Centre for Sustainability
University of Otago

Prosumer collectives: a review

A report for the Smart Grid Forum

Report Prepared for New Zealand's Smart Grid Forum

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Front cover photo: Solar panel installation at the Blueskin Resilient Communities Trust office. Photo: BRCT.

Executive Summary

The widespread growth globally of micro-generation (particularly PV) means that consumers are interacting with electricity systems in new ways, becoming 'energy prosumers' – both producing and consuming energy.

We define an energy prosumer as *"a consumer of energy who also produces energy to provide for their needs, and who in the instance of their production exceeding their requirements, will sell, store or trade the surplus energy".*

Growing prosumerism has the potential to create challenges for grid management, particularly if local generation becomes concentrated within a part of a lines network, which can particularly occur with the establishment of prosumer collectives.

For this report we reviewed international and NZ articles and reports on this phenomenon, to understanding how and why consumers were adopting microgeneration, and ways in which prosumer collectives are emerging.

In considering how people become prosumers, we found it useful to differentiate between 'active prosumers' whose decision to adopt microgeneration is self-directed and purposeful, and 'passive prosumers' whose entry is the result of external influences or the by-product of other decisions.

The shift to becoming a prosumer creates many opportunities for people to become more actively engaged with the role of energy in their lives, which opens the door for collective engagement.

We reviewed different forms of prosumer collectives in the UK, North America, Europe and Australasia. From these we identified that different models of prosumer collectives are emerging depending on whether the collective was initiated by a community or third party, and whether the microgeneration facility is on a focal site (e.g. a wind turbine cluster) or multiple sites (e.g. PV on many houses in a community).

A further influence is the emergence of new business models and smart technologies that enable prosumers to manage energy production and consumption on a personal and collective level. Some businesses now offer peer-to-peer platforms that enable power-sharing within a microgrid, as well as supporting spatially dispersed collective engagement. For example, prosumers who have surplus power can sell or exchange it directly with others.

We identified and named five models of collective prosumerism: *multi-site community initiatives; focal-site community initiatives; multi-site third-party initiatives; focal-site third-party initiatives; and dispersed-site third-party initiatives.* The common theme is that multiple non-traditional players are consciously engaging with each other in generating and sharing energy and/or the proceeds of energy generation.

We identify a range of drivers, barriers and enablers to collective prosumerism. The decreasing cost of microgeneration and storage is a significant driver, along with aspirations for greater independence, control, sustainability and community cohesion.

Both community and third-party developments are largely initiated by organisations that have not traditionally been part of the electricity industry. If the industry ignores or attempts to suppress this emerging interest by consumers in collective prosumerism, it may find itself becoming increasingly irrelevant in the lives of electricity users.

1. Introduction

Most parts of the globe are experiencing a rapid growth in micro-generation, particularly photovoltaics (PV), which, in many nations, this has been stimulated by the introduction of subsidies to support uptake of renewable distributed generation (Groba, Indvik & Jenner, 2011; Schleicher-Tappeser, 2012). Other nations, including New Zealand, have not provided financial subsidies, but the declining costs of PV panels along with other drivers are (more belatedly) resulting in a surge of uptake (Tyagi et al., 2013; Aanesen, Heck & Pinner, 2012). The ability to self-generate electricity means that consumers are interacting with electricity systems in new ways, becoming 'prosumers' – both producing and consuming energy. This change has to potential to be more than simply functional; the self-production of energy could lead to much broader implications, such as how prosumers understand and use energy in their everyday lives, and how this may lead to new forms of collective engagement with other prosumers and with the electricity industry. This report aims to explore how prosumerism is emerging within New Zealand and globally, and identify some of the emerging implications to the electricity industry.

New Zealand prosumers are primarily those who are producing energy in the form of electricity from solar or wind resources, at private residences or small community owned facilities, through on-site generators[1]. Within New Zealand, the level of most other forms of distributed generation has been relatively low for decades, but uptake of PV has been near-exponential since 2012 (Figure 1). This rise in PV adoption has been largely due to the decreasing costs of purchase and installation, alongside factors such as desire for less dependence on the electricity grid, increased self-resilience, greater control of future outgoings into retirement, and lack of trust in power companies (Ford et al., 2014). As of 31 January 2016 there were 8738 solar installations, of which 8261 were residential. The installed capacity of the residential PV was 29 MW – still low compared to countries like Australia, UK and Germany, but (in contrast to these) purely market-driven

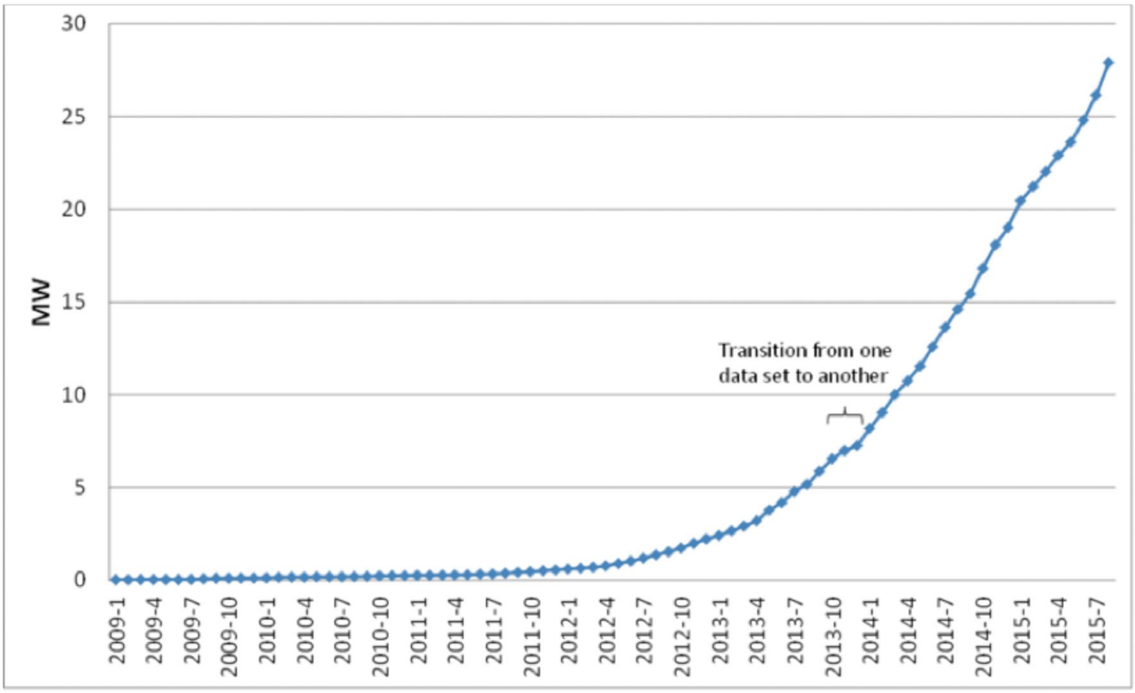

Figure 1: Installed capacity of PV in New Zealand, 2009-2015 (Miller et al., 2015 & Electricity Authority 2015)

PV uptake is not progressing evenly around New Zealand. While the majority of installations of PV are occurring in Auckland and Canterbury (Figure 2), the highest installed capacity per capita (as of December 2015) is in the Tasman and Nelson regions (Figure 3).

1 http://www.emi.ea.govt.nz/Reports/VisualChart?reportName=GUEHMT&categoryName=Retail&reportGroupIndex=7&reportDisplayContext=Gallery#reportName=GUEHMT

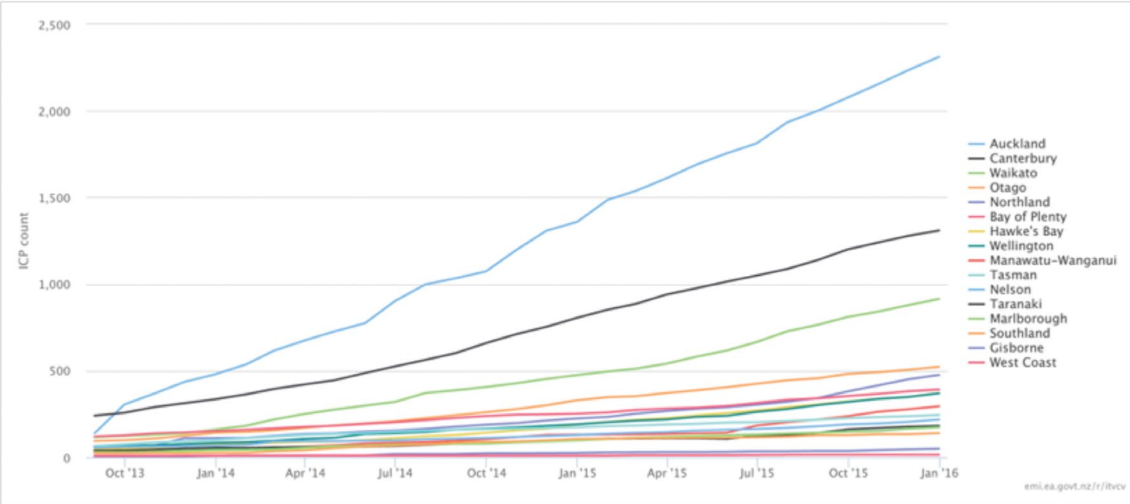

Figure 2: Installed PV in New Zealand by regional council (Electricity Authority 2015)

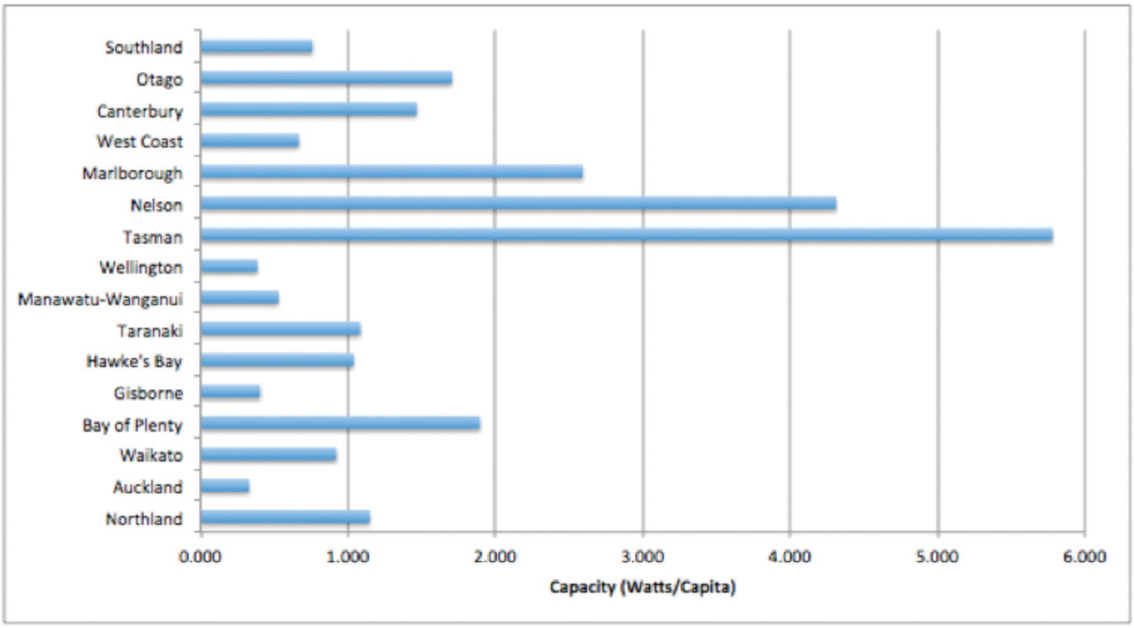

Figure 3: Installed residential PV capacity per capita by regional council (at December 2015)

Within regions, uptake is not uniform either. As an example, the Blueskin area just north of Dunedin, which consists of a cluster of small settlements totalling around 1000 homes, has experienced a rapidly growing interest in and uptake of PV compared to the uptake rates in surrounding areas. Blueskin represents only 6% of the OtagoNet lines network, but in November 2015 had 40% of the residential distributed generation connections and capacity.

Clustering of micro-generation can create issues for the management of the grid, relating both to power quality issues and safety issues, so it is important to understand how and why this may be occurring (Eltawil & Zhao, 2010). Some clustering may be occurring simply because of individual decisions made by consumers, for example, due to the power of interpersonal relationships in encouraging uptake beyond those few innovators and early adopters (Rogers, 2003). However, there are increasing opportunities for consumer-driven collective engagement and new business models (e.g. peer-to-peer) made possible by technological developments. This ability of prosumers to be able to engage more dynamically with a smarter grid and with each other could present additional challenges for distribution companies and power companies.This report describes the emergence of prosumer collectives that are creating (and responding to) new opportunities to collaborate on localised electricity generation, storage and/or use.

The report is based on a review of websites, reports and academic papers to explore how prosumer collectives are developing in different political and geographical contexts. From this literature, we identified drivers, barriers and enablers of transition, the emergence of new expectations and norms relating to energy, and the policy, infrastructure and business model changes that have supported transition and emerged from it. The report is intended to inform consideration of the broader implications of these changes on existing infrastructure, incumbent industry, and local and national energy strategies.

2. Method

The research that informed this report was undertaken in four phases (see Figure 4).

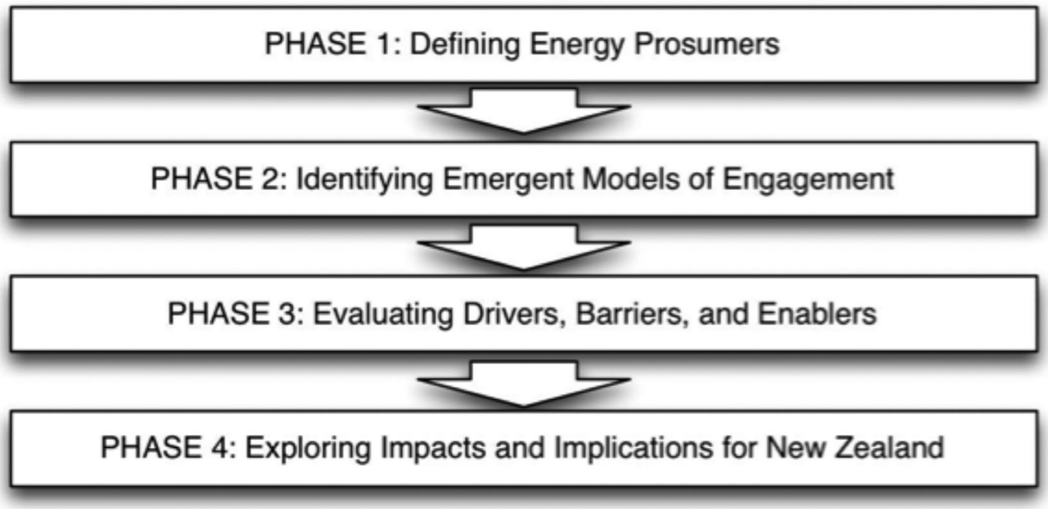

Figure 4: Research roadmap

The first phase of the research aimed to create an operational definition of energy prosumers. We use 'energy prosumers' rather than 'electricity prosumers' because, while the main focus of this report is on prosumers because of adopting PV, some prosumers are involved in other forms of energy capture such as solar thermal, or energy generation such as from biomass.

Keyword searches were conducted in Google Scholar using the keywords "prosumer", "prosumer community" (and "prosumer communities"), "community solar" and "community energy", which, when restricted to articles in English or with available English translation, returned 270 relevant results. Because the purpose of the literature search was to establish the current landscape (as opposed to generating an exhaustive list of all literature on prosumers and community energy), additional databases were not used to identify further articles. From the articles identified, we excluded those that didn't relate specifically to energy (e.g. those describing other types of prosumerism such as collective content creation observed in social media, cloud computing, and web 2.0), as well as those that didn't address groups or collectives of prosumers.

Of the 270 articles identified, 44 were identified as relevant to the current study and retained for review. Backward searches were performed on these papers, whereby the reference sections were reviewed for additional potential articles. Twenty-one studies were identified by this method. The resultant 65 papers were reviewed for any definitions relating to the use of prosumers, of which 30 were used to create an operational definition of energy prosumers (see Section 3).

In the second phase of the research a more detailed analysis of the 65 papers was undertaken to explore how collective prosumerism and community owned energy has been evolving, and how this has led to changes in the way that households interact with traditional energy systems. In particular, we examined two key distinctions in activity: (1) household scale vs. community scale renewable energy systems, and (2) community-initiated uptake at the collective level vs. collective projects driven by third parties. Further, we explored new business models emerging that are starting to enable prosumers to trade energy with others and/or engage in new models of energy management.

In the third phase of the research, the 65 articles were reviewed to explore and document drivers, barriers, and enablers of community or collective prosumerism. Content analysis, a technique of compressing large amounts of text into a manageable data set by creating and coding the text into categories based on a set of specific definitions (Neuendorf 2001; Stemler 2001), was used to identify and define a set of drivers, barriers, and enablers of action. Initial categories were hypothesised based on previous work conducted by the study authors, with additional categories added as needed. An overview of the drivers, barriers, and enablers of community action is presented in Section 4.

In the fourth phase, the data was drawn together to determine the key lessons learned from the review and analysis.

3. Prosumers

While research on microgeneration and residential uptake of solar PV has been abundant in recent years, there seems to be a gap in the literature regarding a specific operational definition of 'prosumer'. This term was originally coined by Alvin Toffler in the 1980s, and was an amalgamation of 'producer' and 'consumer'. Initially the term was used to refer to the blurring of consumers and producers made possible by the digital revolution, but it now has many applications including in cloud computing, technology self-customisation, and energy.

In the energy-related papers we reviewed, the meaning of the term 'prosumer' is generally sourced to Toffler's definition, but there are substantial variations in how it is used in practice. A summary table of definitions is in Appendix 1.

Some authors use a very broad definition of a prosumer such as a "type of energy user who both consumes and generates energy" (Rathnayaka, 2012: p483), while others include a financial element, such that prosumers are those customers who produce energy and sell their excess electricity to make it available on the network (EURELECTRIC, 2015; Karnouskos, 2011). There are also much more specific definitions used, for example that prosumers are limited to those customers who "resonate with the market, responding in real time to supply and demand signals to optimize a product for personal benefit" (Bremdal, 2011: p1)or at those that are an "economically motivated entity that: (1) consumes, produces and stores power, (2) operates or owns a power grid small or large, and hence transports electricity, and (3) optimizes the economic decisions regarding its energy utilization" (Grijalva, S, 2011: p2).

We considered a clear operational definition was needed for the purposes of this report. To tackle this, we reviewed the various uses of and definitions of energy prosumer and identified the common characteristics. From this we came up with the following definition of an energy prosumer:

An energy prosumer is a consumer of energy who also produces energy to provide for their needs, and who in the instance of their production exceeding their requirements, will sell, store or trade the surplus energy.

Active and passive prosumers

In trying to better understand the emergence of different kinds of prosumer collectives, it is useful to consider how people come to be prosumers in the first place. The review of articles about prosumerism makes it clear that some households or businesses become prosumers as a result of a self-directed process that may involve personal research into options and costs, active engagement in commissioning the system, and sometimes personal involvement in installation. Others become prosumers more passively, for example buying into a neighbourhood where PV is part of the package of appliances that come with the house. Furthermore, once people become prosumers they tend to think about and use their energy differently to consumers.

In considering changes involved in moving from being a consumer to a prosumer, it is helpful to think about prosumerism as a change in 'energy culture' (Stephenson et al., 2015). Energy culture (Figure 5) is the interplay between a household's material objects, their practices and their norms. *Material objects* include the buildings, infrastructure, appliances and other technologies that the household owns or controls. *Practices* are the household's actions and activities that result in energy consumption. *Norms* are the household's expectations and aspirations relating to energy and the services it provides. A household's combination of material objects, practices and norms is their *energy culture*, and will give rise to particular patterns and levels of energy use.

A household's energy culture is not simply about their own choices and decisions, but is also shaped to a greater or lesser extent by external influences. For example, choices relating to material culture might be influenced by energy performance standards; practices may be influenced by energy prices; and social marketing might affect norms. These are the red arrows in Figure 5.

A household's energy culture may become habitual in when norms, practices and material cultures are strongly self-reinforcing, and/or where external influences support the status quo. Culture change does occur, however, as a result of choices made by households, together with influences from 'outside'.

Households that become prosumers are a good example of a change in energy culture, as they are changing their material objects (e.g. adopting a PV installation and possibly other technologies such as storage or energy management systems). The research evidence also points to many prosumers changing other aspects of their energy culture once they have adopted PV. For example, they may start to shift their timing of activities in line with their energy generation, they may install additional smart grid edge technologies (e.g. storage or energy management systems), or they may be inspired to get involved with other prosumers (or aspiring prosumers) on collective energy projects.

Some households are more active in initiating the adoption of micro-generation than others, and we have found it useful to differentiate between active and passive prosumers.

Active prosumers are those whose adoption of generation technologies is largely self-driven. The decision to become a prosumer is mainly self-directed and purposeful, although it may have been influenced to some extent by external circumstances (e.g. decreased price of PV, or seeing others in the neighbourhood installing PV). Examples are when households set up their own PV system, or when they actively seek out prosumerism through moving into homes which already have solar installed (e.g. in purpose-built neighbourhoods). Figure 6 indicates this with the solid red arrow indicating that it is the household's own action that is the primary cause of the change.

In contrast to this, 'passive' prosumers are those whose adoption of PV is a result of external influences or as the by-product of other decisions. For example, they may have moved into a house which already has PV (but didn't choose the house because it had PV). Figure 7 illustrates this as a change initiated from outside of the household.

In reality, there will be varying degrees of 'active' and 'passive' prosumerism. For example, people who have been encouraged to take up PV as a result of subsidies are active, but have also been strongly influenced by an external condition (the existence of a subsidy) so can be considered less 'active' than people who do not have this support. The active-passive continuum is useful to keep in mind when we go on to consider the emergence of collectives of prosumers.

They key message here is that being a prosumer is markedly different to simply being a consumer of electricity. The shift to becoming a prosumer by its very nature creates many opportunities for people to become more actively engaged with the role of energy in their lives, and to develop new aspirations, which opens the door for engagement at a collective level.

We now turn to considering collectives of prosumers, which have the potential to engage in quite different ways with the electricity system than at an individual level.

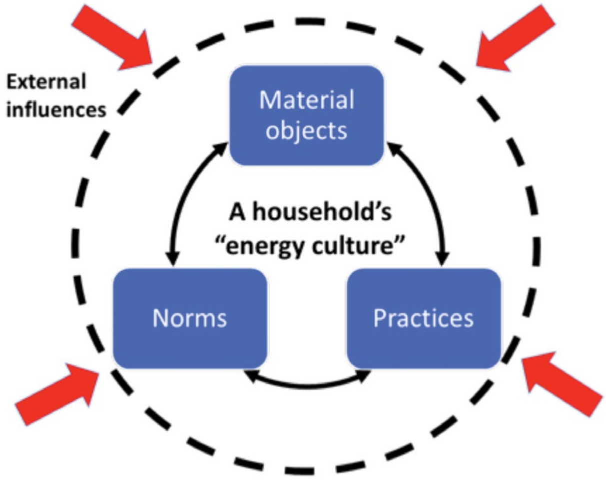

Figure 5: The Energy Cultures Framework

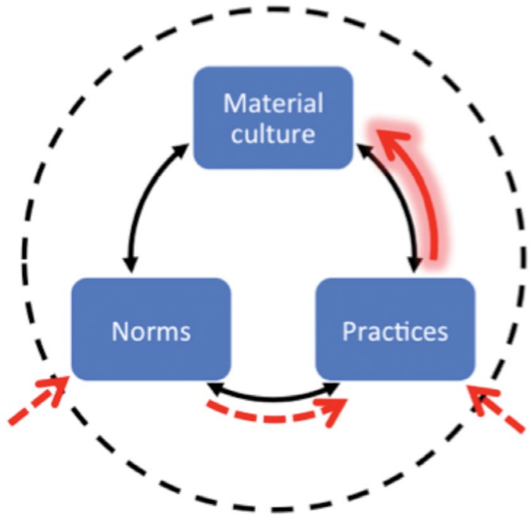

Figure 6: Pathway for active prosumerism. Material change is ultimately driven by actions undertaken by household

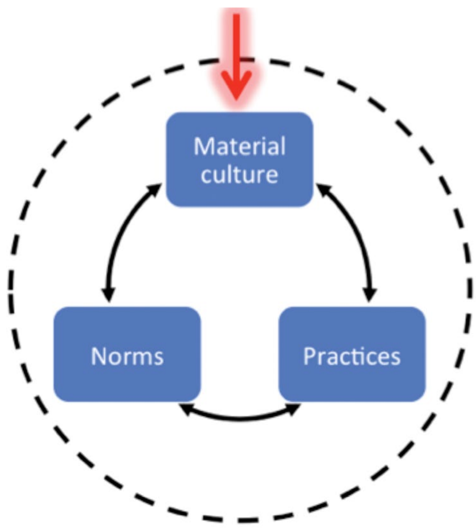

Figure 7: Pathway for passive prosumerism. Material culture change is driven by external influence or contextual changes.

4. Prosumers collectives

This section reviews examples of collective prosumerism in the United Kingdom, North America, Europe and Australasia. The examples mainly relate to solar energy, but some involve wind energy and potentially biomass. Many of the examples are at least partially supported by government incentives, but this aspect was outside of the scope of this report. The examples are explained by country below, and then summarised into four models.

A fuller list of examples is given in Appendix 2.

4.1 United Kingdom

The evolution of prosumer groups in the UK began in the form of community-initiated and community-owned projects in the mid-2000s. The first community-owned wind turbine was installed in the Dulas Valley in Wales, in April 2003.

DULAS VALLEY

The idea for a community-owned wind turbine was conceived in October 1999. From start to finish, the entire project was community-led – the Dulas Valley Community Wind Partnership (DVCWP) formed in December of that year, with sub-groups taking responsibility for different aspects of the project. In April 2003 a second-hand 75kW turbine was installed on the hill above the Centre for Alternative Technology (CAT), who agreed to buy the entire electricity output for the lifespan of the turbine; the income is paid in dividends to members of DVCWP.

http://www.ecodyfi.org.uk/pdf/windcs_broddyfi.pdf

Since Dulas Valley, there have been many community-owned and operated projects launched - wind, solar and biomass. The increased amount of community-owned generation has led to the need for new business models to enable prosumers to trade surplus energy. This gap in the market has been identified and companies such as Piclo have emerged to offer a solution.

PICLO

Piclo, currently undergoing a trial period, describes itself as an "online peer-to-peer energy marketplace," providing a link between producers and consumers in terms of energy sharing, as an alternative to buying and selling from the grid. A sense of self-empowerment has been identified as valuable to prosumers, both by the prosumers themselves, and by the industry. Piclo has recognised this; subsequently consumers and producers can choose where and who they buy from and sell to, based on values, goals, or a desire to support specific projects and initiatives.

www.piclo.uk

We also found a number of community initiatives that coordinate community investors to finance jointly owned generation, such as Brixton Energy:

BRIXTON ENERGY

Brixton Energy is a not-for-profit organisation who facilitate community-owned projects on social housing estates. They completed their first community solar project in March 2012, and have since completed two similar projects; members of the community buy shares in the projects, and a portion of the income generated is invested in the Community Energy Efficiency Fund (a fund to be put towards improving the local area's energy saving practices). Brixton Energy have identified four goals to (1) generate energy in Brixton, (2) increase Brixton's energy resilience and security, (3) raise awareness about energy efficiency and how to tackle fuel poverty, and (4) provide training and employment for local people.

www.brixtonenergy.co.uk

4.2 North America

As in the UK, there are many community-owned, small scale solar/wind projects in Canada and the US. Solar farms established by third parties have also become popular, whereby people buy shares or lease panels and are subsequently entitled to either power output or profit from sales - such as Solar Pioneer II.

SOLAR PIONEER II

Solar Pioneer II, which follows from Solar Pioneer I (a 30kW project launched in 2000) is a 63.5kW project on the roof of the City service centre in Ashland, Oregon. The project is maintained by the city, and comprises 363 PV panels. Ashland residents can "adopt" part or whole solar panels, entitling them to have the output of the panels credited to their electric bill for 18 years.

http://www.ashland.or.us/Page.asp?NavID=14017

Another growing trend is purpose-built prosumer neighbourhoods. Drake Landing Solar Community is an early version using solar thermal.

DRAKE LANDING SOLAR COMMUNITY

Located in Alberta, Canada, Drake Landing Solar Community (DLSC) was built in 2005. A purpose-built neighbourhood comprising 52 homes with space and water heating supplied by solar thermal from an 800-panel garage mounted array. A combination of seasonal and short-term thermal storage facilitates collection and storage of solar energy in the summer for use in space heating in winter. Borehole storage provides energy to the community over the winter months.

www.dlsc.ca

In another example, PV was incorporated in affordable housing developments.

RIVER GARDEN APARTMENTS

This development in Louisiana has 420kW of PV installed on 89 houses over a square mile. Each house has between 4kW and 6kW installed. The project was funded by investments from governmental agencies, with the goal of increasing resilience after Hurricane Katrina. Residents save around 50USD per month on their power bill.

https://www.energysage.com/project/6540/pv-420-kw-river-gardens-solar-neighborhood/

With high-density housing it is not always feasible for an individual (e.g. someone living in an apartment block) to install PV. This barrier has been recognised and responded to, both with solar farms, as discussed above, and with business models designed to link prosumers with consumers who are unable to produce electricity.

YELOHA

Yeloha is split into 'Sun Hosts' (prosumers) and 'Sun Partners' (consumers) and is designed to offer solar to those who cannot have PV on their roofs. A Sun Host is provided with free installation and power, in exchange for 'sharing' the surplus of their energy with Sun Partners. Sun Partners stay with their current utility provider, and buy membership to Yeloha who then offsets their power bill.

www.yeloha.com

4.3 Europe

PV installation in Germany has boomed since the mid-2000s, in part due to the feed in tariffs (introduced by the Renewable Energy Sources Act in 2000) coupled with the rapidly decreasing price of PV. At the end of 2015, there were approximately 1.5 million PV installations in Germany, with a total installed capacity of ca. 40 GW, and PV generation supplied approximately 7.5% of Germany's net electricity consumption for that year (Wirth, 2015).

The sector has responded to this largely decentralised means of energy production, by looking into new ways for consumers and producers to interact and trade. An example of this is Sonnenbatterie, which is due to launch in 2016.

SONNENCOMMUNITY

In 2015, Germany energy storage company Sonnenbatterie launched a peer-to-peer community energy trading platform, sonnenCommunity. Referred to by the CEO of Sonnenbatterie as the "Airbnb of energy", sonnenCommunity connects sonnenbatterie owners to consumers of energy online. It utilises decentralised power generation, battery storage technology, and digital networking supported with a self-learning software platform to enable the sharing of surplus energy across a virtual community, with advantages including cheaper power.

https://www.sonnenbatterie.de/en/sonnenCommunity

As in North America, German developers have recognised that purpose-built prosumer neighbourhoods offer a point of difference in the market, offering the prosumer opportunity to households that may otherwise not become prosumers due to the hurdle that technology installation poses. An example is the Schlierberg Solar Settlement in Freiburg:

SCHLIERBERG SOLAR SETTLEMENT

The Solar Settlement is a collection of 59 apartments grouped into townhouses, and a service centre (the "Sun Ship"). All the houses are "PlusEnergy" houses, meaning their production exceeds their consumption; peak PV output from the settlement is around 445kW. The Sun Ship, also a PlusEnergy building, contains the EcoInstitute, retail spaces, and office space.

http://www.rolfdisch.de/

4.4 Australasia

Australia has high levels of solar irradiance, and also has had a variety of subsidies to encourage solar generation. Collective prosumer projects have emerged both out of a desire for sustainability, and because, particularly in rural areas of Australia, connecting to the grid can be far more costly than self-generation.

Community projects similar to Dulas Valley, where community members co-invest in a small-scale generation scheme, have emerged all over Australia. An example is Hepburn Wind:

HEPBURN WIND

Hepburn Wind, established by the Hepburn Renewable Energy Association (SHARE) launched Australia's first community wind project in 2007. The project was conceived in 2004, and comprises two turbines, totaling 4.1 MW. Hepburn Wind is volunteer-run (the volunteers are members of the project and thus receive returns on investment) and has an agreement with Energy retailer Red Energy, who have committed to buying the entire output of the turbines, and have developed a scheme whereby they encourage people to choose Red Energy as their provider, and in return RE will contribute part of their takings back to the Hepburn Wind Community Fund.

www.hepburnwind.com.au

Other forms of cooperatives are emerging that facilitate the development of prosumer collectives, providing funding, labour and/or management expertise. An example is Community-Owned Renewable Energy Mullumbimby (COREM).

COREM: MULLUMBIMBY

Similar to Brixton Energy, COREM is a volunteer-run group who are interested in setting up community-owned projects. They source funding from the NSW Office of Environment and Heritage, and from donations, with the aim of using the income from successful projects to fund more local projects. COREM have two main projects: the first is a 10 kW PV system on the roof of the Drill Hall in Mullumbimby, the second is a proposed 60-90 kW community solar farm formed in conjunction with the local council, and funded by member investments.

www.corem.com.au

Although New Zealand has seen a significant rate of uptake of PV in recent years (Ford et al., 2014), absolute levels are substantially lower than seen in the other nations discussed above, likely due to the lack of government subsidy, and the consequently higher upfront costs associated with the technology. However, there are pockets of where uptake is occurring in a concentrated fashion; one of the most notable and documented examples being the Blueskin Bay area in the South Island:

BLUESKIN BAY

This area comprises 9 settlements and about 1000 households, spread over a stretch of coastline 15km north of Dunedin. Spurred on by a flooding event in 2006, members of the community created a vision for a resilient community, including local generation and improved home energy performance. The Blueskin Resilient Communities Trust (BRCT), established in 2008, has been leading research, funding applications, and establishment of what they hope to be New Zealand's first community owned wind cluster. Research undertaken in the community also identified a strong desire for solar PV, so the BRCT supported residents on this journey through promoting the technology, providing trusted information, and facilitating purchase. The result was a relatively high level of PV compared to the surrounding area – as at September 2014, 23 of the 35 PV connections within the OtagoNet lines network were in the Blueskin substation area. At that time, Blueskin households represent only 6% of OtagoNet's connections, but comprised 70% of installed DG capacity in OtagoNet's network (King et al., 2014). As a result of clustered uptake, some Blueskin Bay prosumers are now actively considering how to establish a form of collective power-sharing amongst neighbours, with a mix of generation, storage and smart energy management.

www.brct.org.nz

4.5 Models of collective prosumerism

It is clear that collective prosumerism is occurring in a variety of ways.

In some instances, collective action within a community results in the initiation and development of community scale micro-generation using a co-operative model. Generally there will be a small group at the core of a project to drive progress, with other members of the community (and potentially external investors) coming on board at later points in the project, perhaps through share offerings or other means of involvement. The most common technologies seen in these types of project are PV arrays, wind and biomass. Projects tend to be on community or government-owned facilities (e.g. social housing, schools), or on land leased from utilities/councils. Funding for these is generally via grants, however some are utility and/or member financed. They do not generally include storage as they tend not to run at a surplus. Examples include Dulas Valley, Blueskin's proposed wind development, and Hepburn Wind.

These projects tend to follow a number of steps (see Figure 8), with community members being involved from the outset.

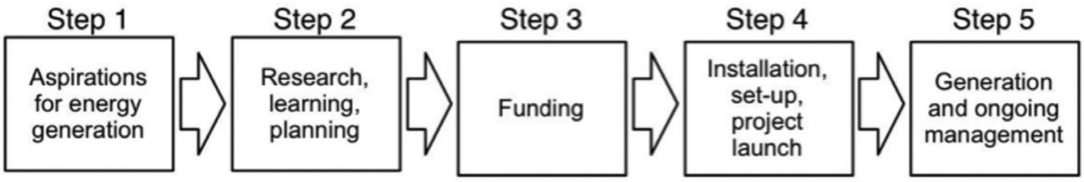

Figure 8: Steps undertaken to initiate energy generation projects

Another form of community-initiated collective prosumerism may start to emerge from the fact that micro-generation often tends to develop in clusters, whereby many houses in a street will have PV, for example. Factors that drive clustering of PV will vary with location but are likely to include visibility, word-of-mouth recommendations and social desirability, along with locally specific characteristics such as suitable levels of solar irradiation. Clustering creates an opportunity for individual prosumers to engage with each other and work out how they might improve their collective interests by selling or exchanging surplus their electricity with others in the neighbourhood, or storing their or others' surplus for later use. We did not find any examples of localised exchange in our review, but it is technically possible and certainly has been seriously discussed in the Blueskin community. Such exchanges could occur through the local network using peer-to-peer services (see section 4.6), or (if they could be legally established) through dedicated lines directly connecting the prosumer houses.

Third parties (i.e. neither consumers nor (usually) electricity retailers) are initiating some other models of collective prosumerism. At the household micro-generation scale, the most common example is a purpose built community (for example Drake Landing Solar Community, Schlierberg Solar Settlement). In these instances, third parties (e.g. housing estate developers) often build homes in a new suburb that have household level generation as part of the home package (or the wired-in potential for this). The main examples are solar PV and often with storage. In this instance a prosumer collective emerges because of the development initiated by actors external to the community itself.

Similar to this at the community scale are electricity generation developments, initiated by third parties, whereby community members are offered the ability to buy into solar and/or wind farms and in return are entitled to a portion of the energy produced, and/or profits from the business. The Solar Pioneer projects are an example.

In summary, four different models can be identified, depending on the initiator (i.e. whether the project has been initiated by a community or by an external party); and ownership (whether the project is multi-site, based on micro-generation owned by multiple households, or is a focal site (i.e. one or several collectively owned installations). Figure 9 illustrates these different models.

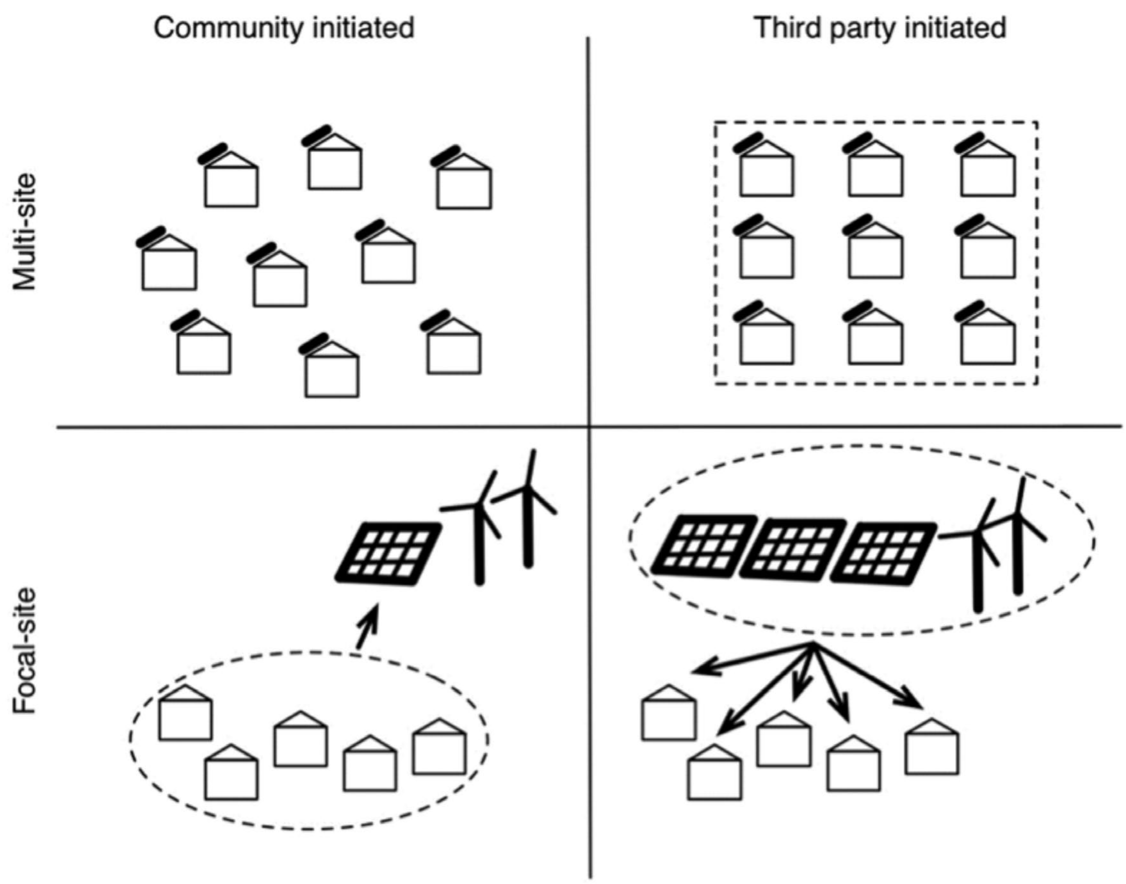

Figure 9: Models of prosumer collectives according to initiator and ownership

4.6 A fifth model – Dispersed Collective Prosumerism

A further novel development is the emergence of dispersed collective prosumerism, made possible by new business models offering ways for prosumers (or prosumers and consumers) to interact at distance for the benefit of both. Companies such as Sonnenbatterie, Piclo, and Yeloha are emerging as a response to new aspirations by consumers to shift from consuming centrally generated power to consuming and sharing renewable generation. This may be a similar societal shift to the interest in the provenance of foods, clothing and other consumables – i.e. people wishing to know the source, production method and ethical basis of goods and services. Start-up companies and social enterprises are responding to the appetite emerging in the market, and developing solutions that use smart technologies and ICT to enable prosumers to more independently manage energy production and consumption. Three examples identified in this work (Piclo, Yeloha, and SonnenCommunity) all provide platforms that enable those who have surplus energy generation to sell power to other consumers using a variety of different peer-to-peer business models. In keeping with the language of the four models identified in section 4.5 we have called these *dispersed third-party initiatives*.

The predicted ongoing lowering of the price of PV and battery storage, together with business offerings that support collective prosumerism, suggests it is here to stay and may well grow to become a significant part of the electricity market. At least one commentator suggests that such developments could eventually lead to a "death spiral" of the traditional power grid, whereby power from renewable micro-generation is used or traded locally in preference to centrally generated power, leading market prices to drop and even go negative.[2] Peer-to-peer trading platforms could open up additionally possibilities that are economic in their own right, and give consumers even greater choice over where their power comes from.

Understanding why collective prosumerism is emerging, and identifying the barriers and enablers of action, is therefore critical to ensure that the incumbent industry is equipped to respond to the emergence and potentially rapid rise in such projects.

2 http://www.greentechmedia.com/articles/read/this-is-what-the-utility-death-spiral-looks-like

5. Drivers, barriers and enablers

Collective prosumerism appears to being driven both by the desire of consumers and prosumers to engage more directly with electricity generation in ways that give them more control; and also the new opportunities arising from co-localisation – the combination of local distributed generation and interest by local investors.

There has been substantial research undertaken globally to attempt to identify the variety of drivers (things that motivate people to want to take action), barriers (things that prevent people from taking action) and enablers (things that help people to overcome barriers to take action) relating to household level adoption of micro-generation, particularly PV. We first l briefly summarise findings relating to individual prosumerism, and then discuss what is known about drivers, barriers and enablers for collective prosumerism.

Individual prosumerism

The most commonly identified drivers include environmental motivations to live a "green" or low-carbon lifestyle, a desire to save energy and outgoing on power bills, aspirations of greater autonomy (in relation to both energy needs and future outgoings), and the 'norming' of PV (increased prevalence and popularity of PV amongst social peers who seemed satisfied with their choices).

The major barriers identified in the literature relates to the cost of PV panels and installation, and while this is coming down, there are still lengthy payback periods and financial risks. Others barriers are concerns over the technology: both its reliability (over time) and compatibility with current household energy demand patterns. Another commonly expressed barrier is a general lack of knowledge and information about micro-generation and its costs and benefits.

Subsidies for renewable technologies, as offered in many countries has been important in helping overcome cost barriers, , although research has shown that it is not the subsidy alone, but the interaction between policy design, electricity price, and electricity production cost, that is the important determinant in stimulating renewable development (Jenner, Groba & Indvik, 2013). New business models have also entered the market that reduce the cost of entry into PV. Other key enablers of uptake at the household scale have resulted from provisions of guarantees and assurances around system maintenance, and improvements in the industry leading to greater trust in installers and simpler and easier installation procedures providing minimal disruption to household practices.

Collective prosumerism

Unsurprisingly, there are many similarities between drivers, barriers and enablers of individual and collective prosumerism. However there are a number of additional aspects observed in the literature that motivate, prevent, and support action at the collective level. While many of these have a direct influence, some are more complex, simultaneously having more than one impact. For example, cost is simultaneously a barrier and a driver for action (while collective scale projects are expensive and financing can be a barrier to action, increasing power bills and decreasing costs of technology means micro-generation is becoming comparatively more affordable, and this a driver). The drivers, barriers and enablers are elaborated on below, and summarised in Figure 10.

5.1 Drivers

Worldwide, there is growing interest in shifting towards more environmentally sustainable and ethical ways of living. A strong desire to cut carbon emissions has been identified; and in the energy sector this has driven a desire by consumers to use renewable energy sources. As popularity is increasing and collective prosumer projects are proving successful, a 'knock-on effect' has been observed; more local projects are taking place on the back of news of successful similar projects. An example of this is the success of Solar Pioneer I (a 30kW project) leading to the launch of Solar Pioneer II (63.5kW)[3]. Prosumer collectives are also driven by the attractiveness of self-empowerment – more local control, less reliance on centrally-generated electricity and, especially among rural communities, an increase in energy security.

The potential for financial benefit is another driver. With decreasing costs of at least some forms of distributed generation, and rising energy costs from traditional sources in many instances, self-production is becoming comparatively more affordable. Local collective projects may often have a better potential for financial return than individualised prosumerism as they have lower upfront costs per capita, the ability for bulk purchasing, and reduced need to outsource labour. In the long-term they also have the potential to create employment, and return on investment from sale of surplus electricity to specific users or back into the grid. Groups can feed energy back into the grid at a larger scale than individuals, meaning higher bargaining power with utilities.

Another attraction is the potential for profits to be channelled into further collective projects. This has been recognised by COREM and subsequently they have set up a "Revolving Community Energy Fund" into which some of their savings and investments are channelled, in order to ideally induce a cascade of community-owned renewable energy projects[4]. This is also the aim of the proposed Blueskin wind cluster.

3 http://www.ashland.or.us/Page.asp?NavID=14017
4 www.corem.com.au

5.2 Barriers and enablers

Collective prosumerism would not be possible without the ability for prosumers to be well-informed, trust the data, and easily interact with others so as to gift or trade surplus power. The emergence of new technologies and infrastructure (e.g. smart grid, smart technologies) are important enablers of the successful formation and management of prosumer groups. The ability of prosumers to interact (both with energy and with each other) has been largely facilitated by advances in energy management systems and ICT.

Storage of surplus electricity can greatly assist in the ability to optimally manage power flows. The cost of storage (e.g. a battery pack) is another potential barrier, but battery costs are falling as technology improves and production increases (Nykvist & Nilsson (2015). Some collective prosumer developments - for example Drake Landing Solar Community - have invested in mass storage. A future enabler is the massive investment globally in battery development and other forms of storage, and the emergence of a wide variety of storage solutions at different scales, and with increasingly viable prices.

Funding community-level projects is not easy - the sheer cost involved with the setting up of such projects tends to be a deterrent. Additionally, grants tend to be channelled into short-term projects, and are often not allocated to longer-term projects. However, with policy in some countries shifting to be geared more towards encouraging renewables, prosumer collectives are quickly becoming more feasible. A strong enabler in terms of the financing of projects is the "collective" nature of such projects; the sense of pride and community that comes with collaboration means that people want to invest in these types of projects. Funds, skills and resources can be pooled, and the increasing normalisation of collective prosumerism means it is no longer seen as risky as at the outset.

Management of projects is hugely important to success, and community projects are often hard to manage with different interests and personalities. Third-party owned and managed projects may be filling the need to simplify the complexity of collective ownership and is perceived to provide a much higher level of security. In addition, utilities are coming up with new methods of managing prosumers and their energy, and distributing this in different ways; for example Yeloha's "sun hosts" and "sun partners".

While the collaborative nature of community-initiated prosumer collectives is attractive, lack of collective commitment can be a barrier. The shift from individual to collective prosumer alliances requires social cohesion. Strong community-level engagement, particularly when accompanied by local aspirations for community resilience and the presence of community members with high levels of technical know-how, can help build commitment such as that observed in Blueskin Bay in New Zealand.

Grouping prosumers with similar goals and beliefs has been identified as another method of increasing success and effectiveness of collective projects (Rathnayaka, 2011). Businesses have recognised this potential gap in the market, and business models that allow consumers to choose where their energy comes from (if buying off a prosumer) have emerged.

These drivers, barriers and enablers are summarised in Figure 10. The overlaps represent where a factor can be in more than one category. Social cohesion sits at the centre – a driver (in the sense that people desire the sense of cohesion that can result from a collective project); a barrier (in that a lack of cohesion can make it hard to act collectively) and an enabler (in the sense that strong cohesion can make it happen).

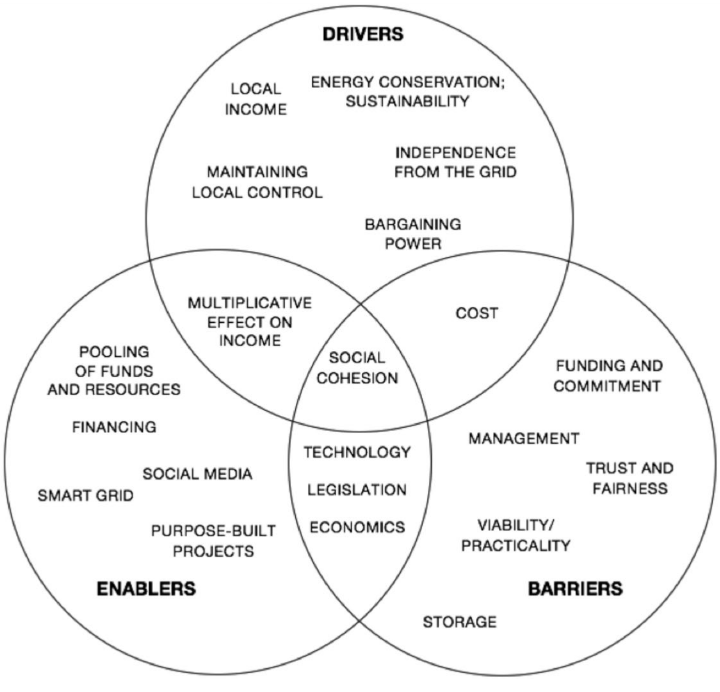

Figure 10: Overview of drivers, barriers, and enablers of collective prosumerism

6. Conclusion

An energy prosumer is a *consumer of energy who also produces energy to provide for their needs, and who in the instance of their production exceeding their requirements, will sell, store or trade the surplus energy*. Prosumerism is increasing rapidly at a global and local scale, as it becomes increasingly straightforward and cost-effective for households (or businesses) to be prosumers.

Collectives of prosumers are a newer phenomenon, and are emerging in many forms. We have identified and named five models that are evident in the examples we reviewed: *multi-site community initiatives; focal-site community initiatives; multi-site third-party initiatives; focal-site third-party initiatives;* and *dispersed-site third-party initiatives*. The common theme is that multiple non-traditional players are consciously engaging with each other in generating and sharing energy and/or the proceeds of energy generation.

If prosumer collectives expand at a similar rate to prosumers, they may start to create challenges for traditional electricity generators, distributors and retailers. Both focal-site and multi-site initiatives, unless they are completely off-grid, may raise issues of power quality and safety through feeding electricity back into the grid in more geographically concentrated ways than is likely from more randomly dispersed prosumers. Questions may arise as to the suitability of the local grid to handle the amount of electricity fed in by a prosumer collective, and regarding the ability (and cost) for generators to be able to supply sufficient electricity to the collective at times that it is not producing. Pricing models for distribution may need to be revised to account for these new patterns of use. But these are operational issues, likely to be able to be resolved with technical and pricing solutions.

At a more fundamental level, prosumer collectives also challenge the structure of the electricity industry. One description of collective prosumerism was like Airbnb in relation to the hotel industry. It could also be seen as the Uber of the taxi industry. Collective prosumerism similarly appeals to people's interest in personal engagement and personal control, and a similar willingness to trade the level of service for less upfront cost. As with Airbnb and Uber, it is enabled through developments in ICT and data management, together with nimble new entrants thinking outside the square.

How widespread collective prosumerism will become depends on many factors, with the changing price of microgeneration being probably the most significant. Another factor is likely to be the new models of operation and business that emerge in coming years, and either fly or fail. Battery storage will be a game-changer if prices continue to drop significantly, as they give prosumers greater control, greater ability to optimise their energy exchanges with others, and the option to go completely off-grid should they choose. A further factor will be the response of the incumbent industry to this clear signal by consumers that they want something different. It is notable that the third-party developments are largely initiated by organisations that have not traditionally been part of the electricity industry. If the industry ignores or attempts to suppress this emerging interest by consumers in collective prosumerism, it may find itself becoming increasingly irrelevant in the lives of electricity users.

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Appendix 1: Prosumer definitions

Author	Title	Year	Location	Definition
Alcarria, R., Robles, T., Morales, A., Gonzales-Miranda, S.	New Service Development Method for Prosumer Environments.	2012	Madrid, Spain.	An acronym formed by the fusion of the words producer and consumer… is applied to those user that are at the same time consumers and producers of services or contents.
Brand, L. et al.	Smart district heating networks – A simulation study of prosumers' impact on technical parameters in distribution networks.	2014	Lund, Sweden.	A customer that both produces and consumes direct heat.
Bremdal, B.A.	Prosumer Oriented Business in the Energy Market	2011	Norway	Consumers who also produce. Consumers that resonate with the market, responding in real time to supply and demand signals to optimize a product for personal benefits.
Bremdal, B.A.	The Impact of Prosumers in a Smart Grid based Energy Market.	2013	Norway	Not merely consumers that also produce energy, but active participants in the market… [with] the capacity to sell their flexibility both as producers and consumers to different players in the energy market.
Da Silva, P.G., Karnouskos, S.	The Impact of Smart Grid Prosumer Grouping on Forecasting Accuracy and its Benefits for Local Electricity Market Trading.	2014	Karlsruhe, Germany.	A consumer that has its own production capacity.
EURELECTRIC	Prosumers – an integral part of the power system and the market.	2015	Brussels, Belgium.	Customers who produce electricity primarily for their own needs, but can also sell the excess electricty.
Gaetan Mason, I.	PV Development as Prosumers: the role and challenges associated to producing and self-consuming PV electricity.			PV producers who consume a part of the electricity produced. i.e. consumers who are also producers of their own electricity.
Grijalva, S., Tariq, M.U.	Prosumer-Based Smart Grid Architecture Enables a Flat, Sustainable Electricity Industry.	2011	Atlanta, USA.	An economically motivated entitiy that: 1. Consumes, produces and stores power, 2. Operates or owns a power grd small or large, and hence transports electricity, and 3. Optimizes the economic decisions regarding its energy utilization.
Grijalva, S., Costley, M., Ainsworth, N.	Prosumer-Based Control Architecture for the Future Electricity Grid.	2011	Atlanta, USA.	An entity that can do at least one of the following: consume, produce, store, or transport electricty.
Izvercianu, M., Seran, S.A., Branea, A.M.	Prosumer-oriented Value Co-creation Strategies for Tomorrow's Urban Management.	2013	Timisoara, Romania.	Prosumers are expanding their traditional consumer role, becoming knowledgeable active participants in value creation, creatively engaged in organizational activities, with a high impact on brand equaties.
Kastel, P., Gilroy-Scott, B.	Economics of poolng small local electricity prosumers – LCOE and self-consumption.	2015	UK	Entities/households that are producer and consumer of energy in one.

Author	Title	Year	Location	Definition
Nazari, M.H. et al.	Distributed Frequecy Control of Prosumer-Based Electric Energy Systems.	2014	Atlanta, GA. USA.	Economically motivated agents… able to produce, consumer and/ or store electricity, as well as make strategic decisions enabled by deployment of communication and information technologies.
Picciariello, A., Vergara, C., Reneses, J., Frias, P., Soder, L.	Electricity distribution tariffs and distributed generation: Quantifying cross-subsidies from consumers to prosumers.	2015	Stockholm, Sweden.	Users with self-production… that both consume and produce.
Rathnayaka, A.J.D. et al.	A Methodology to Find Influential Prosumers in Prosumer Community Groups.	2014	Bentley, WA. Australia.	An emerging entitiy in the energy value network who not only consumes energy but also generates and shares the green energy with the utlity grid.
Rathnayaka, A.J.D. et al.	An Innovative Approach to Manage Prosumers in Smart Grid	2015	Perth, WA. Australia.	Those that both generate and consume electricity.
Rickerson, W.	Residential Prosumers – Drivers and Policy Options (Re-Prosumers)	2014	Boston, Ma, USA.	Energy consumers who also produce their own power from a range of different onsite generators.
Ritzer, G., Dean, P., Jurgenson, N.	The Coming of Age of the Prosumer.	2012	MD, USA.	One who is both producer and consumer.
Timmerman, W., Huitema, G.	Design of Energy-Management Services – Supporting the Role of the Prosumer in the Energy Market.	2009	Gorningen, The Netherlands.	Energy-producing consumers.
Timmerman, W.	Energy Management Services for Prosumer Communities.	2012	Goeninen, Netherlands.	They can (partly) provide for their own energy supply, and whenever there is a surplus of production in relation to the momentary consumption, this surplus is fed back into the grid.
Toffler	Powershift	1990		Consumer and producer fuse into a 'prosumer'

Appendix 2: Case studies

Name	Location	Year Est	Description	Source
Blueskin Bay	Otago, NZ	2008	Area comprising 9 settlements and ~1000 households. The Blueskin Resilient Communities Trust (BRCT) was established in 2008 to develop a resilient community, with a strong focus on energy resilience. Plans for NZ's first community-owned wind cluster are well advanced. Many households in the area have also purchased and installed solar, thus there are unusually high levels of distributed generation feeding into the local substation.	www.brct.org.nz
Brixton Energy	London, UK	2012	A not-for-profit organisation who have been facilitating community-owned projects since 2012. Members of the community buy shares in projects, and income generated is invested in the Community Energy Efficiency Fund (a fund aimed at improving the local area's energy saving practices).	www.brixtonenergy.co.uk
COREM: Mullumbimby	NSW, Australia	2014	Community-Owned Renewable Energy: Mullumbimby (COREM) is a volunteer group funded by the NSW Office of Environment and Heritage, involved in setting up community-owned projects. Two main projects – a 10 kW and a 90 kW PV project funded by member investments. COREM aims to eventually use the income from these projects to fund future projects.	www.corem.org.au
Drake Landing Solar Community	Alberta, Canada	2005	A purpose-built neighbourhood comprising 52 homes with space and water heating supplied by solar thermal from an 800-panel garage mounted array. A combination of seasonal and short-term thermal storage facilitates collection and storage of solar energy in the summer for use in space heating in winter. Borehole storage provides energy to the community over the winter months.	www.dlsc.ca
Dulas Valley	Wales, UK	2003	A 75 kW turbine installed on the hill above the Centre for Alternative Technology, who agreed to purchase the entire output of the turbine. Run by the Dulas Valley Community Wind Partnership; the income from the turbine is paid in dividends to DVCWP members.	http://www.ecodyfi.org.uk/pdf/windcs_broddyfi.pdf
Findhorn Ecovillage	Scotland, UK	1989	Four community-owned turbines totalling 750 kW, connected to a privately owned grid. The community imports from and exports to the grid, and overall are net exporters, only using around 50% of the electricity produced. Funding was sought from a trust, the Findhord Foundation and the Caledonia Renewable Energy Co-operative. The community also invests in projects surrounding organic food production, ecological waste water treatment and the construction of ecological buildings.	http://www.ecovillagefindhorn.com/
GobNob Wind Turbine	Illinois, USA	2009	Installation of a 900kW turbine on land leased from the Illinois Department of Natural Resources, feeding power to ~380 members' homes and farms. Run by the Rural Electric Convenience Cooperative (RECC) Board of Directors. Initial cost of the turbine system was ~$1.8 million (funded by grants) - remaining cost funded by Clean Renewable Energy Bonds.	http://www.recc.coop/renewable-energy/gobnob-wind-turbine/
Hepburn Wind	VIC, Australia	2007	Hepburn wind launched the first community wind project in Australia; two turbines totalling 4.1 MW and providing power to ~2000 homes. Entirely volunteer run, and has a scheme with Red Energy (RE) whereby RE buys the output, and contributes part of their customers' bill back to Hepburn Wind Community Fund.	www.hepburnwind.com.au
Piclo	UK	2015	An "online peer-to-peer energy marketplace," which provides a link between producers and consumers in terms of energy sharing, as an alternative to buying and selling from the grid. Consumers and producers can choose where and who they buy from and sell to, based on values, goals, or a desire to support specific projects and initiatives.	www.piclo.uk

Name	Location	Year Est	Description	Source
River Garden Apartments	Louisana, USA	2011	420kW of PV installed on 89 houses over a square mile - each house has between 4kW and 6kW installed. Funded by investments from governmental agencies, with the goal of increasing resilience after Hurricane Katrina. Residents save around 50USD per month on their power bill.	https://www.energysage.com/project/6540/pv-420-kw-river-gardens-solar-neighborhood/
Schlierberg Solar Settlement	Frieburg, Germany	2005	59 apartments in townhouses with PV installed, creating "PlusEnergy" - i.e. their production exceeds their consumption. Also a service centre (the "Sun Ship"), also a PlusEnergy building, which contains an EcoInstitute, retail spaces and office space. Peak output is around 445 kW. The settlement also has a car-sharing system and communal parking underground.	http://www.rolfdisch.de/
Solar Pioneer II	Oregon, USA	2008	363 PV panels totaling 63.5 kW, on the roof of the city service centre, maintained by the city. Ashland residents can "adopt" part or whole panels, which entitles them to have the output of their panel(s) credited to their electric bill for 18 years.	http://www.ashland.or.us/Page.asp?NavID=14017
sonnenCommunity	Germany	2015	Peer-to-peer community energy trading platform launched by German energy storage company sonnen. sonnenCommunity connects sonnen owners to consumers of energy online, utilising three technologies: decentralised power generation, battery storage technology, and digital networking supported with a self-learning software platform.	https://www.sonnenbatterie.de/en/sonnenCommunity
University Park Community Solar LLC	Maryland, USA	2010	The University Park LLC sought membership and investments used to buy PV which was installed on the roof of the University Park Church of the Brethren by Standard Solar inc., who also maintain the system. The church purchases the power produced by the panels from the LLC, who also sells their Solar Renewable Energy Certificates (SRECs) – the revenue from these go towards maintenance and operating costs, and to ROIs for members.	http://www.universityparksolar.com/
Verendrye Electric Cooperative	North Dakota, USA	2006	Verendrye Electric Cooperative began a program in 1990 that involved leasing PV panels to farmers to save on the cost of extending lines (Verendrye serves ~11,000 customers in a 6-county area which requires maintaining 4,000 miles of lines). The panels power farmers' stock wells which are only used in the summer months, making PV highly practical. Verendrye received a grant in 2006 to expand and purchase high efficiency pumps which will benefit both Verendrye – in terms of no longer having to maintain remote and underused lines – and farmers – who receive the pumps at no extra cost to their PV lease.	http://farmenergy.org/success-stories/rural-electric-cooperative/verendrye-electric-cooperative
Westmill Solar Cooperative	Oxfordshire, UK	2012	Owns and operates the "first cooperatively owned, community-owned solar farm in the UK", a 5 MW farm comprising more than 20,000 PV panels spread over 30 acres. Westmill Solar has over 1600 members who own shares and receive an annual return. The cooperative is led by a board of directors and have commissioned third parties to manage the solar park and the cooperative.	www.westmillsolar.coop
Westmill Windfarm Co-operative	Oxfordshire, UK	2004	Run by Westmill Co-operative which has ~2400 members who tend to be local to the windfarm, and involved construction of five turbines on land owned by an organic farmer. The public could buy shares in the project; the balance was funded by a bank loan.	www.westmill.coop
Whittier Affordable Housing Project	Denver, Colorado	2012	In northeast Denver, Colorado, a partnership of community stakeholders came together to pilot the first U.S. low-income housing project to take on solar. The Whittier Affordable Housing Project has 30 affordable housing rentals across 12 buildings which has received residential-scale solar PV systems.	
Yeloha	Massachusetts, USA	2015	Yeloha is designed to offer solar to those who cannot have PV on their roofs. A Sun Host is provided with free installation and power, in exchange for 'sharing' their surplus energy with Sun Partners. Sun Partners stay with their current utility provider, and buy membership to Yeloha who then offsets their power bill.	www.yeloha.com

PROSUMER COLLECTIVES: A REVIEW

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