display, web solution |
| I4 | 30–45 | M | Web solution, app |
| I5 | 45–60 | M | Advanced display |
| I6 | 45–60 | M | Web solution |
| I7 | 30–45 | M | Display (real time) on inverter |
| I8 | 30–45 | M | Web solution, app |
| I9 | 30–45 | M | (Uncertain, but has full overview) |
| I10 | 30–45 | F | Web solution |
| I11 | 45–60 | M | Web solution |
| I12 | 30–45 | M | Advanced display |

[a] Key: H = Hurdal ecovillage, S = Skarpnes, K = Kirkenes, I = individual prosumer.

2) Experiences with the technology and needs or wishes for improvements.
3) Motivation for investing in PV/moving into a house with PV.
4) The PV's effect on energy practices. Here we started with a general mapping of their energy use and then we asked about practices associated with the PV. Self-consumption versus delivering electricity to the grid was an issue raised in this part.
5) Barriers for acquiring a PV/moving into a smart home or using the PV and the equipment associated with it.
6) Perspectives for future development of the PV market for households and views about prosumer policies in Norway.

Five researchers (all female) conducted the interviews, most of them individually (seven had two researchers present).

We took notes of all interviews and recorded and transcribed 24 of them. To help structure the analysis, we produced a coding tree with key issues from the interview guide, and systematised and coded the material manually. We also used an excel-sheet to register key answers to gain an overview of the results.

## Results

### *Appropriation*

The prosumers interviewed for this paper acquired PV panels in different ways. In Hurdal, Kirkenes and Skarpnes, people had moved into a house with a panel already installed, while the 'individual prosumers' had personally taken the initiative to get PV panels. Hence, the process of appropriation differed between them.

#### *Prosumers living in houses equipped with PV at the time of moving in*

In Hurdal ecovillage, the interviewees said that their motivation for moving to the village had been the possibility to live an environmentally friendly lifestyle. They had actively searched for a type of housing that could enhance sustainable living (ecohousing, farming etc.), and they had obtained information through social networks, the Internet and/or a broadcasted television documentary. Several interviewees had been in a situation when they were having or wanted to have children, hence about to enter a new phase in their life cycle (cf. Henning, 2005). In general, the PV panels formed part of the ready-made ecovillage architecture and were installed before the ecovillagers' arrival. The panels had not been the decisive factor for moving to the ecovillage, but were a minor but positive part of the total housing concept, according to ecovillagers.

In Kirkenes and Skarpnes, the PV panels also formed part of the housing concept. These householders, who were living in 'smart houses', had found the houses based on advertisements on the web (www.finn.no). The three families in Skarpnes emphasised that the location of the houses had been important as they had been living away from Arendal for a while, but since either one of the spouses or their parents had grown up in Arendal, they wanted to 'move home'. They also said that the area's proximity to the sea makes it beautiful. Also, importantly, their expectations for increased comfort (heating) and convenience (automatised control of light and appliances) had been a key factor in choosing to live in these houses, sometimes in combination with environmental concern (S2). However, one interviewee (S3) stressed that environmental concerns had not informed his decision. To him, the most important factor was the increased comfort they could expect compared to a conventional house. Compared to the market price of conventional houses in these areas, this group had paid approximately 800,000 NOK extra (30%).[10]

In Kirkenes, one family referred to the favourable market conditions that had triggered their interest in purchasing the house. The other family in Kirkenes appreciated the 'modern technology', as expressed by the woman: (K1):

> It's great to live in an ultra-modern house that's also environmentally friendly. So we moved in, got solar cells, and then it was wonderful to see that we could produce our own electricity.

Hence, these participants expressed different expectations and motivations for *moving into* these particular houses: ecovillagers referred to the value of ecofriendliness/sustainability, while the 'smart home' dwellers expected a high level of comfort and appreciated the modern association.

When assessing the house and the PV panels *in everyday use*, all the householders moving into ready-made houses (Kirkenes, Skarpnes and Hurdal) highlighted the high level of comfort. To ecovillagers, this had not been their primary motive for moving in, but was more regarded as a bonus outcome. What these two groups (smart home owners and ecovillagers) share, is that during the acquisition process, they did not spend time considering technical aspects in detail or the choice of suppliers. However, despite their overall satisfaction, these interviewees often complained that they had received little information about the technology and said they had not received any training in how it would work. In all three sites with ready-made houses, inhabitants reported the occurrence of 'childhood illnesses' with respect to the functioning of control and monitoring equipment and a need for adjusting solutions as problems occurred.

#### *Individual prosumers*

As noted, the individual prosumers interviewed were living in different geographical locations in the western, eastern and northern parts of Norway. Not surprisingly, given that they as individuals had taken the initiative to acquire PV panels, this group had spent considerable time and effort investigating PV options. With one exception (I10), a man had been in charge of the process and was the one being interviewed. Sometimes the female partner was described as having been engaged in the topic (e.g. I1) or even as the person having suggested the idea of acquiring solar panels (I11). However, the overall process of acquisition had mainly been driven by men.

[10] The extra amount was approximately 800.000 NOK, or 82.000 EURO.

Being pioneers in an almost non-existing market, they described a long acquisition process. Eight of the 12 worked professionally with environmental and/or energy related issues either technically, as consultants, or in administrative/governmental bodies. One interviewee (I9) had a background from Germany where he first learned about PV panels. Others also referred to Germany when accounting for their interest in PV (I1, I6). They observed that the potential for PV production in Norway is in some places almost the same as in Germany:

> M: I've also read or seen how solar cell production took off in Germany, and I checked early on about the solar conditions in Norway. And they were actually similar to many of the places in Germany and had many hours of sunshine that made it possible to use solar capture technology and solar cells. So I had it installed in 2012. (I6).

The individual prosumers had actively searched for information about suppliers and PV solutions in the acquisition phase, often drawing on their own social networks and/or also established interest organisations promoting solar energy and electric cars in Norway (The Norwegian Solar Energy Society, Norwegian Electric Vehicle Association). In three cases, there had been uncertainty as to whether or not such installations require a formal application to building authorities in the municipality. In Oslo, after months with correspondence between a prosumer-to-be and the municipality, it was concluded that permits through application were not required. Another individual prosumer attributed the considerable time spent on researching solutions to the lack of an existing PV sector (I11).

Despite the unclear bureaucratic procedures, the individual prosumers rarely complained about their time use on their solar project. Some referred with enthusiasm to instances when various service companies gained new experience and knowledge when installing the systems (I12):

> M: …it was the roofer who physically mounted the solar panel. We also called in a local electrician to do the hook-up. There were more electrician bills than I had anticipated…but that's often the case…it's always a little more expensive and more complicated than you imagine beforehand. And then he fixed a few other things in our house since he was there already.
> I: Had the roofer installed solar cells before?
> M: No, he never had, so he thought it was quite fun…he hoped he could get more jobs like it. After all, now he's got experience with it here.

To feed power into the grid, one needs to have the PV system connected. The interviews took place at a time when national regulations did not require grid companies to connect prosumers. Among the individual prosumers, all were connected to the grid and were generally positive towards the services received from the local grid company (DSO) although the prosumers in Kirkenes had ensured connections themselves but were not compensated for the electricity fed into the grid. Becoming a prosumer also often involved having conventional meters replaced with digital/smart meters (covered by the company). In the eastern, southern and western parts of Norway, the grid companies reported that prosumers would get spot price plus 4 øre per kWh for the electricity fed into the grid. Prosumers themselves were sometimes not sure about the amount they would get.

The installed capacity of the PV systems was typically 3–4 kW, but in some cases smaller or larger. Depending on the prosumers' own capacity/work hours and from where the components were purchased, investment costs varied between 5900 USD (I8) to 108 00 USD (I5).[11] As investment support, several of the individual prosumers had received 1300 USD from Enova[12] as a base support and in addition 150 USD per installed kW, up to 3700 USD as maximum support.

When we probed the individual prosumers about their underlying motivation, seven stressed their wish to contribute to a better environment while five highlighted their interest in the technology. At the same time, as noted, many had a job related to energy and expected that their experiences with the technology would be useful to their work. When asked about profitability, a man who had imported equipment from abroad and done most of the installations himself (I3) thought the investment cost might be paid off after 8–9 years. Few interviewees thought that the installation of PV panels would be financially profitable in the short run, though possibly in the long run (I6):

> I1: Have you calculated any profit from your solar heating system?
> M: Yes, I have … but I probably have a payback period of about 15 years.
> I1: Was profitability a consideration at all when you were deciding…?
> M: Yes, it was. But it wasn't the deciding factor. I wanted to have it no matter what, because I wanted to see how it worked in practice.

The growing uptake of electric vehicle in Norway forms an important backdrop to the individual prosumers' interest in PV. Five of them (I5, I6, I7, I8, I9) had an electric vehicle and three (I12, K1, K2) said they had considered buying one. Some explicitly said that they consider PV as a natural ‘next step’ towards living an environmentally friendly lifestyle after achieving an electric vehicle. In contrast to the households living in ready-made houses in Skarpnes and Kirkenes, none of the individual prosumers referred to increased comfort as a rationale for acquiring PV panels.

Clearly, the individual prosumers were ready to invest time and effort in searching for information and suppliers and in acquiring and installing PV. One of them had in fact played a central role in developing the first prosumer regulations and procedures for the DSO that he belonged to. These individual prosumers were prepared for the relatively high transaction costs with limited expectations for financial profitability. Below we discuss these findings in light of the other types of prosumers.

*Incorporating PVs in daily routines*

*Interacting with the PV system*

All of the individual prosumers kept track of their production and related their production levels to comparable systems, for instance in their community. One informant said this about his engagement for following his production of electricity:

> I3: Some people follow football stats, some follow the stock market. I follow solar production. It's much more fun.

Most of the individual prosumers knew exactly how much electricity they used and at what time the system produced the most electricity, and they actively interacted with the system to utilise it effectively. It is among this group we encountered the expression ‘solar/sun laundry’ (‘solvask’), meaning that they turned on the washing machine during the daytime to utilise the electricity produced:

> Interviewer: How are you when it comes to your interest in energy? What about your children, your wife? Is this a topic of discussion?
> I4: Yes, you could say what happened after we got the solar panel and became used to it is that we put on a load of ‘sun laundry’ when we leave the house in the morning to make sure we use the solar energy that's here.

[11] Exchange rate used: USD = 7.8 Norwegian krone.

[12] Enova SF is a public enterprise owned by the Royal Norwegian Ministry of Petroleum and Energy. Enova's main mission is to contribute to environmentally sound and rational use and production of energy in Norway.

Hence the individual prosumers engage intensively with the PV technology and monitoring equipment, In contrast, most people who had moved into houses already equipped with PV either had infrequent or no interaction with the PV technology:

> H9: Only Jens (her husband) goes in there, especially if it's a very sunny day, and he says oh, now we're producing so much, and then I say, ok, what does that mean, it doesn't tell me much, yes, our stove uses so much, isn't that right, and things like that.

Some informants (in Skarpnes), expressed a certain level of interest in monitoring production, saying they checked the display once in a while to get an overview of their production level (using web and/or app). However, while the objects had the charm of novelty (*nyhetens interesse*) in the beginning, their interest declined after a while (S3):

> Interviewer: How much have you produced since you moved in, do you remember roughly?
> M: I can look it up on my iPad.
> K: I have it here.
> Interviewer: Do you check it often or not?
> M: It was like a game at first…
> Interviewer: Was it more fun in the beginning to check the electricity?
> M: Yes, to check the daily production. We get an email everyday with how much we produce, but I don't check anymore.

*Consequences for energy use and perceptions of comfort*

The difference between the price of electricity delivered from PV to the grid and the cost of electricity purchased from the grid makes our interviewees consider self-consumption to be most profitable. Although the reasons for self-consumption vary, many informants (18 in total) explained that they had moved their electricity use (e.g. dishwasher, washing machine) to periods when they produce solar power, hence daytime on sunny days. Others (8 interviewees) said they had not rescheduled consumption either because they did not bother or because it was impractical since they are away at work all day or they had not thought about adjusting the time of use of electricity.

> K: In the summer and such, when I was home during the day, I would think 'Now the sun is shining brightly, now I'll turn on both machines'. The solar power should be used when you can. But otherwise, when we come home from work, I don't bother. I don't know, set the washing machine to start at such and such a time. I mean, we live a *normal* life. (S2).

The most often mentioned practices that were rescheduled because of solar power production was use of the washing machine (clothes) and the dishwasher. However, some had also altered other practices for energy use such as putting on the heat pump, baking bread and dehydrating tomatoes when they produced solar power. One interviewee explained that they turn off the boiler for water heating during night time to let it be heated by solar power during the day.

Overall, none of our informants thought they had reduced their energy consumption as a result of having a PV. As noted, the individual prosumers were generally very engaged and knowledgeable about their production and had correspondingly gained insight into their energy consumption. They had made many investments (such as heat pumps, insulation and energy saving lighting) and expressed that their energy use was at the lower end compared to others. For the 'smart home' dwellers (Skarpnes and Kirkenes), living in a comfortable house was perceived to be most important (see Appropriation section), and they were not very preoccupied with their energy use. Generally, these houses are very well insulated, and therefore they thought that the energy use would not be very high even with a low focus on energy saving.

> S3: It's good to know that you really can use almost as much energy as you want, because the cost won't be so high in any case.

In Hurdal ecovillage, the PVs initially formed part of an environmentally friendly concept, and in daily life they also experienced the houses as providing a high level of comfort. Many of the informants said they were preoccupied with saving energy as part of an environmentally friendly lifestyle, as they had also been before moving to Hurdal. However, three informants said that they were using more energy than previously, having moved from a very frugal home, for instance straw bale houses, to what they described as a rather luxurious house in Hurdal ecovillage.

*Identity and social meaning of PV (conversion)*

When we asked prosumers how they would describe themselves, for example, if they were to apply a specific term to their new role, our interviewees became uncertain. The exceptions were people familiar with prosumer regulations, who referred to the term employed by the authorities: prosumer.[13] The majority described themselves simply as 'somebody with solar panels on the roof'. When probed further on this issue, the notion of 'producer' sometimes came up, and in one case, a man referred to exporting power (Norwegian: *vi går på eksport*) (S3):

> W: (…) We are electricity producers.
> M: Hmmm, I don't have a word for it. We joke a little about it at work, when the sun is shining, we don't need to work…
> M: This means that we let it run on export. But that's because I worked on international cables to Denmark….

In general, our interviewees expressed genuine pleasure thinking about having solar panels on the roof. Residents in the ecovillage sometimes stated that the use of solar energy connects them more closely to nature and natural cycles. This woman in Hurdal ecovillage was particularly articulate on the matter (H3):

> W: But it also feels good. It's a feeling, to know that we're using solar energy. If I try to be more concrete about that feeling, why it feels so good…I don't know if it's the contact with nature or that I feel that it's natural, that it has to do with the rhythms of the day, you know? The sun rises and sets…the fact that our routines also sort of follow the nature outside makes me feel that I have a closer connection with nature. And that in itself is valuable.
> W: But it also has to do with knowing that when you see the sun and you feel the warmth and you sit outside on the porch and you feel it, you know that it hits the wall and that it's what makes your coffee or plays your music, there is something special about it, it's a direct relationship.

Others, both in Hurdal and elsewhere, referred to the value of being able to supply electricity for the benefit of society. Many whose motivations were founded in environmental concerns regarded PV panels as a way to help reduce the stress on the electricity system and the natural environment (avoid exploiting more rivers in Norway) and/or avoid importing electricity produced by fossil or nuclear sources. Contributing to meeting demand was seen as important, for example as H8 explains: 'No, I think it was only very positive, so that you, yourself, can help to meet some of the local energy needs.'

[13] In Norwegian regulations, the term used to denote prosumers is *plusskunde*, literarily 'plus customer', which some interviewees thought of as rather confusing because houses which are designed to produce more energy than they consume are referred to as 'plus houses' (*plusshus*). Having solar panels on the roof does not alone qualify for designating a house as a 'plus house' because the residents may still consume more than they produce.

We also raised the issue of whether increased independence from the central grid formed part of their positive evaluation (as has been found in Germany, see Inderberg et al., 2016), but this thread was rarely followed up by the interviewees. For example, a man responded: 'okay, if there's a power outage, as long as we have sunshine we have …(laughter)…have power. Actually I haven't thought a lot about exactly that.' (S1).

From these and similar quotes, the interviewed prosumers in Norway appear more preoccupied with contributing to provision of power (and having a back-up in case of power cuts) – than wanting (politically, economically) to distance themselves from central units. Many stressed that their involvement with solar power could help stimulate further market developments.

When discussing people's motivation for acquiring PV panels, we noted the individual prosumers' drive to engage with the new technology. This aspect of dealing with technology also came up when they described how they engage with it in daily life. As noted, most individual prosumers were closely following their own production, sometimes comparing their levels with other prosumers through websites.

While most of the individual prosumers closely followed their own production, and sometimes compared their own production with that of other prosumers through websites, they appeared less interested in what their general social surroundings would think about their solar panels. Some had even entered into conflicts with neighbours because of the panels or other interventions. In return for a bottle of red wine, one man had convinced his older neighbour to let him use some of her roof for the production, in an amicable spirit.

People living in ready-made houses with PV related more passively to the PV technology but they spoke with passion about the positive responses they had received from family and friends, though we should note that they often spoke about the house as such rather than the panels in particular (K2):

> Interviewer: But the people who come here? Your friends who come to visit, what reactions have you got?
> W: Very positive. As I said, it's high…(a higher standard)…White walls…But I don't know. I'm not quite sure if I had just taken the basic package, would people have been just as enthusiastic? You need to see the bath afterwards, it's very…People are rather impressed with the solar cells and the smart system and such.

Some of the interviewees explained that visitors thought solar panels were exciting but required a lot of competence to operate (S3):

> M: Some of my friends are construction engineers who have also visited and seen the system and such. They think it's exciting, but they're surprised when they see how much equipment you need to have a handle on. Also, they probably think it's more advanced than it is. If you go into the technical room, there are lots of lamps that blink and lots of buttons that you could push. Half of it is their monitoring equipment that I don't bother with, so…

One of the interviewees who highlighted heating comfort as a key motivation for moving into the house referred to his friends' interest in the solutions, although he commented that such a house would probably be beyond the reach of most of them (S1):

> Interviewer: Are there many of your friends who are interested in coming for a visit and such? Do you need to show them around like you're doing with us now?
> M: Yes, they really wonder what this is all about. And you see that, I have friends who've built relatively new houses and they see that the dimensions are somewhat larger than what they have. The walls are thicker and…so…
> …
> Interviewer: Yes, they are, and what about these friends of yours who come and look, do any of them hint that they want to do the same? Or are you a more unusual modern man?
> M: No, they…I'm sure they think about it, but it's probably too expensive for most of them. It's like buying a very expensive car and putting it on your roof, but you don't get to use it very often. So…(laughter).

When using the image of 'a very expensive car' this interviewee referred to a Tesla, which is one of the most expensive electric cars that have become relatively common in Norway. With his statement, he almost makes fun of the idea of putting non-profitable solar panels on the roof and heating, while comfort (heat pumps, passive house standard with good insulation, nice indoor climate) remained his most important concern.

Both the comfort seekers living in 'smart houses' and the ecovillagers preoccupied with sustainability highlighted the positive reception they have received from their social surroundings. The solar panel constitutes one of several markers of comfortable and sustainable and comfortable living. Because the houses are often perceived as both modern and environmentally friendly, they are compatible with current desirable cultural values in Norway (Westskog et al., 2018). And as if further increasing their social status, the houses are regarded as more expensive to buy than conventional houses. In Hurdal, this triggered further admiration from the local community in which the ecovillage is located (Westskog et al., 2018).

## Discussion and conclusion: three paths towards domesticating solar PV in Norwegian homes

The presented results show that currently there are different paths towards appropriating solar panels and becoming prosumers in Norway. Because this kind of practice is relatively new, we denote all the studied prosumers as pioneers, of which we found three main types: ecovillagers, 'smart home' owners, and individual prosumers. Each group has followed a specific appropriation path, implicating a particular set of identities, motivations, competencies, social networks and willingness to invest time and effort. Their different initial positions also affected the ways they relate to the PV technology and monitoring equipment in everyday life. However, as also found in Denmark (Hansen & Hauge, 2017) and the UK (Turner, 2015), a shared trait across the three groups relates to their patterns of using electricity: By becoming prosumers, most households started to use certain appliances at different times during the day, running appliances when the sun was shining. The embedded economic rationale for this rescheduling to maximise self-consumption is also similar to other countries. However, with respect to the perceived political significance of such behaviour, our Norwegian findings differ from findings elsewhere (e.g. Germany) where people were motivated to be prosumers to become more independent of the central grid (Inderberg et al., 2016:28, see also Ford et al., 2014 for a treatment of this aspect New Zealand). Our Norwegian interviewees expressed that by prosuming, they help to ease the pressure on the central electricity system.

None of our interviewees believed that their total electricity consumption had been reduced, but they had obtained increased awareness of electricity. The active rescheduling derived from their awareness of the link between production and consumption, including the (modest) financial gain obtained through self-consumption. Their search for ways to use electricity while the sun is shining supports Bahaj and James' (2007) contention that the increased visibility of electricity provided through local production (PV) may enhance people's awareness of their energy use (see also Turner, 2015). In combination with our prosumers' expressed pleasure of producing electricity, this increased visibility has led to a new type of 'energy engagement', as suggested by Pierce and Paulos' (2010:121). However, we found that feedback technology did not necessarily increase prosumers' active engagement (Bergman & Eyre, 2011), rather, that different types of prosumers (see below) have various needs and drives for obtaining and using monitoring equipment. Also, we found no support to the thesis that self-production may lead to increased consumption that has been found in other studies (Abi-Ghanem & Haggett, 2010).

The application of the domestication framework helps illuminate the way identity formation was a key issue across our three categories of prosumers. However, the trajectory of this process differed across the three groups. When taking the initiative to obtain PV panels, the individual prosumers, in almost all cases men, had been driven by a personal interest in solar technology, and they were often professionally involved with energy. Sometimes they also expressed a concern for the environment and/or thought of themselves as contributors to initiating a new market. Many possessed an electric vehicle and considered PV as a natural next step. They incorporated the PV technology and feedback technologies into daily routines and related to them in an active way. This level of engagement gives associations to the notion of 'sheer play', which Annette Henning used to denote one of the three categories that men in Sweden used for socially legitimising their investments in renewable energy technologies (Henning, 2000). The other two rationales for investment, which according to the anthropologist ranked higher than 'sheer play' in a hierarchy of values observed in Sweden, were economic profitability (highlighted by men) and environmental benefits (highlighted by women). Our individual prosumers had modest expectations regarding profitability, but in contrast to the two other groups they had actually looked into the financial aspect of investing in PV panels.

Due to the individual prosumer's reference to technical knowledge as a central element in how they present themselves, this group of prosumers fits Strengler's category of 'resource man' or Winther and Ericson's (2013) 'knowledgeable engineers'. Hence, they both literally and figuratively invested in this identity position of being/becoming knowledgeable engineers. They were rewarded for this by important others who were not primarily found in their immediate social network of family and friends. Rather, their significant others were a wider audience of 'equal' knowledgeable engineers whom they meet on the web for comparing levels of solar radiation and PV production. In terms of the domestication framework, conversion was accomplished in that the individual prosumers made use of the PV technology to signal their values and who they are.

Interviewees living in ready-made houses with PV regarded the solar panels as part of a package, hence their motivation for acquiring PV and moving into the houses can hardly be separated. They were clearly less interested in the technology than the individual prosumers. They rarely kept monitoring equipment beyond the real time display on the inverter that was located in a technical room, hence in a space distanced from daily life and concealed from social inspection. The overall picture here is that they only lightly incorporated the PV technology, the adhering monitoring and feedback technology in daily life. Nonetheless, the PV panels played a highly meaningful and social role in the lives of these interviewees. The many reports of positive responses from family and friends commenting on their particular choice of home testify to the impression that also here, the domestication process implicated that the object was used to mark identity (conversion). The PV panels on the roofs, highly visible for social inspection (cf. objectification), became a symbol of their way of living. However, the type of values underpinning their particular way of living differed slightly across two types of households. Those living in 'smart homes' tended to mention increased comfort, including heating comfort, as their primary motivation for having purchased the house, while economic reasons ('good timing of investment') and environmental concerns were also sometimes noted. This resonates with practice oriented studies of consumption (e.g. Shove, 2003) which shows that people's concern for comfort (and convenience) is an important driver for increased demand. These interviewees also made the point that smart homes are more expensive to buy than conventional houses, indicating that a sense of social comparison was involved. In sum, smart home owners consider their dwellings to be modern, comfortable and environmentally friendly houses associated with social prestige. The role of PV in this picture is not insignificant as the PV can be considered as a flag (Tesla) put on the roof to signal the owner's particular position.

In contrast, people who had moved to Hurdal ecovillage had primarily been motivated by their environmental concern in addition to searching for a community of like-minded people (Westskog et al., 2018). To them, the PV panels gave associations to environmental issues on two levels, first, as a symbol of the emphasis on sustainability to which the whole ecovillage was committed. Secondly, on the individual level, ecovillagers referred to the PV panels as an important way of connecting to nature. They emphasised a sense of pleasure in being reminded about the cycles of the sun, as if the PV panels primarily constituted a new medium for following the natural cycles (Pierce & Paulos, 2010).

This discussion has highlighted that the three groups of prosumers followed rather different paths towards domesticating the solar panels and equipment. In everyday life, their levels of engagement with the technology vary considerably, as do their underlying values for prosuming. Hence though they resemble each other through the common pattern of self-consumption, their 'styles of prosuming' differ. The analyses have also shown that at the heart of all three groups' drive for PV panels, they share a key feature observed in the consumption literature (Pantzar, 1997); they all make use of the solar panel to signal identity. In Norway at present, PVs are clearly objects of desire. Across our material, the object has reached the stage of conversion in the domestication process in that it is continuously used for displaying the values of the home and defines them in relation to other groups. The materiality and physical position of the PV panels on the roofs partly contribute to creating this social significance, but only because the dwellers and their observers associate the object with particular values. Each of our three groups draws a particular meaning from PV that serves to strengthen their desired identity.

A question moving forward is what these findings may tell us about prosuming in Norway in the future. We think the issue of massive uptake is highly uncertain because the studied pioneers do not necessarily represent a general segment of the population. Our interviewees did not highlight economic profitability as a significant aspect of prosuming, at least not in the short term. Rather, their rationales were linked with environmentalism, comfort and/or desire for new technology. If solar power continues to be neglected in national policy and support schemes, prosuming might only be used as a way of stating identity to a limited segment of the population. However, new actors have recently entered the market offering instalment contracts, which may reduce the financial risk and the transaction costs for installing PV. With the growing Norwegian EV market, more householders may consider PV as a natural next step for managing their own electricity. Also, against the backdrop of Demand Side Response initiatives (e.g. capacity pricing to achieve flexible electricity use) and the ongoing full roll-out of smart meters (see Henden et al., 2017), batteries can be used in combination with PV to avoid purchasing power in peak-load periods with high prices and thus lead to reduced costs of energy consumption. It is still unclear how such developments might affect the economic basis for prosuming, but it is possible that PVs might increase their general appeal by also signalling economic rationality in addition to a modern/comfortable/technically interesting/environmentally friendly lifestyle.

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