

The dynamics of solar prosuming: Exploring interconnections between actor groups in Norway

Abstract

Solar prosuming is an emerging phenomenon in which many actor groups are involved in shaping new solutions. Here we study national policymakers, relevant stakeholders such as grid companies, and the prosumers themselves – and the interconnections between them – to provide a contextualised exploration of positions, perceptions and interconnections that influence prosuming activities. Our 65 in-depth interviews in Norway, 33 of which with pioneering prosumers show that this group is not attracted to prosuming primarily for financial reasons, but for pursuing particular identities. However, our results also indicate that if prosuming were to become more widespread, economic considerations would be central. Further, the interplay among actor groups, mediated through current regulations and technologies, and the related perceptions, affect the uptake and organisation of solar prosuming activities. Third-party market actors such as the solar and building industry play important roles, as do grid companies and municipalities that are expected to facilitate prosuming activities. Given the current policy framework in Norway, we conclude that if increasing prosuming activities becomes a desired political goal, this will require stronger financial incentives for individual prosumers, and a deeper understanding of the interplay among actors across arenas and sectors.

1.0 Introduction

Private households are increasingly engaging in the micro-generation of electricity. More and more electricity consumers are utilising the opportunities enabled by technical developments and policy instruments to produce, consume and sell electricity based on photovoltaics (PVs) and wind turbines [1]. This *prosuming* movement has been especially notable in Australia, Germany, the UK and parts of the USA. Schleicher-Tappeser [2] argues that prosuming is likely to have an important role in the bottom-up transition of the energy system, noting that the speed and ease with which this change will take place depends on regulatory frameworks, business strategies and energy practices. Prosuming has influenced electricity market dynamics, triggering new needs for regulations and support schemes to encourage prosuming and deal with the associated technical challenges [3–6]. Some analysts claim that the prosuming trend, in combination with distributed battery storages and smart grid solutions, can transform national electricity systems [7–9].

Scholars have tended to focus on distinct analytical levels and actor groups in prosuming. To account for the increasing speed of PV uptake, *regulatory approaches* have often focused on the national policy level, finding that public support schemes have been important in stimulating prosuming [1,4,10,11]. However, in New Zealand, and partly in Australia, household PV uptake has developed with minimal or no public support [12,13]. *Economic approaches* have linked the increasing speed of PV uptake to

experience-building [14]. There is also a growing body of literature on *prosumers' motivation and ways of engaging with energy* [15–24] and on the gender dimension of solar-power use and prosuming practices [25]. Finally, *technical aspects* of prosuming [26] have been studied from the perspective of traditional actors in the electricity system: energy producers, system operators and policymakers [20].

To explore emerging prosumer activities we scrutinise the wider stakeholder environments surrounding prosumers [20]. Market actors may hold more nuanced positions towards prosuming than merely being incumbent 'resistors' to change or new entrants inducing disruptive change [27]. Especially for grid utilities, research on stakeholder roles appears limited, particularly regarding how conventional and new stakeholders perceive and relate to each other, as well as policy frameworks and household prosumers. More integrated analyses of different actor groups involved in prosuming are needed. Here the current study aims to make a contribution.

Drawing on a mix of methods, we explore how analysis across relevant actor groups and arenas can contribute to a better understanding of prosuming. Drawing on 65 qualitative research interviews, policy analyses, a national survey, and using Norway as a case study, we offer a deep, contextualised examination of factors that influence emerging prosuming activities as these are shaped within and through the interplay involving three main types of actor groups: national policy, prosumer stakeholders and prosumers.¹

Norway represents a special case in prosuming. Given Norway's comparatively low electricity prices and its fully renewables-based electricity system, along with scant promotion of solar prosuming by the authorities, one would not *a priori* expect prosuming to be high. From 2011 to 2015 when this study was initiated, the number of registered household prosumers in Norway grew from zero to a modest 150–200 households. One year into our study (2016) there were approximately 700 [1]. Since then, however, and despite almost non-existent policy and support systems until recently, the market has grown considerably. The case of Norway illustrates how prosuming may fare at an early stage in a liberalised, low-carbon, natural-resource-intensive context. Using Norway for a case study – a country in its infancy in terms of prosuming numbers and installed PV capacity – we can analyse the early stages of prosuming as an apparently demand-driven process, as well as the barriers to householder adoption and use of solar PV technology.

In Section 2, we present our analytical framework and methods. Section 3 introduces the Norwegian context and the emerging prosumer market and regulations. In Section 4 we present project findings relating to the three arenas for empirical investigation. In Section 5 we discuss enabling and hindering factors for prosuming and the implications of the new knowledge for policy. We conclude in Section 6 by reflecting on the merits of multi-disciplinary approaches and analysis across actor groups in order to understand prosumer activities as an emerging phenomenon driven by certain forces and hindered by other mechanisms.

¹ The results derive from an empirical research project 'Power from the People? Driving forces and hindrances' (PfP), funded by the Research Council of Norway (project no 243947/E20). The main objective was to identify the driving forces and hindrances to Norwegian households becoming prosumers. PfP grounded the study of prosumers in their social, material and historical context.

2.0 Literature review and analytical framework

The rise of prosuming can be seen as part of a socio-technical transition, representing ‘shifts in the technology, markets, user practices, policy and cultural meanings relating to key societal functions’ [12]. Prosuming has received significant academic attention, as have related fields of research like smart grids, energy communities, energy democracy, empowerment, energy practices, and policies [13,25,28].

Hansen and Hauge [20] see prosuming as an idea based on studies about ‘the future energy user mainly from the point of view of the traditional actors in the electricity system’. Such studies often focus on technical aspects and related economic or management schemes [26,29,30].

Other studies address the policy arena. Schleicher-Tappeser, for example [2], argues that prosuming is likely to have an important role in the bottom-up transition of the energy system, noting that the speed and ease with which this change takes place will depend on regulatory frameworks, business strategies and energy practices. Other authors have elaborated on aspects of transition [3,5,31]. The increasing speed of PV uptake has been linked to the accumulation of experience: late adopters may have higher deployment speeds [14]. In some countries, public economic incentives have been important in stimulating prosumer developments [1,4,10,11]; in others, household PV uptake has occurred with minimal or no public support [12,13].

Many of these analyses do not consider factors within the stakeholder environment or associated with the prosumers themselves. A partial exception is an article by Parag and Sovacool [30], stressing that successful integration will be achieved only if actors facilitate markets that are differentiated with respect to services, roles and functions. Also other studies show that stakeholders and market actors have more nuanced approaches than simply serving as incumbent ‘resistors’ to change [27,32]. Also the learning effects between installers can be significant drivers for uptake [33], although research on wider stakeholder roles – grid utilities in particular – appears remarkably limited. Skjølsvold et al. represent another exception to the lack of prosumer environment focus, by studying various ‘collectives’ relevant to prosuming [34].

National uptake of PV prosuming has been studied in the institutional context or as part as future visions [1,35], as well as in terms of household characteristics [36]. Due not least to official policies aimed at making PV more profitable, such uptake has been high [37], although trends have varied greatly among countries, with differing implications of the specific design elements of support policies [10,38]. This research strand includes analyses of public benefits in solar-power subsidies [39] and how different policy designs can have different economic effects [40]. However, such research tends to rest on the assumption of rational end-users.

Several studies address motivations for PV investment, experiences with prosuming technologies and how micro-generation might affect prosumers themselves or the wider system [15,19,21–23,26,41]. For example, PV micro-generation can influence energy practices or foster greater ‘energy literacy’, as well as clearer expectations towards the energy company [15,20,42]. Other research, however, indicates that prosuming can pacify energy practices, generally or as regards roles in the household [17,25,28,43–48].

Relationships and interactions among prosumers, stakeholders and policy remain under-studied. Exceptions include Skjølsvold et al. [34], who investigate collectives of relevance to prosumers and

related activities, and Olkkonen et al. [42] and Thronsen et al. [32], who study more limited interactions. There is a general lack of comprehensive, actor-oriented studies that explore and contextualise solar prosuming dynamics. What is needed is a clearer focus on the actors and their roles for prosuming. Approaching the study of prosuming on the assumption that various categories of actors meet at different arenas, we use these arenas to shed light on prosuming as an emerging phenomenon, and the barriers across analytical levels that may hinder further expansion.

We identify three arenas for exploring prosumer interactions: the *policy* arena, the *stakeholder* arena, and the *prosumer* arena. The policy arena is where central framework conditions are designed and implemented. The framework conditions for prosuming are generally found at the national level (policies, laws and regulations, support schemes) – but this arena also includes local regulations and support schemes.

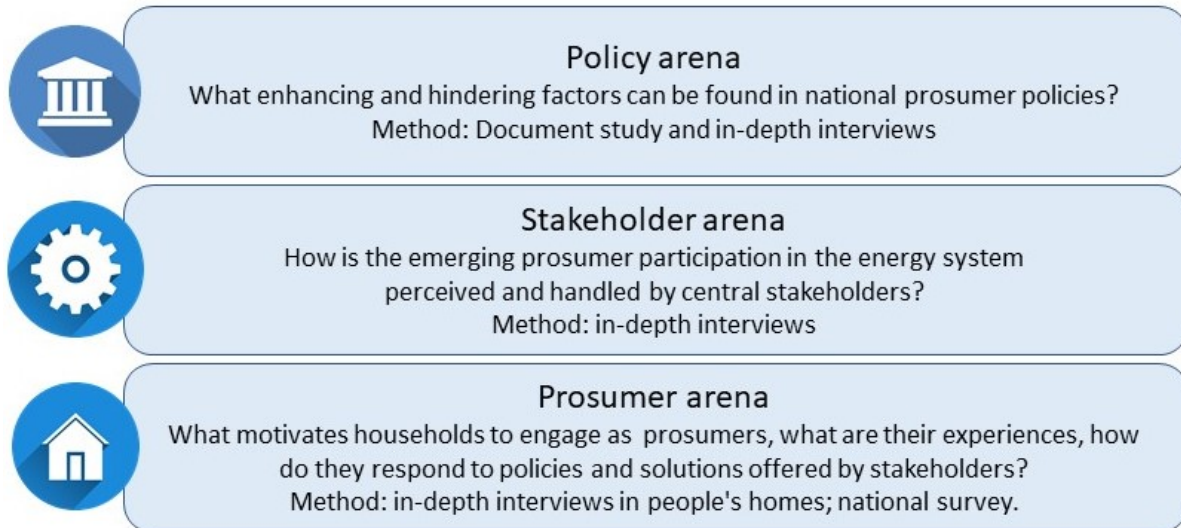
In the stakeholder arena we find the most relevant actors with whom prosumers stay in direct contact.² Stakeholders hold particular significance for the upscaling potential through reducing (or impeding) ‘soft costs’ [33]. This group includes bodies engaged in providing prosumer solutions: the regulator/authorities, District System Operators (DSOs), architects and consultancy companies promoting solar PV, and interest organisations. Analysis of this arena can show how stakeholders perceive the emerging prosumer market (barriers and opportunities) and their own role, and their views on the future role of prosuming in Norway.

The third arena is the prosumers themselves. Here we highlight the motivations for becoming a prosumer, drawing on a detailed account of prosumer motivations, experiences and energy practices [23]. In the present study, we provide an integrated analysis of these results and the arenas that prosumers engage with – policy and prosumer-related stakeholders.

Our focus on actor groups and the concept of ‘arenas’ enables a wider and deeper analysis of the main factors for prosuming, barriers as well as drivers. Some elements overlap with other frameworks, like the Multilevel Perspective – which shows how established national socio-technical regimes, like the electricity sector, work as barriers or facilitators for new technologies [49,50]. Our aim here is more limited and explorative compared to other ‘arena approaches’ (see e.g. [51]): we chart the actor dynamics and attitudes for each level, for a comprehensive approach to the conditions that drive, hinder, or influence prosuming in Norway. (See Fig.1) Some actors, particularly the DSOs, have received less attention in the literature, warranting further empirical exploration of emerging prosuming interactions and dynamics.

² Few prosumers construct their own PV installations, but reply on stakeholders here.

Figure 1: Analytical focus and methods applied



2.1 Methods

To explore how analysis across prosuming relevant actor arenas can illuminate barriers and drivers, we ran interviews, a survey, document studies and dialogue with selected stakeholders. In combination, these have elements of a 'mixed methods' approach to the research objectives [52], and should give a robust picture of the various arenas. However, the fact that Norway has so few prosumers entails limitations to our survey.

The study was conducted between 2015 and 2018. Several research methods were combined to shed light on prosuming in different ways and from various perspectives [53]. Our core material rests on qualitative methods. At the time (2015–2016) there were few prosumers in Norway, so we searched across the entire country, and included housing cooperatives with installed PV as well as individual households (for details, see [23]). This wide geographical spread proved advantageous with respect to our chosen methodology, because we expected to find that local regulations and stakeholders (municipalities, grid companies) would play a role in prosumer recruitment and operations. This enhanced the study of the interconnections between prosumers and stakeholders in various contexts. As a result, our material includes interviews with prosumers and stakeholders in the north of Norway (Kirkenes), the south (Arendal), the west (Bergen), the south-east (Oslo region, Hurdal) and mid-Norway (Trøndelag). In total, we conducted 65 semi-structured, in-depth interviews: 27 with policymakers and stakeholders such as DSOs, solar system providers and promoters; 33 with prosumer households (mainly home visits), and five households who had prosumers living nearby (see Appendix).

Second, in 2016 we conducted a national survey. This allowed contextualisation of the qualitative findings (e.g., how typical are the interviewed households?) and provided information on perceptions of prosuming among the general population.³

Third, we conducted a document analysis (White Papers, laws and regulations and official reports, as well as relevant research documents: see section 4 for details). Fourth, a group of practitioners were involved in regular discussion meetings. This reference group included actors representing the authorities, DSOs, solar installing companies, and consultancy firms. The group introduced ideas for examination, helped to identify relevant stakeholders for interviews, and commented on draft reports. They also shared insights and opinions on prosumer-relevant policies.

Throughout, we aimed to analyse factors that hinder or enable prosuming in Norway, and understand how various involved actor groups perceive and experience prosuming. For the policy-arena investigation (national policy documents and central policymakers), we focused on framework conditions, including-energy related regulations, price levels, support policies, numbers and kinds of actors involved, the future role of solar power in the national mix, and organisational matters (e.g. degree of decentralised vs. centralised solutions). In studying the stakeholder and prosumer arenas we focused on people's practical prosuming experiences, their motivations and their perceptions of the future role of prosuming. We also mapped local policies of support associated with the stakeholder arena, such as planning-related regulations and practices, energy-related regulations and policies that influence the prosuming situation, including obstacles to expansion of the prosumer markets (see [1]).

3.0 Prosuming in Norway

PV-based prosuming has followed different trajectories in different countries. In Australia, Germany, Spain, the UK and the USA, the prosumer market grew rapidly 5–10 years ago. For Germany, the UK and Spain, these developments were closely linked to large national support programmes, which had a significant effect on prosumer uptake but have recently been reduced [1]. In New Zealand, partly Australia, household PV figures rose, despite minimal or no subsidy schemes [11,12,54]. Compared to all these countries, prosumer developments in Norway have been slow.

According to the legal definition, prior to 2010 there were registered prosumers in Norway, with some informal exceptions. In March that year the regulator NVE⁴ adopted a general exemption from the regulatory requirements, opening for prosuming [55]. A prosumer regulation entered into force in January 2017. Here, a 'prosumer' was defined as an end-user with production and consumption behind the point of connection to the grid, and where the electricity fed into the grid at no point exceeded 100 kW [56,57]. The DSOs then became obliged to facilitate connection for prosumers.

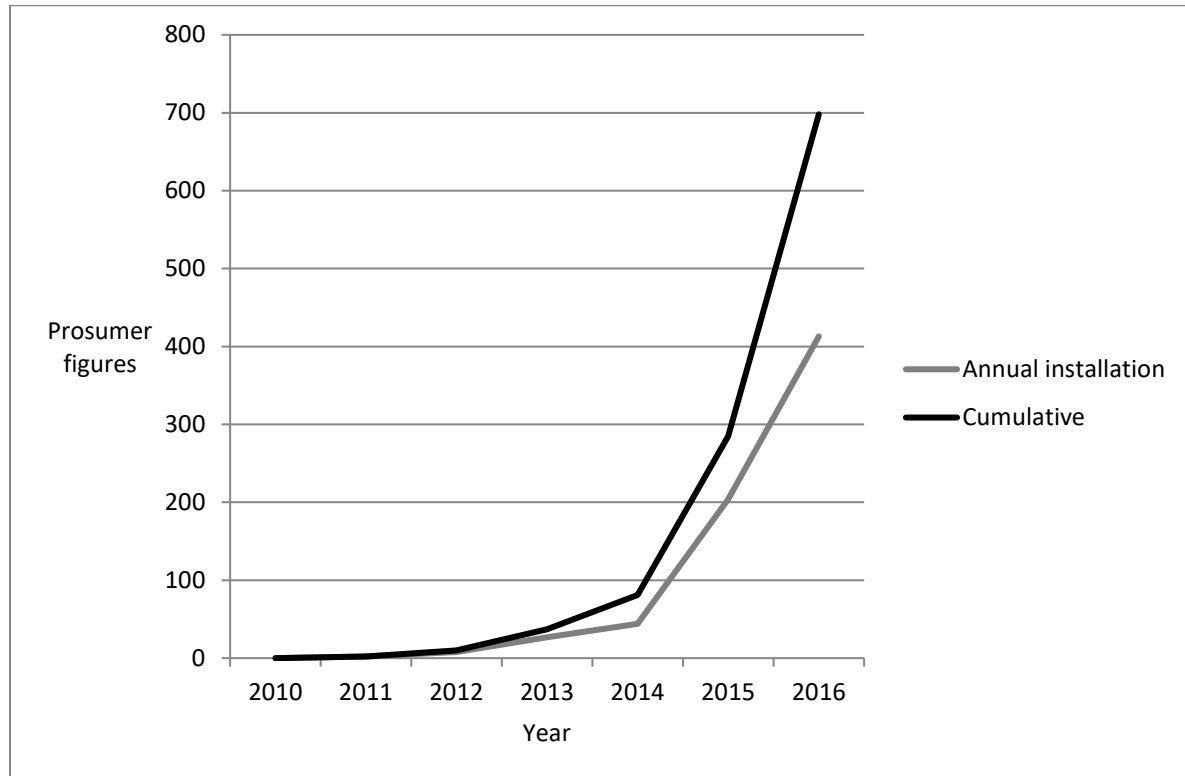
The year 2014 was important: the number of grid-connected PV panels started to increase [58], albeit slowly. In 2015 there were approximately 200 prosumers nationally (of approx. 2.5 million electricity end-users in total). By 2016 the number of prosumers had increased to roughly 700, and has increased exponentially since then. Over the course of 2018, 837 roof-top installations accessed a national

³ The survey was sent to a random and representative sample of the Norwegian population between March and May 2016; descriptive statistics and several regression models (binary, multinomial, ordinal) were used to analyse the results. Altogether 1102 respondents completed surveys; however, only three respondents were prosumers with a PV system installed in their home. For details, see [70].

⁴ The Norwegian Water Resources and Energy Directorate (Norges vassdrags- og energidirektorat, NVE).

investment support scheme for households (energy savings and micro production),⁵ almost all involving PV [59]. Although the trend points upwards,⁶ and is dominated by urban areas, the Norwegian market for PV has remained comparatively very small.

Figure 2 Prosumer figures for the six largest DSOs in Norway, until 2016 Source: Inderberg et al. (2018)



This modest development has unfolded against a background of Norway's hydropower-dominated, basically well-regulated electricity system. Studies of the end-use of electricity in Norway show that electricity is often considered a common good that should be universally accessible at a modest cost [60–62]. Electricity in Norway has traditionally been cheap, compared to Western European prices. Denmark and Germany, for example, continue to charge almost twice Norwegian electricity prices for private consumers; also the UK is significantly more expensive [63].

4.0 Results

4.1 The policy arena

In analysing the prosuming policy arena, we mapped developments in Norway, examining national characteristics, the kinds and levels of economic support schemes, and other regulatory measures.

⁵ The general support scheme is offered by Enova SF, an agency under the Ministry of Climate and Environment.

⁶ More recent estimates based on numbers from Enova SF indicate that in 2020 the number of prosumers passed 4000.

Our initial document study of the political frameworks showed the perceived ‘need’ for prosuming to be closely linked with national characteristics such as natural resource endowments, electricity systems, political systems, and electricity prices. We found two important features that could account for Norway’s modest prioritisation of prosuming activities. Firstly, the existing *carbon-emissions portfolio* within which prosuming and prosumer policies are developed has probably been important in connection with creating a role for prosuming in the national electricity system. Significantly, Norway already had a fully renewables-based electricity sector, so it was necessary to establish official goals and narratives linking the need for decarbonisation to prosuming: prosuming represents more of a decentralisation dimension than decarbonisation [64]. Prosuming is often associated with ‘green’ activities and seen as part of the modernisation of Norway’s electricity system, but its role in the electricity system remains to be defined [65].

Secondly, linked with general perceptions of prosuming as being of limited relevance to decarbonisation of the national electricity system, there have been few efforts at achieving political leverage for prosuming support schemes. Comparative studies indicate that economic incentives are most effective if they provide stable and predictable economic support for prosumer investments, especially when combined with risk-reducing elements like a purchase obligation [1].

Norway has had no significant support arrangements. The national scheme gives modest investment support towards installation costs, but there has been no feed-in tariff. Some Norwegian municipalities have established local support schemes. Oslo municipality covered 40% of PV investment costs, although this programme was later discontinued. Another municipal scheme reduced the ‘soft’ transaction costs of PVs by offering readymade packages including the PV system and installation, and simplifying the routines for applications to the authorities – information-based assistance and facilitation to boost prosuming [66]. These initiatives led to local clusters of higher prosumer numbers – a clear indication of effectiveness.

Our interviews with representatives of the national policy arena and stakeholder arena (including interest organisations for grid and solar industries, see below) echoed this point: the low financial support levels for prosumers explain the low prosuming figures in Norway. Interviewees also mentioned the lack of ‘need’ for prosumers in the electricity system, low electricity prices and market/organisational issues, high trust in grid companies, few installation companies, high transaction costs, and implicit resistance from parts of the Norwegian electricity sector.

4.2. The stakeholder arena

The stakeholders surrounding prosumers in Norway represent a broad range of actors of the socio-technical system. ‘Stakeholders’ are here understood as organisations or individuals involved in prosuming-relevant activities, related business, or technologies, and are recognised as having interests and influence regarding such developments [67]. Stakeholders include public agencies, grid companies (DSOs), energy producers, installation companies, service companies, consultancies, and interest organisations promoting the use of solar technology. Also included were ‘concept house’ developers, three of which were housing cooperatives/ecovillages with PV. (See Table 1.)

Table 1: Main actors and roles on the prosumer stakeholder arena

	Regulator/National authorities	Stakeholders I: DSOs (monopoly)	Stakeholders II: Electricity Suppliers (commercial)	Stakeholders III: Solar and Building sectors	Prosumers
Mandate 2010- 2016	Preliminary regulation making PV possible	Option to connect PVs, Voluntary compensation	No role directly related to prosumers, but share market	Promoting PV	Awaiting, few signs of initiatives, technological enthusiasts invest
2017 –	Prosumer regulation	Compulsory to connect PVs to the grid, Not allowed to purchase electricity	Invited to take active part in purchasing electricity produced by prosumers	Promoting PV	Increasing interest, PVs also included in new housing concepts

4.2.1 National authorities: defending a dinosaur, accommodating parasites or simply making an effort at modernisation?

The Norwegian Water Resources and Energy Directorate (NVE) is the energy market regulator. A sub-ministerial agency, it prepares legal provisions regulating the electricity system, including prosumer-relevant activities, which include smart-meter requirements, DSO monopoly regulation, and tariffing.

Some interviewees among solar interest organisations and consultancies characterised the NVE as ‘a bit conservative’ in approach, implying that it tends to work with established technologies and regulatory solutions. One interviewee characterised the NVE’s system and regulatory approach as a ‘dinosaur’ (Interview 1), focused on hydropower and a system of centralised production-consumption, less adapted to new forms of production. Also other representatives from solar interest organisations were deeply critical of the NVE, which they saw as primarily representing the interests of actors in the established electricity system. The green certificates renewables support scheme was mentioned by several interviewees as illustrating NVE ‘conservatism’. This scheme, shared with Sweden, is officially technology-neutral, but interviewees involved in solar development and environmental organisations pointed out that the barriers to accessing the support scheme often result in marginal and small-scale technologies like PV losing out, because of the high threshold for participation.

However, the NVE and DSOs (as also expressed by their interest organisation, Energy Norway), consider the 2017 regulations to be favourable to prosumers, for other reasons. Several of these interviewees mentioned that prosumers are exempted from paying point tariffs to supply power to the grid, as larger producers must.

Several stakeholders noted the dilemma between self-consumption on the one hand and solidarity in paying for the grid dimension. The grid infrastructure is planned on the basis of peak capacity needs, whereas financing, through grid tariffs, is based on (the amount of) energy used. This can put pressure on grid financing and distribution of costs. One interviewee who was critical of prosumer ‘free riding’ (not paying point tariffs) likened them to parasites: ‘Remember that in reality the small-scale producers are like parasites on the system services’ (Interview 2).

The Norwegian authorities, represented by NVE and Enova, saw prosuming developments as a ‘modernising’ aspect, a step towards new technology and smart grids. They appeared keen on removing formal obstacles so as to avoid criticism for obstructing prosuming. However, just what PV represents or should represent in the Norwegian system was not clearly expressed during interviews.

4.2.2 Grid utilities: Facilitating solutions at a modest pace

Most of the DSOs interviewed had not actively marketed the possibilities for engaging in prosuming activities. The distribution of PV prosuming in Norway is skewed towards the larger companies, often in fairly urban areas, but there has been some variety in grid-company approaches and attitudes to prosuming. As the DSOs are regulated monopolies, usually publicly (often locally) owned, they are wary of reputation issues – which includes avoiding being seen as an obstacle for prosumers. One DSO (Agder Energi) installed PV on its own rooftop to gain practical experience. Our general impression from interviews with prosumers and other stakeholders, and with the DSO, is an attitude of relative passivity towards prosumers, without being an actual hindrance: ‘We wouldn’t want to stand in the way of new technology. We’d prefer to be part of it’ was a typical statement from a DSO representative (Interview 14). Several DSO interviewees admitted to some degree of reluctance, citing unfamiliarity and lack of expertise with prosuming technologies, and the need to establish routines.

DSOs are the gateway to the rest of the electricity system for the prosumer. Most prosumers interviewed had been helped by their DSOs; however, but two prosumers in Kirkenes in the far north of Norway had not received technical support from their DSO, and had turned to private actors for assistance. They did not receive compensation for the electricity supplied – that was voluntary under the provisional regulation, later becoming mandatory under the permanent regulation.

As the grid companies are geographically specific monopolies not exposed to regular competition, they can share experiences and information not protected by law. The DSOs do collaborate on how to manage prosuming bilaterally as well as through their interest organisation, Energy Norway. This does not mean that DSOs are ‘interest-free’. They own and run the distribution grid with the mandate to provide power to end-users; they are under local-area balancing obligations, and are monitored by the media: thus they have a keen interest in avoiding disturbances to grid stability. Changes to the traditional supplier–consumer model are sometimes seen as representing a challenge, as if the DSOs were losing control over load management. For example, one interviewee stated, ‘if a prosumer has signed up to feed in 10 kilowatts, but starts to bring in 20 to 30, that will be a problem we’ll have to deal with’, then we will have to make grid reinforcements and so on.” (Interview 14). For DSOs, prosuming is something of an odd newcomer in their daily practices, and they are highly aware of the limitations imposed by the monopoly regulation. Interviewees expressed considerable uncertainty in how to interpret the legal and practical limits to the DSO role, in view of traditional national interpretations of monopoly activity, as well as new trends and future developments in EU energy policy.

The importance of grid quality was a central topic. Almost all grid-company interviewees were concerned about technical requirements for connecting PV installations to certain phases and as regards phase-frequency stability. They were preoccupied with ensuring high-quality components and professional installations, but differed considerably in terms of how to achieve this. Some had introduced procedures for pre-qualifying installers and equipment; others dealt with prosumers on a

case-by-case basis. They highlighted other problems: low competence among installers, and technical issues such as balance problems. Some noted the need for objective, national quality control or certification requirements for individual installers or installation companies.

Other DSO interviewees, including representatives with technical competence, opined that grid companies should not exaggerate the problems. Discussing the reconfiguration of the German electricity market after the rapid increase of prosumers, one interviewee commented that some Norwegian DSOs were unreasonably worried about balance, especially since no-one expects rapid developments in Norwegian prosuming' (Interview 7). They felt that scepticism towards prosuming was unwarranted, as prosuming can also enable new grid service opportunities.

In sum, primary concerns among the DSOs interviewed were energy security and load quality; they welcomed prosumers as long as numbers remain fairly low. No DSOs actively promoted prosuming as an option among their customers, but they appeared interested in offering solutions, rather than constituting an obstruction' to prosuming. They noted the need for increased competency (among installers/electricians and in their own organisation), and prosumer-adapted procedures.

4.2.3 Organisations, NGOs and consultancies promoting solar PV

To the Norwegian Solar Energy Society and other interviewees promoting solar power in Norway, international developments served as an important reference for their involvement. They emphasised that, in contrast to widely-held assumptions, solar irradiation in Norway is comparable to that in countries like Germany; moreover, the colder climate makes PV technology more effective in producing electricity. 'Any roof is suitable for producing electricity' (Interview 2). They also noted the need for incentives, recalling how electric cars have been successfully promoted and accommodated in Norway.

This stakeholder group has the role of spreading knowledge to promote the uptake of PV. In contrast to the grid utilities, they did not express concern about the competence of installation companies – but they complained about the low competence in the building industry (interviews 3, 4, 5) which was held to be 'utterly hopeless' (Interview 3). A consultancy interviewee mentioned another challenge, related to mismatching references between sector actors by pointing to the different units referred to when designing projects: the unit Euro/kWp is used in the solar electricity industry; the energy sector refers to Euro/kWh – and the common unit among constructors is kWh/m² (Interview 1). He concluded that such calculation model deviations create barriers for integrating PV in buildings. In addition, new materials that can accommodate several functions, like building integrated solar cells, tend to be ignored because current cost calculations do not reflect sophisticated alternative costs.

4.2.4 Emerging third-party installing companies: facilitating solar PV

The solar installers – usually third parties who are newcomer market actors in the electricity sector – play a crucial role for increasing prosumer numbers in Norway. Companies like Otovo, Fusen, Solcellespesialisten and others have developed business models that facilitate the entire process of becoming a household prosumer. Whereas the pioneering prosumers interviewed for this study related directly to their grid companies, an increasing share of new prosumers require the services of third-party installing companies for various arrangements like roof leasing, power purchase agreements, or direct household ownership. Such companies are crucial stakeholders and barrier-breakers for prosuming, serving as information disseminators and process facilitators, offering the

know-how for reducing the obstacles encountered by ordinary households. This effect is observable through geographical distribution: prosumers are far more prevalent in areas where such third-party installing companies operate. Although our study has limited material here, newcomer market actors emerge as a strong facilitating factor for increased prosuming in Norway. The role of solar installers in facilitating the spread of prosuming is confirmed by experiences from several municipality-based local incentive arrangements, some of which aimed at facilitating the process of becoming prosumers. Among the main factors noted by our informants were the reduced 'soft' transaction costs for prosumers, made possible by these arrangements (interviewees 22, 23,24,25), particularly as regards access to information.

4.3 The prosumer arena

In the Norwegian context, with limited economic incentives from the system side, the prosumers themselves constitute the main driver. We find three main generic motivations for becoming prosumer (or the added interest in moving into houses with PV, see [23]):

1. Environment. Many prosumers emphasised the environment as an important motivation. Some attached great importance to the fact that electricity from PVs is part of a sustainable lifestyle that can bring us closer to natural processes and cycles by utilising energy from the sun. Others mentioned the prospect of creating technology shifts towards greater use of PVs and contributing green electricity to the grid.
2. Technology. Many of our prosumer respondents were interested in technology and saw the installation of PVs as an attractive 'next step'. Many of them were already at the forefront with other new technologies like electric cars; several had in fact developed their own businesses related to PV technology.
3. Comfort. For several prosumers who had moved into PV-equipped homes, comfort was an important motivational factor. The technological solutions installed in these dwellings made it possible for them to live comfortably, without thinking much about energy consumption.

However, most prosumers who had acquired the PV equipment on their own initiative had experienced considerable transaction costs searching for information about suppliers, PV solutions, and regulations. In some cases, they had engaged in lengthy dialogues with the municipality regarding whether the PV system would require a formal application or not. This group often monitored their own production cautiously, and were generally highly knowledgeable and interested in their own energy consumption – many had already taken energy-saving measures prior to acquiring PV. Most of them adjusted some of their electricity consumption to increase self-consumption. For example, one interviewee talked about 'sun laundry' ('solvask') (Interview PI4) – using the washing machine during the daytime to utilise the electricity produced (see also [42]). Similar views have been confirmed by studies of other countries [68,69].

In view of their expressed motivation for acquiring PV and also their accounts of how they engage with the technology, it is clear that economic aspects played a limited role for the prosumers we interviewed. Rather, PV installations were 'domesticated', further signalling the owners' status as environmentally friendly, technology enthusiasts and/or comfort-seeking, living in a modern, PV-equipped home [23]. PVs appear to suit various types of identities and could in principle be attractive to many types of Norwegian households.

However, the pioneering group in our study might not have been representative of the wider population at the time. To contextualise our qualitative findings, we conducted a national survey in 2017, to map potential interest in PV (see [70] for details). Of the total sample (N=1102), only three households had acquired solar PV – not surprising, given the low share of prosumers at that time. A further 11% said that they had considered installing PV; 74% had not. Reasons for lack of interest in PV systems (alternatives were provided) included: the technology is too expensive (34.6%), I am satisfied with the current system (28.5%) and I am not familiar with the advantages of PV (25.5%). Also mentioned were uncertainties: about the technology (21.3%), regulation and/or support schemes (20.8%), and whether their housing conditions were suitable for PV (17.2%).

Our survey also presented a hypothetical scenario where respondents could indicate their willingness to purchase a PV system at one of three costs (equivalent to €2000, 4000 or 6000)⁷. The results confirm the expected importance of PV system price: the responses were consistent with the law of demand, where higher cost leads to less interest.⁸

Summing up, the pioneering Norwegian prosumers whom we interviewed had high levels of personal motivation beyond economic incentives for engaging as prosumers, and had spent considerable time and resources on acquiring information, solar panels and the related technologies. They were important early drivers for prosuming in Norway, despite the high transaction costs. For the majority of the population, as our survey results showed, the financial aspect is important – as a perceived barrier to obtaining PV, and as a motivational factor for reducing future electricity costs. The high costs and lack of compensation measures act as obstacles to prosuming. We also note that unfamiliarity with PV and uncertainties regarding regulations, subsidies and practical arrangements constitute further barriers to prosuming in Norway. As emerging solar installation market with third-party actors grows, this is likely to mitigate some of these problems.

5.0 Discussion: enabling and hindering factors for prosuming

5.1. Modifying the assumption of the economic end-user

Our findings show that householders' motivations for taking up prosuming may vary according to the segment under examination. The pioneering prosumers interviewed for this study may have been 'early adopters' [71]: other groups who otherwise resemble them might follow suit as time passes and the market matures. Alternatively (or in combination with the above), the interviewed prosumers may be seen as 'lead users' or 'expert users' [72], more experienced and interested than the average potential prosumer. There was probably a mix of these: people who had taken individual initiatives to become prosumers might be labelled 'expert users', where those who moved into houses where PV was installed resemble 'early adopters'. Regardless, the overall finding among our pioneering prosumers is that economic considerations were generally not a major factor. They had not become prosumers on the basis of meticulous calculations as to whether prosuming would be a good financial investment. In practice, this consisted in making sure whether the overall costs would be *reasonable*.

⁷ -estimates⁷ In our survey, the costs options were given in NOK, respectively NOK 20,000, 40,000, and 60,000. The €- equivalents are approximate

⁸ Some 45.7% of respondents indicated willingness to purchase a PV system costing €2,000. The rate of positive responses dropped to 30.5% for a system costing €4,000 and to 25.7% for one costing €6,000.

Their primary motivations to taking up prosuming were rooted in concerns for the environment, interest in technology and/or comfort. PV is associated with climate and environmentally friendly behaviour, and becoming a prosumer has a strong symbolic effect, as indicated by earlier findings (see[73]). Likewise, PV indicates technology interest or modern, progressive attitudes. A more novel factor which we identified as a comfort dimension is linked to the fact that some new dwellings in Norway come with already-installed PV, which was seen an additional attractive aspect.

These findings are in line with the results of interdisciplinary studies highlighting that the energy behaviour of individuals is formed by a complex set of factors [74,75]. In contrast, a study on prosuming in Austrian energy cooperatives found that economic considerations were a key factor for adoption [76]. But more generally, motivational factors other than maximising economic gain have been observed; such studies can be useful in determining what groups are likely to become prosumers [77,78]. However, we would stress the importance of examining at how practical arrangements (and interactions with other actor groups) influence the likelihood of PV adoption. In our study, the *symbolic effect* of PV emerges as more significant than the case with many other types of household energy measures: this is probably linked to the physical position of PVs and their visibility from outside. Even though research shows that indirect peer effects are less important than direct peer contact [79], [80] the more specific mechanisms for this are less clear. Among pioneers in Norway, becoming prosumers has carried social meaning: solar is indeed 'like having an electric vehicle on the roof' [23].

We have also identified obstacles to the further spread of prosuming. The general population showed little interest in investing in PVs. There were many reasons, but one of them is clearly economic: PV must be perceived as profitable. As long as PVs cannot compete fully here, prosuming solutions may remain of interest only for certain groups who are motivated by factors other than economic ones. This points to the importance of incentive schemes for triggering the widespread expansion of prosuming in Norway. Further, our study confirms that transaction costs constitute a major barrier for household investment in PVs. Incentive schemes geared towards reducing these costs might promote prosuming among the general public [23] [66].

5.2 The stakeholders

As numerous actors are involved in prosuming activities, the present study contributes to a largely under-researched area [42]. First of all, the grid companies (DSOs) are gatekeepers, connecting prosumers to the grid. This means that the existence of varying practices among DSOs can act as a barrier to prosuming barriers in some areas while not in others. Further, ensuring well-functioning services from DSOs will be important here.

Other stakeholders are important for enabling prosuming activities. Of particular importance are third-party market actors – often small companies that assist end-users with access to energy services and new products. Although our findings nuance the widespread myth that traditional actors like grid companies actively resist new services and products [27], PV installing companies do play a key role in providing expert knowledge and reducing transaction costs.

Our study has shown the complexity of the interplay between traditional and new market facilitators, support schemes, and household interest in prosuming. These actor groups and arenas should be considered jointly in order to grasp how prosuming is constituted and how it could be facilitated. As other research has shown [81], our study confirms that transaction costs constitute a major barrier to prosuming. There is a need for readily-accessible knowledge on the practical transaction costs, also as

regards obtaining information, the bureaucratic obstacles, and other practical and time-consuming steps involved in becoming and performing as a prosumer – and how these costs can be mitigated. While local and national governance have clear roles to play, such as reducing bureaucratic burdens and regulating rights and obligations [82], some of this work could be handled by other actors and stakeholders as well.

5.3 Prosumer policy

As Norway is a country with historically low electricity prices, high electricity consumption, an almost fully renewable and flexible electricity sector and no ‘green need’ to reduce emissions from electricity production, it is hardly surprising that it has been a latecomer to prosuming. Additionally, we note the very limited levels of economic support – a factor otherwise found to be important in many energy markets. The lack of financial support provides weak incentives for the general population to take up prosuming. Grid companies and other stakeholders need to build competence and reduce the transaction costs involved in becoming prosumers, and should establish routines for managing such processes internally with other stakeholder groups. Even then, a stronger incentive scheme may well be necessary to achieve upscaling of prosuming activities in Norway [1]. While the literature indicates that the political attention is not absent, and that incumbent actors are not actively opposed, the picture is somewhat mixed, and we find no concrete reasons to expect prosuming to be pushed much higher on the agenda in the near future. In today’s Norway, with a fully renewable electricity sector, an unclear role for prosumers in the electricity system, and few reasons for policymakers to prioritise prosuming, most actors – beyond the pioneering groups and those actively engaged in the solar business – appear reasonably satisfied with the current situation.

Our study has shown that the links *between* the arenas are important, also confirming indications from other countries. For example, in the Swedish market there is prosumer development, and new kinds of cooperation are being established between what could be seen as ‘unlikely bedfellows’: traditional utilities cooperating with the ‘new’ kind of third party market actors to develop new business models [27]. In the UK, the ‘established’ actors and the ‘new’ market actors may be more separate, as even the policy support tools have been designed separately with a FiT for small scale (all but terminated today) with more market-based instruments for large-scale producers [83,84] (but see [85]). In Germany and the USA, this separation of actors has – at least up to a point – resulted in a large number of energy cooperatives [4]. This unfolded while the larger traditional utilities protected their home market assets, often within fossil fuels, and chose to invest in renewables in other markets than their home ones [86]. Another example of divided markets with high prosuming figures is Australia [11]. Further, Spain saw a significant boost in PV up to 2011, before sudden changes in support led to abrupt brakes on installation rates [6]. By contrast, Denmark has a firm footing in distributed ownership and generation within renewable energy, and a national stake in increasing windpower developments, enabled through generous support schemes [87].

The picture is therefore mixed. Some countries, such as Australia, New Zealand and Norway, show that prosuming can occur and increase, even with limited or no economic support [1,12]. Other evidence indicates that subsidies still have an important role to play – a point strongly supported in the literature [6,11,21,88].

Our findings indicate the crucial importance of understanding the stakeholder arenas and the interactions between the actors there, for a better grasp of the dynamics and obstacles to prosuming.

These barriers are often anchored in perceptions and norms about how things used to be done, how they 'should' work. Such impediments, found within these various arenas and in the interconnections between them, have their origins well beyond the realm of rational perspectives. We find that the economic rationale of becoming a private prosumer features mainly as something to be checked so as to ensure that it is not 'too bad'; other drivers and barriers seem to be at least as important.

6.0 Concluding remarks

This study has explored prosuming as an emerging phenomenon in Norway, analysing drivers and obstacles in three arenas and the interactions between the respective actor groups: national policy, prosumer stakeholders, and household prosumers themselves. Concerning the policy arena that currently facilitates but provides few financial incentives for prosuming in Norway, we showed that early prosumers have been motivated by environmental, technological and comfort-related aspects connected to identity construction, as well as expectations of possible longer-term economic benefits. In contrast, results from the national survey (indicative of customers in a future 'mass marked') show that the majority of the population would focus on financial gains before becoming prosumers. Here we see two possible scenarios for future developments. A strengthening of economic incentives would probably motivate more householders to take up prosuming. Alternatively, if policymakers remain focused on the economic factors in future support programmes, while failing to deal with the considerable transaction costs experienced by the pioneers, this could create barriers to uptake.

The interactions between prosumers and various types of stakeholders pose another potential obstacle to prosuming, requiring a wide and deep research design that includes a range of methods. Here, we identified the obstacles related to different types of actors. Of particular importance are prosumer relations with their grid company (DSO) – the gatekeeper as regards prosuming. We found significant variations in how DSOs approach prosuming activities. In some cases, this has meant obstacles, with prosumers having to devote considerable time and resources (transaction costs). Other types of stakeholders, such as the building administration (municipalities) and third-party installers, are also of crucial relevance in their facilitative or restraining capacities.

Internationally, national carbon-emissions portfolios and the need to decarbonise the electricity sector have been significant factors influencing prosuming policies.⁹ In Norway's already fully-renewable power system, this is not a policy-driver, so prosuming should not automatically be linked to decarbonisation. Nonetheless, Norwegian policies are currently pressing for an expansion of power production – windpower in particular, which has become a highly controversial issue. In the quest to meet future power demands, solar PV may well receive increased attention also in Norway.

A main contribution of this article has been to highlight the interlinkages between actors in different arenas and how these interlinkages shape household adoption of PVs, and we hope to have opened several possible new venues for further research. Understanding how to boost prosuming is indeed useful – but the decision to stimulate prosuming is ultimately a political question.

⁹ In other countries this is relevant, as it indicates the link between decarbonisation needs and support policies.

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Appendix A: Interview List

Sector Stakeholders			
Number	Interviewee identifier	Actor category	Interview date
1	1	Private consultancy	9 June 2015
2	2	Solar interest association	9 June 2015
3	3	Independent consultancy	17 June 2015
4	4	NGO	17 June 2015
5	5	Municipality	18 June 2015
6	6	Entrepreneur	24 June 2015
7	06 cont.	Entrepreneur	15 Sept 2015
8	7	DSO	20 Oct 2015
9	8	Entrepreneur	26 Oct 2015
10	9	Municipality	29 Oct 2015
11	10	Tech. company	03 Nov 2015 (Phone)
12	11	Public agency official	23 Nov 2015
13	12	Municipality	12 Jan 2016 (Phone)
14	13	Municipality	8 Mar 2016
15	14	DSO	9 Mar 2016
16	15	DSO	9 Mar 2016
17	16	Public agency official	9 Mar 2016
18	17	Municipality	10 Mar 2016
19	18	Municipality	10 Mar 2016
20	19	DSO	5 Nov 2015
21	20	Municipality	8 Mar 2016
22	21	Municipality	8 Mar 2016
23	22	Municipality	14 Mar 2016
24	23	Consultant/analyst	28 Mar 2017 (Phone)

25	24	Municipality	20 Apr 2017 (Phone)
26	25	Consultant/analyst	02 Jun 2017 (Phone)
27	26	Municipality	12 May 2017 (Phone)
Sum: 27			
Prosumers			
1	PS-1	Prosumer, village	26 Oct 2015.
2	PS-2	Prosumer, village	26 Oct 2015
3	PS-3	Prosumer, village	26 Oct 2015
4	PI-1	Prosumer, independent	18 Jun 2015
5	PI-2	Prosumer, independent	22 Jun 2015
6	PI-3	Prosumer, independent	09 Nov 2015
7	PI-4	Prosumer, independent	10 Nov 2015
8	PI-5	Prosumer, independent	17 Nov 2015
9	PI-6	Prosumer, independent	20 Nov 2015
10	PI-7	Prosumer, independent	24 Nov 2015
11	PI-8	Prosumer, independent	25 Nov 2015,
12	PI-9	Prosumer, independent	01 Dec 2015
13	PI-10	Prosumer, independent	08 Dec 2015
14	PI-11	Prosumer, independent	08 Dec 2015
15	PI-12	Prosumer, independent	09 Dec 2015,
16	PI-13 (PK-1)	Prosumer, village	18 Jun 2016
17	PI-14 (PK-3)	Prosumer, village	18 Jun 2016
18	PH-1	Prosumer, village	20 Sept 2016
19	PH-2	Prosumer, village	20 Sept 2016
21	PH-3	Prosumer, village	20 Sept 2016
22	PH-4	Prosumer, village	20 Sept 2016
23	PH-5	Prosumer, village	22 Sept 2016
24	PH-6	Prosumer, village	22 Sept 2016
25	PH-7	Prosumer, village	22 Sept 2016
26	PH-8	Prosumer, village	22 Sept 2016
27	PH-9	Prosumer, village	23 Sept 2016
28	PH-10	Prosumer, village	23 Sept 2016
29	PH-11	Prosumer, village	27 Sept 2016
30	PH-12	Prosumer, village	28 Aug 2016
31	PH-13	Prosumer, village	28 Sept 2016
32	PH-14	Prosumer, village	28 Sept 2016
33	PH-15	Prosumer, village	28 Sept 2016

SUM: 33			
Local population, Hurdal Eco Village			
1	HL-1	Individual	20 Sept 2016
2	HL-2	Individual	28 Sept 2016
3	HL-3	Individual	28 Sept 2016
4	HL-4	Individual	28 Sept 2016
5	HL-5	Individual	20 Sept., 23 Sept 2016
Sum: 5			
Sum Total: 65			

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