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Power from the People?

Prosuming conditions for Germany, the UK and Norway

Tor Håkon Jackson Inderberg, Kerstin Tews and Britta Turner

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Abstract

Across Western electricity systems, private households are increasingly engaging in the micro-generation of electricity. Previously traditional end-users of electricity consumers are utilizing the opportunities made possible by technical developments in photovoltaics and wind turbines, becoming prosumers: small-scale end-users who, in addition to using electricity from the grid, generate power for own consumption and/or to be fed back into the grid. By addressing the research question "what factors enable or constrain developments in prosumer figures in national electricity systems?" the report maps incentive structures (support schemes); direct regulatory requirements; and information practices and market availability, while controlling for national characteristics of the three countries. It finds that that the most important single factor for increasing prosumer numbers is the existence of a stable, robust and generous support scheme. Natural characteristics such as the need for reducing carbon emissions is a significant background factor, as are bureaucratic hurdles, and third party market availability for technical solutions for consumers who are considering becoming prosumers.

Key Words

Electricity market; prosumers; transformation

Contents

Acronyms

BEA	British Electricity Authority
BEE	German Renewable Energy Association
BEIS	Department of Business, Energy and Industrial Strategy (UK)
BkartA	Federal Cartel Office *(Bundeskartellamt)*
BMWi	Federal Ministry for Economic Affairs and Energy (Germany)
BnetzA	Federal Network Agency *(Bundesnetzagentur)* (Germany)
BPVA	British Photovoltaic Association
CAT	Centre for Alternative Technology (UK)
CEGB	Central Electricity Generating Board (UK)
CfD	Contracts for Difference (UK)
CHP	Combined Heat and Power
ct/kWh	Cost of electricity by source
DECC	Department of Energy and Climate Change (UK)
DSO	District System Operator
EEG	German Renewable Energy Act
EMR	Energy Market Reform
EnWG	German Energy Industry Act
EPC	Energy Performance Certificates
EST	Energy Saving Trust (UK)
FIP	Feed-in premium *(often regarded as a sub-type of FIT)*
FIT	Feed-in Tariff
FoE	Friends of the Earth
GEMA	Gas and Electricity Markets Authority (UK)
GPDO	General Permitted Development Order (UK)
GW	Gigawatt
IEA	International Energy Agency
IHD	In-Home Display
LNG	Liquefied Natural Gas
kWh	Kilowatt hours
kWp	Kilowatt peak
MW	Megawatt
NGET	National Grid Electricity Transmission (UK)
NVE	Norwegian Water Resources and Energy Directorate
OFFER	Office of Electricity Regulation (UK)

OFGEM	Office of Gas and Electricity Markets (UK)
PBA	Plan and Building Act (Norway)
PV	Photovoltaics
RES	Renewable Energy Source(s)
RO	Renewables Obligation
SME	Small and Medium-sized Enterprises
TSO	Transmission System Operator
TWh	Terawatt hours

1 Introduction

Across Western electricity systems, private households are increasingly engaging in the micro-generation of electricity. Previously traditional end-users of electricity consumers are utilizing the opportunities made possible by technical developments in photovoltaics and wind turbines, becoming *prosumers:* small-scale end-users who, in addition to using electricity from the grid, generate power for own consumption and/or to be fed back into the grid. This movement has been especially notable in Germany, the UK and parts of the USA, and has in some cases contributed to reducing the stock market value of traditional energy companies (Kungl 2015), as well as bringing changes in regulations and markets (Beermann and Tews 2016; Overholm 2015) and the need for capacity adequacy regulations (Tennbakk et al., 2013). New prosumer market segments and market actors have been established, and interest constellations in some electricity markets have been significantly influenced (Kungl 2015; Berge 2016). According to some analysts, this trend, alone or in combination with developments like smart grids and electric vehicles, may have the potential to transform national electricity systems (IEA-RETD 2014; Skjølsvold and Ryghaug 2016; Berge 2016).

This report does not engage with the questions of transformation, but takes a step back and asks the simple question: *What factors enable or constrain developments in prosumer figures in national electricity systems?* We address this question by qualitatively analysing Germany, the United Kingdom and Norway, with the focus on prosuming related to private households using photovoltaics for micro-generation of electric power.

The three cases vary significantly along several dimensions. Germany and the UK are prosumer frontrunners in different ways, whereas Norway has very few prosumers. The Norwegian and British electricity sectors de-regulated early, whereas Germany has liberalized more slowly. Germany has committed to decarbonize and de-nuclear its energy sector, while the UK appears to going about de-carbonization partly by increasing the share of nuclear in its energy mix. Norway, by contrast, is almost fully renewables-based, thanks to its natural endowments. The political systems in the three countries vary significantly as well.

The shift from a situation where households consume only grid-connected electricity to one where they also generate power that is fed into the grid infrastructure may be part of the next major steps in electricity system developments. However, this will require national and system-level coordination for shaping electricity companies and prosumer behaviour and opportunities. Some countries, such as Germany and gradually the UK, have many active prosumers, but best practices, related policies and regulations are still being developed and adjusted. Norway, by contrast, has been a progressive frontrunner in the liberalization of its electricity sector, but has few prosumers as yet. What lessons can be learned from these national differences?

1.1 Analytical approach

1.1.1 Comparing prosumers and prosumer figures

We approach the research question by identifying, mapping, comparing and attributing the effects of structural characteristics and regulatory developments in the three countries to prosumer activities and phase-in. These are then compared in a structured manner. The dependent variable 'prosumer inclusion numbers in the electricity system' allows for variation that represents a necessary flexibility for the national case-studies, enabling us to identify relevant prosumer activities. In this report we focus on prosumer micro-generation for private households by photovoltaics. This brings flexibility and makes it possible to identify prosumers also where there is no officially stated policy regarding 'prosuming'. In fact, in none of the three case countries are the terms 'prosumer' or 'prosuming' part of the official vocabulary. Germany and the UK tend to use the term 'micro-generation', while Norway the term employed translates as 'plus customer'. However, we find the term 'prosumer' appropriate for the focus of this report, and it is here used to refer to *private households which, in addition to traditional energy consumption, also produce their own electricity that may be used on site and/or fed back into the grid.*

Measuring the dependent variable – 'prosumer inclusion numbers in the electricity system' – entails further challenges. National statistics vary in organization and categories, and are thus not always directly comparable. In line with our concept of prosumers, national figures would ideally be reported according to grid-connected private households' engagement in micro-generation based on PV. This is not always possible to establish directly, so some approximations have been necessary. For Germany there is no reporting that distinguishes clearly between ownership of micro-generation systems, and small and medium enterprises as part of official reporting, which is bound to the feed-in tariff support scheme. Rough estimates indicate that there may be 850,000 prosumer systems, but this figure is likely to include some SMEs (see section 2). Categorizations of installed production capacity complicate things further. For the UK, reporting has generally followed the various support schemes, which may overlap partly. The Renewable Obligation (RO) scheme includes roughly 650,000 prosumers. Additionally there are other schemes that have offered support for micro-generation – with their own separate reporting systems. For Germany and the UK, the exact figures may not be completely crucial, and in any case the estimates are high – on a very different scale than for Norway. There, the measurement challenge does not concern large-scale statistics, as there are very few prosumers in Norway. Despite recent indications of a trend towards more prosumers, the figures are still between 200 and 300 – *nationally*. As there is no central registry of these, the bookkeeping is done by the individual District System Operators (DSOs), so we have contacted the most relevant DSOs directly. This approach may entail some under-reporting, but not to any significant extent; while accurate figures are important, the differences in scale are more relevant for this report, which is based on qualitative research. Here we are interested in finding which factors can explain differences in trends – and for such a focus, the approximation approach of defining national prosumer figures is adequate.

1.1.2 What factors may explain differences in prosumer figures?

It is difficult to attribute the effects of a wide set of circumstances. To establish as robust a framework as possible, we provide two sets of explanatory factors for the differences in prosumer figures in a country. The first is based on *basic national structural conditions and problem characteristics* (Bailey et al. 2012; Inderberg and Wettestad 2015), which shape the way to achieving high numbers of prosumers. These factors are often path-dependent; they may vary in type and relevance and must to some extent be determined for each case. Typical factors are natural resource endowments and institutional structure (polity, etc.), price levels, energy sources, emission portfolio, and long-term interest constellations in the electricity sectors.

The second explanation recognizes these conditions, but emphasizes how national dynamics have led to a further shaping of such differences. As the structural conditions may be static or slowly changing, the main policy relevance lies within the dynamic factors that can be influenced politically and can lead to differences in prosumer figures – controlling for the structural conditions. We have approached this by seeking to map the most likely relevant factors that are under the control of politicians and regulators, while controlling for structural and slowly changing characteristics in the countries themselves.

In dividing up such dynamic factors, it is important to note that all such factors can work as barriers or as drivers for prosuming (IEA-RETD 2014). We discuss each factor below, sorted into three categories: economic incentives; direct regulatory requirements; and information practices and market availability. There are several factors under each of these headings:

- **Incentives**, such as support schemes, renewable energy schemes, tax benefits, electricity prices, etc. These can also be non-economic.
- **Direct regulatory requirements**, of direct or indirect effect. These may include building codes, (local) planning regulations, smart-meter requirements, and other relevant energy market regulations. Also relevant for this mechanism is 'official prosumer bureaucracy', like the degree of official facilitation, or absence of goal conflicts, for becoming a prosumer.[1]
- **Information practices and market availability**, such as governmental bodies at various administrative levels with mandate to forward prosumer practices and inform about relevant support schemes, assist in application and regulatory processes, spreading general knowledge about prosumer opportunities, etc.

[1] Perhaps this should be a fourth category of mechanisms – official bureaucratic facilitation to becoming a prosumer – as a separate part of prosumer policy. For simplicity, we include it in the second category.

Also in this category are certification practices, and the existence of a third-party market for technical installations.

The literature has variously identified these factors as influencing the motivation to become a prosumer, and influencing aggregate prosumer figures (IEA-RETD 2014). As all three countries have similar obligations under EU regulations – Germany and the UK (as of this research) as full members and Norway under the EEA agreement – we assume that the EU influence is fairly similar. Further, as the three have access to the same general global and European markets on the aggregate, we assume that access to *general* technical developments are roughly similar. However, the establishment of local third-party markets may vary significantly, and this is therefore included in the factors analysed (in the third group of explanatory factors).

1.1.3 Structuring the comparison

In view of the large contextual differences, establishing a relatively rigid structure – mapping the same factors for each country – is intended to increase comparability. This may prove challenging, as precise comparison of several aspects of the explanatory factors can be difficult. Tax benefits, incentive programmes and other factors comprise a complex whole and are difficult to compare in a structured manner. Therefore we draw on interviews and qualitative data where quantitative data are not available, seeking to compare the influence on the dependent variable *national prosumer figures*.

This amounts to a *focused and structured comparison* of the national cases. Here, 'focused' relates to scope: we analyse a limited set of propositions (George and Bennett 2005, 67), which can be further narrowed down as we progress. 'Structured' means that we map the same factors for each country case, so as to ensure systematic comparability (Collier 2003).

Attribution of effect of policies deserves further explanation. Attribution will never be perfect, but there are some tools available to increase reliability. The first, *cross-case comparability*, represents cross-case structured comparisons. Examining factors that are as similar as possible, by controlling for national characteristics, enables us to identify factors that lead to similar outcome across the cases. Second, diachronic comparison, or within-case comparison, help us to isolate the effects where change in one factor leads/ does not lead to a difference in prosumer uptake. For example, in Germany and the UK, there have been changes in support systems that facilitate comparison of circumstances prior and subsequent to alterations, with greater robustness for the findings. Thirdly, through *expert interviews* we can elicit competent opinions as regards the effects of the various factors on national prosumer figures.

The main analysis includes attributing effects of incentive structures and other framework conditions on prosumer uptake, under the main assumption of a rational actor. However, the assumption of a rational actor in a strict sense is not likely to be complete, especially not for early adopters. First movers necessarily have a lower threshold for certain kinds of behaviours, not least as regards risk taking. Additionally, in other parts of the project, we find that there are certain motivations and factors for becoming prosumers that may differ from what an aggregated rational actor model would predict. For example, Norwegian prosumers have tended to be male. However, these findings are neither sufficiently processed nor theorized usefully to generate insights for a qualitative national case-study; and, as this report seeks to analyse macro-trends for when more prosumers become phased into the Norwegian system, a rational actor model seems reasonable for large numbers. Here it should be borne in mind that motivating factors are likely to change from those of the first movers, to resemble more traditional patterns of individual market behaviour.

The PfP project indicates that in Norway the existence of a ‘first mover’ group of prosumers, who do not always fit ordinary consumer (prosumer) profiles in terms of motivations [Ref: Bell and Winther *unpublished/2016]. Such persons tend to find the idea of prosuming very attractive; we have seen several examples of such individuals going to great lengths to become prosumers, also at unfavourable economic costs.

As the market evolves, the first movers seem to be contributing by influencing procedures, routines and even regulations, ironing out certain bureaucratic difficulties, and thus becoming part of the process that enables more ‘ordinary’ prosumers to emerge. However, as this report studies the reasons for prosumer numbers comparatively, it is more logical to focus on what is expected to be more traditional behaviour, and use the rational perspective in explaining this.

1.1.4 Data availability and acquisition

The national studies rest on quantitative (mostly statistics) and qualitative data from a range of sources, depending on the availability and organization of relevant information in the three countries. Mapping of relevant factors for the dependent and the independent variables involves desk-study approaches, like collecting official information (public statistics, assessment of regulations, etc.), as well as high-level interviews with officials and stakeholders with expert knowledge. We have mapped and analysed available documents: official reports, public hearings, internet web sites, research articles and reports, laws and regulations, as well as third-party consultancy reports.

In addition, in order to map processes for future regulation, interviews were conducted with the regulator and an electricity utility. We have also benefitted from more than 70 interviews conducted in Norway, of stake-holders, prosumers and authorities. The need for interviews varies, depending on the availability of other sources of information, and has been determined for each country case. Norwegian interviewees were also asked to assist in mapping relevant measures, in addition to attributing the effects of these. Such subjective but external attribution of effect has served as an important measure for reducing the problem of potential researcher bias in attributing effect to prosumer uptake in the system.

1.2 Structure of the report

The report proceeds as follows: Chapters 2, 3, and 4 present individual analyses of Germany, the UK and Norway, respectively. These chapters follow a similar structure and use the same framework in analysing prosumer numbers for these countries. Chapter 5 then compares the findings from the case countries at a general level, discussing how different starting points (natural characteristics), different incentives, direct regulations, or information practices and access to third-party markets may have influenced prosumer numbers. In Chapter 6 we conclude that the absence of bureaucratic hurdles, combined with the presence of economic incentives (typically feed-in tariffs: FITs), has been instrumental in providing a market, technological development, and high prosumer numbers. These factors are not necessarily readily transferable to Norway – although if achieving high prosumer numbers is an official goal, this mix is likely to prove effective there as well.

2 Germany

Germany is often seen as a frontrunner in transforming its electricity system from one based on fossil and nuclear fuels into an energy system based on renewables. Key legislation shaping the course of this energy transition was enacted back in 2000. It has since been adapted several times to meet the new requirements of system and market integration of renewables, as well as further market and societal developments. These developments have also had implications for the growth of prosuming.

The most striking feature of Germany's energy transition is the rise of new energy actors: small-scale investors in renewables, like private households, farmers and energy cooperatives. This is particularly evident in photovoltaics, where these actors accounted for some 46% of installed PV capacity in 2012 (trend:research/Leuphana 2013). Photovoltaics has become the most rapidly growing source of renewable energy for the residential sector, in Germany as well as worldwide.

Most German residential PV system operators today also consume some of the electricity they produce on-site. However, the concept of 'prosumers' has not yet been officially used in German energy policy. Political incentives have served to trigger household micro-generation in particular, but the main objective was to stimulate RES production more widely. Germany's renewable energy policy is motivated by concerns for climate protection, not least the desire to transform a CO_2-intensive energy system into a low-carbon energy system without further use of nuclear power. Households and other small-scale actors proved more responsive than established energy-actors to the regulatory framework, which included a support scheme for renewables.

Prosuming in Germany should be analysed against the backdrop of the core aim of national energy policy: to organize a low-carbon transformation of the entire energy system. This can explain why specific stimulation of prosuming has never been the overarching goal of energy transition efforts. In fact, up until 2009 it was mandatory to feed into the grid any renewable electricity reimbursed within the German Feed-in-Tariff scheme.

Consequently, the self-consumption aspect of prosuming was not explicitly desired in the early phase of the transition process – except for a brief period, for reasons of grid stability. And then, the achievement of grid parity by about 2012 provided the economic rationale for self-consumption of residential PV power, and prosuming became a new business model for the whole solar branch in Germany.

Germany now finds itself at the beginning of a new phase in the transformation of its power system; however, prosuming is not uncontested. Distributed power generation on the one hand, and more decentralized consumption in the form of a certain degree of grid defection on the other, have consequences for the future architecture and functioning of a formerly centralized electricity system, as well as for actor structures.

The current German debate on prosuming centres on issues of grid stability, system integration of the greater amounts of distributed and volatile renewable energy sources, and grid-optimized demand and feed-in management. Also important are the societal costs of this transition.

Although prosuming, as understood in this report, is now practised extensively in Germany, that is more the result of a dynamic incentive structure set by regulatory provisions as well as market developments and the continuing interplay between these factors, and less the result of a targeted prosumer policy. This case-study maps these factors and their interplay over a period of more than 20 years, also noting Norwegian efforts to stimulate prosuming.

In Germany, official statistics are not categorized in terms of prosuming and self-consumption. This case-study has used and combined official German data concerning residential PV micro-generation to achieve approximate figures on prosuming. That is not a perfect approach but is the most robust, given the statistics available.

The typical size of *residential small-scale* PV systems is a maximum PV system's capacity of <10 kWp. This nominal capacity is relevant, as all official statistics in Germany on installed capacity of RES distinguish by system size and not by ownership. The PV system size of <10 kWp is used in this report as a proxy for residential PV.

By 2014 this segment (i.e. below 10 kWp) accounted for 56% of all PV systems installed in Germany: in practice, that means 850,000 PV systems (1.5 million PV systems in total). In terms of *total* installed PV *capacity* as of 2014 (around 38 GW) the segment of PV systems below 10 kWp accounted for 13% (5,062 MW).

2.1 Germany's national energy sector: mapping the contextual background

2.1.1 Historic developments and national energy transition efforts[2]

From the 19th century, coal constituted the main energy source for power generation in Germany. The Ruhr Valley mining area became the country's core industrial region, shaping cultural and economic development at that time. In the 1950s the use of oil and nuclear power became more common, while the use of coal started to decline. In the 1970s, nuclear power began to become the target of major national public protest and a grassroots movement evolved.[3] In the aftermath of the 1986 Chernobyl disaster and triggered by the greening of the electorate, in the 1990s Germany began to establish a legal framework aimed at promoting the deployment of renewable energies. With the Electricity Feed-In Act of 1991 and the adoption of the Renewable Energy Act (EEG) in 2000,

[2] For a detailed overview see Hake et al. 2015.
[3] The German anti-nuclear movement evolved into one of the origins of the Green Party, founded in 1980 in West Germany.

the basic policy instruments were created for politically prioritizing renewable over conventional power (Hake et al. 2015).

The first agreement on phasing out Germany's nuclear plants was reached in 2000 under the Social Democrat–Green coalition government. In 2010[4] this decision was reversed by the new conservative–liberal government, but then the nuclear disaster in Fukushima in March 2011 later prompted the same government — driven not least by Chancellor Merkel's responsiveness to the anti-nuclear public mood — to agree to a renewed nuclear phase-out.

Although key pieces of legislation regarding the energy transition, such as the Renewable Energy Act, had been enacted a decade earlier, the policy programme that became known worldwide as the *Energiewende* ('energy turnaround') is often attributed to the decisions made in 2011 by the Conservative-Liberal government. Immediately after the Fukushima disaster, the government shut down Germany's seven oldest nuclear power plants and appointed an Ethics Commission for a Safe Energy Supply, mandated to prepare political consensus on German nuclear policy after Fukushima (see Schreurs 2014). The Commission's recommendation to phase out nuclear energy by 2021 legitimized the final phase-out of nuclear power, adopted by Cabinet decision in June 2011.

On the basis of the recommendations of the Ethics Commission and important policy decisions made by the German Bundestag, the pathway to a low-carbon energy system came to involve nuclear phase-out, increased RES in the energy mix, and greater efficiency. In 2013 the new 'Grand Coalition' government adjusted the official target, adopted in 2011, of increasing the share of renewable energies in the country's power mix to 40–45% by 2025 and 55–60% by 2035. The coalition government added legal provisions for defining corridors or caps on annual capacity additions by RES technology.

2.1.2 The technical system and the energy market

Electricity production

By 2015, total gross electricity production in Germany stood at around 647 TWh. With a share of approximately 42%, coal (hard coal and lignite) still dominated the power mix, but the importance of renewables has been growing, with a share of 29%. Nuclear power, to be phased out by 2022, had become less significant, accounting for only 14% of the total power production in 2015 (see Figure 1).

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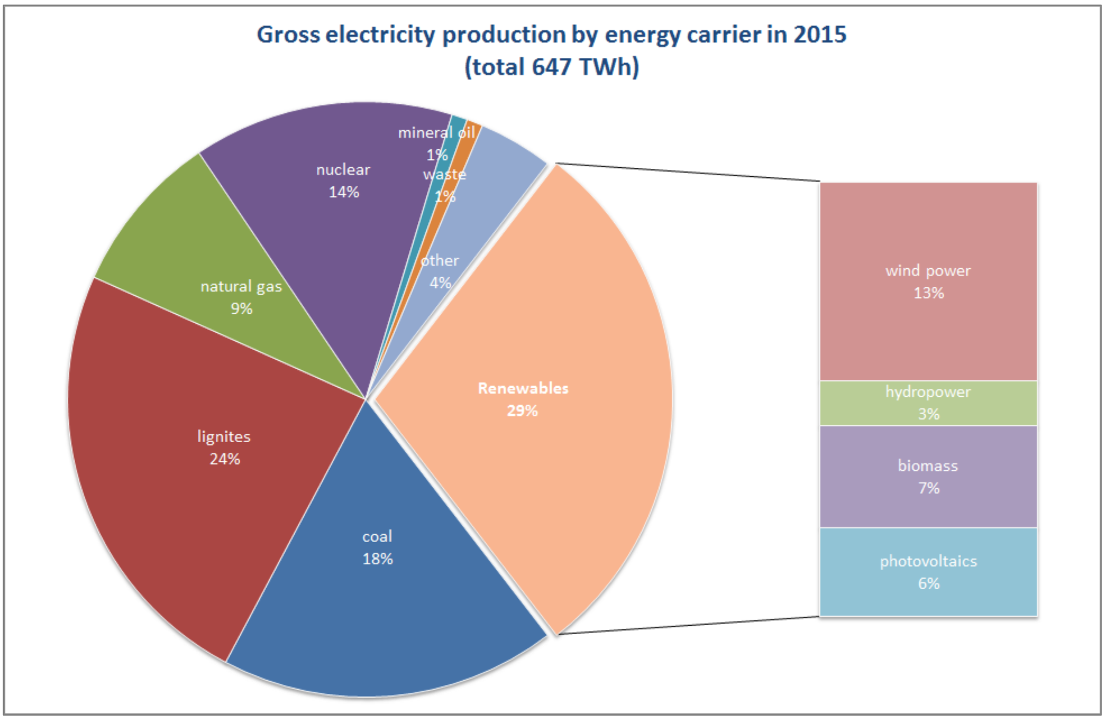
[4] In 2009 a coalition government of Christian Democrats and Liberal Democrats came to power. Under pressure from the new liberal coalition partner (FDP), the government decided to follow a market-oriented approach to energy and climate policy that would treat all low-carbon technologies equally, instead of 'discriminating' in favour of certain technologies in order to achieve climate targets. The new government rejected the nuclear phase-out and announced significant extensions to the lifetimes of the country's existing nuclear power plants.

Figure 1: Germany's Power Mix, 2015



Source: Own illustration, based on BMWI Energiedaten, (n.d.) version 05.01.2016, table 22.

Germany is amongst the European countries with the highest share of renewable power — mostly photovoltaics (PV) and wind — in terms of installed capacity. Distributed over 1.5 million power plants, the total nominal power of installed PV increased to approximately 38.5 GW in the year of 2014, contributing significantly to Germany's power supply (Fraunhofer ISE 2015).

Consumption patterns

Electricity consumption by industry accounts for half of the total consumption, with the residential sector and smaller business customers each accounting for about a quarter of electricity consumption (Agora Energiewende 2015). Further same year, electricity in private households accounted for 19% of final energy consumption in the household sector (Arbeitsgemeinschaft Energiebilanzen 2014).

Germany aims to reduce its gross electricity consumption by 10% (base-year 2008) by 2020. In 2014, gross electricity consumption was 576.3 TWh, which was 3.8% less than in 2013 (Agora Energiewende 2015). Although electricity consumption in general has been declining for about a decade (BDEW 2014), private household electricity consumption rose by 18.1% between 1990 and 2013 (Bundesumweltamt 2015).In fact, that increase can be attributed to the increase in the *number* of households: *average household size* is decreasing. In 2014 there were 40.2 million households in Germany – and single-person or two-person households accounted for 75%. Single-person households now account for 41% of all

German households, an increase of about 9% in the past 10 years (Destatis 2016). Average electricity consumption in the German household sector is about 3,100 kWh/a.

About half of German households live in rented flats or houses. Home-ownership rate was just 52.5% – rather low compared to other European countries (Eurostat 2013).

Electricity prices

Electricity prices have risen for households and industrial customers in recent years. Much (but not all) of this increase can be attributed to the cost of the energy transition — increases in the EEG surcharge in particular.[5] The costs of the EEG surcharge are distributed among the various consumer groups, whereby non-privileged consumer groups[6] (such as private households) bear the highest economic burden (Mayer and Burden 2014; see Figure 2).

The debate on the social acceptability and affordability of the energy transition in Germany has focused on the level of the EEG surcharge and its fairness. As there has been no comparably fierce public debate on rising prices for other household energy carriers (gas, heating oil, petrol), strict governmental regulation of electricity prices serves as a kind of invitation to politically renegotiate administered price components, whereas other price components or rising prices for other energy carriers that are contingent on anonymous market mechanisms escape such influence (for a critical discussion see Gawel et al. 2016).

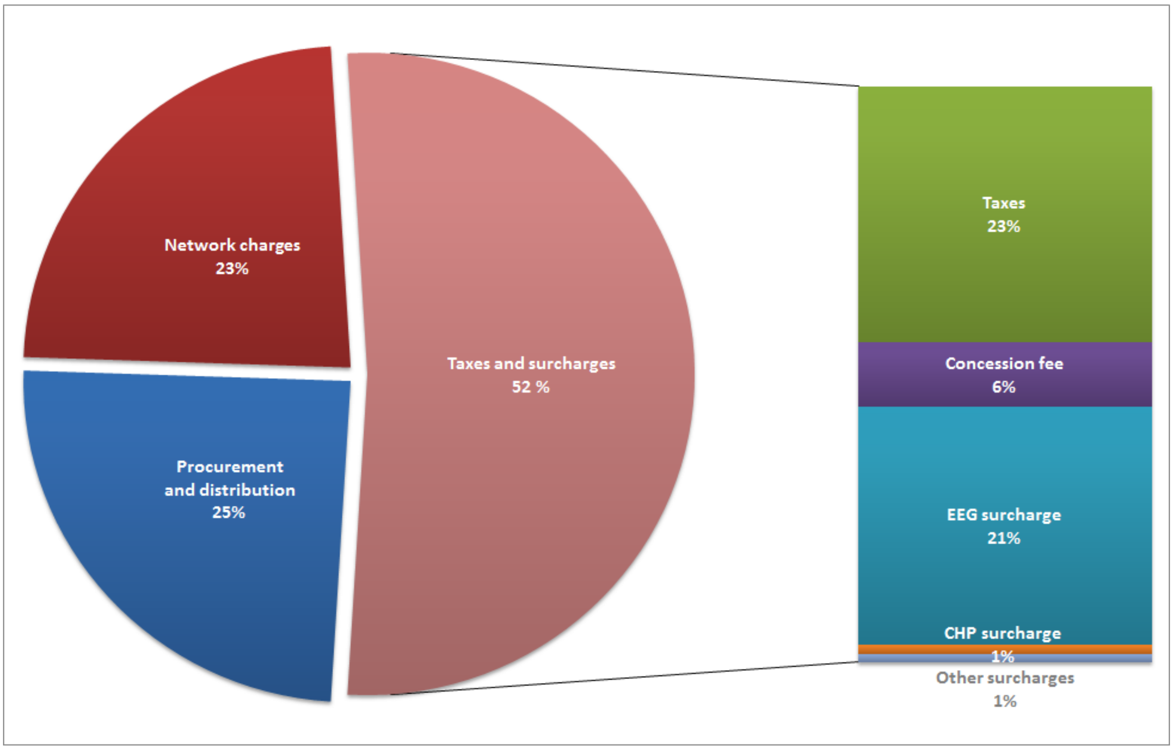
In general, German residential consumers pay very high electricity prices – in Europe exceeded topped only by household electricity prices in Denmark (Eurostat 2014).

[5] The EEG surcharge is added to the price of electricity per kWh consumed; it serves to cover the additional costs of promoting electricity generated from renewable energy sources.
[6] Non-privileged consumers are those who pay the full EEG surcharge. In contrast, exemptions to the EEG surcharge are granted to German electricity-intensive companies for reasons of international competitiveness.

Figure 2: Average household electricity prices, Germany, 2007–2015

Source: Own illustration based on BDEW 2015

Figure 3: Composition of the German average household electricity price in 2015



Source: Own illustration based on BDEW 2015

Status of smart-meter rollout in Germany

Germany has lagged behind in introducing ‘smart meters’ in private households. The main driver for the introduction of smart metering was the EU regulation on the liberalization of the electricity market, energy efficiency policy and — associated with both — the legal provisions for the introduction of smart tariff structures, which offer customers active participation in the liberalized market and/or electricity suppliers and energy service providers active demand-side management.

Through an amendment of the German Energy Industry Act (EnWG) in 2008 and the introduction of a law on the liberalization of metering, the regulator transposed basic EU provisions into German law. The regulator had relied exclusively on market dynamics – the demands of electricity end-users in particular (Tews 2011a: 22pp). However, it soon became clear that this was not a sufficient incentive to trigger a large-scale rollout of smart meters.

Since the amendment of the Energy Industry Act (§21c, EnWG) in 2011, the regulator has an obligation to install smart meters for the following cases:

- final consumers with annual electricity consumption over 6000 kWh,
- *new* generation facilities pursuant to the national Renewable Energy Act and the Combined Heat and Power Act with an installed capacity of >7 kWp, and
- final consumers in new and renovated buildings (this provision is to be abolished by the next reform of the EnWG).

According to the provisions of the EnWG (2011), smart metering is meant to enable consumers to participate better in the market by offering a choice of smart tariffs (time-of-use, etc.). Furthermore, it is intended ensure transparency and control of electricity consumption by the final user, in order to tap into energy-efficiency and cost-saving potentials.

In November 2015 the cabinet adopted the government’s draft bill on ‘The Digitization of the Energy Transition’. Unlike most other EU member states, Germany will not pursue a large-scale rollout of smart meters or smart-metering systems. The cost-benefit analysis for Germany, according to EU Directive 2009/72/EC (Ernst & Young 2013), did not recommend such large-scale rollout targeting all households by 2020, because the costs of smart-metering systems for final users with low annual consumption levels would far outweigh the average potential for annual energy and cost savings. A stepwise rollout of at least basic smart meters and/or advanced metering systems is expected to start in 2017. Priority will be given to large consumers with greater potentials for energy saving and load-shifting. However, the installation of at least basic smart meters for *all* consumers should be finalized by 2032. The draft bill also introduces price/cost caps for the installation and operation of smart meters, based on cost–benefit analysis which considers the cost of the smart meters and the benefits they offer in terms of savings and load-shifting. (See also Tews 2016.) Following public consultation, the law was adopted by the Bundestag on 23 June 2016. The Federal Council (Bundesrat) is finalized the law on the 8th of July 2016.

2.1.3 Main actors

Energy policy actors

The national regulatory framework for energy policy is developed at the federal level. However, Germany has a multilevel federal system, so the subnational level not only implements federal law but also enjoys legal, administrative and budgetary competencies. States, counties or municipalities can, for example, specify their own renewable energy policy targets and the policies and measures for achieving them. Particularly relevant for the deployment of renewables — especially for those with a spatial impact — are the subnational level's competencies with regard to spatial planning.

The most obvious political challenge to Germany's current process of energy transition is the lack of multi-level coordination, due to the multiplicity of strategies for expanding renewable energy that have been developed by municipalities, counties, regional states and the federal government, often with scant inter-connection. Thus far, governments in different jurisdictions have primarily heeded their own interests in making decisions about renewable energy targets and implementation policies (see also Ohlhorst et al. 2013; Klagge and Arbach 2013; Schreurs and Steuwer 2015).

At the federal level, primary responsibility for the electricity sector lies with the Federal Ministry of Economic Affairs and Energy *(Bundesministerium für Wirtschaft und Energie: BMWi)*, although the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety *(Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit: BMUB)* has some competencies in the electricity industry as well.

Independent regulatory authorities

With the liberalization of European energy markets, also the German electricity market began to open up in 1998, allowing new actors to enter for the sale of electricity and provision of services. In addition to the core EU-level regulation, supervision of competition at all levels of the market remained the responsibility of the Federal Cartel Office *(Bundeskartellamt: BkartA).* The Federal Network Agency *(Bundesnetzagentur: BnetzA)* is responsible for the regulation of natural monopolies like grids, telecommunications and postal services. Its central task in the energy field is to ensure non-discriminatory third-party access to the grids and to authorize calculations on the network charges made by grid operators. The BnetzA and the regulatory authorities at the state level are responsible for expansion and/or optimization of the electricity grids. Both agencies fall under the authority of the BMWi.

Energy industry actors: incumbents and challengers

Even though Germany has unbundled much of its electricity generation, transmission, distribution and retail activities, the four large power companies E.ON, RWE, EnBW and Vattenfall are still the ‘big’ players in the power market. However, with the growing share of renewables in the power mix, the ownership profile of electricity production has changed. The price-based support scheme for RES (Renewable Energy Act, see section 2.2.1) worked as a shield, allowing small-scale renewable electricity producers to develop in a niche. For the ‘big four’, the returns on investment were apparently not seen as sufficient to trigger investment in the then-niche segment of the electricity market. However, faced with increasing losses in their traditional business and with renewables becoming less of a niche, they realized the need to adapt their strategies to the new realities (Kungl 2016). Here it should be noted that in Germany there is still a substantial difference between the ownership profiles of conventional and renewable electricity generation. Whereas the ‘big four’ control most conventional generation, they hold only a 5% share of renewable resources (Agora Energiewende 2015). New actors have challenged established interaction patterns in domestic energy policy through experimentation and innovation at a decentralized level (Beermann and Tews 2016). According to a survey conducted by trend:research GmbH and the Leuphana Universität Lüneburg (2013), nearly half (46.6%) of total RES capacity installed in Germany is owned by members of the public and energy cooperatives.

In the transmission sector, the key players are the four regionally fixed transmission system operators (TSO) TenneT TSO GmbH, Amprion GmbH, 50 Hertz Transmission GmbH and TransnetBW GmbH.

The distribution and the supply branches are more complex, and are characterized by a vast figure of companies. Approximately 900 distribution grid operators (DGO), including the four major companies, as well as around 700 municipal utilities *(Stadtwerke)*, currently serve 20,000 municipalities (Agora Energiewende 2015).

There is an ongoing trend to *re*-municipalize distribution grids: energy services are being returned to public municipal management. This move has been buttressed by the expiry after 20 years (since the Energy Industry Act (EnWG)) of many ‘concession agreements’ - private law contracts between municipalities and contractors for the use and operation of local distribution grids. Thousands of ‘concessions’ for operating electricity grids are to be awarded within the next few years. Several municipal utilities have become crucial drivers for local innovation. In some cases, the municipal energy utilities have even been ‘re-founded’ by members of the public and local political actors, to serve as decentralized local innovators in support of the renewable energy transition from below and to create added value at the local level (Beermann and Tews 2016).

2.2 Prosumer-relevant framework conditions in Germany

Various regulatory features and (predominantly politically induced) market developments are relevant for presuming. These may:

- enable or constrain private household investment in on-site RES, and PV in particular
- enable or constrain connection to the grid for feeding in RES power
- enable or constrain self-consumption of power produced.

2.2.1 Incentives for investing in household micro-generation

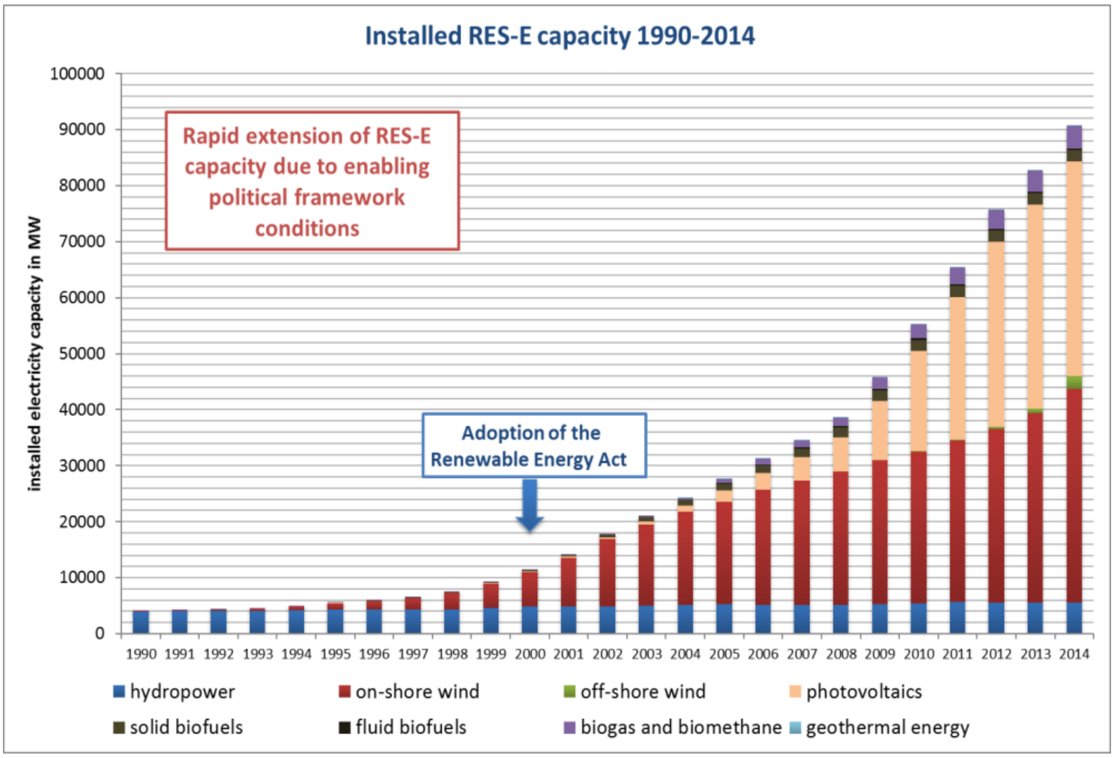
As early as 1990 the German government and the sub-national states had adopted a globally unique PV subsidy programme aimed at testing the practical functionality of small, decentralized, grid-connected PV systems: the ‘1,000 roofs programme’. The programme was aimed at first-mover households, for whom up to 70% of the costs of a small PV system (1-5 kWp) were subsidized. This programme ran until 1995 and led to the installation of around 2,000 PV rooftop installations on detached and semi-detached houses. The subsidy was linked to an obligation to submit yield data on the system for scientific evaluation of the maturity of the technology. Despite the rather high funding rate of 70%, households still had to make a personal contribution of on average around EUR 10,000 for a small 2.6 kWp PV system (Hoffmann 2008). Such investments were made mainly by early ‘pioneer’ adopters without realistic expectations of financial returns.

Another predecessor of the cost-covering remuneration scheme and a further milestone in the upscaling of PV in Germany was the Feed-in-Law *(Stromeinspeisegesetz)* passed in 1991, which set the first remuneration for PV electricity fed into the grid at an average of 8.5ct/kWh. Compared with the PV power generation costs of 90 ct/kWh at the time, this first feed-in-tariff was not really meant as an economic incentive intended to attract large numbers of investors: it targeted the pioneers who engaged in this ‘uneconomic’ investment. However, in 1999 a new grant programme was enacted under the name of the ‘100,000 roofs programme’. This programme supported the installation of PV systems larger than 1 kWp. Loans, with interest rates of 4.5% below market conditions, were offered with a repayment period of ten years and two years of deferred payment. The programme aimed to develop 300 MW of additional capacity. By the end of the programme in July 2003, support had been provided to some 55,000 installations and 261 MW of additional capacity.

Basic provisions of the Renewable Energy Act enabling household RES-investment

The most fundamental shift from experimentation to a programme for broader market diffusion occurred in 2000 with the adoption of the Renewable Energy Act (EEG). From the outset, this was a fine-tuned legal framework which mixed diverse policy instruments to stimulate the wide deployment of renewable energy sources. Since adoption in 2000 it has been amended five times: in 2004, 2009, 2012, 2014 and 2016.

Figure 4: Total installed RES-E capacity 1990–2014



Source: Own illustration based on data from BMWI Energiedaten (n.d.)

The basic provisions of the Act include

- a support scheme for electricity from renewables
- a purchase obligation for grid operators
- the solidarity principle in bearing the costs of RES deployment

Until the most recent reform of the Renewable Energy Act (EEG) in 2016, Germany applied a price-based support scheme for renewables, where also roof-top PV was eligible.[7] Support schemes for renewables can generally be divided into price-based and volume-based schemes (ecofys 2014). In contrast to volume-based support schemes that determine quantity targets for the expansion of RES (e.g. quota and auction systems), the support level for price-based schemes is administra-

[7] In 2014 and 2016 the support scheme underwent a fundamental instrumental shift. Direct marketing became mandatory for all newly installed renewable energy facilities with capacity of more than 500 kW (by August 2014) and 100 kW (by January 2016). In addition, instead of the existing feed-in tariff or premium tariff, by 2017, the level of support granted will be determined by a competitive bidding process. This is a volume-based auction system fundamentally different from the previous price-based support scheme with administratively fixed prices for RES. However, small-scale residential RES producers are still exempted from this instrumental shift (for details, see Tews 2015, Beermann and Tews 2016).

tively fixed: either independently of the market price by a set remuneration for every kWh of RES electricity produced, as with a guaranteed feed-in tariff (FIT), or linked to the market price with an additional fixed or floating premium, the feed-in premium (FIP). For a long time, the German support scheme was based solely on a FIT, which guaranteed producers a set remuneration depending on the specific RES technology for a certain period (usually 20 years). In 2012 the FIT was supplemented by the introduction of a floating FIP, which producers could choose as an option, in order to stimulate the market integration of renewables.

This price-based support scheme was complemented by a purchase guarantee and priority feeding-in of renewable electricity into the grid. Grid operators were obliged to accept electricity from third-party renewables actors, to feed in the electricity and to pay the fixed prices to the RES-producers.

The support scheme is financed by an EEG surcharge on electricity consumed in kWh (solidarity principle). This surcharge must be paid by all electricity consumers who are not exempted through special regulations (as are, for instance, the energy-intensive industries). The surcharge is calculated annually by the transmission system operators and reflects the differential between the grid operator's expenditures for funding payments to RES operators and revenues from selling RES electricity on the wholesale market. As of 2016, the surcharge amounts to 6.354 euro-cent/kWh (see also Figure 2).

The provisions of the EEG (as introduced in 2000) offered conditions that enabled private households to invest in on-site RE capacity.

Firstly, these provisions reduced the risks for investors through:

- fixed prices per kWh fed into the grid over 20 years
- technology-specific remuneration rates according to the maturity of the technology.

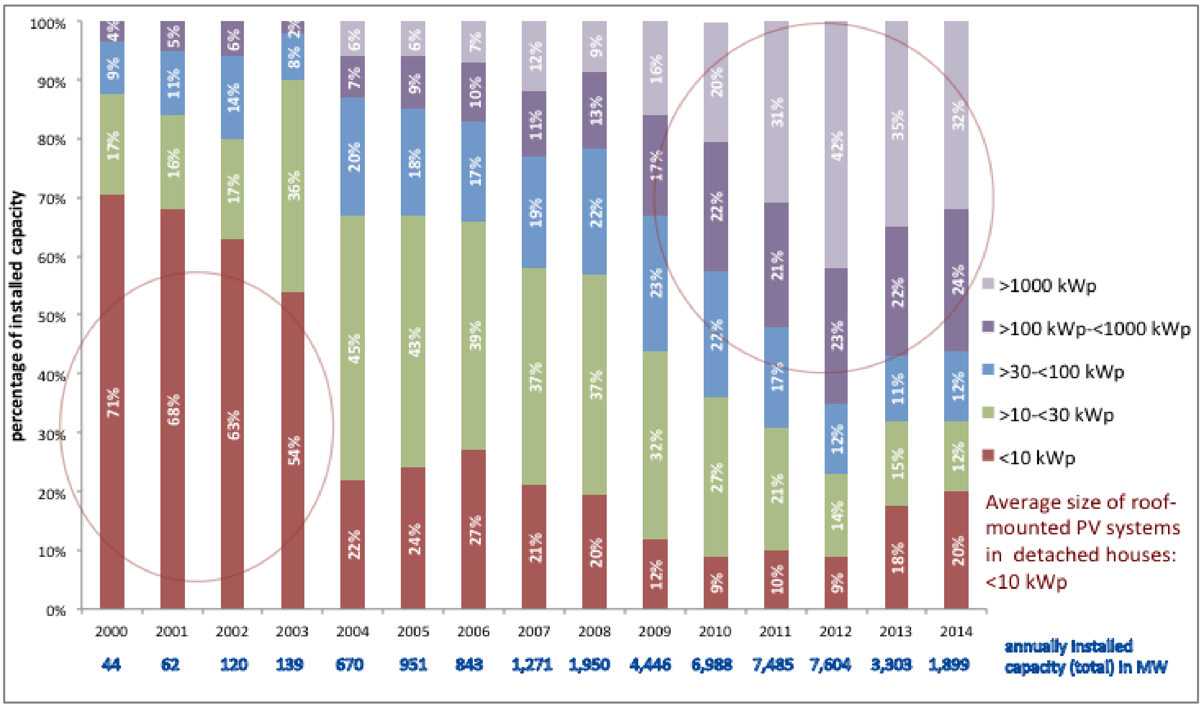
As risk reduction is most relevant for those actors who cannot diversify risks, these provisions offered favourable conditions for investment in PV by small actors, such as households or small-scale enterprises.

Secondly, further provisions, like the purchase obligation for grid operators and priority access for RES to the grid, minimized the transaction costs associated with selling RES. Low transaction costs in the trading of power are particularly relevant for new actors unfamiliar with the established rules in the energy field or market.

Thus, the Renewable Energy Act has offered a high degree of planning security for investors. It has shielded the investments of small-scale and new actors, and fostered small-scale RES -growth in a niche for over a decade.

This can be seen in the development of annually installed PV capacity, by system size, as shown in Figure 5.

Figure 5: Annually installed PV capacity by system size 2000–2014 – changes in structures (investors?) of newly added PV capacity/ over time



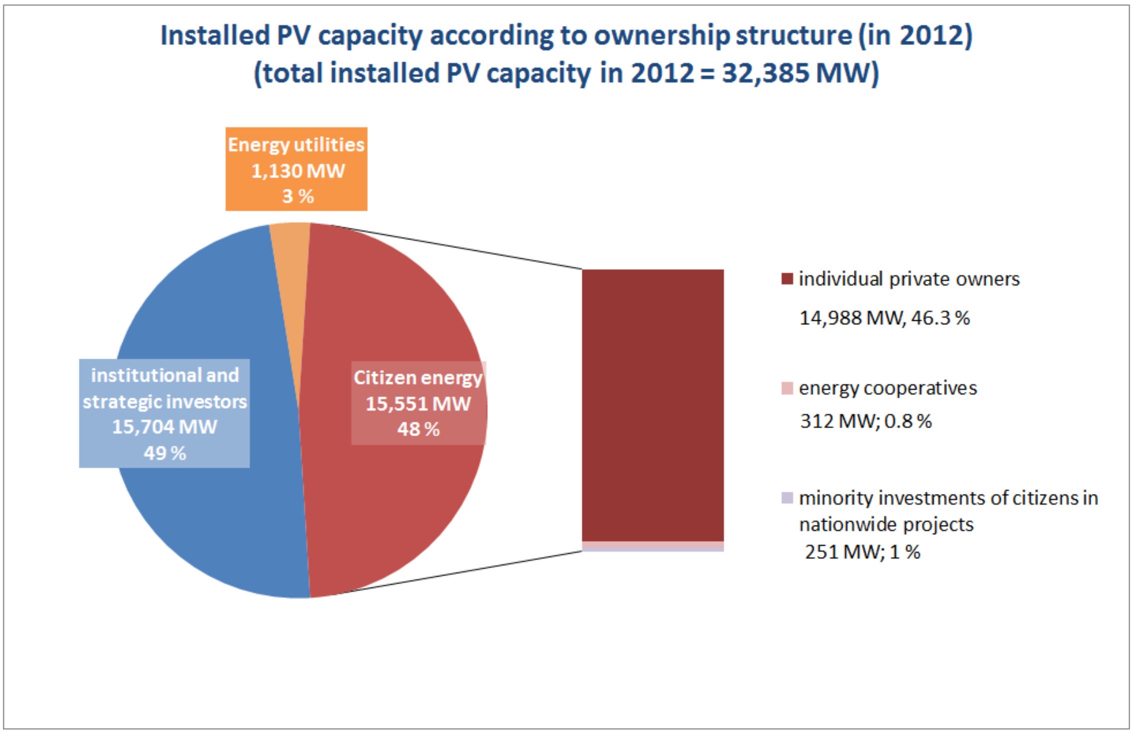
Source: Own illustration based on data compilations from ZSW 2014 (2000-2013) and Proteus Solutions GBR (2014) and BMWI Energiedaten (n.d.) (total installed PV capacity/year in MW)

Initially, newly added capacity mainly took the form of small-scale PV systems, but that has now changed. In 2014 small-scale investment accounted for only 20% of newly added *capacity*. However, regarding the absolute figure of annually added installations, systems below 10 kWp are still dominant.

Figure 5 indicates the significance of the EEG provisions for stimulating small-scale investment by private actors. The EEG politically pushed the market diffusion of this technology; investments by small-scale actors — households in particular— in roof-mounted PV encouraged further technological innovations in PV systems and lowered the price of PV systems.

This is one of the most striking features of the German energy transition: it was mainly driven by new actors — private individuals and energy cooperatives — often referred to as ‘citizen energy’. An ownership analysis of the German RES market has shown that, in photovoltaics, ‘citizen energy’ accounted for almost 50% of total installed capacity in 2012 (trend:research/Leuphana 2013) (Figure 6).

Figure 6: Almost half of installed PV capacity is 'citizen energy'/'power from the people'



Source: Own illustration (translation) based on trend:research/Leuphana 2013.

Note: The group '*citizen energy*' comprises individual private owners (single households, farmers and small cooperatives that install an RES plant/PV system in their region). Energy cooperatives are characterized as such only in cases where the individual's investment is at least 50% and investors come from the region where the RE plant is installed. The group '*institutional and strategic investors'* comprises investors such as banks, funds and insurance companies as well as actors from industry and business, for example agro-businesses and project developers. '*Energy utilities*' refers to the traditional 'big four' energy utilities as well as regional/municipal and international energy utilities.

Diverse additional grants at federal and sub-national level for PV

In some countries, grant-based financial support for renewables has been replaced by more comprehensive economic instruments like volume- or price-based support schemes for electricity fed into the grid. By contrast, in Germany there still exist, parallel to the FIT/P-scheme, various investment-support schemes at the federal and sub-national level for PV and other technologies aimed at reducing CO_2 emissions. The current grant for PV-system installations offered by the public KFW-Bank[8] is applicable only for grid-connected systems; additionally, there is a requirement for a storage system or DSM-enabling technology. This

[8] The German Bank KfW *(Kreditanstalt für Wiederaufbau)* is among the world's leading promotional banks. It is committed to improving economic, social and ecological living conditions in Germany and around the world on behalf of the Federal Republic of Germany and its federal states.

programme design reflects the requirements of a new phase in the transition process —integrating distributed electricity into the system, for reasons of security of supply.

Regulatory developments which worsen investment conditions for households

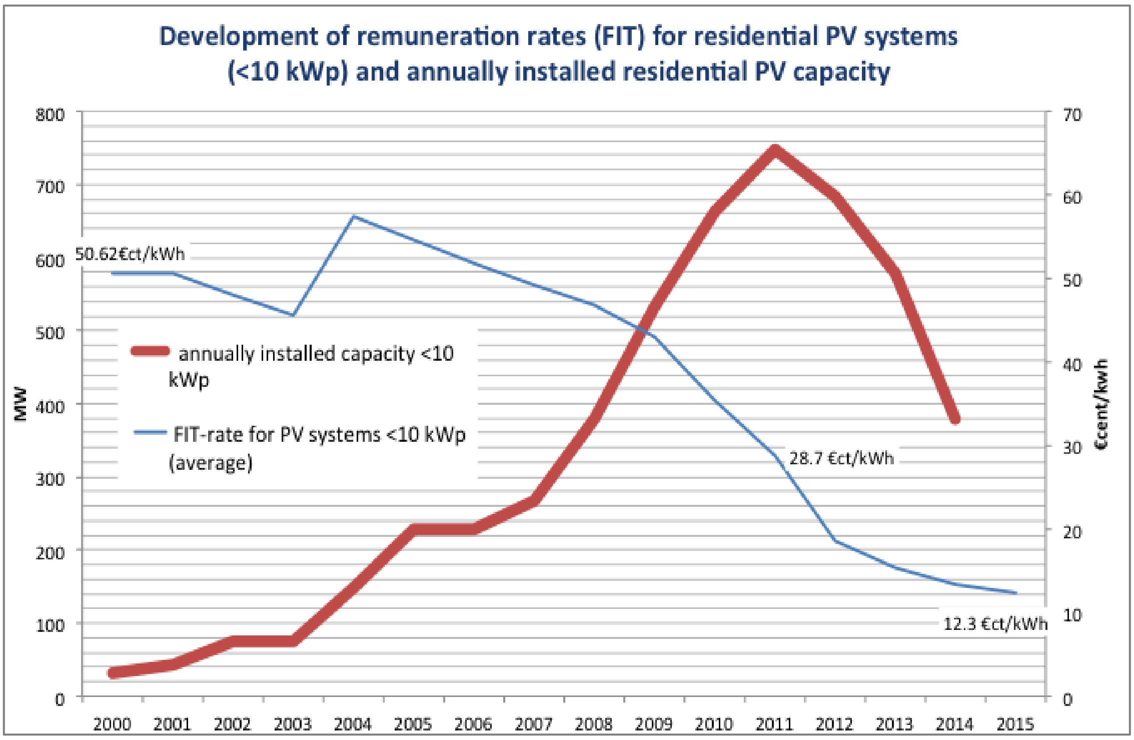
From the outset, the Renewable Energy Act has involved a kind of degression in remuneration rates according to decreasing system costs, i.e. the maturity of the technology in question. Thus, size of the feed-in tariff that an investor can expect depends on when the PV system/plant was commissioned. From that point on, the investor receives this specific remuneration for the next 20 years.

In the early phase of the support scheme, remuneration rates for PV were rather high – according to some critics, much too high – resulting in a boom in the PV market. But this boom also brought a considerable increase in the EEG surcharge, and much discussion about over-subsidization, social fairness and the erosion of the solidarity principle.

This led the government in 2012 to announce that the FIT for PV would be discontinued when a total cap of 52 GW installed PV capacity had been reached (at the time of writing, 38 GW PV have been installed). In addition, the government introduced in 2014 a soft cap of 2.4–2.6 GW per year and a *responsive* degression framework, i.e. the FIT was lowered on a monthly basis in response to the performance of the cap (flexible ceilings/corridors); these measures were to remain in place until the point that the total cap was reached.

If the rate of solar power expansion is placed within this defined annual corridor, that means a basic degression in remuneration of 0.5% per month. However, if more PV power is added beyond the defined annual cap, the degression of the FIT will be raised as well. Should less PV be added than defined in the annual corridor then there will be a degression lower than 0.5% or no degression at all (§13 EEG 2014). The rate of degression is calculated by the BnetzA. The remuneration rate for small residential PV systems of <10kWp has not changed since September 2015, and remains at 12.31ct/kWh (BnetzA 2016). This indicates a lower amount of annually added PV than defined in the annual corridor: between December 2014 and November 2015 only 1.4 GW of PV power was added (ibid).

Figure 7: Decrease in annually added PV capacity due to degression in remuneration rates

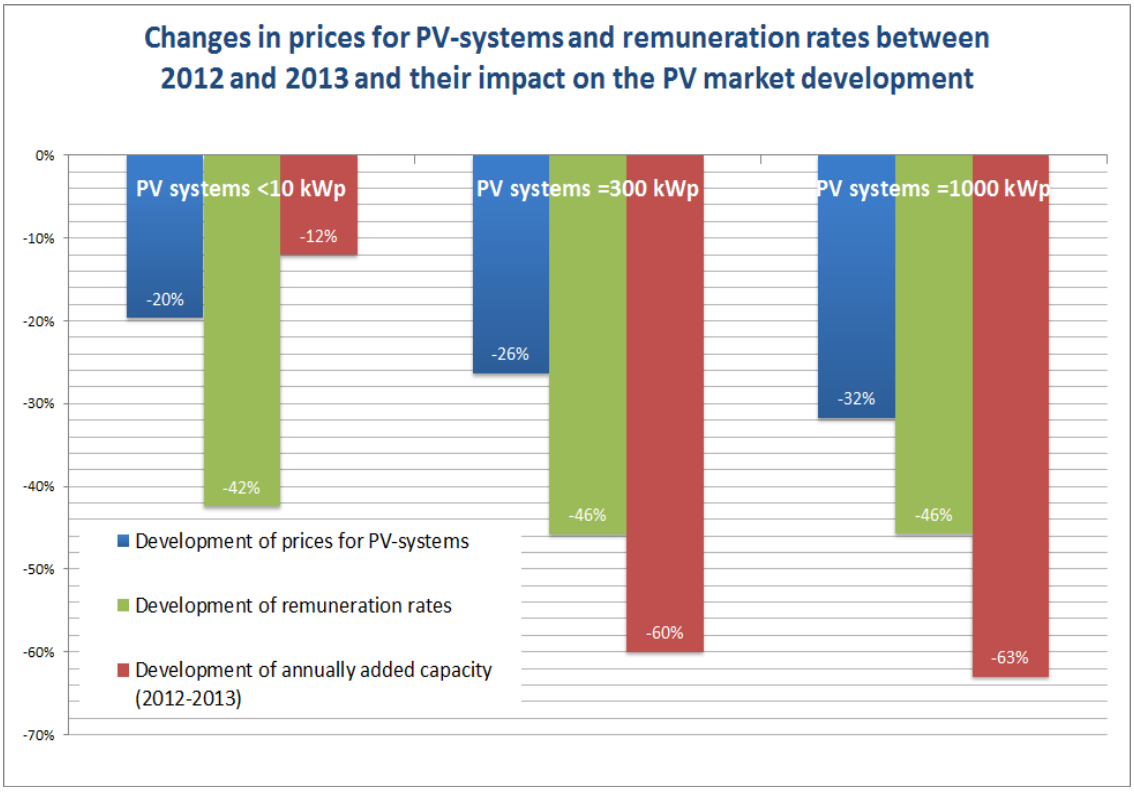


Source: Own illustration based on data from https://www.netztransparenz.de (remuneration rates); ZSW 2014 (installed PV capacity <10 kWp/year).

Especially since 2012, degression in the remuneration rates has already caused a massive drop in investment in PV capacity in the residential sector (Figure 7). This can indicate growing uncertainty among residential investors as revenue calculation becomes increasingly risky, with possible monthly fluctuations in remuneration rates as well as very low remuneration rates for PV.

However, the drop in the PV market has not been limited to small residential PV systems: it applies to larger PV systems as well. Remuneration rates decreased to an extent that cannot be balanced by the equally decreasing PV system prices (Figure 8). Thus, there is in general greater economic uncertainty across the entire German PV market. For residential systems, a study has even calculated that newly installed small systems can no longer operate economically without a high share of self-consumption (ZSW 2014: 37).

Figure 8: Uncertainty in the PV market due to decreasing remuneration rates



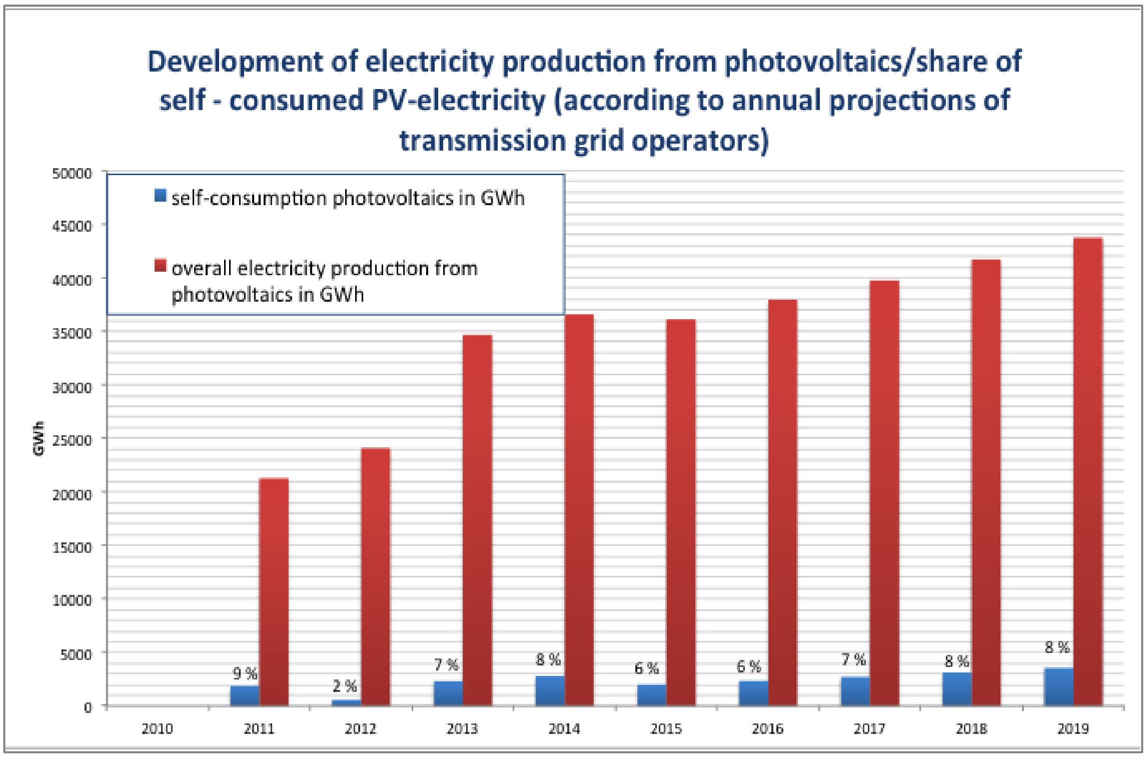
Source: Own illustration (translation) based on an illustration in BSW Solar 2014: Positionspapier des Bundesverbandes Solarwirtschaft e.V. zur EEG Novelle 2014, May 2014, page 1.

2.2.2 *Incentives for self-consumption*

Almost all PV systems in Germany are grid-connected systems. With the regulator's introduction of the Renewable Energy Act in 2000, self-consumption was not originally an intended policy. All electricity generated, subject to the EEG-support scheme, was to be fed into the grid. According to projections of the transmission system operators, self-consumption in the *whole* PV segment will be marginal in the future as well (Figure 9). For smaller PV systems, the situation has changed totally, compared to the earlier phases of the FIT-scheme — self-consumption has now become necessary to operate economically.

However, self-consumption of PV is highly contested in the debate about the cost-efficiency and social fairness of the German transition process — for different reasons. We begin with a brief overview of the development of the regulations relevant for self-consumption. Then we turn to relevant framework conditions, such as how to increase the rate of self-consumption, and finally the pros and cons of self-consumption, with special reference to the debate in Germany.

Figure 9: Share of self-consumption of solar power in Germany



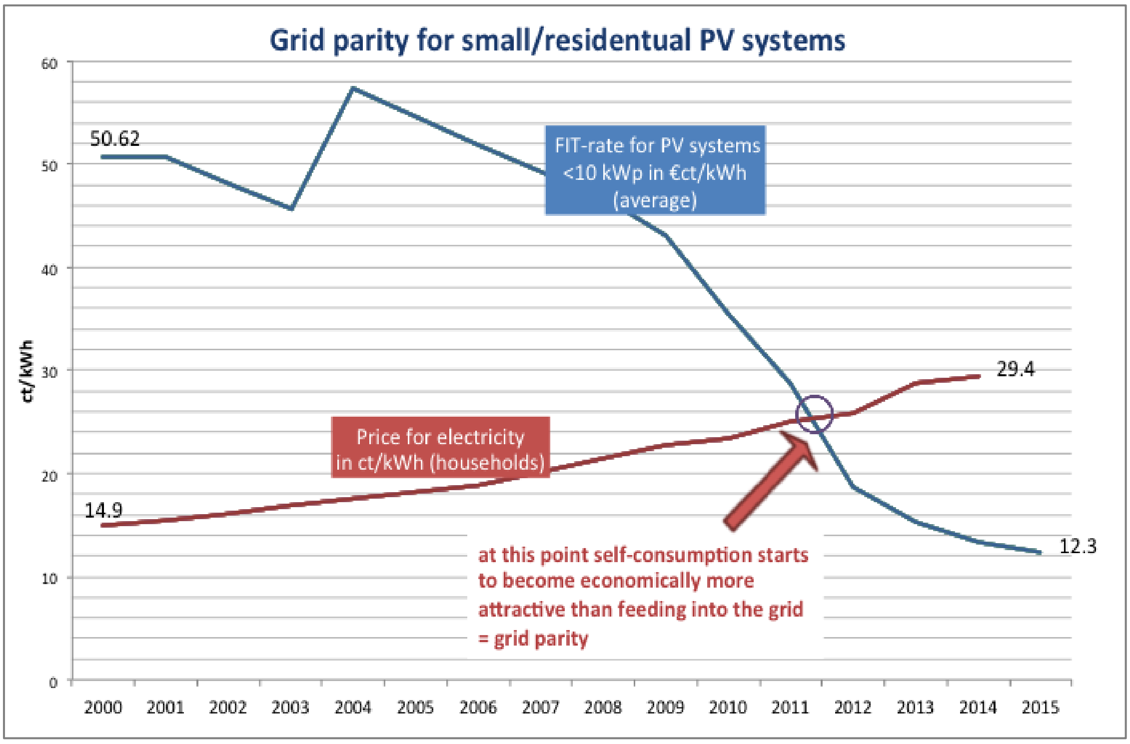
Source: Own illustration based on annual projections of the transmission grid operators (PROGNOSE DER EEG-UMLAGE NACH AUSGLMECHV, 2010-2015) and https://www.netztransparenz.de/de/file/2014-11-11_EEG_Mifri_bis_2019.pdf 2016-2019).

Interplay between regulation and market development relevant for household self-consumption of PV power

Up until 2009 all PV power had to be fed into the grid. High remuneration rates have triggered an extreme increase in PV production, especially from smaller distributed PV systems (see Figure 5). With the massive expansion of new distributed and volatile power capacities, the distribution and transmission grids were not sufficiently adapted to meet the challenges associated with integrating these volatile capacities at the same speed. Thus, in 2009, a ‘self-consumption bonus’ was introduced by the regulator in the context of the second reform of the EEG. This bonus was intended to stimulate self-consumption in order to prevent grid overload. The self-consumption bonus even allowed producers of solar power to receive payment from the support scheme (a reduced FIT rate) for the power they did not feed into the grid but consumed at home.

For prosumers, it became economically attractive to consume a portion of their own electricity instead of feeding all PV power into the grid, as the self-consumption bonus, plus the reduced costs of electricity purchased from the grid, guaranteed a surplus. However, the intended effect of reducing the risk of technical grid overload was not achieved. Most PV system operators could not increase their rate of self-consumption significantly, due to lack of storage capacity (high cost of battery systems) or the low potential for load-shifting in the household sector. The self-consumption bonus predominantly caused windfall effects.

Figure 10: The economy of self-consumption: grid parity



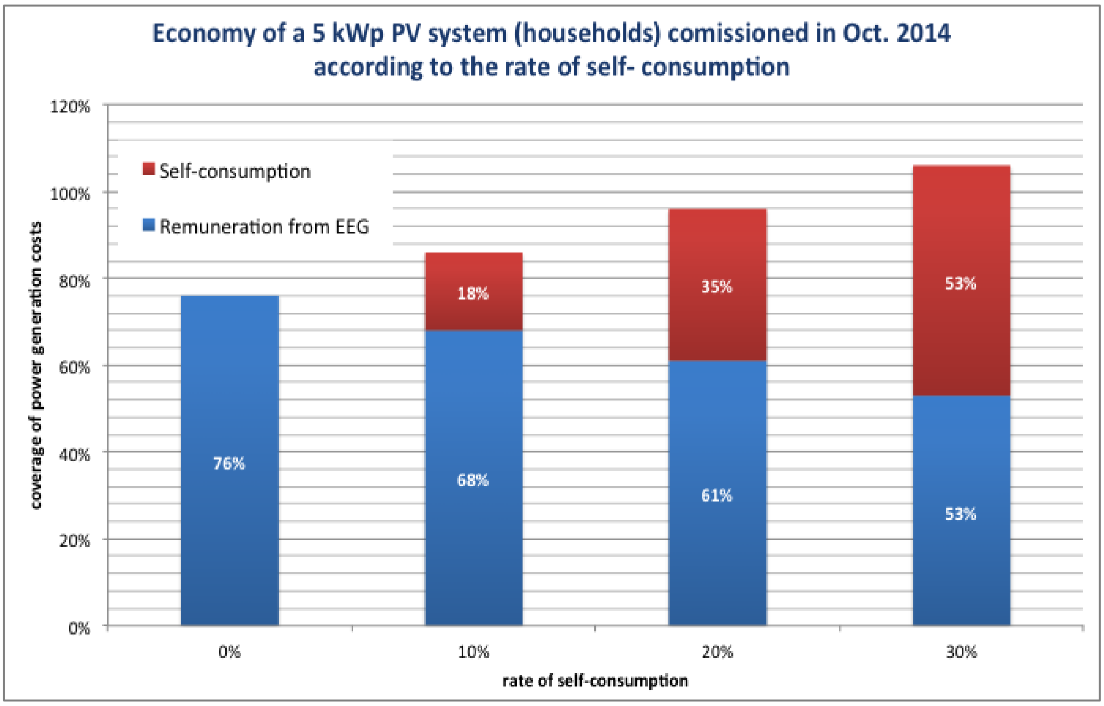
Source: Own illustration based on BMWI Energiedaten (n.d.) (prices) and https://www.netztransparenz.de (remuneration rates).

Note: Retail prices for electricity in Germany traditionally consist of a basic component, independent of the amount of consumed, and a price per kWh consumed, the 'working price'. For exact calculation of the grid parity it would have been better to use only the 'working price' for electricity consumed, as also prosumers will always have to pay the basic component as long as they consume power from the grid. However, due to lack of data and transparency on the composition of the retail price, I have used the retail price, as it is as a proxy for this illustration of grid parity.

In 2012 with the third reform of the EEG the self-consumption-bonus was phased out. However, the bonus was no longer necessary for incentivizing self-consumption, which had become economically attractive anyway by then. Grid parity was reached in around 2012 for small residential systems: rising retail prices for electricity and decreasing remuneration rates provided the economic rationale for self-consumption (Figure 10).

In 2014 with the adoption of the fourth reform of the EEG, the government introduced an EEG surcharge on self-consumed electricity. However, this surcharge was less than the general EEG surcharge (in 2015 it was 30% of the regular EEG surcharge, in 2016 35% and in 2017 it will be 40%). This provision was a response to fears of eroding the solidarity principle in bearing the costs of the renewable energy support scheme. The argument is that, since self-consumers satisfy their electricity needs partly with the power they produce themselves, they do not pay the EEG surcharge for all the electricity they consume – only for the electricity they purchase from the grid. That means that all other consumers who do not produce their own power must bear more of the total costs of the support scheme, which would result in an increase of the EEG surcharge.[9]

Figure 11: Economy of small-scale PV systems according to rate of self-consumption



Source: Own illustration (translation) based on data and illustration of ZSW 2014: 37.

A study commissioned by the Energy Ministry (BMWi)showed that small-scale PV systems cannot operate economically without both self-consumption *and* remuneration (ZSW 2014:37). Even at the current maximum rate of self-consumption (currently 20% is feasible) a residential PV system cannot operate economically without remuneration (Figure 11). The study recommended not extending the surcharge on self-consumed electricity to small PV system operators (ibid.). The regulator followed this recommendation; thus far, residential PV systems below 10 kWp have been exempted from the EEG surcharge on self-consumption.

[9] Although the logic of the argument seems clear at first glance, it ignores the fact that the solidarity principle has already been eroded by those legal provisions, which exempt an extensive number of (more or less) energy-intensive companies from paying the (full) surcharge, for reasons of competitiveness.

Opportunities and barriers to increase the rate of self-consumption in Germany

Achieving grid parity self-consumption became the most important business model for the further expansion of residential PV power in Germany. However, grid parity alone will not suffice to significantly scaling up the rate of self-consumption. As a reminder: only a maximum rate of about 20% self-consumption is currently technically feasible for small-scale residential PV systems without significant changes in consumption patterns (AEE 2014). Economically attractive operation of a residential PV system, on the other hand, is feasible only with a higher rate of self-consumption – 25% or more (ZSW 2014: 37, see Figure 11).

Technical studies indicate that an optimal match of on-site demand can be achieved only with battery systems. With these storage capacities, the self-consumption rate can be scaled up to 70%. Other means of increasing this rate, like smart-load or smart-consumption management, are estimated to bring the figure up to just 30% (AEE 2014). Both these options, however, are still deemed economically unattractive for small prosumers, for the following reasons:

1) The potential for households to switch consumption patterns is limited

Households have the potential to save electricity, in part simply triggered by understanding, and getting feedback on, their own consumption patterns (Fischer 2008, Vine et al. 2013, Fraunhofer ISE 2011). Households are equally able to shift consumption to a certain degree in order to respond to the market signals given by load- or time-variable tariffs (see e.g. Fraunhofer ISE 2011). However, studies have shown that these potentials are rather low (Ernst and Young 2013).

2) The necessary technical infrastructures and price incentives are not in place

Residential prosumer systems are already required to have meters or metering systems for:

- power consumed from the public grid (consumption meter)
- number of kilowatt hours fed into the public grid and remunerated according to the EEG (feed-in meter)
- number of kilowatt hours produced by own PV-system (yield meter).

These meters guarantee some transparency and feedback on own consumption patterns, but most of these meters are not fully prepared or developed to standards that can communicate with home appliances, etc., for a ‘smart home’ in the full extent of the word, or allow external control steering consumption and load patterns. Moreover, electricity providers do not offer electricity tariffs that might trigger load-shifting or electricity-saving behaviour, because of established accounting rules for residential customers and the lack of adequate intelligent metering systems. This results in a negative incentive structure for electricity providers to offer tailored tariffs for residential customers (Tews 2011a).[10] With the bill on digitization of the energy transition, adopted in June 2016, the government has introduced a stepwise rollout of smart-metering systems, to be mandatory from 2017 in all residential prosumer systems with capacity of >7 kWp. However, the primary reason for that provision is not to match on-site demand better with on-site production from the prosumer's perspective, but to match distributed feed-in of volatile renewable electricity better with grid capacity – especially as regards security of supply (see section 2.2.6).

3) Investment in storage capacity is still risky, but early adopters seem to be paving the way

The market for stationary energy storage[11] is still in its infancy and prices are relatively high. Investments in residential battery systems are risky from an economic perspective due to the uncertainty of future returns, which depend on the development of various factors, including household electricity prices, remuneration rates for feed-in and surcharges on self-consumption, as well as technological developments.

However, some early storage-adopting prosumers have started to invest in stationary storage capacities. Their motivations are often not economic, but to increase self-sufficiency and reduce dependence on grid electricity. Furthermore, grants offered by the public KWFbank for battery storage since May 2013, where systems smaller than 30 kWp are eligible, have offered an additional market incentive.

Further technological advances in battery systems and the potential decrease of storage prices are estimated to reduce investment costs, making them economically attractive from the prosumer's perspective in the near future (Fraunhofer Umsicht/Fraunhofer IWES 2014). Combined with the expected further decline in EEG remuneration rates and rising electricity prices, a high growth potential in the storage market is expected. Still, developers of storage and related systems (e.g. Tesla and Lichtblick) complain of regulatory uncertainties in Germany's partly unclear regulatory framework for electricity from battery storage.

4) Concerns about the environmental desirability of certain options for increasing the rate of self-consumption

Lastly, certain technical opportunities for increasing self-consumption are by some seen as ecologically undesirable, as for example the concept of

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[10] Electricity providers usually apply the Standard Load Profile (SLP) as an accounting rule for residential consumers in Germany. SLP is used for approximating the customer's electricity consumption, i.e. the consumption pattern is fixed. Providers have no advantages in SLP-based procurement to pass on to customers. The lack of 'smart' metering infrastructure to individualize consumption patterns prevents them from developing attractive tariff options (see Tews 2011a; for an English summary of the study, see Tews 2011b).

[11] The market for *mobile* energy storage (e-mobility) is even less developed in Germany. However, currently there is considerable political debate on adequate instruments for stimulating e-mobility. The debate focuses on whether to subsidize the purchase via a premium, or to improve infrastructure for e-mobility and/or the capacity of e-automobile battery systems.

'Power to Heat'. Although it can increase the rate of self-consumption, the CO_2-emission factor (CO_2/kWh) of German electric power is – due to the country's electricity mix (see Figure 1) – twice as high as the CO_2-emission factor for heat. Thus, it is argued that PV power should replace fossil-fuel power and be fed into the grid instead of being transformed into heat.

2.2.3 Grid connection provisions

Grid connections, technical requirements, transmission and distribution are regulated by several provisions of the Renewable Energy Act. Provisions in section two of the Act ('Connection, purchase, transmission and distribution) regulate the relationship between grid operator and the operator of a RES installation, and their respective obligations.

According to section 8 of the Act, a grid operator is obliged to offer the grid connection for installations to generate electricity from renewable energy sources without delay. This obligation generally applies to grid operators technically suited for connection (grid voltage level) whose (linear) distance to the location of the installation is the shortest. In the case of one or several installations with total maximum installed capacity of 30 kWp which are located on a plot of land with an existing connection to the grid, the point of connection of the plot of land with the grid system is to be deemed the most suitable connection point (informal English translation of the EEG)[12]. Further:

- The operator of the RES installation must send an application for grid connection to the respective grid operator. In practice, the firm charged with installing the PV system by *the private homeowner often takes care of this application.
- The grid operator must transmit to those wishing to feed into the grid a precise timetable for processing of the application for connection to the grid system. This document must state
    - the procedural steps whereby the application to connect to will be processed
    - what information those wishing to feed in must transmit from their field of responsibility to the grid operators so that the grid system operators can determine the point of connection.
- Grid operators are then required to provide, within eight weeks, the following information to those wishing to feed in:
    - a timetable for establishing the connection to the grid system, showing all the necessary procedural steps;
    - all the information needed by those wishing to feed in to test the connection point, and, on application, the grid system data required for a system compatibility check;

[12] A translation of the EEG can be downloaded from the official BMWi website: http://www.bmwi.de/English/Redaktion/Pdf/renewable-energy-sources-act-eeg-2014,property=pdf,bereich=bmwi2012,sprache=en,rwb=true.pdf

- an estimate of the costs incurred by the (technical provision of) installation operators due to connecting to the grid system.

2.2.4 Building code regulations and local planning practices

PV installations are subject to building law, which differs among the subnational jurisdictions at state level (Bundesländer) in Germany. However, roof-mounted PV systems — as a rule — do not require formal permission. PV installations on the roofs of historic buildings need a permit, but this is generally granted if the installation will not disrupt the building or alter its visual qualities. Although municipalities in Germany have relevant competencies with regard to the main elements of spatial planning, the respective legal provisions are not relevant for roof-mounted PV systems, which do not have a spatial impact.

2.2.5 Information practice and third-party market

Private households seeking to become prosumers encounter fairly little bureaucratic complexity or burdens. Moreover, with the emergence of actors in the third-party market of the solar branch (installation firms, PV leasing firms) and the extensive information provided by several actors, transaction costs have been further reduced. It would go far beyond the scope of this study to detail all the information practices offered by formal institutions at various levels of the German federal system, consumer organizations or associations in the solar branch. Only a few examples are given below:

Individualized energy-related counselling

As part of their on-site counselling on energy-related renovations of private homes, the federal consumer organization *Verbraucherzentrale Bundesverband e.V.* and its decentralized member organizations at the state level offer information on grant and subsidy programmes for PV, renewable warmth and power storage, as well as *individualized* calculations and recommendations on the economic benefits of investing in the various measures.

Online guidebooks and interactive calculation tools

There are a few online guidebooks and interactive tools available for calculating the returns offered by the specific roof conditions of particular houses. Such web tools are provided by various organizations and platforms in the solar branch. These webpages often directly forward the requests of an interested user to installer firms in the area.

Solar land maps

A few municipalities or counties (like Ahrweiler in Rhineland-Palatine) already offer online solar land registers of the entire city or county. Such tools enable each homeowner to get an initial idea of the suitability of a roof-mounted PV system, as these registers show all houses and indicate whether a solar system can be operated economically.

2.2.6 Ongoing political debates and regulatory provision for smart-grid integration of prosumer systems

Germany is somewhat of a latecomer to the development of smart grids, and accordingly to the rollout of smart meters. Up until 2011 there were no smart-meter requirements for small PV installations. The amendment of the Energy Industry Act (EnWG) in 2011 introduced the obligation for *new* PV installations >7 kWp to install smart meters.

New legislation on smart-meter rollout has been adopted recently. The scale of the rollout and the purpose of smart meters for prosumer systems were heavily contested in the political debate. The rapid expansion in volatile renewable-generation capacities in the German electricity grid and the electricity market has made security-of-supply arguments increasingly important, calling for smart-grid integration of distributed renewable energy generation for better balance of supply and demand.

Accordingly, the technology and the associated debate on regulatory implications differ. On the one hand there is basic bi-directional infrastructure to increase transparency of consumption patterns in order to tap into saving potentials (basic smart meters). On the other hand there are advanced intelligent metering systems equipped with a smart-meter gateway with the ambition to allow for remote readout of meters by an external control centre (grid operator) in order to control grid-optimized consumption and generation patterns.

The new discussion on smart metering, particularly on integrating small prosumer systems into a smart grid, heated up with the publication of two studies in 2013 and 2014 (Ernst & Young 2013; Dena 1014) which recommended the installation of smart-metering systems for 'active feed-in-management' (i.e. cut-offs/curtailment of RES systems) by grid operators. These studies recommended mandatory installation of smart-metering systems even for small systems with capacity of 0.25 kWp, or 0.8 kWp, respectively. Both studies argued that such measures of active feed-in management would reduce the costs of further grid expansion.

Complaints have come, especially from consumer protection associations and the Federal Association for Renewable Energies (BEE), that the integration of such small residential systems would impose unreasonably high costs and risks (due to external cut-offs) to these small producers, preventing further economically viable operation of their small PV systems. They have also argued that grid operators will not depend on the provision of system services from such small residential producers in order to balance grid stability (VZ NRW 2014, Vzbv 2015, BEE 2015).

In February 2015 the BMWi published its 'Key Issue Paper on a Package of Ordinances Regarding Intelligent (Smart) Grids' (BMWI 2015). It includes the following prosumer systems recommendations, clearly referring to security-of-supply argumentation: Small systems below 7 kWp are deemed only *potentially* relevant for system stability in the future. However, PV systems >7 kWp are considered relevant for grid stability. Thus, the installation of advanced smart-metering system should be made obligatory by 2017 for *all (new and existing)* RES and CHP systems with capacity of >7 kWp. Systems with capacity of between 0.8 kWp and 7 kWp are not obliged to install advanced smart-metering systems. The Ministry argues that installed capacity of PV systems below 7 kWp currently accounts for only 7% of total installed PV capacity. However, by the year 2021, the Ministry intends to evaluate whether smart-system integration of this residential segment will be necessary from the security-of-supply perspective and economically feasible.

Accordingly, the draft bill on the ‘Digitization of the energy transition’, published in November 2015, did not mention small residential prosumer systems, neither in the case of mandatory installation of smart meters nor as an option available to meter operators who comply with the defined price caps.

However, the bill, as adopted on 23 June 2016, contains a surprising new provision which takes into consideration an amendment of the governmental coalition. For new small distributed installation between 1 and 7 kWp, meter operators have the *option* of choosing by 2018 to install smart-metering systems if they comply with a price cap of 60 EUR/a. The renewable energy branch, the opposition parties as well as consumer protection organizations were astonished at this last-minute change. As of this writing, no detailed assessment of the background and the implications of this new provision is yet available.

2.3 Conclusion: factors that have influenced prosuming levels in Germany

With a total installed capacity of 38 GW (2015). PV power in Germany has become of systemic importance for the whole power system. Although residential PV (<10 kWp) accounts for only 13% of total installed PV capacity, it is an important segment, for several reasons. ‘Prosuming’ — although never defined as an official term in Germany — is both a subject and driver of the adaptive legislation on the RES support scheme and on system integration of RES.

The generation of PV by new, small-scale residential investors was implicitly intended by the ‘founding fathers’ of the Renewable Energy Act (EEG) to dismantle the barriers imposed by the hesitancy of established energy actors towards renewable energies (see Scheer 2005).

The Renewable Energy Act has long offered a high degree of planning security for investors and has shielded small-scale and new actors’ investments to develop a long-term niche. The reductions in risks and transaction costs ensured by clear regulation of the relationship between PV operator and grid operator, and the long–term security of returns achieved by administratively fixing a technology-specific remuneration for 20 years, are especially relevant for those actors who cannot diversify risks and/or are unfamiliar with the established rules in the energy field.

The success of the EEG stimulating precisely these small-scale actors to invest in residential PV forced re-adaptions of legislation and a change in the attitudes and strategies of established energy actors. The rapid spread of residential PV spurred provisions that introduced incentives to increase self-consumption for greater grid stability. These residential adopters of the new technology became a critical mass, not only bringing about rapid market diffusion of this technology but also lowering system prices. The subsequent (rather late) reduction in remuneration rates and rising electricity prices — partly in consequence of the EEG surcharge — created incentives to increase self-consumption as an economic rationale for operating PV systems. This in turn stimulated research and innovation in storage capacities, as well as the political necessity of increasingly taking into consideration security-of-supply issues and the solidarity principle in bearing the costs of the transition process.

Future regulations on incentives enabling self-consumption as the sole economic rationale for operating a residential PV system will increasingly need to differentiate between:

- optimization of self-consumption rates from the prosumer's perspective, or
- optimization of self-consumptions patterns from the system perspective.

Whereas the first perspective would guarantee the economic attractiveness of residential PV for the investor, the latter perspective is relevant for security of supply and would require grid-optimized operation of prosumer systems.

The latter is of increasing systemic importance for the whole transition process; however, it is likely to come into conflict with the interests of individual prosumers. Such conflicts will have to be counterbalanced with an incentive structure that can reward grid-optimized operation of the residential PV system when required.

3 The UK

In the UK, support for and diffusion of micro-generation renewables, particularly domestic solar electricity, were intensified for a while after the turn of the century. Various policy incentives and initiatives (not least, the generous Feed-in Tariff introduced in 2010) created an environment which made possible the rapid growth of domestic solar PV prosumers (producers *and* consumers of solar electricity) particularly in the years 2010-2015. This UK case-study begins with background information about the broader energy context within which these events took place, before focusing on the developments and circumstances specific to the growth in prosumers, in particular domestic solar PV system-owners in this period.

Whilst the concept of ‘prosumers’ works well as a heuristic device to describe individuals who both produce and consume electricity, it is important to be clear about the definition in the UK context. Firstly the policy literature and most of the literature referred to in this report do not operate with ‘prosumer’ as a concept, but refer to prosumers indirectly, by focusing on the technology, using terms such as ‘micro-generation’ or ‘decentralized energy generation’. The term ‘prosumer’ is also not used in official statistics in the UK. The most relevant data on prosumers in the UK come from the official Feed-in Tariff data, which record domestic installations, which this case-study uses as a proxy for prosumer figures in the UK. Domestic installations in the UK are typically installations of <4 kWp.

When the term ‘prosumer’ is used, it is to distinguish prosumers from consumers, signalling the added component of production but without a clear distinction between self-consumption (of solar electricity) and consumption (of grid electricity). This differs considerably from the German case-study, where self-consumption is a constituent element of the term. Self-consumption of solar electricity is not currently metered in the UK, so the exact degree of consumption of self-generated as opposed to grid-supplied electricity cannot be accurately established.

3.1 Mapping of contextual background of the national energy sector

3.1.1 Historic developments and national characteristics

In the early 1900s electricity in the UK consisted of a patchwork of small supply networks. The Central Electricity Board was set up in 1926 in order to create a nationwide grid supply system. It began operating in 1933 as a series of regional grids, and becoming a national integrated 132 kV grid in 1938. The Electricity Act of 1947 nationalized the grid by merging the then 625 electricity companies and setting up twelve area electricity boards which were vested with the British Electricity Authority (BEA). The BEA upgraded the grid by adding 275 kV links in 1949. Further increased demand and the need to build larger power stations led in 1965 to the beginning of what would become the 400kV super grid, for transmission over great distances. Before 1990, generation and transmission activities in England and Wales were under the responsibility of the Central Electricity Generating Board (CEGB).

The Electricity Act of 1989 provided for the privatization of the electricity supply industry in the UK. The Act also established a licensing regime and a regulator for the industry, the Office of Electricity Regulation (OFFER), which has since become the Office of Gas and Electricity Markets (OFGEM). According to the Act, unless an excemption applies, a licence is required for the following activities: generation, participation in transmission, distribution, supply and participation in the operation of an electricity interconnector. The Electricity Act 1989 enforces separation of activities by prohibiting an entity within common ownership from carrying out other licensed activities. For example, the transmission licence of National Grid Electricity Transmission (NGET), which operates the UK transmission system, prohibits NGET and all affiliated and related undertakings from owning electricity supply or generation interests. Similarly, an interconnector licensee cannot hold a generation, transmission, distribution or supply licence.

Additional recent primary legislation that regulates or affects the electricity sector particularly relevant to renewable energy and prosumers includes:

- The Utilities Act 2000, which established the Gas and Electricity Markets Authority (GEMA) as the governing body of OFGEM, and the Gas and Electricity Consumer Council 'Energy watch' (which has since become 'Consumer Focus'). The Act further provided the legislation for the Renewables Obligation (RO), one of the main support mechanisms for large-scale renewable electricity projects in the UK, which came into effect in 2002 and which requires electricity suppliers to supply a certain proportion of their total sales in the United Kingdom from electricity generated from renewable sources. The mechanism issues Renewable Obligation Certificates (ROCs) to operators of renewable electricity power stations, which are traded to enable suppliers to meet their Renewables Obligation.
- The Climate Change and Sustainable Energy Act 2006, which aimed to boost the figure of heat and electricity micro-generation installations.
- The Energy Act 2008, which made improved provisions for renewable energy and allowances for a feed-in tariff scheme for small-scale renewable generation.
- The Energy Act 2010, which deals with arrangements for carbon capture and storage development.
- The Energy Act 2011, which implemented the Green Deal Framework.

The Energy System in the UK is large-scale and centralized. The potential contribution of a more decentralized energy production has been argued and proposed by advocacy groups and academics; political support for micro-generation has increased recently, following the

Climate Change and Sustainability Act of 2006 and followed by the Climate Change Act 2008. The Climate Change Act – the world's first legally binding legislation on climate change – made it the duty of the Secretary of State for Energy and Climate Change to ensure that the net UK carbon account for all six Kyoto greenhouse gases by the year 2050 is at least 80% lower than the 1990 baseline.[13] It further aims to enable the UK to become a low-carbon economy, giving ministers powers to introduce the measures necessary to achieve a range of greenhouse gas reduction targets. Pursuant to the EU Renewable Energy Directive 2009 on the promotion of use of energy from renewable sources, the UK further committed to have 15% of its energy consumption derive from renewable sources by 2020. The support for renewables can be seen as aimed primarily at providing environmental abatement in order to meet these targets, whereas it is argued that little points in the direction of fundamental changes to the highly centralized energy system (Devine-Wright and Wiersma 2013, Wiersma and Devine-Wright 2014).

Following a period of support for decentralized renewable energy technologies and domestic prosumers, described in more detail in section 3.3, recent developments within energy and climate change policy indicate a shift towards greater emphasis on affordability and energy security.

The 2010 – 2015 coalition government in the UK initiated the Energy Market Reform (EMR), which was designed to decarbonize the electricity system, keep the lights on and minimize the cost of electricity to consumers, with the ultimate aim of creating a competitive environment in which low-carbon technologies would compete fairly on price, to deliver the best deal for consumers (DECC 2015a). The EMR was first set out in a 2010 government White Paper on energy security, and came into effect in 2014. It consists of two key mechanisms – the Contracts for Difference (CFD), which provide long-term support for investment in low-carbon plants; and the Capacity Market, which provides incentives for owners of generating capacity to keep their power available as back-up for times when output from renewables is low (DECC 2015a, EVOenergy 2015). As regards support for prosumers, the EMR represents rather an emphasis on larger-scale generation. Whilst it is the current view of Energy UK – the trade association for the UK energy industry, representing over 80 suppliers and generators – that the EMR broadly provides the right framework to attract the required investment into renewables, it has also indicated that more emphasis is needed on demand- side policy and decentralized energy in particular (EnergyUK 2015). The energy industry anticipates that residential solar could reach grid parity within the next few years, but argues that an alternative model, if not the Feed-In Tariff, is still needed to ensure that there are no barriers to future development (EnergyUK 2015).

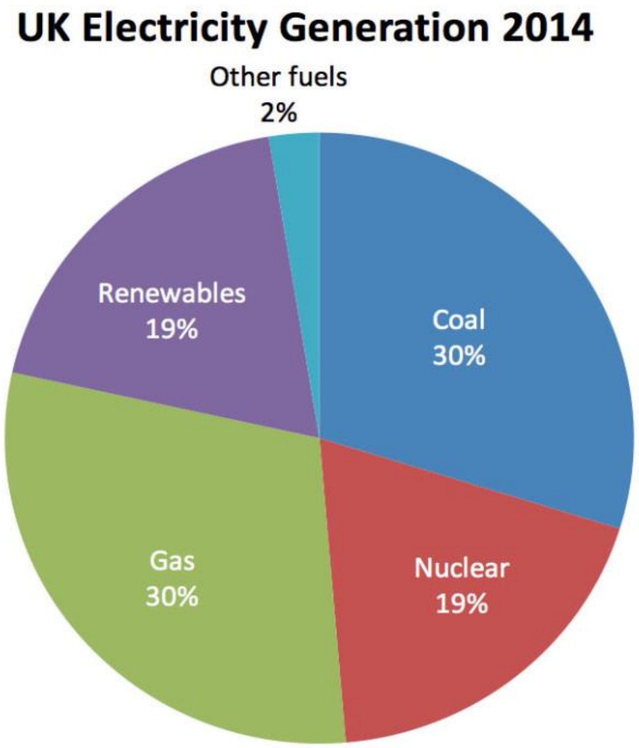
[13] After this case-study was written, a UK government re-shuffle in July 2016 dismantled the Department of Energy and Climate Change (DECC) and hence the Secretary of State for Energy and Climate Change whose responsibilities have been folded into the new Department of Business, Energy and Industrial Strategy (BEIS), headed by the Secretary of State for Business, Energy and Industrial Strategy. Climate change issues have become the responsibility of the Minister for Climate Change and Industry (see also section 3.1.3).

With the election in 2015 of a Conservative government, further changes to official energy strategies are currently underway. An emphasis on ‘balancing the need to decarbonize with the need to keep bills as low as possible’ (Gosden 2015) has led to the scrapping of previously announced green policy initiatives, and points towards a UK energy and climate change agenda dominated by concerns over affordability and energy security. A recent speech by the then Secretary of State for Energy and Climate Change, Amber Rudd, outlining the 'New direction for UK Energy Policy', indicated a clear focus on energy security as the top priority. This includes phasing out coal, to be replaced by new gas and nuclear power stations, and also an end to what Rudd called ‘the pursuit of green energy at all costs’, which she suggested has meant that ‘domestic households face paying over-the-odds for energy for years to come as previous governments have handed out expensive subsidies to wind and solar farms’ (DECC 2015b). This new direction in energy and environmental policy has led to the government being widely criticized for abandoning commitments to climate-change mitigation and renewable energy and ‘undoing years of effort’ (Bergman et al. 2015), by abandoning policy initiatives such as the Green Deal and the Zero Carbon Housing Policy. The latter, announced in 2006, would have required new-builds to be carbon-neutral from 2016. Along with cuts to the UK Feed-In Tariff, these recent policy withdrawals are predicted to endanger the solar PV market in the UK because investors will pull out (Observer 2015). There is also concern that these measures will lead to increased $C0_2$ emissions (Harrabin 2015).

3.1.2 The technical system and the energy market

Electricity generation in the UK stood at 339 TWh in 2014; the UK remained a net importer of electricity, with imports contributing 5.7% of the total supply of 359 TWh (DECC 2015c). Since 1970, the fuel mix has moved from a reliance predominantly on solid fuels to gas, with gas-fired power stations currently accounting for 33 of the 69 400MW + power stations in the UK (UKEnergywatch 2015). In 2014 the shares of fuels used for electricity generation in the UK were (see Figure 12): gas 30%, coal 30%, Renewables 19%, Nuclear 19% and Other fuels 2.6% (DECC 2015c).

Figure 12: UK Electricity Fuel Mix 2014, based on DUKES 2015 (model by Groundsure.com)



The UK 'dash for gas' which initially saw large increases in gas infrastructure and generation in the 1990s has continued with large investments. The recent announcement of the building of a new 1800MW gas-fired power station in Lincolnshire led commentators to speak of a new 'dash for gas' (Bullock 2015), aimed primarily at replacing coal. The UK has been a net importer of gas since 2004, with 57% of imports in 2014 coming from Norway and 15% from the Netherlands. Liquefied natural gas (LNG) accounted for 27% of gas imports, 92% of which came from Qatar (DECC 2015c). In 2010 the UK government permitted private suppliers to build up to eight new nuclear power stations (the Scottish government, however, stated that no new nuclear power stations would be built in Scotland). A report found public opinion divided on nuclear in the UK (Spence et al. 2010); after the 2011 Fukushima disaster and the debate which ensued, several suppliers pulled out, leaving uncertainty about the future of nuclear. In 2013, however, the UK government announced that the nuclear Industry had plans for new power stations that would add an additional 16 GWe to UK nuclear capacity by 2030. Plans to build the country's first new nuclear plant in decades at Hinkley Point in Somerset have been controversial, although the new government of Theresa May has now approved the construction decision.

Fossil fuels remain the dominant source of energy supply in the UK, although supply from renewable sources has increased. The most significant growth in the contribution from renewables is in electricity generation, where the total production of 64.7 TWh (or 19% of generation) in

2014[14] was made up of onshore wind (35%), followed by solar photo-voltaics (22%), offshore wind (18%), bioenergy (18%) and hydro (7%) (DECC 2014).

The UK energy system separates the transmission, distribution and supply of energy. The transmission network is owned and operated by the National Grid. Technically it consists of the national transmission network (275 kV and 400 kV lines), with (part-owned) interconnectors to France, Northern Ireland, the Republic of Ireland and the Netherlands. National Grid is a FTSE 100 Index British-based multinational company.

The distribution network of towers and cables that bring electricity from the transmission network to homes and businesses consists of 14 electricity distribution networks, operated by 14 separate Distribution System Operators (DSOs, known as Distribution Network Operators/DNOs in the UK) each responsible for a regional distribution centre. Under the Utilities Act 2000, the DSOs (currently owned by six different companies) are prevented from supplying electricity; this is done by separate electricity supply companies that make use of the distribution networks. The DSOs are responsible for the distribution of power in their networks (including maintenance and future investment) on behalf of the supply companies, which pay the DSOs for use of their assets.

Final consumption of electricity in 2014 was at 303 TWh, out of which 108.9 TWh were used directly by the domestic sector (DECC 2015c).

Whilst prosumption relates primarily to domestic electricity use in the UK, it is useful for the understanding of domestic consumption rationales to note that people in the UK often give little thought to the different capacities and properties of gas and electricity at work in their homes. The terms 'energy' and 'electricity' are used interchangeably, reflecting a situation in which relative reliance on gas and electricity is almost equal in most homes. The majority of UK households have gas-fired central heating, which accounts for most domestic gas consumption, along with water heating and gas cookers. Domestic electricity consumption accounts for just over half of household carbon emissions (DECC 2013).

According to the 2011 Census there were 26.4 million households in the UK; and average (weather-adjusted) household electricity consumption was 4,115 kWh and gas consumption 14,263kWh in 2014 (DECC 2015e). Average home size in 2013 was estimated to be 96.8 square meters (LVInsurance 2014), and average household size was 2.3 people, with two-person households accounting for nine million dwellings or 34% (ONS 2013). One-person households were the second most prevalent type (8.1 million), substantially higher than three-person (4.1 million), four-person (3.4 million) and five-person or more (1.8 million)

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[14] Provisional figures for 2015 are 83.3 TWh DECC (2016). UK Energy Statistics 2015 and Q4 2015.
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/513244/Press_Notice_March_2016.pdf.

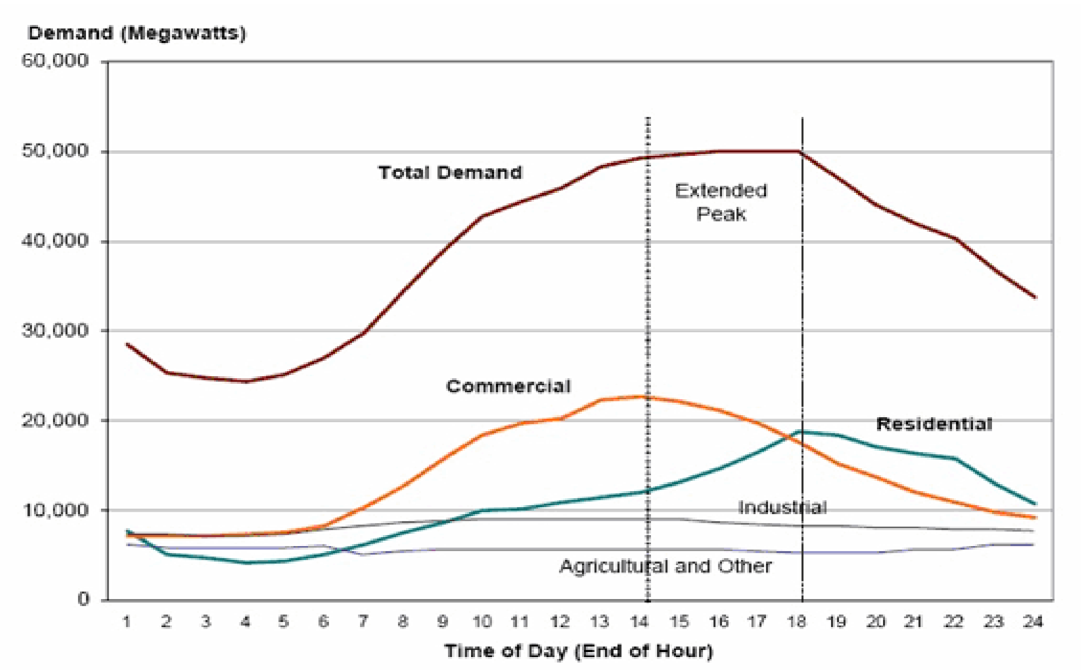
households (ONS 2013). Homeowners make up 65% of dwellings; private renters 18% and social housing 17% (LVInsurance 2014). Private rentals increased sharply between 2001 and 2011, whereas social housing rentals have gone down. Higher house prices and stricter lending conditions for first-time buyers have meant fewer young homeowners in the past decade (ONS 2015).

Typical energy bills for a medium-sized (median) UK household in 2014 were £666 (€834) on gas and £487 (€609) on electricity (OVOEnergy 2015).

In 2014, average UK domestic electricity prices, including taxes, were the eighth highest in the IEA, third highest in the G7, and were 17% above the IEA median. Gas prices, including taxes, were the eleventh lowest in the IEA, third lowest in the G7, and were 8.2% lower than the IEA median (DECC 2015a).

Understanding patterns of household electricity consumption not merely in quantitative terms but also temporally is useful, particularly in relation to domestic solar electricity, which has specific temporal properties and presents special challenges as regards balancing wider supply and demand in the National Grid. Figure 13 shows the temporal patterns of electricity demand relative to domestic and commercial sectors in the UK.

Figure 13: UK Energy Demand by Sector (National Grid Visitor Centre, 2015)



Domestic electricity consumption shows an evening peak between 5pm and 10pm, with the 6pm to 8pm period being more than three times the average base load (Owen 2012, Palmer et al. 2013). This pattern is not a straightforward match to the generation pattern of a solar PV system, so prosumers who wish to maximize the impact of their systems and 'use their own electricity' frequently need to moderate the time of day for certain electricity-consuming activities. Here we can note similarities between the emphasis on self-consumption in relation to micro-generation solar and previous incentives to encourage domestic load-shifting by other means, most notably the Economy 7 differential tariff.

The Department of Energy and Climate Change (DECC) has been responsible for the UK smart-meter rollout which is set to install 53 million smart meters with In Home Display monitors in UK homes and small businesses by 2020 (Ofgem 2015b). Following the July 2016 government re-shuffle (see section 3.1.1), this has now become the responsibility of the new Department of Business, Energy and Industrial Strategy (BEIS). The initial foundation stage of setting up the regulatory framework, the necessary organizations and infrastructure is currently underway. Following delays, the installation stage has been further postponed, with some installers currently installing early-generation smart meters. Installations are projected to rise sharply in 2016, peak in 2019 and finish in 2020. The smart-meter rollout in the UK is framed primarily as a service to enable customers to have better information about their energy use and enable more accurate bills (eliminating the need for estimated bills), as well as making it easier to switch to a different supplier.

With the Feed-in Tariff preceding the smart-meter rollout, this process has not directly impacted on decisions to install domestic solar. The expected rollout of smart meters, however, is cited as a reason for the lack of export meters in standard installations, as smart meters will eventually take on this task.

3.1.3 Main actors in the energy sector

Until July 2016, energy and climate-change policy in the UK was the responsibility of the Department of Energy and Climate Change (DECC), created in 2008 as a ministerial department headed by the Secretary of State for Energy and Climate Change. Following the recent government re-shuffle it has become the responsibility of the Department of Business, Energy and Industrial Strategy (BEIS), headed by a Secretary of State for Business, Energy and Industrial Strategy, with responsibilities divided among a Minister of State for Climate Change and Industry, a Minister of State for Energy and Intellectual Property, and a Minister for Industry and Energy. While it is beyond the scope of this case-study to anticipate how this change might impact future support for prosumers, a statement from the new Secretary of State for Business, Energy and Industrial Strategy, Greg Clark, about the future framing of energy and climate change policy gives an indication: 'One of the main challenges in tackling climate change is to try to reduce carbon emissions without jeopardizing economic growth. This merger will enable a whole economy approach to delivering our climate change ambitions, effectively balancing the priorities of growth and carbon reduction.'[15]

The government has no direct control over the energy markets in the UK. The electricity and gas markets are regulated by the Office of Gas and Electricity Markets (Ofgem), which is a non-ministerial government department and an independent National Regulatory Authority, recognized by EU Directives and governed by the Gas and Electricity Markets Authority (GEMA).

The electricity supply / energy market is dominated by the 'Big Six Energy Companies', which are Britain's largest energy suppliers: between them they supply gas and electricity to over 50 million homes and businesses in the UK. The Big Six (British Gas, EDF, E.ON, npower, Scottish Power and SSE) are also the oldest energy companies, having been created following the privatization of the energy sector in the 1990s. However, since 1997 many smaller independent suppliers have entered the UK market, aiming to provide competition for the Big Six, and creating a fairer market for consumers in the process. Several of these companies are specifically 'green', such as the not-for-dividend Ecotricity, the world's first green electricity company that seeks to turn 'bills into mills' – invest the revenue from electricity bills in new sources of green energy. The supply of electricity and gas is complex, with a high degree of difference between different tariffs, not just among suppliers but internally too, as suppliers offer a portfolio of different tariffs, which change very frequently. Consumers find it confusing to navigate this market, as shown by the growing numbers of online price comparison sites. This further fuels customer distrust of the 'Big Six' (Rodden et al. 2013).

In relation to prosumers, the solar industry has become immensely important in terms of diffusion of domestic solar from 2010 onwards. The British Photovoltaic Association (BPVA) reports a general trend whereby the number of UK-registered solar installers went from around two hundred in 2009 to five thousand installers at the peak in 2011, and to 1680 registered solar installers today. The spreading of information about solar technology and the relevant incentives for prosumers has undoubtedly played a central role here.

As well as the installers themselves, various NGOs and advocacy groups have been active in providing information to potential prosumers about the potential benefits of solar PV and other micro-generation technologies. Two organizations have been especially important: the Energy Saving Trust (EST), which is an independent, not-for-profit organization funded by the government and the private sector, and the Centre for Alternative Technology (CAT), which is a Welsh-based education and visitor centre that demonstrates practical solutions for sustainability. Both organizations offer independent research, information and advice about renewable technologies, the related policies and

[15] https://www.carbonbrief.org/nick-hurd-confirmed-climate-minister-new-uk-department

incentives, as well as web-based services like PV calculators that enable potential prosumers to estimate return on investment.

The environmental NGO Friends of the Earth (FoE) has the country's largest grassroots environmental campaigning network, with groups in some 200 communities. FoE has been an outspoken supporter of renewable energy; its campaigning for climate change legislation played an important role in paving the way for the Feed-in Tariff, through political pressure and increased public awareness. FoE has been very critical of recent cuts to renewables subsidies and is currently running the campaign 'Save our Solar'.

3.2 Prosumer-relevant framework conditions in the UK

This section focuses on domestic solar photovoltaics in the UK and maps the various policies and conditions relevant to the uptake of domestic solar PV and rise in prosuming. Political support for prosumers in the UK is perhaps better framed as support for renewable energy technologies, particularly micro-generation, and it is useful to consider this policy framing before turning to the specific initiatives which incentivized so many people to become prosumers.

It has been argued that a 'window of opportunity' for radical change in energy and climate change policy between 2005 and 2013 enabled the UK for a while to be seen as a world leader in climate change (Carter and Jacobs 2014). During this period, the main political parties in the UK came to compete to be 'greener than' the others. With growing scientific evidence of the urgency of action to combat climate change and increased pressure from NGOs such as Friends of the Earth came heightened public awareness. Also the business community began to recognize potential commercial benefits of green economy markets. Thus, instead of environmental politics being a Left/Right party-political issue, UK climate policy became an issue of 'competitive consensus'. Developments like the publication of the Stern Report in 2007 made possible the shift from an environmental to an economic framing, and the term 'low-carbon economy' gained currency (Carter and Jacobs 2014). It is in this context that support for renewable energy technologies was stepped up in the UK – with support for prosumers almost as a follow-on effect from that.

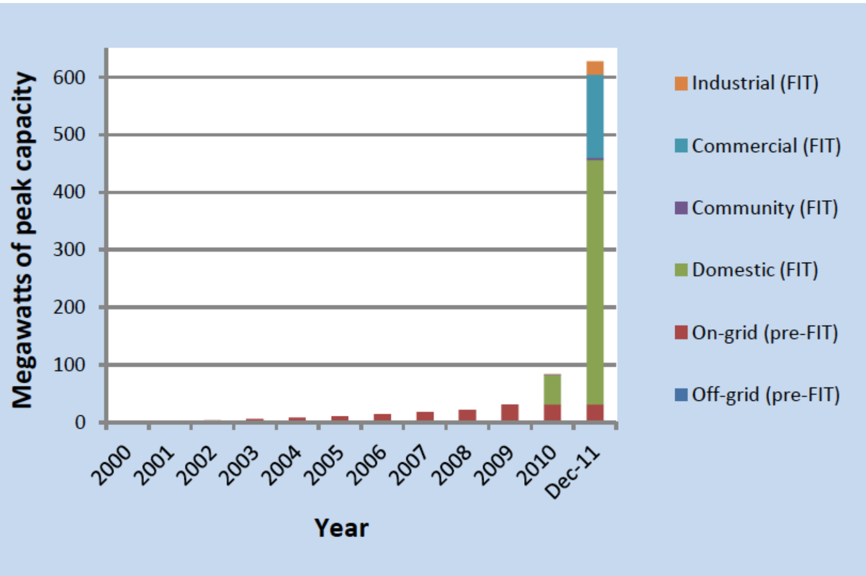
3.2.1 The Feed-in Tariff and prior support for prosumers

The RO was considered too complicated for small-scale installations, and repeated calls were made for the Labour government to introduce feed-in tariffs for small-scale generation. Shortly after the creation of the new Department for Energy and Climate Change (DECC) in 2008, the Secretary of State Ed Milliband introduced a clause in the 2008 Energy Act to allow for the introduction of a feed-in tariff along with similar tariffs for renewable heat and gas, called the Renewable Heat Incentive (House of Commons 2011).

In 2010, the government launched the Feed-in Tariff (FiT) Scheme specifically for installations of less than 5MW (later reduced to 50kW) to encourage homes and businesses to generate their own renewable, low-carbon electricity using solar photovoltaic panels, wind turbines or other renewable technologies. After consultations, the final design of the Feed-in Tariff was published in February 2010, announcing the specific tariffs, set at differing rates depending on installation size, with the most desirable tariff going to <4kWp installations. This tariff was designed to give an 8% return on investment; the added benefit of index-linking was expected to raise this figure to around 10% (Fitariffs 2010)

The Feed-in Tariff became the most important policy driver for the uptake of small-scale solar in the UK. However, the government had already been supporting the growth of small-scale renewable technologies through two grants-based schemes, the Major Photovoltaics Demonstration Programme introduced in 2002 which assisted with PV installations, and the Clear Skies programme, introduced in 2003, which aided other micro-generation installations. Both schemes were replaced in 2006 by the Low Carbon Buildings Programme, also essentially a grant scheme for partially covering the cost of installing micro-generation technologies in households or not-for-profit sector buildings. With no remuneration for generated electricity, however, the scheme was not sufficiently attractive to potential prosumers to stimulate significant levels of domestic micro-generation. This can be seen in Figure 14, which shows cumulative installed PV capacity in the UK 2000–2011. Note that, prior to April 2010, systems were distinguished only by whether they were grid-connected or not, making it difficult to establish exact numbers of domestic installations prior to that date.

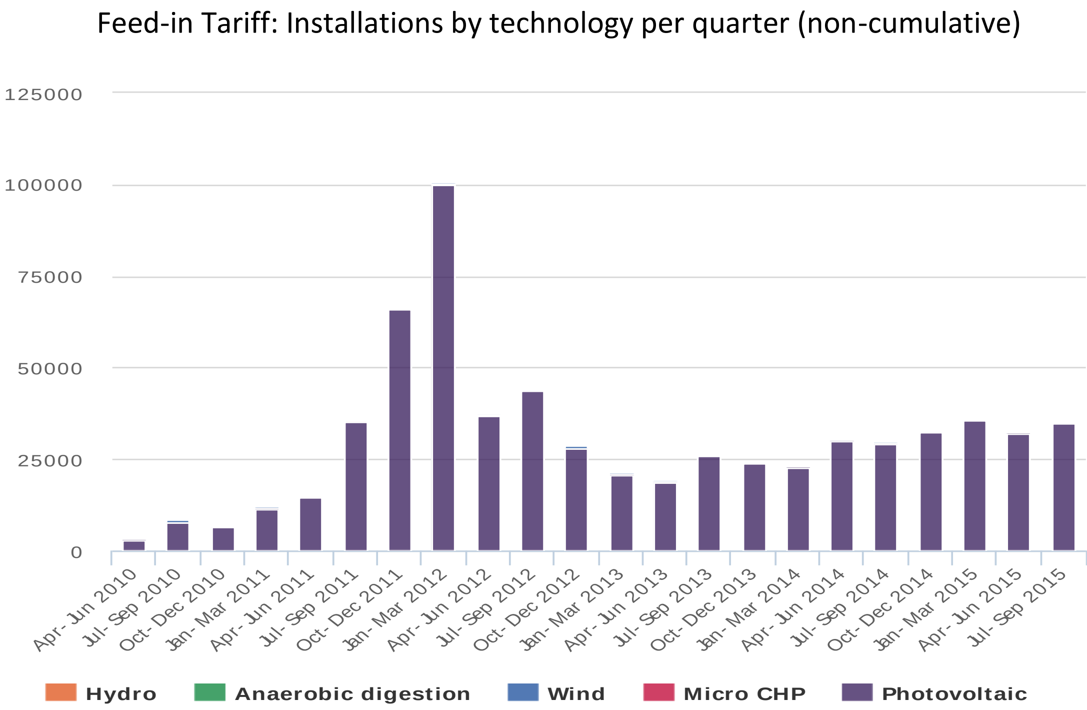
Figure 14: UK Cumulative Installed PV Capacity (Houses of Parliament 2012)



Although none of the support schemes prior to the Feed-in Tariff scheme resulted in significant take-up of micro-generation installations, they did begin to build the regulatory frameworks and infrastructure to underpin the diffusion of small-scale renewables in the UK (which later became the Microgeneration Certification Scheme).

The period 2010–2015 saw an explosive increase in prosumers in the UK (excluding Northern Ireland). These were predominantly households that invested in small-scale (up to <4 kWp) roof-mounted solar PV installations, as seen in Figure 15.

Figure 15: Number of Feed-in Tariff installations per quarter 2010 – 2015 (Ofgem.gov.uk)



New domestic PV installations increased rapidly, especially during 2010, peaking in early 2012. The return on investment on domestic PV installations during this time was considerably better than, for example, high-interest individual savings accounts or other readily accessible financial products available to householders. This encouraged more households to install (Balcombe et al. 2014) as ‘being green’ became not only affordable, but also financially attractive as an investment.

Whilst the Feed-in Tariff presented a good investment opportunity for consumers, it is important to emphasize the business opportunities this opened up for new solar installers, enabling a rapidly growing market. As is clear from Figure 15, solar PV has dominated the Feed-in Tariff scheme uptake with 658,160 installations by September 2015 – compared to 6,643 wind installations, 637 hydro, 505 Micro CHP and 207 Anaerobic digestion installations (Ofgem 2015a). Of the installations registered under the Feed-in Tariff scheme by the end of 2015, 641,793 were classed as domestic; 2,483 were classed as community, 20,575 as commercial[16] and 1,301 as industrial (Ofgem 2015a)

The initial UK Feed-in Tariff model combined a high generation tariff with a low export tariff. This combination reflected the assumption that a design that encouraged on-site use would probably be the most efficient technically, as well as most likely to 'engender widespread behavioural change' by reducing energy consumption in prosumer households (DECC 2010, Mendonça 2011 see also Mendonça 2011). However, the main focus of the FIT was diffusion. The initial rate of FIT was high: with a split rate including a 41.3p (€0.52)/kWh generation tariff and 3.1p (€0.04)/kWh export tariff. In view of the future smart-meter rollout, export meters were not fitted: export was estimated at 50% of generation. The rate was index-linked and guaranteed for 25 years. Whilst self-consumption featured in official Return on Investment calculations and in information material – like the advice given by the Energy Saving Trust, as a means of 'making the most' of the potential to save on energy bills – in the absence of capacity for accurately metering export before the smart-meter rollout, little attention was paid to this issue.

The Feed-in Tariff presented a good investment opportunity not just for private households, but for commercial investors as well. This led to the growth of a market of 'free solar': domestic solar installations which were not owned by the householder, but where the householder benefitted from being able to use the electricity generated at no cost. The 'free solar' schemes, also referred to as 'Rent-a-Roof' schemes, were initiated by private companies that installed PV systems on private dwellings at no cost to the owner, enabling householders to use the electricity generated by the system, while the Feed-in Tariff payments went to the investor. This model created a different kind of self-consumption incentive, as householders under the free solar scheme could benefit financially from the panels only through potential savings on their energy bills. The UK market leader in free solar, A Shade Greener, has now installed some 67,000 free PV systems across the country. Some local government authorities have followed a similar model and invested in domestic solar installations in their social housing buildings; some have also offered this deal to certain owner-occupied households.

The Rent-a Roof model came under widespread criticism in the period up to the first review of the scheme for not being 'in the spirit of the Feed-in Tariff'. The rapid uptake of installations led the DECC to move forward a review of the scheme (originally set for 2012) to 2011, following the argument that the tariff had initially been set too high and that continued installation at this rate would be unsustainable and threaten the viability of the FIT scheme. It was further argued that, following a major fall in costs, the solar industry would be heading for a 'boom and bust' situation which DECC wanted to avoid. A cut on the generation tariff to 21p

[16] There is some uncertainty in relation to domestic installations owned by commercial companies or local authorities. The Installation type is determined and selected by the FIT Licensee when registering installations and comes down to the discretion of each FIT Licensee. Some installations owned by multi-site generators are therefore registered as domestic; others as non-domestic.

(€0.27)/kWh was therefore scheduled, with effect from December 2011. The review and the subsequent cut were challenged and delayed until April 2012, following a successful joint appeal in late December 2011 to the High Court by Friends of the Earth and two solar companies, Solar Century and HomeSun, who argued that the cut was unlawful as sufficient notice had not be provided to enable the industry to adjust. The case received extensive media coverage, and the period between the announcement of the cut and its eventual implementation represents the peak of UK installations (see Figure 15).

Further reviews have followed, with further cuts in the generation tariff made in 2012 to 16p/kWh and 15.44p/kWh. After 2012, a principle of degression has been introduced whereby the Feed-in Tariff is subject to reduction in relation to deployment and installation cost. The latest review of the FIT resulted in a further cut to 4.39p per kWh (as against 41.3p per kWh in the initial FIT) implemented on 1 January 2016.

3.2.2 The Green Deal

A further prosumer relevant initiative was the Green Deal, an energy-efficiency scheme introduced in the UK (excluding Northern Ireland) in 2013 as a way of enabling people to finance and benefit from energy-efficiency home improvements through a loan to be paid back via savings made on energy bills. The Green Deal consisted of various different schemes for homeowners, tenants and businesses. For homeowners, the scheme was aimed at retrofitting energy-efficiency measures such as insulation and double glazing, but could also include energy-generation measures such as micro-generation PV, solar thermal, biomass boilers and ground-source heat pumps.

The intention behind this loan scheme was that savings on energy bills would outweigh the initial cost of the energy-efficiency measures, with a golden rule stating that the estimated energy savings to be achieved over a 25-year period should be equal to, or more than, the initial cost of implementing the changes. However, the issue proved more complex than anticipated, due to the difficulty of predicting future energy costs. The Green Deal did not offer potential prosumers any benefits comparable to the kind of return on investment available under the FIT did. Compared to the simplicity of the FIT, it was a complex scheme that required a significant amount of initial research by the householder; moreover, there was far more uncertainty as to the return on investment. There was uncertainty also about the consequences of selling a house that was committed to the deal, because the loan followed the house rather than the person who took out the loan (which is unusual in UK law) – meaning that potential new owners or tenants would be liable for a debt they had not entered into. There were also concerns as to the financial viability for domestic households. In order to qualify for any loan an energy-efficiency assessment had to be carried out. Such an assessment could cost as much as £150, which the householder had to pay. The loan rate of 6.92% was also relatively high compared to standard home loan rates at the time. In the first six months 38,259 Green Deal assessments had taken place, but only four Green Deals had been arranged. In total only around 15,000 people took out a Green Deal. Out of these, 4,737 arrangements involved a form of micro-generation technology[17] (DECC 2015d) – a figure far short of the uptake that the government anticipated. A second version of the Green Deal, introduced in 2014, offered grants rather than loans – but, almost immediately after the general election in May 2015, the new Conservative Energy Secretary announced that the Green Deal was to be scrapped, because it had failed to deliver its objectives.

3.2.3 Incentives and disincentives for self-consumption

Self-consumption is difficult to quantify in the UK, as export is generally unmetered. Research on prosumer households in the UK has shown great difficulties in establishing the degree of self-consumption for prosumers (Turner 2016), who rely on secondary sources of information like impact on electricity bills which fluctuate for complex reasons. Prosumers who have participated in smart-meter trials (Powells et al. 2014) or bought smart meters themselves, whether as part of the installation or as external Wi-Fi devices, appear to be more interested in self-consumption. Many prosumers who do not have smart-meters go to great lengths trying to calculate their export by comparing generation figures from their solar monitoring devices with their own consumption data; some purchase devices like immersion heater switches to direct unused electricity to heat water; and others pay to have export meters installed. However, not all suppliers accept metered export: some prefer to offer only the 50% assumed export. Although, with the relatively low export rate, self-consumption does maximize the financial benefit for prosumers, the amounts are not very large. Anecdotal evidence indicates that prosumers who have installed in recent years with less favourable FIT rates have greater incentives for self-consumption, but this point has not been investigated.

Self-consumption has not yet received much political attention, but is an issue closely related to the technical challenges of intermittent generation faced by the transmission network. Although current levels of solar PV are still manageable, ever since the beginning of the Feed-in Tariff the National Grid has issued warnings about potential difficulties in balancing the transmission network following increases in the installed capacity of intermittent sources, specifically solar. The main concern for the National Grid is the balancing of supply and demand and 'keeping the lights on', whereas DSOs are concerned about the ability of the distribution networks to cope. One challenge concerns increased voltage rises that may exceed the thermal capacity of the local network if entire distribution areas become net exporters of electricity. This problem arises when domestic PV systems export electricity at times of the day where there is local demand is low (DEI 2013). Matching peak performance with patterns of electricity demand in prosumer households becomes important as the rollout of domestic PV could lead to increased pressure on the network at the times of greatest network stress – for instance, during peak demand times on dark winter evenings when PV installations are not likely to be generating (DEI 2013).

[17] Figures do not specify how many of these were solar PV

A 2014 briefing note from the National Grid (working in cooperation with the DSOs) presents various suggestions as to how these issues could be managed in the future. One suggestion involves creating a ‘turn down’ scheme for solar PV generators who would be paid to cut the amount of electricity they generate when there is limited capacity to accommodate it on the grid (Nationalgrid 2014).

Unlike the case of Norway, there have not been any local support schemes at the municipal level to support uptake. Some local authorities in the UK have invested in PV installations on their social housing stock, but the present case-study has not gone further into this.

3.2.4 Other Relevant Regulations

The DECC-supported MCS (Microgeneration Certification Scheme) is an industry-led and nationally recognized quality assurance scheme dating back to the Low Carbon Building Programme in 2006, which replaced the Clear Skies register. The government’s 2009 Renewable Energy Strategy made it mandatory for all PV installations to be MCS certified, to be eligible for the Feed-in-Tariff. MCS provides third-party certification, and also provides installers with information on matters like planning permission requirements, metering requirements, notifications to DSOs and various certificates needed for installations to receive the MCS certificate. The MCS scheme provides prosumers with assurance that their installation fulfils certain quality/safety standards, and that calculations of expected yield have been conducted using approved standard assessment procedures. Not least because of the MCS requirements, self-installation in the UK has been very rare, and most prosumers have little or no involvement in the administrative or regulatory framework around grid connection: responsibility for this lies with the installer.

Procedures for becoming a prosumer were simplified in 2008 by the Permitted Development Rights, which lifted the requirements for planning permission for most domestic micro-generation technologies in the UK. The General Permitted Development Order (GPDO) grants rights to carry out certain limited forms of home development, without the need to apply for planning permission, although planning permission might be required in particular conservation areas or on listed buildings. Installers will usually be aware of these requirements and offer advice, for instance on specific kinds of solar panels that are acceptable in different areas – but the responsibility for obtaining planning permission under these circumstances lies with the prosumer.

3.2.5 Degree of bureaucratic complexity and burden in becoming prosumers

As noted, most responsibility for planning, certification and registration lies with the MCS certification and thus with the installer, making it quite simple for private households to become prosumers. They will need to get involved in acquiring planning permissions only under special circumstances; moreover, most installers will assist in filling in the form needed to register with a FIT Licensee / supplier. Thereafter, the only requirement to the prosumer is to send quarterly meter readings to the supplier in order to receive the FIT payments.

From 1 April 2012, customers must provide an Energy Performance Certificates (EPC) at level D or above (ranging from A = very efficient to G = inefficient) with their FIT application, in order to be eligible for the FIT at standard rate. It is the customer's responsibility to obtain the EPC from an approved EPC organization (currently at a cost of around £45 (€57) before applying for the FIT. In some cases this has meant that households have had to make energy improvements to their homes. However, installers are expected to advise their customers of this requirement if the quotes and payback time are calculated on the basis of FIT rates.

3.2.6 Information practices and third-party market

The rapidly growing solar industry, with the related marketing and competition, brought considerable expansion in information. Some information about the FIT was available from government sources, but the main vehicle for spreading information about domestic solar to prosumers was advertising. Ethnographic research on prosumers and installers during the period 2011–2013 notes reports of household receiving many leaflets and quotes from various companies, along with adverts in local and national newspapers, and installers reporting on rapidly growing numbers of new local and national installers, including High Street companies like B&Q, IKEA, and Tesco (Turner 2016).

Both DECC and Ofgem provided information about solar on their websites, whereas NGOs were active in providing non-marketing information about micro-generation solar – as regards the cost and return on investment, and how best to utilize the technologies to maximize the economic and environmental benefits.

Several environmental and solar trade organizations also played an important role in providing information about solar. Some these were local, like the Sheffield Solar Farm at Sheffield University, which hosted information events where members of the public could attend talks and meet installers. National organizations like the Energy Saving Trust and the Centre for Alternative Energy also participated in spreading non-commercial information about solar and the FIT, as previously noted.

3.3 Conclusion: factors that have influenced prosuming levels in the UK

Support for prosumers in the UK focused primarily on renewable energy in the context of an existing energy system that relied on fossil fuels, and the shift towards a greening of the economy – arguably more about climate than about energy as such. The very rapid diffusion of micro-generation solar in the UK is perhaps better understood in terms of a technology push, rather than in terms of prosumer development. With the highly lucrative Feed-in-Tariff, domestic solar became an excellent investment which it was easy to make for domestic households and a lucrative product in a rapidly growing solar industry. What made solar installations visible and attractive to domestic households and what fuelled the uptake of solar was that this was made ‘a good deal’. Most households in the UK became aware of it through the advertising efforts of local and national installers as well as media coverage, not least of the controversial High Court Appeal in late December 2011.

The relative lack of any requirements for private households to change their energy-consuming behaviour due to assumed/deemed export and not actually metered export made it possible to frame solar PV as a ‘Fit and Forget’ technology which would generate returns on investment regardless of whether any load-shifting took place. Self-consumption was considered an added bonus – at least until the rates were dramatically reduced. With recent cuts to the tariff this is likely to have changed, but it is too early to say what impact the introduction of smart meters will have.

Political support for domestic solar has dwindled in recent years. However, the energy landscape in the UK remains volatile. There is uneasiness about new nuclear power stations, and arguments have been voiced for a return to nationalized power production. Such unknowns add to the general air of uncertainty that afflicts the British economy in the wake of the referendum decision to leave the European Union. All this makes it difficult to predict the fate of domestic solar power, at least in the medium term. For the longer term, and in relation to the contribution to overall carbon emissions reduction, domestic solar power seems set to play an important role, especially if further technological improvements can improve efficiency and lower the costs to consumers.

4 Norway

Norway has been a global frontrunner in the liberalizing of electricity markets and an innovator in regulating grid companies in that sector (Bye and Hope 2006; Inderberg 2011). However, in some other areas its electricity sector is less developed compared to other European countries – and one such area is household micro-generation, or *prosuming*. At the time of writing there are probably some 200 prosumers nationally, out of approximately 2.5 million end-users and a population of about 5 million, although figures are currently increasing. The Norwegian market for PV is very small; and by the end of 2015 total installed capacity was about 15 MW, against 160 MW in Sweden and 790 MW in Denmark (WWF/Accenture 2016). Suggested explanations have ranged from Norway's low electricity price, high trust in grid companies, low support levels for prosumers, weak formal facilitation and high bureaucratic burden, and resistance from important actors. Additionally, as Norway has an almost fully renewables-based electricity system, the need for prosuming is sometimes questioned.

4.1 Mapping the contextual background of the national energy sector

This section provides a brief background information to the national context and relevant structural (slow-changing) energy and non-energy system obstacles and characteristics that may influence prosuming in Norway.

4.1.1 Historic developments and national characteristics

From the late 19th century, Norway developed its electricity system from river-based hydropower, in close interaction with local energy-intensive industry like steel and aluminium smelters, and artificial fertilizer production. The system developed under national protectionist licensing regulations that secured national, and usually county- or municipality-owned, ownership of hydropower resources. Industrial expansion required more power, and several large waves of development followed. Especially in the 1960s and 1970s numerous large-capacity dams were constructed. This continued into the 1980s, and then bega-n to taper off. After this large-scale building phase, the system entered a phase characterized by low investment, due in part to the radical de-regulation of the country's electricity system in 1991. Ownership unbundling and dismantling of the vertical company structure followed; new actors entered the scene; and annual electricity generation figures of approx. 123 TWh were achieved, remaining relatively stable since then. In his 2001 New Year's address, Prime Minister Jens Stoltenberg announced that 'the time for large-scale hydropower in Norway was over': few of the country's major river systems were still intact, and the electricity system was all but fully renewables-based. While this statement has later been challenged, at this stage Norway's land-based electricity was 99% hydropower-generated, representing a significant share of European combined hydro-storage capacity for power generation. The power balance is positive in a normal year, but annual electricity generation is highly dependent on precipitation levels and winter temperatures. Transnational interconnectors are important for securing own supply as well as for export purposes. Norway is tightly connected to the Nordic electricity market, that of neighbouring Sweden in particular.

4.1.2 The technical system and the energy market

Today, electricity generation in Norway is approx. 98% hydropower-based, with annual production of about 131 TWh depending on annual precipitation levels. The hydropower potential is technically higher, and some rivers are still being dammed and regulated, but the focus in recent years has been on increasing windpower production, still poorly developed in Norway despite the high technical potential (Blindheim 2013). A shared 'green certificate' scheme with Sweden came into effect in 2012, and is expected to run until 2020, with the goal of phasing in 26.4 TWh new renewables between the two countries. Norway's part of this development will involve mainly windpower and new hydropower, with new hydropower expected to represent the lion's share up to 2020. Windpower construction has experienced some obstacles, but important new developments may well be in the pipeline. The most significant project is probably the Fosen Peninsula windpark outside the city of Trondheim. This will include 209 new wind turbines with aggregated installed effect of just over 750 MW.

Generation capacity is spread out across the country, with hydropower plants located near local resources in a supplier-centric model. The transmission and distribution grid connecting production, transport and end-users in 2011 measured about 129,000 km in total, of which the central transmission grid stands for 11,000 km (St. meld. nr 14 2011–2012, 16). The arrangement has been characterized as relatively weak since there is no continuously connected corridor of 420 kV transmission grids running between the north and south of the country, and Norway depends partly on Swedish transmission capacity for such transport of electricity (Inderberg 2012). Electricity in Norway has traditionally been cheap compared to general European prices. Although prices have been growing closer to European levels, they are still comparatively cheap, especially if purchasing power is taken into consideration. There is also less price volatility over different times of the day, but considerable seasonal variation compared to most other parts of the European market. Demand response is less used in practice, as hydropower supply response has been able to cope with most fluctuations. Eastern European prices are significantly lower, but Denmark and Germany still charge almost twice the electricity price of Norway for private consumers and the UK is also significantly more expensive (Eurostat 2015).[18] These prices are set in a fully liberalized market and on an hourly basis by the power exchange Nord Pool, adding grid tariffs and taxes for the end-user. Electricity is traded on the Nordic retail market where there are no price safeguards

[18] Eurostat rates electricity prices for the following countries inclusive taxes in € /kWh as follows: Norway: 0.166; Denmark 0.304; Germany: 0.297; UK: 0.201. The cheapest countries are the Balkan states, which prices ranging from 0.059 to -0.082, and then the Eastern European countries, from around €0.1 /kWh and upwards.

and free switching of retailers is allowed (von der Fehr and Hansen 2010).

On the consumption side, Norway's electricity system comprises about 2.5 million end-users. Some 2.3 mill. of these are private households (Statistics Norway 2016), but the country's energy-intensive companies represent a high share of energy use. These range from large-scale users (100,000 kWh per year), with hourly metering introduced in 2004, to private customers (Inderberg 2015). Home-ownership stands at about 79%. Recent strong trends toward urbanization have led to some 80% of the population living in urban areas (Statistics Norway 2005). Electricity represents a high share of household energy consumption, which averages at just over 20,000 kWh, with electricity predominant at 16,000 kWh (Statistics Norway 2015b) and firewood second most important at 3,200 kWh. However, these figures hide large variations connected to location, urbanization, and not least type of dwelling. The typical Oslo flat consumption totals at about 12,000 kWh (Statistics Norway 2015c). By 2012 27% of households had installed heat pumps, and for 73% of dwellings the main source of heating is electricity (Statistics Norway 2015a). The district heating has increased in urban centres over the last 10–15 years, and represented 4.5 TWh nationally in 2014 (Statistics Norway 2015d).

Smart meters are to be fully rolled out across Norway by 2019, in order to modernize the electricity grid (Venjum and Hagen 2015). Although they are generally thought to facilitate the installation of home generation, such required meters are not a necessary condition for prosuming: national regulations require that meters must be able to measure both in- and outgoing electrical power (Inderberg 2015).

Norwegian consumers are considered to have generally high levels of trust in actors in the electricity industry, but this is difficult to confirm without extensive survey-based data gathering.

4.1.3 Main actors in the energy system and developments in prosuming

In Norway, the public administrative body relevant for supervision, control and development of the energy and electricity market/system is the Ministry for Energy and Petroleum, with its subsidiary agency the Norwegian Water Resources and Energy Directorate (NVE). In climate-related issues, the Directorate for the Environment and the Ministry for the Climate and Environment are the competent bodies. Salient energy-relevant issues for the Norwegian electorate are workplaces and petroleum developments versus environmental protection and climate change, and electricity prices. In the Norway's weather-dependent electricity system the latter, prices depend considerably on annual precipitation levels and winter temperatures (Inderberg 2015). Important issues tend to be channelled through the multi-party proportional representation election system, while more technical issues of developing the electricity system, including advanced meters, smart grids and prosuming, fall within the domain of the electricity sector and the NVE.

As of 2012, a total of 136 District System Operators (DSO) or grid utilities owned and operated the local grids, often under municipality ownership (Reiten 2014, 19). They range in number of customers from about 5000 to more than 680,000 (the latter applying to Hafslund nett in the Oslo region). Of these grid companies, 20 have regional grid responsibilities for voltage levels between the district and the transmission grid levels, although this is subject to change with a reorganization of grid ownership at the regional level. The third grid level, the transmission grid, is owned and operated by the Transmission System Operator (TSO) Statnett, itself state-owned. This structure, involving many small grid utilities, has been challenged in recent years. There is considerable variation in grid companies, many of them being very small: 103 of the companies with monopoly regulation have fewer than 10,000 end-users each: thus, about 75% of the companies deliver electricity to some 10% of the end-users (Reiten 2014).

Various generation companies operate in or from Norway. The largest, the state-owned Statkraft, is a significant European and global actor within renewables. Other companies, such as Hafslund, BKK, or Agder Energy, are municipality-, state- or privately owned and represent generating companies under the same ownership structure as the grid companies, but unbundled in organizational structure.

As to relevant interest organizations, Energy Norway organizes the grid and some generation companies, representing some 150 organizations, including companies like Hafslund, Agder Energy, Lyse, Statkraft, as well as various smaller ones. DEFO organizes the smaller energy and grid companies in the country districts, whereas KS Bedrift represents the municipality ownership of energy organizations. El & It Forbundet is the major trade union organization for technical personnel in the electricity sector. The Federation of Norwegian Industries *(Norsk industri)* represents the process industry (usually intensive users of electricity), and parts of the offshore petroleum companies. Renewable Energy Corporation (REC) and Elkem Solar are companies producing PVs. Solar development interests are represented by the Norwegian Solar Energy Society, representing private and company members.

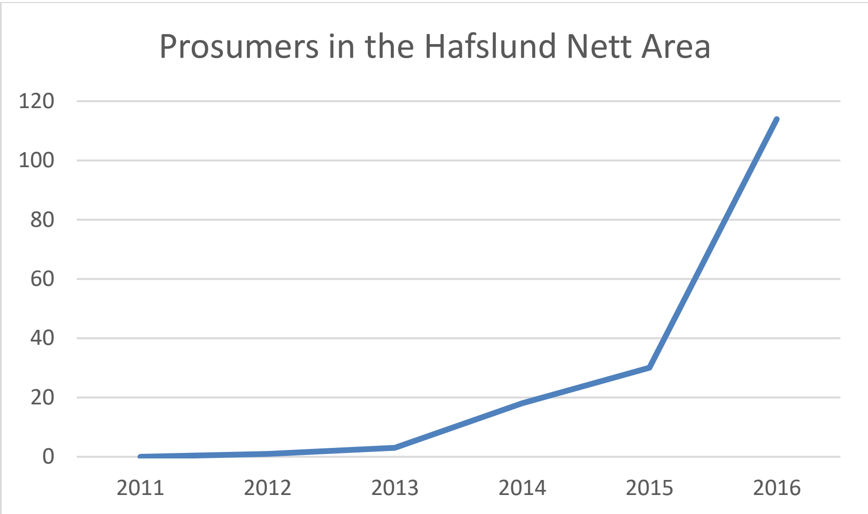
However, interest organizations representing private customers are few in Norway. The Consumer Ombudsman and the Norwegian Consumer Council represent consumer interests in a broad range of general areas including prosuming, but have limited capacity and technical knowhow in matters of electricity regulation. The Norwegian Data Protection Authority is an important public body for protecting private data. End-user organizations are few and there are no organizations specifically for prosumers, although the Norwegian Solar Energy Society is involved. Further, the interest organization for owners of electric vehicles (EVs), Norsk Elbilforening, has some clout, as Norway has the world's highest EV ownership per capita.

Enova SF, a public body for the support of environmentally friendly consumption and energy generation in Norway, was established in 2001. It organizes specific support schemes, for example for eligible renewables and energy-efficiency measures in companies and private households.

According to interviews with DSO representatives, until 2011 there were no officially registered prosumers in Norway. Hafslund considers itself the first DSO that connected a prosumer in Norway (Hafslund nett AS 2015). This prosumer was grid connected after initiating contact and follow-up with the DSO Hafslund in spring that year. By 2014 and 2015 interest spread, and by end of 2015 the company anticipated about 105 prosumers. Almost half of these live in a large eco-development project known as Hurdal Ecovillage, which offers photovoltaics and prosuming as part of the package deal when selling newly constructed homes in the village. The remainder are independent private households that have been connected on private initiative.

Major actors as regards prosuming in Norway are Hafslund Energi Nett in the Oslo region, the DSO BKK in the Bergen area, the Agder Energi Nett in the Kristiansand/Arendal area, Lyse Energi Nett in the Stavanger region, Skagerak Energi Nett Southern Norway, and Fredrikstad Energi Nett. Of these, most have more than ten prosumers in their grid, and Hafslund and Fredrikstad are amongst those with the highest numbers. Our interviewees regarded the utilities mentioned here as progressive grid utilities; they can be said to represent the larger companies amongst Norway's approximately 136 grid utilities. Figure 16 shows the development of prosumer figures for the DSO Hafslund, as an illustration of recent trends.

Figure 16: Prosumer figures for the DSO Hafslund Nett (data from Hafslund, with consent)



Amongst the other grid companies in Norway there are fewer prosumers, according to NVE interviewee. While it has not been possible to interview representatives from all of Norway's 136 DSOs, our interviewees were asked about any perceived differences in company attitudes towards prosumers between utilities and types of companies. Grid company practices range from being explicitly positive to more 'passive', or even direct resistance. This is because national regulations require a voluntary agreement between the grid company and the willing prosumer. There is no firm basis for conclusions, but the larger companies appear to have greater capacity for incorporating new business-models into their routines than do the smaller companies. Some DSOs seem be holding back until after the rollout of advanced meters is finalized in 2019 (TU 2013). This is consistent with previous findings that smaller grid companies have limited organizational capacity for managing change (Inderberg and Arntzen Løchen 2012).

Regulations are currently being developed to provide a Norwegian model for prosumer selling/feeding electricity into the grid. The national definition of a ‘prosumer’ household under the dispensation regime is that ‘annual sum demand of electricity is larger than its generation, and that the household in periods generates more than it uses’ (NVE 2015, no page). A new definition has been adopted. Here, the prosumer is understood to be 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 exceeds 100 kW (NVE 2016a; b).

4.2 Prosumer-relevant framework conditions in Norway

National goals for prosuming have not been specified by the Ministry for Energy and Petroleum. NVE, the main body in charge of managing prosuming developments, has been explicitly positive top prosuming, while recognizing that there can be challenges involved. In recent years, NVE been developing a regulatory framework aimed at reducing the barriers to prosuming. However, national goals are not clear in this area and there are no official targets or views as to just how many prosumers represent a feasible level, or similar measures. On the contrary, reasons for boosting prosuming have not been widely discussed and remain somewhat unclear due to the already high share of renewables in the system. Our interviews confirm this impression, although some respondents cited rather vague reasons, such as private end-users should have the opportunity to choose for themselves, that this is a natural development in a future electricity system, and that (renewables-based) prosuming contributes to the green shift. Others, like the PV association, mention that photovoltaics have the potential to promote further expansion of Norway’s EV stocks. Political interest in prosuming appears generally low, perhaps because it is not seen as a significant contribution to the low-carbon transformation of the electricity system.

The NVE argued in 2013 that there are several reasons for special treatment of prosumers (Fladen 2013). Amongst these are the wish to increase renewables production; the greater focus on energy use in buildings; that power production is not the primary task of a prosumer and that prosuming is expected to have limited effects on the grid, whether positive or negative. Also noted was the potential for further simplification of the regulatory framework, which had been created at a time where the distribution of roles between electricity producers and consumers was clearer. NVE saw the need for greater control and overview of prosumer developments and schemes in Norway (Fladen 2013).

Developments in prosumer regulations

The first explicit legal opening for Norwegian households to become prosumers came in 2010, when the NVE made its first dispensation decision to this end, although in practice there had already been informally arranged prosuming, based on agreements between end-users and DSOs and various generating sources. We may note three phases in regulatory regimes. The first, as indicated, was informal prosuming before 2010. The second period started March 2010 and lasts until January 2017. Temporary measures have been implemented to facilitate prosuming, with specific procedures in place to manage this. The NVE issued a general prosumer dispensation with temporary and light regulations, and it is under this scheme Norway has seen the formal establishment of prosuming, and some increases. With the third period requirements and systems for the permanent administration, tariffing and obligations for and around the prosumers will be adopted.

Up to 2010: prosuming possible in practice but no adapted regulations

According to interview information from the regulator NVE, prosuming existed prior to 2010 in the form of some local farms that had adapted their tariff schemes. This might involve micro-generation hydropower plant in a stream, for example. However, no formal exemption was given to allow prosuming, and the practice was not widespread. In other cases, tariff regulations were followed. All in all, then, Norway has a prosuming tradition of at least ten years – although the practice was not labelled as such. The main regulatory basis for this practice were metering- and control regulations. Additionally, the status of prosuming under the national licencing regulations has been unclear, although amending the exemption rules specifically for prosumers has not been deemed necessary. This is partly because the concept of ‘prosuming’ is relatively new in Norway; previously this was simply thought of as micro-generation with practically adapted tariffs from the DSO level.

The current regime: general dispensation scheme from March 2010

The decision to allow more prosuming through special provisions and administrative routines on managing these came with a letter from the NVE dated 16 March 2010. It offered an assessment of the situation and opened the door to connecting and feeding private households’ small-scale electricity generation into the grid. The current regulatory setting involves exemption from the regulations on metering, calculation and coordinated action of power distribution and billing of grid services (THEMA Counsulting Group 2015b). Under this arrangement, prosumers are exempted from the requirement of registering as ordinary power plants. Because a prosumer is not defined as a power plant in the legal sense, there are various requirements that prosumers do not have to comply with: for example, negotiating and signing a balance contract with the TSO, certain technical requirements, and other obligations triggered by being legally defined as a power plant.

On the other hand, the current arrangement provides no formalized rights for the prosumer: it is up to the grid company to accept the prosumer or not. End-users who want to begin prosuming must inquire if this is acceptable to the local grid utility (DSO). Then, the DSO, under this regime, is allowed to buy surplus power from the prosumer.

The tariffs for the electricity fed into the grid by prosumers are in the dispensation not regulated. However, the NVE has indicated a model for pricing the various parts of prosumer electricity: ordinary electricity consumption *from* the grid; use of *own* generated electricity; and surplus home-generated electricity to be fed *into* the grid. Some variation is allowed, but future regulation is expected to narrow this flexibility.

DSOs such as Hafslund nett (Oslo region), BKK (Bergen region) and Agder Energi nett apply the NVE prosumer approach with minor variations, in line with future expected regulation. Roughly put, this means that consumption from the grid is priced as for all ordinary consumers. For the consumption of self-generated electricity there is no tax or other charge. For surplus electricity delivered to the grid the prosumer receives payment for the value of the reduced loss in electricity from that grid, in addition to the Nord Pool price for the electricity itself. Several DSOs with prosumers have set the grid loss benefit to NOK 0.04 (about €0.0044) that represents between 4% and 7% of the electricity grid loss (depending on season and time of day). This is a low economic benefit. However, prosumers do not have to pay the grid fee for feeding into the grid that power plants are required to pay.

Prosumer will therefore benefit most by consuming from own production, with has no taxes or fees added. Such consumption will be 'behind the meter', as there is only a requirement to meter gross use of electricity (in- and out-flow from the meter), but not net metering of the generation of electricity. This requires a meter that can measure the flow of electricity in both directions, which may be a smart meter of the kind currently being rolled out in Norway, or an intermediate meter. As to the benefits of the current dispensation, a recent report (Kirkeby, Sand, and Sæle 2015) notes that prosumers are exempted from the obligations to:

- pay parts of the grid tariff when feeding power into the distribution grid under the metering regulations
- hold a license for electricity generation under the Energy Act
- meter gross generation in line with metering regulations
- conclude a balance contract with the TSO Statnett.

This regime has involved a few challenges, as pointed out by the NVE and others. Firstly, the definition of a prosumer is not clear for all cases, and there is room for interpretation. This might lead what would normally be seen as ordinary small power plants to call themselves prosumers. Secondly, prosumers have few rights, as the regime allows DSOs to decide whether or not to include prosumers. The practice of including prosumers and managing prosuming in an automatized and effective manner is uncharted territory in Norway; several interviewees held that this will require further regulatory formalization. However, as the rollout of smart meters is due by 2019, new systems for such automatization will in any case have to be created by then; in the meantime, the administration of prosumers in the meantime will generally be done on a case-by-case basis. The NVE sees this as a not-unacceptable burden on the DSOs. Lastly, according to the NVE and the DSOs, the routines and requirements for connecting prosumers are not sufficiently well developed; future regulation will need to address the relationship between the prosumer, the DSO, and the energy company that might purchase surplus electricity generated by the prosumer.

Future regulation of prosumers in Norway

The NVE has seen the dispensation period as a valuable way of running lightweight regulation for prosumers for a period, in order to gather experience. New regulation is in the pipeline. There were public hearings in 2014 with stakeholder inputs, and after some delays entry into force has been set to January 2017. Some minor adjustments may take place but the general regulation seems to have taken shape. It will establish rights and duties for the prosumer as well as the DSOs. Included in the proposed regulation is a formalized definition of prosumer, a tariff structure, and some further clarifications.

The new regulation is not expected to depart greatly from the current dispensatory regime. However, there is likely to be a more precise definition of a prosumer, and the grid feed-in tariff is to be clarified, but along the lines described above. However, there will be third-party buyers of the electricity in a market, and the DSO will not be able to purchase electricity directly from the prosumer. There are some other minor points as well. The prosumer regulation is not likely to include requirements for licenses of any kind, as current regulation provides sufficient room for prosumer activities to operate without license, so no regulatory amendments were deemed necessary. The implication is that prosumers are not power plants by the Norwegian legal definition, but are in a separate category.

The definition of a prosumer will be more precise. The proposal is to define a prosumer as a customer who normally uses electricity from the grid, but also generates electricity, mainly for own use, but which may also be delivered to the electricity grid. The total amount of electricity delivered to the grid may not at any time exceed 100kW. There has been some controversy around this definition, as the installed effect can exceed this limit if no more than this effect is fed into the grid at any given time (metered on an hourly basis). The prosumer will be responsible for not exceeding this limit, with the DSOs monitoring it.

It is likely that consumers who fit the criteria will, under the new regulation, have a *right* to become prosumers if they so choose, in contrast to the current situation where it is voluntary for the grid utilities to accept prosumers. In contrast to today’s arrangement where prosumers can sell surplus electricity to the DSO, under the new regulation a prosumer must find an electricity retailer willing to buy the electricity that is fed into the grid by the prosumer – at market prices. The prosumer is responsible for complying with all technical requirements of the installation (often arranged through certified third-party companies), while the DSO is obliged to facilitate the feed-in of electricity as part of its ordinary services.

In November 2015, the Norwegian State Budget included a right for prosumers to acquire green certificates on production. In order to acquire certificates, however, an additional meter will have to be installed for metering net electricity generation from the installation. This will also trigger some changes in the tariff structure, in combination for many cases not favourable for prosuming.

The tariff structure for prosumers will be more specifically defined. This mainly concerns feeding into the grid for prosumers, as consumption of own electricity will remain free and consumption of electricity from the grid will follow standard customer requirements. However, some future uncertainties may influence the economic aspects for prosumers, related to possible changes in how tariffs are constructed. Several of our interviewees, on their own initiative, brought up the question of future tariffs and the likely shift to more power-based (peak-load) tariffing as relevant for prosumers (and indeed all end-users) as well as the grid at large. Hourly metering for the coming advanced meters by 2019 provides technical opportunities for a more power-based tariff structure (THEMA Counsulting Group 2015a). This may have advantages for the electricity system, but can influence the profitability of prosuming. With today’s tariff structure for household end-users, based primarily on the amount of electricity consumed (kWh), prosumers benefit from using own electricity generated at whatever time of day. Micro-generation, often PV that does not produce high power nor follow grid peak loads, is, according to interviewees, unlikely to benefit as much from power-based (Watt demand) tariffing as it does from tariffing based on the amount of energy generated. More fine-tuned models for large-scale power-based tariffing are expected to be developed over the next few years. Power tariffing has been in place for large end-users (over 100,000 kWh/year) since 2004, but usually not for other kinds of consumers (with some exceptions, as for customers with hourly metering, which in certain cases have been granted the same tariff as for large end-users) (Inderberg 2015).

Meter requirements: Gross metering

Almost all Norwegian end-users are to have their old meters replaced by advanced ones by January 2019. These meters have the required functionality for registering in- and outflows of electricity down to every 15 minutes and reporting back, although in practice reporting will be on an hourly basis. Such meters are widely regarded as enabling factors for various further developments, including the previously mentioned power tariffs, peak-load demand-side management, energy consumption and behaviour illustration (through displays or other interfaces), electric vehicle functionality, as well as various Home Energy Management Systems (HEMS). Smart meters are also seen as a facilitating or enabling factor for the prosumer – at least after rollout.

By 2019, meter requirements may change. In some cases, prosumers who had installed their system before a smart meter is installed in the household must bear the cost of first installing a meter and then replacing it in connection with the full rollout of advanced meters, although increasingly they are likely to be able to use the smart meters due to be installed by 2019. This will probably vary among the different DSOs and geographical areas, and adds a limited extra cost to becoming a prosumer before smart meter rollout is completed. In Norway, shared metering between individual households or trade of electricity ‘behind the meter’ is not allowed.

4.2.1 General incentives for prosuming in Norway

A typical private household installation may range from 2 to 10 kWp, with system price around NOK 18 (approx. €1.8)/Wp (Multiconsult 2016). See Figure 16 for details. Economic incentives can be focused, as with feed-in renewable support programmes or renewable energy schemes, or they can be indirect or even unintended benefits that include but are not limited to tax benefits, lower electricity prices, etc. These can also be non-economic, like higher status or added functionality of a smart house. They can also work ‘both ways’, by encouraging or dis-encouraging people from prosuming. Among the incentives for prosuming activities, our interviewees mentioned the Enova support programme, the Oslo municipal support programme, and some other municipality schemes for support relevant for prosumers. Internet searches have been made for schemes in the most relevant locations, in addition to asking for information from grid companies. This has had a certain snowball effect, and all major schemes for support have probably been identified.

Some interviewees saw the regulation and tariff structure as ‘a kind of incentive’, enabling prosumers to use own-generated power ‘for free’ without the tax that applies to all other energy consumption. Several interviewees noted this as the most important economic benefit for prosumers.

4.2.2 Enova’s investment support incentive

The only direct national subsidization of prosuming in Norway is the Enova prosumer support scheme, launched in January 2015 (TU 2014). It consists of two elements, under the same measure. First there is support that covers 40% of all investments made in the technical installation, up to a maximum of NOK 10,000. Then there an additional installation support of NOK 1,250 (about €130) per installed kW, up to 15kW. This support can reach the level of a maximum of NOK 28,750 (about €3000).

Interviewees generally regarded such support as ‘a contribution’ but insufficient to trigger investments in isolation from other factors. This is confirmed by a study of prosuming in Rogaland county, southwestern Norway. It found that for the cheapest alternative of technical solution, Enova support accounted for 17.84% of the costs of installing a PV system, and that 67.7% of the current prosumers in the area did not see the Enova support as the main trigger for their choice of prosuming (Næss and Roalkvam 2016: 79). In a project interview, the Enova representative opined that making improvements to the building structure was the most important, adding that Enova had made it simple to apply for support to various measures/packages: the customer needs only to produce receipts after installation, and can also enter some expenses as tax deductions.

4.2.3 Local support to prosumers

The best -known local support scheme is that of Oslo municipality. This has been recently changed from NOK15 per kWh produced, to cover up until 40% of the costs of the technical installation. The campaign will continue until the ceiling of NOK 4 mill. is reached. According to the project web page,[19] some 40 homeowners are poised to install PV panels under this arrangement (November 2015).

Other important local support schemes include those in Fredrikstad and Hvaler municipalities, in southeastern Norway. These two schemes are very similar, and are designed to go beyond purely economic support. The idea is to provide knowledge brokering through competent advice to interested consumers plus some economic support, and to include certain more advanced consumer steering and inverter technical elements as well. Customers wishing to start prosuming under this scheme can choose between packages of 2, 3, and 4 kWp installations, with the 3kWp package being most popular. According to an interviewee from Fredrikstad municipality, when Enova support is included, this package comes to 41,000 kroner (about €4,240) fully installed, and the calculated back-payment time with stipulated electricity prices is 10.9 years. In Hvaler, prices have been slightly lower, and more than 70 houses have received grants thus far (TU 2015b; Smart energi Hvaler 2015).

4.2.4 Green Certificates

The Green Certificate scheme is a market-based system for supporting renewables investments, as a flexible collaboration between Norway and Sweden. The goal has been to fund and trigger 26.4 TWh of renewables by 2020, shared between the two countries. As the scheme is intended to be technology-neutral, most renewable technologies – including hydro-power, windpower, and bioenergy – are eligible, although greatest share of support has in practice gone to hydropower and wind energy. Also solar is eligible for Green Certificates, but prosuming has not yet been part of the scheme.

However, in Norwegian state budget negotiations for the 2016 budget, prosumers were made eligible for green certificates. What this means in practice is somewhat unclear, and the NVE has been working to clarify the consequences for the prosumers, although the incentives do not appear feasible for most household prosumers. It seems that in order to trigger such support for power produced (and consumed at location), the prosumer must install an additional meter, to measure net *generation* of electricity, instead of gross generation and net ‘export’ to the grid.

[19] http://www.oslosola.no/stotte.html

4.2.5 The Plan and Buildings Act

The Plan and Building Act (PBA) is a legal structure that has undergone significant revisions recently. It is relevant for prosumers because regulations and practices under the Act determine the degree to which the technical installations require formal applications to the municipality.

Planning regulations have been shown to be obstacles for household PV installation. In some cases, local interpretations of planning and building regulations have not been open for PV. If aspiring prosumers must first prepare and submit an application for changing the building façade, there can be added costs with uncertain outcomes – possibly a significant barrier.

However, some practices have been changed to allow for such façade modifications, so we do not expect this to be a major barrier in the future. Still, planning and building requirements are managed by the local governments, and with 428 municipalities in Norway today, there are likely to be differences in how this is managed and thus variation in bureaucratic burdens for prosumers, depending on where they live.

4.2.6 Bureaucratic goal conflicts between sectors and administrative levels

Goal conflicts can surface between public regulations, policies and practices at different levels and between sectors, in turn influencing prosumer uptake in Norway. While it lies beyond the scope of this report to analyse such goal conflicts fully, mention should be made of some issues that came up from the interviews and documentary materials.

There has been some discussion, as yet marginal, about emissions targets, the price of electricity (influenced by various long-term factors) and phasing in new electricity. Electricity prices in Norway have traditionally has low, and still are, when compared to high-level prosuming countries such as Germany and the UK. Low electricity prices have regarded as an important political goal as such. However, several interviewees saw this as an obstacle to prosuming as well as to more traditional approaches to renewables.

National renewables goals, referred to above under the Green Certificates, are often not deemed particularly important for reducing harmful emissions, nor has increased renewables generation been shown to influence emissions to a significant degree in Norway (Blindheim 2015). Norway already has a very high share of renewables in its energy mix, so prosuming would have only second-order climate-relevant effects. Additional interconnectors to the UK and Germany as well as greater electrification of transport may modify this picture somewhat by around 2020, but the situation is unlikely to change in the immediate future. Similarly, some interviewees have questioned granting special concessions and creating specific incentives for prosuming, and not other kinds of renewables.

4.2.7 Information practices and third-party market

The NVE and Enova are governmental bodies mandated to promote prosuming practices and inform about relevant support schemes, assist in application and regulatory processes, and spread general knowledge about prosuming opportunities. However, the most natural contact-point for support is the local grid company, and/or a third-party company that can provide technical solutions and installation of these.

It seems fair to say that little information was available on electricity prosuming until about 2013/2014. Several interviewees confirmed this on their own initiative, noting the importance of raising awareness of prosuming options, knowledge of accessible economic support, technical solutions, and availability of the third-party entrepreneur sector dealing with the technical installation aspects.

The grid companies' role in information and facilitation is important, and interviewees indicated varying approaches to pushing the issue. Some DSOs are active supporters, while others, in cases the smaller DSOs, are less positive. Other sources of information are Solenergiforeningen and the NVE, but probably most important are the growing numbers of companies like Solel, Otovo and others (see 4.3.3 below). In addition, Enova has a role in providing support and information, but this remains more generic. Availability of information has grown significantly along with the market developments indicated in Figure 16 above. Although centred on certain areas and around cities, the availability of information has increased dramatically, but there is room for further development here.

Official certification and energy labelling bodies

None of our interviewees mentioned certification and labelling bodies as important for the decision to take up prosuming. However, 'ready-made' communities, like the Hurdal Ecovillage, appeal to certain groups, and offer packages of low energy and other 'green' solutions that include prosumer activities. Residents do not actively choose to become prosumers – that is part of the 'package deal' of buying a house in the ecovillage. This has become popular; the DSO Hafslund, which holds the Hurdal area license, reported in interviews that almost half of their prosumers for 2015 were subscribers from the ecovillage.

Availability of market options (third-party companies, etc.)

Since around 2010 and increasingly, a market has been emerging for the technical installation of solar panels in private households in Norway. These are relative newcomers, compared to other and larger markets elsewhere, but new companies and business models are being established, and demand is increasing significantly, with varying degrees of availability in different parts of the country. One example is the recently established company, Otovo, with offices in downtown Oslo: only five days after being established and without significant marketing efforts, it had received 800 inquiries from potential prosumers (DN 2016). This is a high figure in a small market. Otovo's business model is to manage the cost of installation, while the prosumer pay a monthly fee for the services. This emerging company offers third-party ownership solutions where homeowners do not pay for the installation nor own the solar panels themselves, but engage in prosuming by contracting out the roof-top space of the house. This has become popular model in other markets, as in the USA, and has the potential to increase PV-based prosuming by lowering the upfront capital installation costs (Overholm 2015). The market feasibility of these solutions remains to be seen for Norway, but the result may be a lower threshold for installing rooftop PV. The prosumer can use and sell electricity freely. About 2000 customers have now signed letters of intent, according to Otovo. Companies like Solel (which offers technical installation of PV systems by means of more standard contracts) and Otovo have become established and are now catering to larger installations, like the roof-tops of company buildings (warehouses, office buildings etc.) as well as private households.

4.3 Conclusion: factors that have influenced prosuming levels in Norway

Drawing on the context and regulatory framework in Norway, and assisted by interview input, we now turn to factors that are likely to have contributed to the gradual increase in prosuming. Such a discussion is necessarily premature, but is strengthened by increasing the number of interviewees, as well as comparing the cases of Norway, Germany and the UK.

As indicated by figures on available DSOs, the number of prosumers in Norway has increased, but only since about 2011/2012. This is from a baseline of close to zero, and there are large variations amongst the country's 136 DSOs. This should be seen against the background of the specific Norwegian context: near-total renewables share in the electricity generation mix, cheap energy in general and a low electricity price in particular. In addition come very recent developments, like the establishment of a market that enables regulatory conditions for prosuming, and economic support.

Technology

Technological developments in Western Europe, at least at the very general level, can be assumed to be largely similar. However, full-system access to prosuming may vary. The earliest prosumers in Norway imported their own systems, often from Germany or from the USA, and installed them. While the market now appears to be developing rapidly, this was not so until very recently. Prosumers today enjoy the benefit of access to companies that compete and provide full prosumer technical systems, and this appears to have had an effect on the scale of prosuming. The threshold for accessing prosumer solutions is significantly lower than compared to as recently as 2013 or even 2014.

Mention should be made of one minor aspect that may have contributed to delays in developing the market for technical prosuming solutions: the differences in the electricity system in Norway compared to most other countries in Europe and globally. Norway's system has a different phase structure and grounding parameters from those found elsewhere. This is not a major obstacle to finding feasible solutions, but has led to some confusion regarding the technical fit of different prosuming technologies, as standards and requirements do not always overlap.

Prosumer-enabling regulations

Even though it was possible – at least informally – to become a prosumer in Norway before 2011, the opportunity to formally do so has become significantly strengthened after the change in regulations, where the option was explicitly opened. This did enable private consumers to do so, and can be seen as a necessary prerequisite for scaling up prosuming in the electricity system.

The shape of regulatory processes has been seen as important for micro-generation (or prosumer) uptake in other jurisdictions, and there is no reason to expect this to be different for Norway (Burkhardt et al. 2015). Norway's current and near-future regulations are not heavily bureaucratic and, since 2011/2012, appear to reduce the barriers to prosuming, although the burden of mapping the process, technical details and being responsible for getting the system installed might require greater motivation than the case in other countries. This concerns the national regulations for metering and tariffing, although for some areas there have been indications of varying practices as regards façade changes caused by PV installation. However, our interviewees ended to see this as a fringe issue for future prosumers.

Financial support

The Enova support scheme, Norway's only nationwide support scheme (until the Green Certificates are made available), is generally regarded by interviewees as insufficient to trigger prosuming on the basis of economic/ financial considerations. This is supported by an article in the Norwegian periodical *Teknisk ukeblad*, showing overwhelming differences between Norway and Sweden in support and prosumer developments (TU 2015a). However, the Norwegian support schemes have been in place for only a few years; and, together with enabling framework conditions such as technical options and a regulatory framework that explicitly allows prosuming, support schemes are increasingly being utilized by households to start prosuming.

The literature shows that installations increase with the financial benefits of prosuming, and more so, with higher benefits from support schemes beyond grid parity (Bauner and Crago 2015; Simpson and Clifton 2015). A recent US study found that prices were significant obstacles to PV uptake, that subsidies often made the main difference in reaching levels to trigger PV investments, and that installation-cost reductions were critical along with annual maintenance costs (Hagerman, Jaramillo and Morgan 2016). Seen this light, Norway could be expected to have few prosumers.

Additionally, there are still upfront costs for installing household PV, and these factors matter, particularly in the face of low or uncertain return on investments (Bauner and Crago 2015). Schelly (2014) finds that in the US context, financial incentives are important for prosumer uptake, but that high initial costs can be a barrier. This problem is addressed in some recent Norwegian support schemes. Enova support as well as several local support schemes, notably in Oslo, Halden and Fredrikstad, are specifically aimed at lessening this barrier. This appears to have had an effect for prosumers; and all our interviewees expected this to have further effect in the future, with increased prosuming phase-in. Several interviewees held that 10 to 15 years of investment payback should be sufficient to trigger further prosuming. However, metering practices may be important for the attractiveness of prosuming (Eid et al. 2014). That is certainly an area open for change in Norway, and may be a significant future influence as regards prosuming.

Other motivations for becoming prosumers

Motivation for prosuming for ‘green reasons’ may be lower in Norway than in other countries, as it is widely recognized the country’s electricity production is almost 100% renewable. Further there are arguments that new production is not needed in Norway, since country exports electricity in most years. This is connected to the low electricity price, but may also lead to reduced motivation for prosuming. However, even though increasing the renewables share in Norway is likely to have a very limited climate impacts (Blindheim 2015), our interviewees consistently reported ‘green’ motivations as among the reasons for prosuming. Such motivations amongst prosumers appear to relate to climate-friendly associations rather than ‘hard facts’, as the impact on emissions reductions is likely to very low unless other factors outside the electricity system change.

Experience elsewhere (see e.g. Ford et al. 2014 for New Zealand) shows that motivations for prosuming may be grounded in grid independence and trust in grid utilities. In other energy areas, trust has been found to be a relevant factor for prosuming rollout (Eikeland 2014), and trust factors have been found to lead to differences in energy sector behaviour also between countries (Laes, Gorissen and Nevens 2014). Our interviewees have not reported significant confidence in such motivations, and some opined that trust levels are high between DSO and customers in Norway.

While the Norwegian smart-meter rollout has been seen as enabling various behaviours, this probably represents unrealistic expectations for prosuming (Skjølsvold and Ryghaug 2015). In most cases, prosuming will still require changing to a new meter, but smart meters of the kind that will be rolled out in Norway will be ‘prosumer ready’. At present, practices among DSOs vary as to meter requirements. While Hafslund requires its customers to follow the company’s rollout schedule, hence adding costs to early prosumers for two meter changes, other DSOs, among them Fredrikstad and Hvaler, change the meter only once.

However, the coming (in some cases it is already underway) rollout of smart meters has served to raise attention to energy-related behaviour, hereunder prosuming, leading to some noticeable but indeterminate positive effects for prosuming. Potentially inhibiting factors for prosuming are:

- A low electricity price lessens the economic benefits for prosumers
- A full renewable electricity sector may weaken emissions-related motivations for prosuming (although this does not seem to be a strong factor, as several interviewees indicated ‘green’ reasons as contributing to becoming a prosumer)
- As shared metering, e.g. for housing cooperatives, is not possible, the economy of scale for prosumers is reduced for this segment.

Findings for Norway are summarized in Table 1.

Table 1: Findings: prosumer conditions in Norway

Type of mechanism	Prosumer conditions	Indicator
Incentives		
	National support scheme(s)	A national investment scheme (Enova) reduces investment costs and payback time.
	Local support schemes	Several local schemes in areas with many prosumers
	Tax benefits or disincentives	Low relevance
Direct regulatory requirements/ Other regulations	Building code regulations	Some early difficulties in adapting
	(local) planning practices	Some bureaucratic hurdles to becoming a prosumer, but no longer a significant problem
	Smart-meter requirements	Smart meters will be rolled out by 2019; thereafter, new meters for prosumers will not be required, as these meters can manage prosuming. All required smart-meter costs to be borne by end-user.
	Public bureaucratic facilitation	Difficulties for some early prosumers in figuring out for themselves how to manage the installation and requirements from DSOs. Variation in practice among DSOs.
	Bureaucratic goal conflicts between sectors and administrative levels	Some conflict between local planning, technical requirements and different support schemes; coordination is often left to the potential prosumer to navigate.
Information and market practices	Availability of official public information	Some, but this is largely up to the DSO and its practices, as well as the potential prosumer.
	Official certification and energy labelling bodies	Some ‘smart houses’ and ready-made packages in use (roof-top PV) as part of the package; otherwise, prosuming is not part of any certification scheme. In fact, prosuming does not really fit with all certification schemes available in Norway.
	Existence of a third-party market	In some areas (like Oslo, Østfold and Rogaland) there is an emerging market, with third-party prosumer installation companies establishing a presence. These make a considerable difference in facilitation for consumers who are interested but who do not have sufficient technical skills to manage installation themselves.

5 Comparative analysis and lessons for prosumer regulation

Comparing differences in relevant policies among three countries is difficult. Areas of relevant regulations are complex and inter-related, and minor shortcomings in one area can be compensated or modified by other regulations. However, by mapping the relevant regulations and policies we can come closer to a fuller understanding of the most influential aspects likely to affect prosuming. We operate with the categories noted in the introduction: incentives; direct regulatory measures; and information practices and market availability. Before analysing these policy approaches in the three countries we first sum up the developments in prosumer numbers and discuss the findings about the national characteristics of each country, to control for differences right from the start. Detailed information about the individual case countries is presented in the preceding chapters.

5.1 Developments in prosuming: Germany, the UK, Norway

Although official statistics operate with different categorizations in the three countries and are thus not directly comparable, our approximations should give sufficient indications of national figures to the required levels of accuracy. As we have seen, the three countries have followed very different timing and development trajectories as regards prosuming. Germany started with a support scheme that ran from 1990 to 1995 and induced the installation of some 2,000 PV rooftop systems on detached and two-family houses. Further programmes led to a further PV 55,000 installations by 2003. In 2009 the option of own consumption was opened. By 2014 installations smaller than 10 kWp accounted for 56% of all PV systems installed in Germany, 850,000 PV systems in total. Of installed PV capacity in 2014 of approximately 38 GW, the segment below 10 kWp accounted for 13% – about 5,062 MW.

Also in the UK, prosuming figures have been high, starting from around 2000 and peaking between 2010 and 2015. The legal changes in 2000 paved the way for the Feed-In-Tariff (FIT) for micro-generation as complementary support to the larger-scale directed Renewables Obligation (from 2002) and led to some increase in the number of prosumers. Most significant, however, was the rise following the FIT from 2010: more than 100,000 new installations annually, peaking in 2011/2012, roughly around 650,000 in total by 2015.

The odd case in this comparison is Norway, where a formal opening for prosuming came as recently as 2011. A few early prosumers started entrepreneurial projects on a private basis, and only since around 2013/2014 can we note a rising tendency. There are no official national statistics on this, but the number of prosumers as of autumn 2016 is likely to be around 200 and growing.

What caused these differences? Direct support schemes appear to have been important for increasing the number of prosumers, but other factors may have played a role as well. We will discuss the implications of differences in national characteristics, as well as policy differences in support programmes, bureaucratic barriers, access to markets and other factors that may have influenced prosumer figures for the three countries.

5.2 National structural characteristics

The case-studies have presented national characteristics such as differences and similarities in natural resource endowments, in electricity system, political system, electricity price, and other factors. Even though framework conditions stemming from political and regulatory decisions are the main focus of this report, these should not be analysed in isolation from such fundamental structures. Controlled comparison of the relevant structural characteristics of the three case countries is not possible here, but we point out some major differences that form the background against which prosuming policies are decided and implemented.

First of all, we find great differences in the carbon-emissions portfolios, within which prosuming and prosumer policies develop. This is an important point. Both Germany and the UK have established official goals and narratives of the strong need for decarbonization of their electricity sectors, and this has formed a direct backdrop to the implementation of prosumer support schemes. In both countries, coal and gas have high but sinking shares in the electricity mix. Despite differences in decarbonization approaches, prosumers are recognized as a relevant part of this transformation in Germany and in the UK.

For Norway, the situation is quite different. With electricity production almost fully based on renewables, there is little scope for emissions reductions in this sector. In Norway, the need and role of prosuming differ greatly from the situation in Germany and the UK. Prosuming is seen as part of modernization of the electricity system, but its function is significantly less clear, and has yet to be officially expressed in Norway. Thus, there are no official goals for future prosumer numbers: what we find are statements by lower-level officials to the effect that Norwegian public administration 'does not want to stand in the way of prosumer developments'.

As the competence for national prosumer-relevant policies is generally located at the national governmental level, differences in polity structures do not appear to be an important factor. Voluntary support schemes at the local level are an exception here, discussed below in connection with prosumer policies. Regulatory stability is arguably an additional exception. Historically, the UK has been characterized by few political coalitions and the tendency to abrupt policy shifts reflecting changes in political incumbents, although deeper analysis of this aspect is beyond the scope of this report.

5.3 Incentives in Germany, the UK and Norway

Policy-makers can draw on a range of economic incentives, the most important perhaps being the various types of FITs, green certificates, and installation support at the national and local levels.

A striking fact is that, with the most successful cases of increased prosuming in Germany and the UK, a robust and significant FIT has been in place during the periods of highest growth in prosuming. For both countries, the economic incentives appear to have been most effective when they entail a double effect. The first of these effects is stable and fairly predictable economic support for the electricity that is produced and fed into the grid. This provides a sufficiently favourable economic basis for triggering prosumer investments. The second effect is a purchase obligation, or a risk-reducing function for selling the electricity produced. In the periods of the steepest curve in prosumer installations, both Germany and the UK have had economic incentives with this double effect. For Germany, a gradual reduction in FIT rates may have been partly offset by opening up for own consumption (see below) and decreasing system costs. However, reductions in the FIT rates have followed, with implications for prosumer numbers. In the UK, support schemes targeting small-scale PV were significantly reduced, indeed on the verge of being dismantled in 2015, and that led to an abrupt halt in prosumer installation.

Norway has had no similar support arrangements for the period examined here. There has been installation support, nationally and locally, which has probably help to raise prosumer numbers. However, Norwegian support schemes cover parts of the cost of installation, and no feed-in has been in place. At the end of the period studied, green certificates became available also for electricity produced by prosumers; however, this support is generally regarded as inadequate, and incurs further bureaucratic and technical costs for the prosumer. From the experiences of Germany and the UK, we may conclude that, without a stronger support scheme, Norway is unlikely to achieve mass numbers of prosumers, despite the increase in this early phase.

5.4 Direct regulations and regulatory practices

Various regulations and public administrative practices may influence the motivations or opportunities for becoming a prosumer. Our case-studies have mapped the bureaucratic hurdles, as well as other potential factors in this general category. These range from planning-related regulations or practices, to energy-related regulations or policies that influence the prosuming situation, to obstacles to be overcome in order to begin prosuming.

Again, the findings for Germany and the UK are generally quite similar. There are few bureaucratic difficulties, formal procedures or bureaucratic practices for becoming prosumers. Not least in the area of planning there are few obstacles – application procedures or the like – to installing PV on private houses. For Norway, this is somewhat different, although such difficulties should not be exaggerated. While there have been examples of bureaucratic difficulties, they appear to have been reduced, and should in most cases not serve to deter interested consumers.

In other areas, however, we can note significant differences in the three cases. The previous German energy law was far more geared towards prosumers feeding into the German grid than has been the case in the UK.

These differences have been reduced since 2009, but up until then German prosumer electricity had to be fed into the grid, while the UK has allowed self-consumption since the start. Also in Norway, it has been allowed ever since prosuming started, in 2011.

Another matter is the role of smart meters. Smart-meter implementation in Germany and the UK has been a process detached from prosumer implementation, partly because prosuming developments had preceded the development of smart meters by some years. This is partly the case for Norway as well, although the new meters scheduled for roll-out by 2019 will be ‘prosumer-ready’ in the sense of being capable of registering both in- and outflows of electricity. This means that for the future, there will be no need to install a new meter when becoming a prosumer.

In sum, we find that in the initial period, bureaucratic hurdles have been a barrier – albeit minor and temporary – to the development of prosuming in Norway, whereas we find few indications of this more prosumer-advanced Germany and the UK. Also with other kinds of regulations, such as self-consumption and smart meters, there some differences among the case-countries, but they seem to play a lesser role than economic considerations when it comes to influencing prosumer numbers. However, in the future, if smart meters are coupled to prosumer installations, Norway may have as advantage, as the household meter infrastructure for metering prosumer production of electricity will already be in place.

5.5 Information practices and market availability

From an early stage, Germany, and later the UK, politically pushed for the development of a market for technical solutions relating to PV, including micro-PV installations feasible for private households. The presence of such a market is of significance for high numbers of prosumers. This we see in the case of Norway situation, where no such market had been established, but has now begun to appear since 2015/2016. Norway’s first prosumers tended to be people with high technical competence and a special interest in prosuming solutions. They were willing and able to find technical components by accessing markets abroad. Indeed, that was a necessary condition for becoming a prosumer in Norway until about 2014/2015. While this is no longer so , a reasonable assumption for the emergence of large numbers of prosumers is the presence of a market of third-party companies with expertise that can reduce transaction costs. This has been the case for some time now in both Germany and the UK.

Thus, also when it comes to the presence of prosumer-facilitating actors and a relevant market, Germany and the UK are similar, while in Norway there is a less developed but growing third-party market. More actors are coming in, but the market is not yet consolidated, and the presence of and focus for existing market actors is generally around main urban centres, and not households in rural areas.

Table 2: Summing up comparative explanatory factors

Country	**Germany**	**UK**	**Norway**
Prosumer developments	From 1990 to significant increase 2000–2014	From about 2000 to significant increase 2005–2014	Minor increase from 2011
Background characteristics	Strong need for decarbonization and phasing-out nuclear power	Strong need for decarbonization of electricity production	No need for decarbonization of existing electricity production
Incentives	Direct FIT-based support	Direct FIT-based support, but changing and unstable	Some installation support
Direct regulations and practices	Few bureaucratic hurdles	Few bureaucratic hurdles	Some bureaucratic hurdles, but not significant
Information and presence of a third-party market	Well-developed third party market for technical installations	Well-developed third party market for technical installations	Emerging third-party market for technical installations

6 Conclusions: What factors contribute to high prosumer numbers?

This report has investigated the factors that enable or constrain developments in prosuming connected to the national electricity systems in Germany, the UK and Norway. While prosuming is big in Germany and the UK, Norway has only recently opened up for prosuming, and still has few prosumers compared to the two other countries.

We have investigated the possible influence of several types of factors on prosuming: *incentives*, like support schemes, renewable energy schemes, tax benefits, electricity prices, etc.; *direct regulatory requirements*, like building codes, (local) planning regulations, smart-meter requirements or other relevant energy-market regulations, and bureaucratic burdens; and *information practices and market availability*. These have been qualitatively compared in all three countries. Further, we have sought to control for important background characteristics for each country. Such structural factors can make achieving greater prosumer numbers an uphill struggle and may involve influencing policy motivation, or the effect of support schemes or other incentives.

We find that the most important single factor is the existence of a stable, robust and generous support scheme. In the periods with highest growth in prosuming in both Germany and the UK, this took the form of generous FITs, guaranteeing sufficient economic support for electricity fed into the grid by prosuming households. For Norway it is still too early to conclude. As of November 2016, there are signs that a few market actors are willing to increase the price of electricity feed into the grid, which could motivate existing and potential prosumers, but there is little reason to expect any sharp growth in prosuming as long as the support scheme concerns modest investment support, not electricity fed into the grid.

Background factors are also important. Policy strength for supporting prosumers, although not investigated directly in this report, appears connected to such factors as ambitions (and needs) for mitigating electricity-sector emissions. Both Germany and the UK have clear ambitions and official goals for reducing CO_2 emissions in this sector, and achieving high prosumer figures fits in well with this – so prosumer facilitation is in line with official ambitions. High electricity prices are a further strengthening factor. Norway, by contrast, has always had low electricity prices, and with its electricity sector almost fully renewables-based, the role – or ‘need’ – for prosuming is significantly less evident.

Other factors have contributing but not unimportant effects. The existence of few bureaucratic obstacles to becoming a prosumer is relevant, but appears less significant over time for both Germany and the UK. In Norway, such obstacles have had some influence, but predictability seems to be increasing, along with the emerging third-party market of installation companies vital for facilitating prosuming. This is a significantly later development in Norway than in the two other cases, where there have been established markets for technical package solutions for several years now. The one area where Norway might have some advantage involves the national rollout of ‘prosumer-ready’ smart meters by January 2019.

Given the very different situation for its electricity sector as regards the need to restructure, the degree to which Norway should invest politically in promoting and increasing prosuming is open for discussion. However, if that should become a political goal, there might be lessons to be drawn from this report. Stable and sufficient economic feed-in support for potential prosumers is an important element, as it has effects both directly on household decisions as well as in supporting the facilitating market of installation companies. Streamlining of application or registration processes is another point to bear in mind. However, and partly because of the unclear role of prosuming in the Norwegian electricity system, significant and robust feed-in support may not be in place in the foreseeable future. While there is reason to expect some increase in prosumers along the lines of early developments in Germany and the UK, the findings in this report do not lead us to conclude that prosuming developments in Norway are likely to be more than modest. On the other hand, significant prosuming developments in Germany and the UK have had impacts beyond national borders, at least in two regards: by helping to lower the price of PV, and by establishing a market with feasible technical solutions available to private prosumers. These benefits may be accessed also from Norway, and might help Norwegian households to see prosuming as attractive, even without significant financial support.

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