



Original research article

## Is there a Prosumer Pathway? Exploring household solar energy development in Germany, Norway, and the United Kingdom

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## ABSTRACT

Prosuming – where private households use photovoltaics to produce electricity at home – has proliferated across Western countries, but growth rates have varied significantly. Focusing on Germany, Norway and the United Kingdom, this article explores the major factors that influence national prosumer figures between 1990 and 2017, and whether a development pathway can be identified. Support schemes, direct regulatory provisions, information and third-party installer markets are analysed through document studies, controlling for domestic context. This study confirms that changes in support schemes have been influential for the development of prosuming in all three countries; access to information and the presence of a third-party market have also been important. There are indications of differences elsewhere in the domestic context. For Germany and the UK, decarbonization has been a significant driving force for policy, unlike in Norway, where a boost in prosuming is now underway. While all three countries show similar early interactions between market and regulatory provisions, different national policy drivers indicate that different national prosumer pathways are possible.

### 1. Introduction

Private households are increasingly producing electricity at home, utilizing the opportunities made possible by technical developments in photovoltaics (PV) and other technologies. These *prosumers* – small-scale end-users who, in addition to using electricity from the grid, generate power for their own use and export back into the electricity system – have increased in numbers in many places. Australia, Germany, the UK, Spain, and parts of the USA have seen significant growth in prosuming. Household prosuming – often PV-based – has contributed to changes in business models and electricity markets, including the establishment of new market segments, and has influenced the stock-market values of traditional energy companies [1–3]. Prosumers have established new political interest constellations [3,4] and spurred debate on the need for national capacity-adequacy mechanisms [5]. Some analysts argue that prosuming, in combination with other developments like flexible and intelligent smart grids and electric vehicles, can transform national electricity systems in terms of new physical structures, further enabling the introduction of information technology, as well as institutional and social innovation [6–8].

At the same time prosumer growth rates vary greatly across Western countries. As photovoltaic technology developments and significant

price reductions are available across national energy systems, and as factors like solar irradiation do not explain these differences, the main reasons are probably at the domestic level [9]. Moreover, this growth in micro-generation does not always align directly with other renewables policies, for example larger-scale power plants. Few studies have delved into the reasons, holistically investigating the national conditions that influence prosuming figures.

Prosumer developments have varied also in time. Germany implemented its first support programmes in the early 1990s, whereas the UK started some ten years later. Norway, with an electricity sector that is already fully renewable, began supporting prosuming in 2011; thus, a weak trend in prosuming might be expected, but also here the growth curves have been steep. Further, the prosuming curves in Germany, the UK and Norway – at least in the initial stages – show similar exponential shapes. From a rather marginal starting point, prosuming has soared quickly in all three countries, at very different timepoints. This finding is puzzling and warrants further inquiry – especially regarding Norway, which is characterized by low electricity prices and no need for decarbonizing the electricity sector. Here, prosumer numbers are still low, but growth rates are currently high.

This article compares the main policy dynamics that influence household PV prosumer growth in national electricity systems.

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Focusing on private households using photovoltaics for micro-generation, we analyse the similarities and differences in national prosumer developments over time. We ask: *What are the major factors that influence national prosumer figures, and to what degree can a PV prosumer development pathway with similar interactions between policy and market developments be identified?*

We examine prosumer framework conditions in Germany, the UK and Norway – three countries that vary significantly along several dimensions. Germany and the UK stand as frontrunners and today have many active prosumers, while best practices, policies and regulations for developing prosuming are still being developed and adjusted. Germany initiated a pilot subsidy programme for small-scale PV in 1990, aimed specifically at first-mover households [10]; the UK began a programme to encourage prosuming that included wind and PV in 2002—more than ten years later. These programmes proved critical for stimulating public interest in and awareness of renewables and in enabling prosuming to emerge. Norway, despite being a frontrunner in electricity-sector liberalization, legally allowed prosuming only from 2010.

To increase the robustness of our findings, we chose similar and different cases, with a special focus on time and technology sensitivity, as the early developments took place when PV technology was significantly less mature. Germany began to develop prosuming roughly ten years before the UK, and twenty years before Norway. Norway shows some signs of going through similar processes as the two other countries, but there are also significant differences. How similar are the processes, and what are the limits to such comparisons? The Norwegian and British electricity sectors de-regulated early, with Germany following at a slower pace. Germany has committed to decarbonize and de-nuclearize its electricity sector; the UK intends to decarbonize partly by increasing the share of nuclear in its electricity mix. Norway is almost fully renewables-based, thanks to its natural endowments. In combination, and following from Mill's joint method of agreement and difference [11], these similarities and differences in background factors make comparisons feasible.

### 1.1. Comparing prosumer developments

Studies have analysed isolated effects of economic support and other measures on prosuming [1,12–14], and the use of distributed generation in the energy system [15]. However, wider explanations of aggregated micro-decisions in national comparison are rare.

Several studies analyse technical change and optimization, or economic factors, but significantly less attention has been paid to the social aspects, especially at the national or macro-level. However, a growing literature focuses on individuals and household energy choices, including specific decisions related to energy consumption and becoming prosumers, and prosuming uptake through social practice and policy perspectives [16–19]. These studies are often anchored in psychology, behavioural economics, anthropology, sociology or similar disciplines, applying practice theory (or similar) to explain adoption rates, aspects of behaviour, roles, or the scope for change [20,21]. While these studies provide useful micro-foundations for prosumer uptake, they tend to relate to factors like individual values or social practices that are difficult to measure on aggregate levels. Further, they often have limited ambitions regarding generalization.

Little attention has been directed at explaining national prosumer figures, and comparisons across national contexts are difficult to find. However, some studies have addressed prosuming policies. Schleicher-Tappeser [22] argues that prosuming is likely to have a role in changing national energy systems, noting that the speed and ease of this change will depend on regulatory frameworks, business strategies and energy practices. Parag and Sovacool [8] discuss how prosumers could be integrated effectively into electricity markets, underlining that successful integration can be achieved only if markets are differentiated with respect to services, roles and functions. Stakeholders and market actors

are found to hold significantly more nuanced approaches than merely representing incumbent 'resistors' to change and new entrants that induce disruptive change [23].

Other studies indicate that approaches to market developments from a 'Varieties of Capitalism' perspective can have important implications for the general uptake of renewables and PV [24]. This may be connected to the observation that in some countries public economic incentives have had an important role in stimulating prosumer developments [1,25], while in other countries household PV uptake has occurred with minimal or no public support [26,27]. PV developments have been shown to be relatively disconnected from natural resource endowments [28], but have been connected to economic support, reduction of transaction costs and bureaucratic hurdles, as well as maturing markets [6]. That late PV adopters may have higher deployment speeds has been linked to experience reducing transaction costs [29].

It is difficult to establish a limited set of determinants for the national integration of PV prosuming by drawing on the general literature and controlling for wider sets of contextual differences. However, some main candidates for explanatory factors stand out. Against the background of the literature mapped above, we examine two sets of explanatory factors for the differences in prosumer numbers. The first is based on the idea that national developments should be compared against the background of *basic national structural conditions and problem characteristics* [30]. These are factors that can facilitate or impede achieving high numbers of prosumers. Such factors are not immune to change and may fluctuate significantly, but they tend to represent relatively stable national conditions over time [31]. They may vary in type and relevance, and include natural resource endowments and institutional structures, energy sources, emission portfolios, and long-term interest constellations in the electricity sector.

The second set of explanations recognizes these conditions and emphasizes how national policy dynamics may lead to different outcomes in prosumer numbers. The dynamic factors – like direct regulations or economic support levels – can be determined politically. While recognizing potential political feedbacks, we approach this by mapping the most prosumer-relevant factors that are the responsibility of politicians and regulators, while controlling for structural and slow-changing characteristics in the countries

Factors may work as barriers to or drivers for prosuming. We operate with three generic categories. The first is *economic incentives* [6], which includes support schemes or tax benefits. These may take various forms, and have been shown to be a potentially crucial factor for prosumer figures [4]. We map relevant economic support over time for each country. Due not least to official policies for increasing PV prosuming returns on investment, such uptake has been found to be high [32], although the implications of differing design elements of support policies show great variance among trends and jurisdictions [4,25]. There has been a focus on EU policy and national regulation for smart grid, including prosuming and PV [33]. Analyses of public benefits in solar subsidies are part of this research strand [34], as is study of how different support designs may have different effects [35].

Our second exploratory factor includes other *regulatory requirements and institutional frameworks* [6]. These 'soft costs' of PV prosuming [36] are often controlled locally. They are typically not economic in nature, but may have a direct or indirect effect on technology diffusion [37]. Examples include building codes and planning regulations, metering requirements, and other energy-market regulations which can have indirect but significant effects on prosumer numbers. Also relevant here is the existence of an 'official prosumer bureaucracy' which facilitates prosuming.

Our third generic category is *information practices and the presence of an installer market* [38]. For example, governmental bodies may be mandated to promote prosuming practices – by informing the public about relevant support schemes, providing assistance in dealing with the application and regulatory processes, and spreading general knowledge about prosuming opportunities. While we assume similar

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