RESIDENTIAL PROSUMERS - DRIVERS AND POLICY OPTIONS (RE-PROSUMERS)

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Otto Bernsen	NL Agency
Lisa Dignard	Natural Resources Canada
David de Jager	Operating Agent, IEA-RETD
Georgina Grenon	Ministère de l'Écologie, du Développement durable et de l'Énergie, France (PSG Chair)
Gaëtan Masson	IEA Photovoltaic Power Systems Programme (IEA PVPS)
Simon Müller	International Energy Agency (IEA)
Michael Paunescu	Natural Resources Canada
Kristian Petrick	Operating Agent Team, IEA-RETD
Cédric Philibert	International Energy Agency (IEA)
Axel Strang	Ministère de l'Écologie, du Développement durable et de l'Énergie, France
Hoel Wiesner	International Energy Agency (IEA)

LEAD AUTHOR

Wilson Rickerson (Meister Consultants Group – MCG)

CONTRIBUTING AUTHORS

Toby Couture (E3 Analytics), Galen Barbose (Lawrence Berkeley National Laboratory)[1], David Jacobs (Institute of Advanced Sustainability Studies)[2], Giles Parkinson (Renew Economy), Emily Chessin (MCG) and Andy Belden (MCG). Holly Wilson (MCG) and Henry Barrett (MCG) provided research and editorial support.

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EXECUTIVE SUMMARY

Is a PV prosumer revolution imminent? Not yet (without enabling policies) but policy makers should get prepared.

The rise of the solar photovoltaic "prosumer"[3] has the potential to transform the centralized electric utility model that has served the world for over 100 years into a more decentralized and interactive system. In some areas of the world it is now more cost-effective for households to produce their own power from PV than to purchase electricity from the grid. This dynamic has generated significant interest among policy makers about strategies for engaging and managing PV prosumers, and the implications of prosumer development for citizens, industry, and the utility sector.

This new IEA-RETD report provides a comprehensive overview of prosumer related aspects: it analyses the influence of economic, behavioural and technological drivers as well as national conditions on prosumer growth. It provides policy makers with the potential benefits as well as costs and risks in order to articulate the justification for supporting prosumers. Finally, it discusses the different forms that PV prosumer policy strategies can take based on an evaluation of drivers and national objectives.

The emergence of PV prosumers is characterized by several trends:

- Sustained double digit growth in PV deployment, which has demonstrated PV's ability to rapidly scale up.
- The rapid decline in PV costs (e.g. PV modules, inverters, and soft costs) which make PV more competitive when compared with retail electricity market prices.
- The fundamentally decentralized nature of solar PV systems, which enables individual homes and businesses to invest in rooftop systems directly, based on economics but also on other possible motivations.

As a result of these trends, PV has been characterized as a "disruptive" technology which could revolutionize the utility sector just as personal computers and cell phones changed their respective industries. However, a prosumer "revolution" under which decentralized adoption of PV occurs in the absence of supportive policy or regulatory conditions has not yet arrived. Self-consumption of solar PV is a growing trend globally, but its mass expansion remains within policy makers' ability to control.

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[3] The term prosumer is used to refer to energy consumers who also produce their own power from a range of different onsite generators (e.g. diesel generators, combined heat-and-power systems, wind turbines, and solar photovoltaic (PV) systems). This report focuses primarily on residential (non-commercial) PV prosumers in developed countries (i.e. countries with high electrification rates and reliable electricity supply, rather than countries that may require PV systems designed to provide energy access). Future IEA-RETD research may focus on other prosumer segments.

Even though the levelised cost of PV is below "socket parity"[4] in a growing number of countries/areas, prosumer development generally continues to require enabling policies, such as the right to connect to feed-in electricity to the grid or the right to get credit for excess power produced and not consumed (e.g. as net metering). This last case is particularly important because the timing of residential PV output does not always match the time at which power is consumed onsite and PV prosumers can therefore not capture the full value of system output based on their own needs. Only PV prosumers that completely "defect" from the grid can move forward without any grid-related enabling policies. Given the cost of storage, however, widespread grid defection at the residential level is not expected to be cost-effective in most countries in the near-term.

There are four main factors or drivers that can influence prosumer growth either positively or negatively:

- Economic Drivers: the cost of solar PV systems, prevailing electricity prices, the self-consumption ratio, insolation levels, etc.
- Behavioural Drivers: non-financial factors such as the desire for greater energy autonomy, environmental preservation, prestige, etc.
- Technological Drivers: technology trends that could accelerate prosumer development, such as new developments in PV, electric vehicles, storage, demand response, and energy efficiency.
- National Conditions: aspects such as the total rooftop space available for PV, the share of building owners vs. renters, electricity demand trends, electric grid conditions, etc.

Policy makers should monitor a complex mix of jurisdiction-specific conditions to determine whether or not solar prosumers will - or could - emerge and expand massively. There are only a few jurisdictions in the world (e.g. Germany and Australia) where these conditions currently align to drive significant prosumer growth. In Germany, for example, there is evidence that micro-scale systems (e.g. < 2 kW) can be profitably installed and configured for self-consumption without the need to export excess power to the grid.

There is an opportunity for policy makers to anticipate developments and to plan for the potential changes that could be triggered by prosumers in the years ahead. An important step for policy makers is to articulate the justification for supporting prosumers. This can be framed through an evaluation of the benefits and costs of prosumer development. Some electricity industry stakeholders, for example, have characterized prosumers as a threat to grid reliability and to established utility sector business models because of revenue erosion and the prospect of stranded assets. Other stakeholders have argued that these challenges must be addressed and overcome because prosumers represent a beneficial, necessary, and inevitable evolution of the electricity industry.

Based on an evaluation of drivers and national objectives, PV prosumer policy strategies can take a number of different forms. These policy strategies can be grouped into three broad categories:

- Constraining prosumers entails actively working to prevent prosumer development.

[4] The point at which the levelised cost of electricity from a solar home system is cheaper that the after-tax retail price of power purchased from the grid.

- **Enabling prosumers** involves the establishment of basic policies to support prosumer growth (e.g. interconnection and self-consumption policies).
- **Transitioning to prosumers** involves fundamental changes to regulatory and policy structures to anticipate and accommodate prosumer expansion.

Each of these strategies has its own uncertainties or risks. Choosing to constrain the growth of prosumers, for example, creates the risk that PV prosumers could emerge suddenly and in a manner that is much more difficult - and costly - to govern in the future.

There are many examples of countries that are acting to constrain or enable prosumers, but fewer examples of countries pursuing prosumer transition strategies. Most transition strategies represent incremental adjustments to existing policy and regulation – rather than fundamental or structural changes to the electricity industry or market. There may be opportunities to enable prosumer scale-up while at the same time introducing legal and regulatory reforms that encourage "prosumer friendly" structural shifts in current business models. **There is currently no agreed upon "best policy roadmap" to assist policy makers with prosumer transition**, and the blueprint for structural transition will likely need to be created as markets evolve.

This IEA-RETD report aims at providing some structural elements to move forward with this challenging yet unique game changing opportunity which prosumer scale-up offers for the energy sector… and for society.

SECTION 1

INTRODUCTION

IEA-RETD has identified an ongoing need to analyse the extent to which the 'prosumer revolution' will be an issue that requires further attention on the political agenda, understanding the possible legal and regulatory effects of such a transformation on the current electricity market models.

The objective of this report is to empower policy makers to make informed decisions with regards to the legal and regulatory policy options that ease the transition towards a large scale decentralised production of non-incentivised, residential PV. This report primarily analyses if and how 'PV prosumers' will become an issue in the context of present market models and policy frameworks.

1.1 IS A PV PROSUMER REVOLUTION IMMINENT?

"[S]ince everybody can actively take part, even on an individual basis, a solar strategy is 'open' in terms of public involvement… It will become possible to undermine the traditional energy system with highly efficient small-technology systems, and to launch a rebellion with thousands of individual steps that will evolve into a revolution of millions of individual steps."
Hermann Scheer, A Solar Manifesto (2005)

This quote from Hermann Scheer, a long-time member of the German Parliament and an advocate for solar power, reflects a view that solar photovoltaic (PV) systems can and will radically reshape the electricity industry. The market for solar PV has developed more rapidly than many expected and recent growth is reminiscent of the revolutions that occurred with cellular phones in the telecommunications industry and personal computers in the information technology industry. There is significant and ongoing discussion within policy and industry circles as whether the PV "revolution" is inevitable and whether it is perhaps already underway (Hummel et al., 2013). The primary trends that are inspiring these discussions are PV's rapid declines in cost, its rapid growth rates, and its inherent decentralization.

Cost declines. The cost to install PV has fallen dramatically. PV module prices have experienced a well-documented decline from ~$1.90 watt in 2009 to $0.70/watt (and below in some regions of the world) (Jones, 2013). Inverter prices have also declined from $0.60-$1.00+/watt in 2005 to under $0.20/watt in 2013 (Clover, 2013; Navigant, 2006). These hardware price declines have resulted in dramatic improvements in PV competitiveness. Since 1972, PV module prices have experienced a "learning rate" of 22%, meaning that the price has dropped by 22% each time that the market price has doubled (Channell et al., 2013). Although future declines may be less rapid, the cost to install PV will continue to decrease as a result of technological innovation, product optimization, economies of scale, learning by doing, and government efforts to reduce PV costs. These decreases will lower the cost to produce electricity from PV over time (referred to here as the levelized cost of energy or "LCOE")[5]. It is anticipated that PV LCOE will fall below the retail rate of electricity in many countries and will eventually compete at the wholesale level with conventional generation, such as nuclear, coal, and gas.[6]

Figure 1 below shows historical and potential future cost trends of worldwide PV systems. As illustrated, these costs have dropped precipitously over the past seven years. The rapid decline in installation costs and the LCOE has been one of the primary drivers behind the sustained growth of worldwide PV markets.

[5] IEA 2014b (The Power of Transformation) states that the value of PV electricity tends to decline at higher shares. This means that there is actually a "race" of PV cost reductions against value reductions.

[6] There are significant uncertainties as to when PV will compete effectively at the wholesale level given the uncertainties in the wholesale market price, including the impact that renewable generation has on the market. Renewable energy can suppress, or "cannibalize" the wholesale market, which would effectively delay renewable energy competitiveness (WIP et al., 2013).

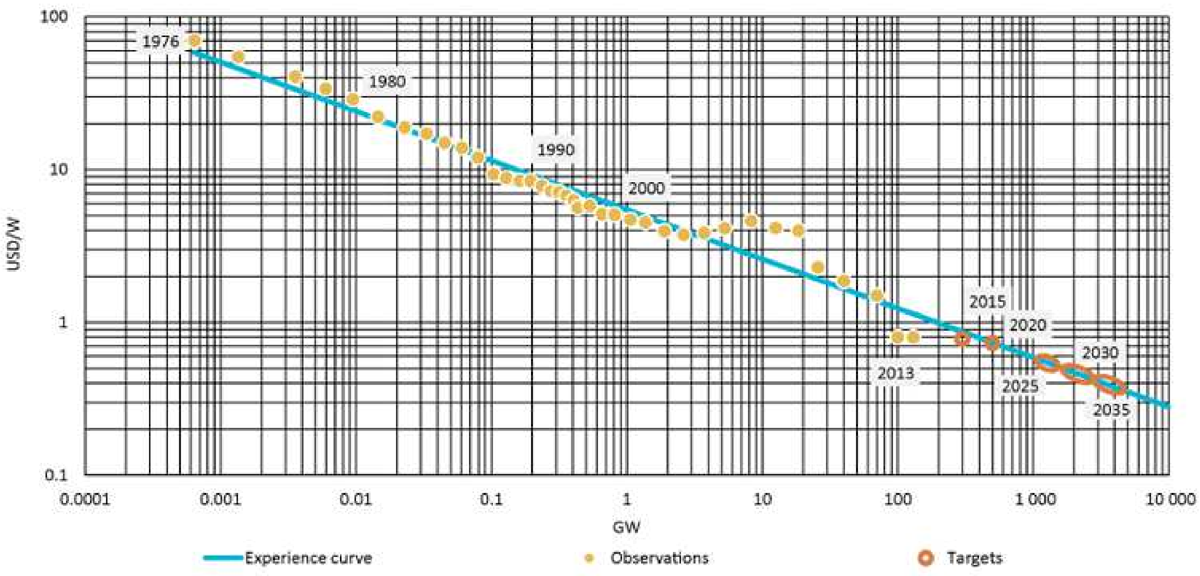

Figure 1: Experience curve for PV modules and extension to 2035 (Scenarios: 2DS and 2DS hi-Ren)
Source: IEA (2014a)

Sustained, double-digit growth. PV markets have grown at an average of more than 40% each year since 2000. As can be seen in Figure 2 below, the cumulative amount of PV capacity has grown from over 20 gigawatts (GW) in 2009 to close to 135 GW by the end of 2013 (IEA PVPS, 2013). This growth has surpassed even optimistic projections developed by industry associations and appears poised to continue. Leveraging the support mechanisms put in place by different countries, the PV industry has consistently surpassed expectations in terms of its ability to scale and it may continue to do so in the future[7]. Figure 2 below shows actual PV capacity trends by year as compared to the IEA's 2006 projection.

[7] The International Energy Agency, for example, forecasted that global PV capacity would expand to 22 GW by 2015 in its alternative policy scenario from the 2006 World Energy Outlook (IEA, 2006). Predictions at the regional level have also fallen far short. In 2008, the US Energy Information Administration (EIA) projected that the US would install 320 MW total by 2015 (EIA, 2008). At the end of 2013, the US had installed over 11,000 MW of PV capacity. In Europe, the European Photovoltaic Industry Association (EPIA) forecast in 2004 that the industry could install 41 GW by 2020 (EPIA, 2004). Europe had already installed over 52 GW by the end of 2011.

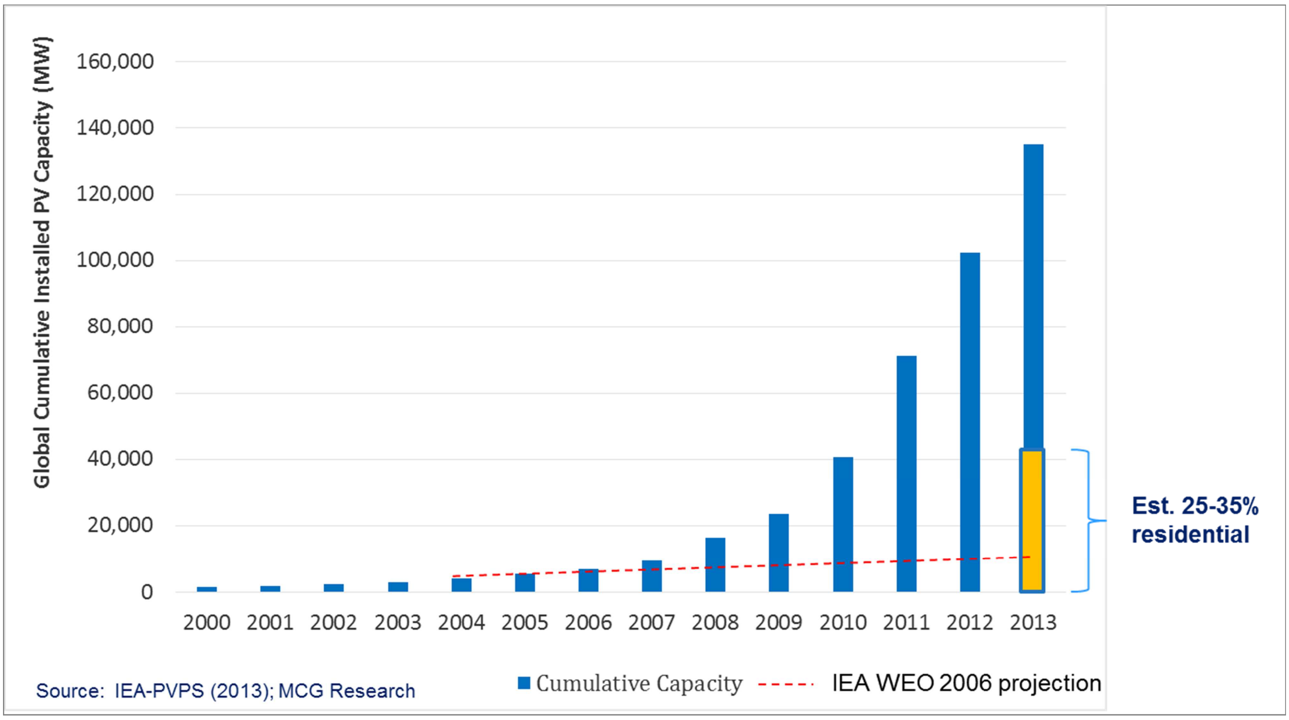

Figure 2: Evolution of Cumulative PV Capacity (MW); global residential share only estimated for 2013
Source: IEA PVPS (2013)

Decentralization. Figure 2 above also shows that a significant share of global PV capacity has been installed at the residential level.[8] Most power plants built during the 20th century were large, centralized generators that often supplied power over long distances to electricity consumers. By contrast, a large proportion of the world's PV capacity consists of distributed, roof-mounted systems that produce electricity at sites close to where it is consumed. There are now millions of PV systems in the world's major markets. Many of these systems are not only distributed – but are also installed at the household level. In Europe and US, ~20% of PV capacity was installed in residential systems at the end of 2013 as can be seen in Figure 3. In 2013, over 20% of the homes in the states in South Australia and Queensland had installed PV systems. Overall, it is estimated that between 25%-35% of global PV capacity is installed at the residential level. From a political perspective, the emergence of millions of distributed generators has created a new class of "solar voters."

[8] This number was estimated for the purposes of this report based on data from PV markets in Europe, North America, and Asia and the Pacific. In some cases, PV data is tracked based on the specific sector in which it is installed (e.g. residential or commercial). In other cases, PV data is gathered based on system size (e.g. 10 kW and below) rather than sector. In these cases, ranges were developed for the number of small-scale systems that were residential, instead of small commercial. It is recommended that more research and data gathering be conducted in this area. It is clear, however, that residential systems constitute a significant share of the global PV market.

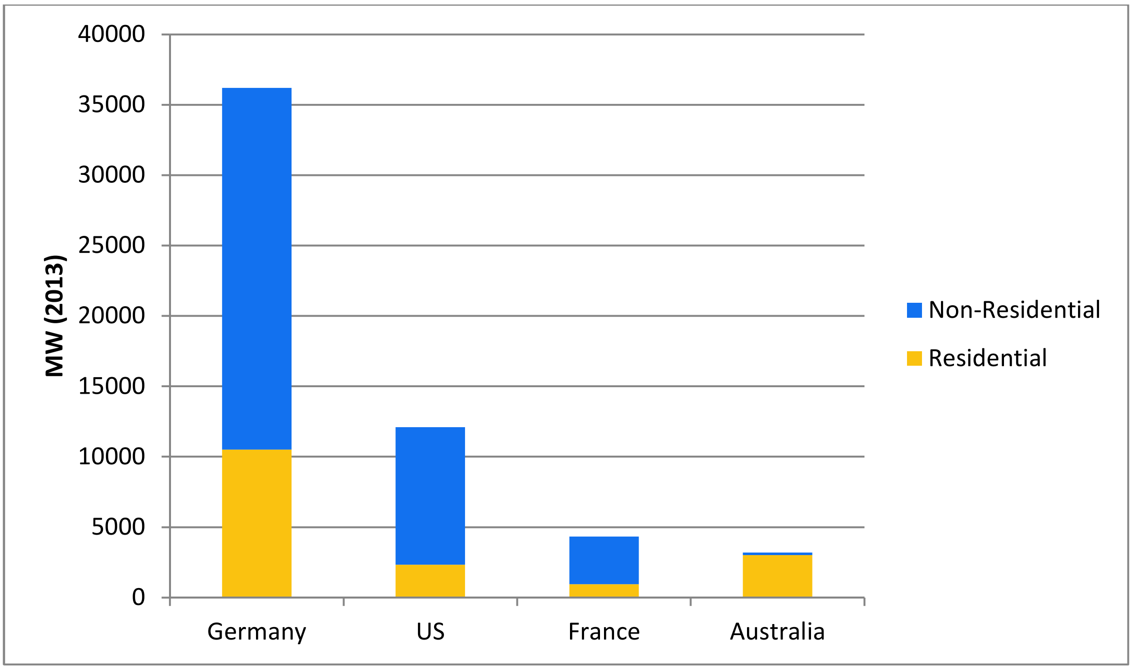

Figure 3: MW of residential and non-residential PV installed in major global markets[9]
Source: (Wirth, 2014; Brazalle, 2014; ERDF, 2014; Sherwood, 2013; Kann et al., 2014)

As a result of these trends, PV could act as a disruptive technology that challenges the incumbent players in its industry. Many analysts have forecasted that the centralized utility model that has served most of the world for over 100 years could give way to new business operating paradigms. Consumers, who have been the passive recipients of commodity electricity, may increasingly opt to become "prosumers" who actively generate power instead of purchasing it from the market. As with other industries that have undergone significant transformation, large and established companies may suffer while others may realize significant profit from the creation of new business models and the provision of new energy services.

The scale-up of prosumers has been identified by the IEA-RETD as an important issue that member nations wish to better understand and address in the near-term. Policy makers may find it challenging to effectively engage with prosumers and the changes they may implicate, however, for a number of reasons:

- It is difficult for policy makers to identify whether or not PV prosumers are "close" to emerging in their country. Could PV prosumers rapidly emerge in the near-term and significantly change the status quo? How can policy makers determine whether prosumers are on the rise? What uncertainties impact prosumer development?
- It is unclear whether prosumers are a positive or negative force. Should policy makers attempt to stop or control prosumers? Should prosumers be encouraged? What are the pros and cons of prosumer development?

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[9] Residential capacity has been defined as <10kW in Germany and <9kW in France.

- There is no standard roadmap for prosumers. If prosumers are scaling-up, what tools can policy makers use to govern their emergence? Would a large influx of prosumers require minor or major changes to current systems?
- Prosumers are emerging against the backdrop of a complex set of forces that are changing the electricity industry globally, including decarbonisation in response to climate change, market reforms, and the introduction of new technologies such as electric vehicles, smart grids and communications networks, and storage. It can be challenging to determine how these issues act upon one another and how policy responses should be prioritized (or integrated).
- The landscape is evolving quickly. As a recent report from Australia concluded, "electricity markets have shown the tendency to undergo major and rapid shifts that are able to outpace the reform processes' ability to implement change" (Future Grid Forum, 2013). In addition to determining whether and how to act, policy makers must also keep in mind that the policy process may not be nimble enough to keep pace with market developments.

There is currently no comprehensive solution to addressing the opportunities and challenges created by PV prosumers, but the intent of this study is to create an inventory of the key prosumer drivers and potential policy decision points.

The next section provides a short definition of prosumers. The remainder of this section introduces the concepts discussed in this report at a high level and provides a "map" to the relevant, more detailed sections contained in the body of the report.

1.2 DEFINING PV PROSUMERS

The term "prosumer" refers to consumers who also produce commodities or services. The term originated in the 1980s and was brought into mainstream use by the information technology and digital business industries. In the world of the Internet, the term prosumers has been used to characterize users who have created their own online products, ranging from open source operating systems such as Linux to informational resources such as Wikipedia. The term has migrated to other industries, and in the electricity industry, the term prosumer is used to refer to energy consumers who also produce their own power from a range of different onsite generators (e.g. diesel generators, combined heat-and-power systems, wind turbines, and solar photovoltaic (PV) systems).[10] This report focuses specifically on residential prosumers that adopt PV technology since PV has emerged as one of the fastest growing onsite generation technologies and has the potential to fundamentally alter the established electricity system.

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[10] Some studies have also recently suggested that a more robust definition of electricity prosumers would also incorporate elements such as the ability to react to dynamic pricing, the use of demand response, and integration with smart grid infrastructure (Bremdal, 2011). Although more technologically sophisticated electricity prosumers may emerge in the future, this report focuses broadly on residential owners of onsite PV generation in order to reflect current conditions in different countries.

1.2.1 Types of PV Prosumers

PV prosumers are defined not only by the fact that they generate their own power, but also by their relationship with existing electricity providers (e.g. utilities). The relationships between prosumers and traditional utilities can take a range of forms, such as:

- Grid defection. Prosumers could cut ties with the existing utility system in order to live "off the grid" and supply 100% of their own electricity needs with PV, storage, and other technologies[11];

- Self-consumption. Prosumers could continue to purchase power from the grid, but reduce the amount purchased by using PV to supply a portion of their own electricity needs (and potentially get remunerated for any surplus generation that they may inject into the grid);

- Commercial electricity production. Prosumers could sell a large share of the power generated into the grid, while continuing to purchase electricity from the utility as well.

Each of these types of relationship diverges from the traditional utility-customer model and could implicate significant changes for established electricity industry structures if scaled up. This report considers all three of these prosumer types but focuses primarily on prosumers that configure their PV system for self-consumption.

1.2.2 PV Prosumer Segments

The explicit focus of the RE-PROSUMERS initiative is on residential PV system owners, which are defined in this report as single family homes that own systems 10 kilowatts in size and below. As witnessed in many of the world's active PV markets, buildings in the commercial, industrial, or multi-family residential segments have also emerged as significant prosumers. However, larger buildings are generally able to more fully absorb PV systems and without the use of additional technologies such as storage or policies such as net metering[12]. Single family residential homes, by contrast, are less likely to have onsite consumption patterns that match PV system output. They therefore more clearly illustrate the regulatory and technical challenges that prosumers can face within the current market paradigm (Section 3.2). RE-PROSUMERS also focuses on residential PV systems in countries with high electrification rates and reliable electricity supply, rather than PV systems designed to provide energy access.

[11] From a semantic perspective, those that defect from the grid may no longer be considered consumers of electricity from the power grid, and therefore the term "prosumer" may not be applicable.

[12] This does not mean though that policy makers do not have to define adequate policies for the commercial sector. IEA-RETD plans to commission another study which deals with this sector.

1.3 THE PROSUMER REVOLUTION IS NOT HERE – YET

Despite the trends identified in the previous section, a central conclusion of this report is that a spontaneous or unintentional prosumer "revolution" has not yet arrived in any specific country, although it could occur in certain parts of the world at some point in the next decade. Although PV growth has been rapid, it has primarily been supported by incentives and enabling regulations (e.g. rules governing interconnection and power sales). Without these policies in place, it is unlikely that PV markets would continue to accelerate on their own in the near term. The generation costs for PV are now substantially below retail electricity prices in countries such as Germany, however. As discussed in the case study in Section 6.4 some PV projects in Germany can now be viably developed without the use of the feed-in tariff under the current policy environment. Developments such as these have led to vigorous debate within Germany about whether additional charges or taxes should be applied to PV prosumers. These issues are discussed in greater detail in Section 5.1.3. This section briefly reviews three scenarios under which a prosumer "revolution" could occur (i.e. socket parity, grid defection, and wholesale competition) and concludes that such scenarios are unlikely to occur in the next few years without an enabling policy framework in place.

1.3.1 Socket Parity

One of the analytical points fuelling speculation about broad PV competitiveness is the concept of socket parity. Socket parity is commonly understood as the point at which the cost of self-generated PV falls below the retail price of electricity. The point at which socket parity is achieved has been analysed in numerous studies during the past several years (Breyer & Gerlach, 2010; Lorenz, et al., 2008; Pourreza et al., 2013; Shah et al., 2014). Although the precise details of these studies vary, they agree that socket parity has arrived in several countries and that a large number of other countries will achieve socket parity during this decade. Socket parity is often described as a threshold that will result in dramatic growth in PV prosumers once crossed. In terms of practical impact, however, socket parity alone will not serve as a market driver for residential prosumers for several reasons:

- Socket parity does not in itself create an attractive return on investment. PV generation cost must decrease below retail electricity prices before the system payback and return on investment become attractive (DBCCA, 2012). Figure 4 illustrates the concept of the competitiveness of PV by comparing PV LCOEs to socket parity over time.[13] It is not until the LCOE decreases below the retail rate that PV becomes competitive on a non-incentivized basis.

[13] This graphic is intended to be illustrative and does not include specific numbers since different countries have significantly different PV LCOEs and retail electricity costs. Individual jurisdictions could construct their own socket parity analyses in order to calculate the economic performance of PV systems compared to retail electricity costs at different LCOEs.

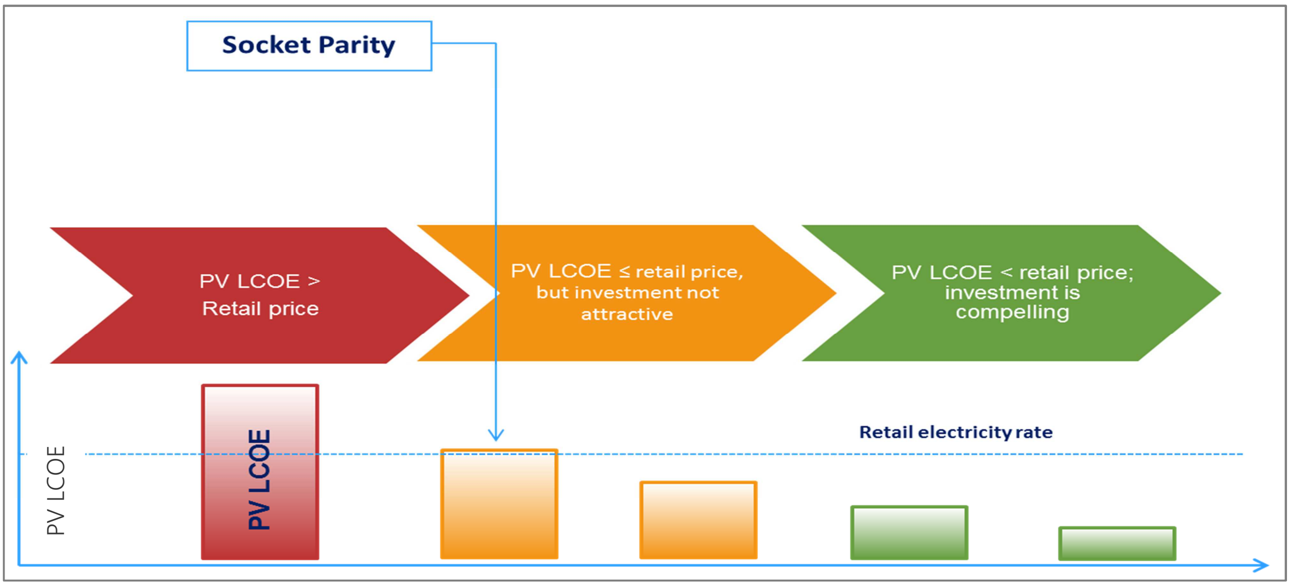

Figure 4: Illustrative PV competitiveness at different LCOE levels
Source: Adapted from (Masson, 2014)

- Socket parity does not guarantee that 100% of PV output will be utilized. Even if PV generation costs decrease below retail prices, it is not guaranteed that PV production will match onsite demand. As discussed in Section SECTION 4, enabling policies or technologies will likely need to be in place in order for residential PV prosumers to realize the full value of their own PV generation.
- Socket parity on its own does not create the conditions for prosumer scale-up. Even if the achievement of socket parity were to create a compelling economic case for PV investment, it would not guarantee that policy makers would create (or retain) a policy framework to enable non-incentivized prosumers to emerge or be sustained at a large scale. Put another way, even if PV LCOE decreased below the retail rate, governments and utilities could still govern (or constrain) the development of prosumers through the use of policy or the removal of enabling regulations (e.g. limiting the amount of PV that can be injected into the grid). Different countries have taken different policy approaches to prosumers as PV LCOEs have become more competitive with retail power prices, and these approaches are profiled in greater detail in case studies included in Section 5.
- Traditional definitions of socket parity also do not take into account the (social and/or private) costs that may be required to accommodate PV prosumer scale-up, such as grid reinforcement and storage (Pudjianto et al., 2013; Sinke, 2009). If these costs are taken into account, the point at which PV becomes competitive will be pushed back further.

Socket parity is an important psychological milestone in the development of PV markets, but it cannot trigger the substantial scale up of PV prosumers without enabling policies in place.

1.3.2 Grid Defection

A second scenario which could lead to widespread and non-incentivized scale-up of PV prosumers could occur if PV system owners opt to “defect” from the grid and become electricity self-sufficient.

The combination of technologies such as PV, energy efficiency, and storage, for example, may enable PV prosumers to cost effectively manage their own energy independently without the need for utilities – and without enabling policies to support their decision. A recent national study from Australia concluded that such "independence" or "defection" scenarios are not currently cost-competitive, but could become an economically feasible option in the period 2030-2050 (Future Grid Forum, 2013).

A study for the United States, which takes into consideration a range of technology and electricity price trends, similarly concludes that grid defection could be broadly cost competitive across the country during the same (i.e. 2030-2050) timeframe (Bronski et al., 2014)[14], see Figure 5.

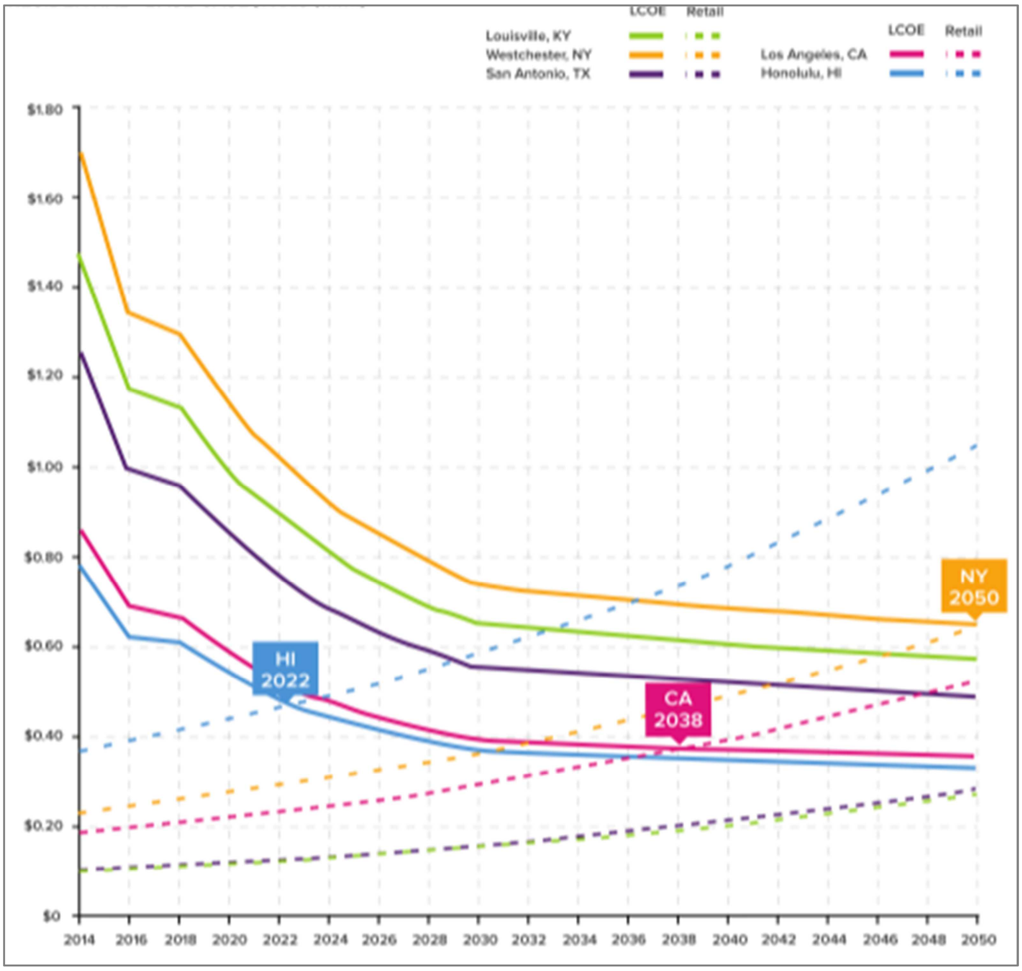

Figure 5: Grid defection LCOE vs. retail electricity prices for different US states: Residential base case (Y-axis $/kWh)
Source: Bronski et al. (2014)

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[14] There are other studies that predict earlier time frames for potential grid defection, depending on technology trends. Morgan Stanley, for example, recently presented an analysis of Tesla's proposed gigawatt-scale lithium ion battery factory which suggests that the plant could significantly reduce battery costs. The analysis concludes that grid defection could occur in the 2018-2020 timeframe (Parkinson, 2014a, 2014b). This outcome would heavily depend, however, on the factory being built on time and on the factory having the price impacts predicted in the study.

The U.S. study finds that certain technology strategies and trends (e.g. onsite load management and declines in battery costs) could accelerate the grid defection timeline by several years, such that grid defection could become a viable option for residential systems in Hawaii before 2020, in California in the early 2020s, and in New York State in the late 2020s. Some studies in Europe have also concluded that residential PV systems with battery back-up in more southern latitudes could also begin to achieve attractive internal rates of return around 2020 and after (Hummel et al., 2013).

1.3.3 Wholesale Competition

A third scenario under which PV prosumers could scale-up without incentives could occur if PV LCOEs become competitive with wholesale generation, rather than with the retail price of power. Under wholesale competition, PV generators would compete with central-station power plants such as coal and natural gas plants. Wholesale competition is unlikely in the near-term for PV, and especially for residential PV systems, since average wholesale prices are in general comparatively low. Residential PV generators could potentially adopt a "hybrid" approach wherein they offset as much power as they can at the retail level at any given time and then switch to selling power at the wholesale rate for the remainder. This type of approach could create an opportunity for residential PV to profitably participate in the wholesale market at an earlier point in time if wholesale prices are sufficiently high. In many countries, however, this type of hybrid market posture would likely require regulatory clarifications or even new policies.

Another consideration is that renewable energy could negatively impact wholesale prices in the future. As will be discussed in Section 3.1.1, renewable energy has a demonstrated capability to suppress wholesale market prices when they push more expensive technologies out of the market due to their very low marginal costs. To the extent that this happens, it would decrease the revenue that PV generators would be able to secure in the wholesale market. This would serve to decrease the competitiveness of PV at the wholesale level. The uncertainties in the wholesale market are reflected in a recent analysis of Italy and Spain, which found that the point at which large-scale PV will become competitive at the wholesale level could vary by up to 20 years - e.g. 2017 to 2040 in Italy, and 2021 to 2040+ in Spain (Lettner & Auer, 2012).

Non-incentivized PV growth under these three scenarios appears unlikely in the near term. Residential PV system economics are insufficient to enable grid defection and wholesale competition during the next decade in most parts of the world, and socket parity will not create the conditions for large PV market scale-up without a supportive policy enabling environment.

As a result, it cannot be said that a non-incentivized PV "revolution" is underway in a manner that policy makers can no longer control. However, the fundamental conditions for such a revolution are moving into place in different countries at an accelerated pace and policy makers have an opportunity to anticipate and react to the potential for large-scale PV uptake in the near term. In particular, policy makers can develop an understanding of the different drivers for prosumer development within their specific national context and monitor their development over time.

1.4 REPORT STRUCTURE

This report is structured as follows:

- Section 2 discusses the economic, behavioural, technical drivers and national conditions as well as the different stakeholders.
- Section 3 reviews the benefits of prosumer development and outlines the potential risks that prosumer pose to existing utility sector business models and to grid reliability.
- Section 4 explores policy strategies for managing prosumer growth through enabling policies and through changes to utility sector regulation.
- Section 5 draws conclusions and discusses potential next steps
- Section 6 presents case studies of prosumer activity in Australia, France and Germany.

SECTION 2

UNDERSTANDING PROSUMER DRIVERS AND STAKEHOLDERS

2.1 OVERVIEW

The trends, drivers, and interests that are shaping the emergence of residential prosumers are complex and they vary from country to country. Economic, behavioural, and technological drivers, as well as underlying national conditions, may each influence PV prosumers in different ways and may be aligned differently in different jurisdictions. Moreover, each driver may have different implications depending on the stakeholder perspective adopted. Figure 6 contains an illustrative framework that can be used to analyse the complex interactions of different drivers and stakeholders. The Appendix provides an example of how this matrix can be filled.

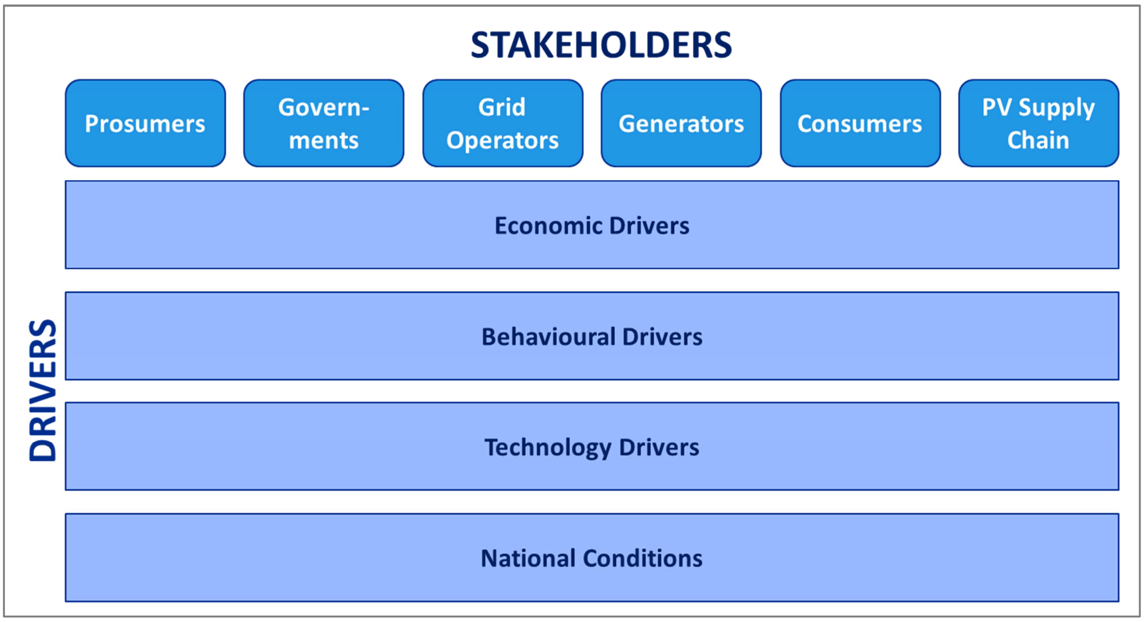

Figure 6: Framework for cataloguing prosumer stakeholders and drivers
Source: IEA-RETD research

Although policy makers need to assess and balance these and other drivers when considering PV prosumer policy, some of these drivers are easier to define and track than others. Economic drivers and national conditions are comparatively easy to define and quantify, whereas technological and behavioural drivers may be more difficult to precisely characterize and predict.

2.2 ECONOMIC DRIVERS

In order to set the stage for prosumers to emerge, the correct mix of economic factors needs to be in place. Prosumer decisions to invest in PV are currently driven primarily by the expected economic performance of the PV system. The economic performance is determined by PV system costs, retail electricity rates, insolation, and the self-consumption ratio. The economic drivers also include factors such as the impact of prosumer development on grid infrastructure and on the utility business model. These topics are discussed separately in Section 3 on costs and benefits.

2.2.1 PV System Costs

The major PV system cost components include the costs to install the system, operating and maintaining the system over time, and the cost of equity and debt required to finance the system. Lower system costs improve the investment case for PV.

Installed costs for PV systems include hardware such as modules and inverters and "soft" costs such as labour, permitting, financing, and customer acquisition. As described in Section 2.2.1, the prices of PV modules and inverters have dropped dramatically. It is projected that hardware costs will continue to decline – although a slower yearly rate than in the recent past – and that soft cost reductions will also occur in many countries as a result of efforts by industry and government. Soft costs vary widely by region as a result of differences in labour costs, permitting processes, market size, and administrative processes. A recent study, for example, found that installed costs for residential PV systems in the United States were $2.70/watt higher than in Germany (Seel et al., 2013). Even with these variations, installed costs are projected to decline over the next ten years. Figure 7 below shows projected installed cost declines in Europe through 2022.

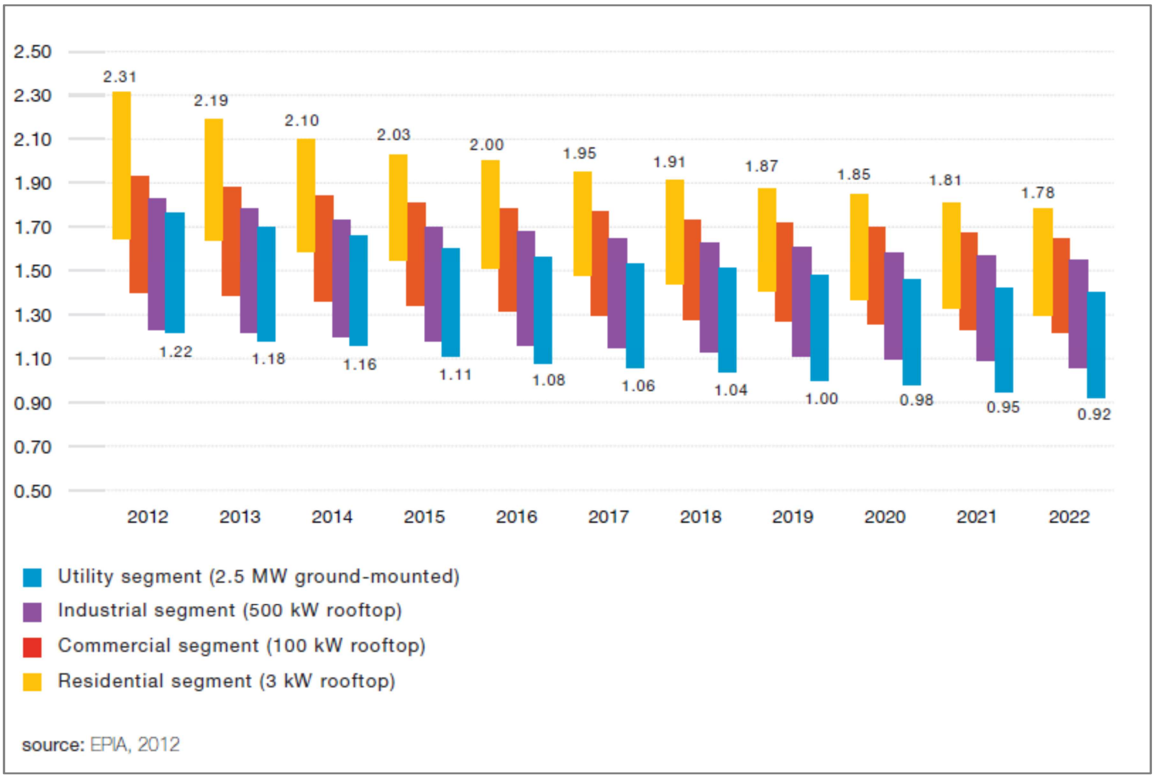

Figure 7: Scenarios for future PV system prices evolution by system segment [€/W]
Source: Adapted from EPIA:(2012)

As can be seen in Figure 7 above, installed costs are lower in the commercial segment of the market than in the residential segment because the larger system sizes allow for lower installed costs. Economies of scale are also evident within each of the segments, however, and are particularly evident in the residential segment. In the United States, for example, 5-10 kW residential systems are currently 28% less expensive than systems of 2 kW and under on a $/watt basis (Barbose et al., 2013), see Figure 8. This differential means that policy environments that encourage homeowners to install

only the smallest system sizes will serve to increase installed costs and delay broad PV competitiveness.

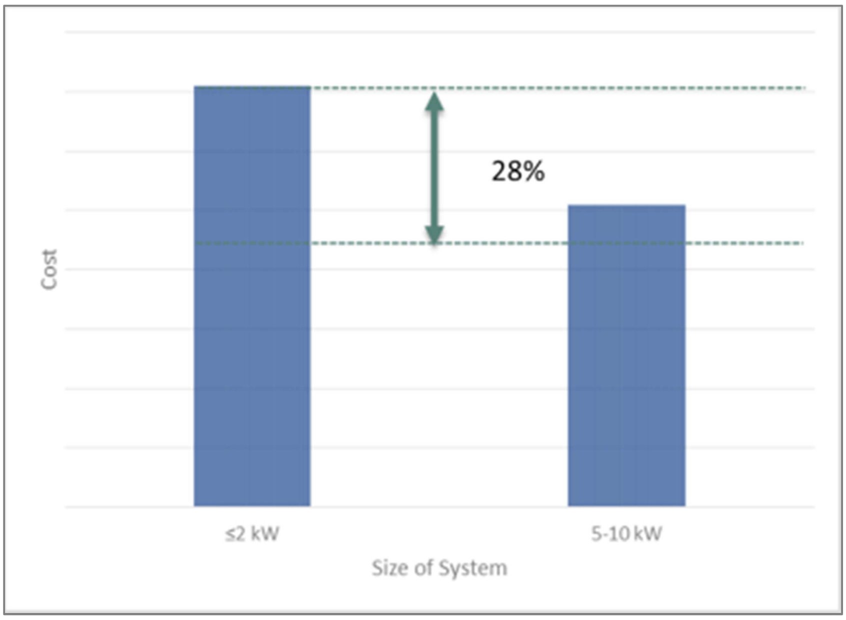

Figure 8: Difference in installed costs for ≤2 kW PV systems and 5-10 kW systems
Source: Adapted from Barbose et al. (2013)

2.2.2 Retail Electricity Rates

2.2.2.1 Retail electricity prices

The retail price for power includes the cost to generate electricity, the cost to build and maintain the electricity transmission and distribution system, and a profit margin. The retail electricity price may also contain additional surcharges and taxes levied by government. Retail prices vary widely around the world, from \$0.01/kWh in the Gulf Cooperation Council states to \$0.30/kWh - \$1.00/kWh and above in island nations and remote areas that depend on diesel fuel.

An illustrative breakdown of the retail electricity rates in Europe is included in Figure 9. As can be seen in, taxes in European countries can range from 10% - 40% of the electricity bill.[15]

[15] It should also be noted that 2011 is used in the figure in order to better compare across countries. More updated information for Germany and France is contained in the case studies in SECTION 6.

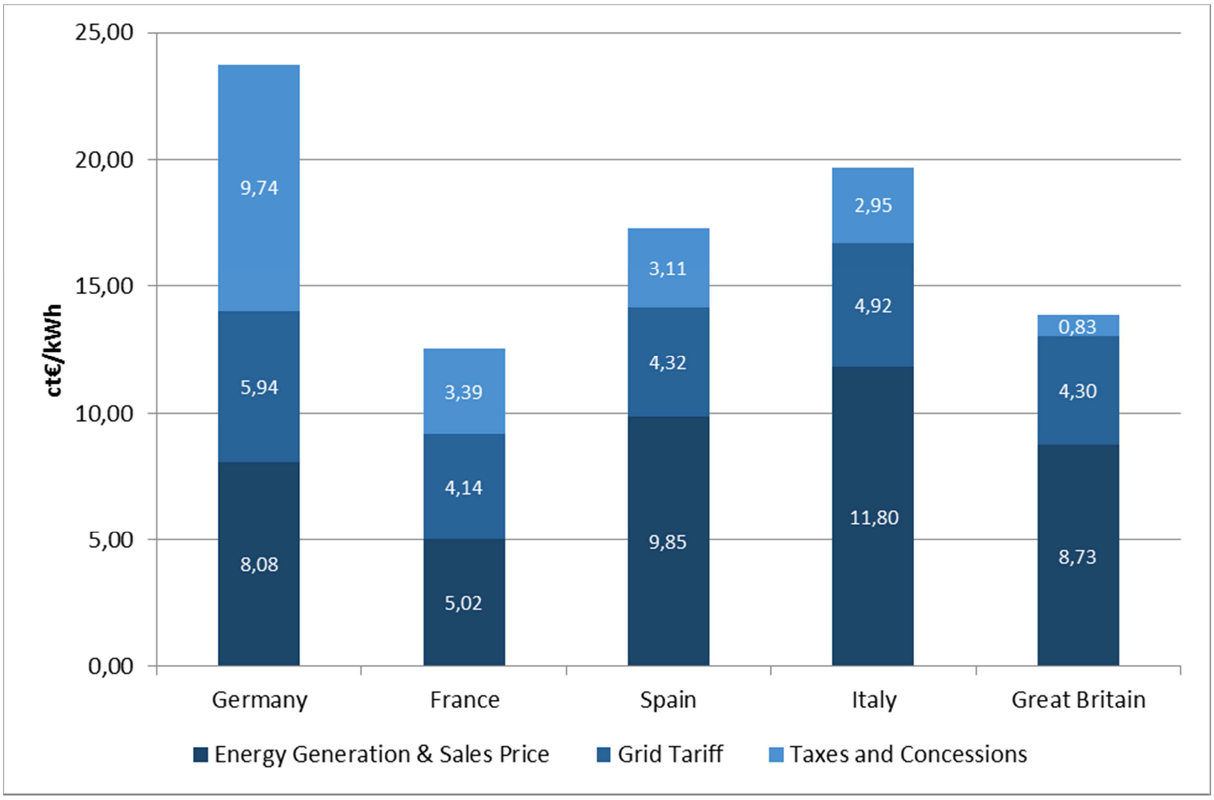

Figure 9: Retail electricity price components in international jurisdictions (2011)
Source: Cassange (2013)

Higher retail electricity rates increase the value of the savings generated by PV and improve the return on investment. Broadly speaking, it is projected that retail rates will rise over time. The IEA projects that $16.9 trillion will be invested in the electricity sector between 2012-2035 in order to build new generation, purchase fuel, and maintain, update and expand the transmission and distribution system (IEA, 2012). These expenditures will ultimately be collected through retail electricity prices from consumers and may push retail rates up. Recent projections estimate that retail rates will continue to climb at least through 2030, at which point they could flatten or even decrease (WIP, 2012).

2.2.2.2 Retail electricity charge structure

Retail electricity rates can include both volumetric and non-volumetric charges. Volumetric charges are assessed on a $/kWh basis and vary with the amount of electricity purchased. Non-volumetric (or fixed) charges are assessed independent of the amount of electricity purchased and can include, for example, fixed customer charges (e.g. $10/month), charges based on demand ($/kW), or charges based on the size of the connection to the grid (e.g. EUR 6.50/month for a 6 kVA connection, as in France). Volumetric charges are advantageous for prosumers since each kWh produced will generate savings equal to the full retail rate. Non-volumetric charges, however, are generally not reduced by PV output[16]. Non-volumetric charges can be advantageous to utilities and grid operators, however,

[16] In certain jurisdictions it may be possible that reduced peak power consumption allows going to lower fixed cost structures. Also, in some tariff systems the fixed component may depend on the volume of purchased electricity, i.e. one may pay less fixed cost if consumption is lower than certain thresholds.

because they reduce exposure to the risk of fluctuations in electricity sales, as will be discussed in greater detail in Section 4.3.2.

2.2.2.3 Time-based rates (e.g. time-of-use rates)

Retail electricity rates can be set to reflect the energy market dynamics during the time period when electricity is consumed. Instead of having a flat retail rate for the entire year, for example, retail rates can be set to be higher in seasons with high demand (e.g. summer in hot climates where air conditioning is used) and lower in seasons with low demand (e.g. winter). Time based rates can also be differentiated on smaller time scales, such as days of the week or different times of the day. Countries with high electricity demand in the middle of the day, for example, may charge more for energy consumed during that period than at night. Time based rates can also be set to vary in "real time" such that the retail rates change frequently based on price changes in wholesale electricity market.

The relationship between PV prosumers and time of use rates is not clear. Some argue that time of use rates reward PV prosumers since PV production matches the periods when rates are highest. Time of use rates do not always mean that the highest prices will occur in the middle of the day, however. A recent study of the United States found that time of use rates would improve PV economics in most cases, but would negatively impact the economic case for 20% of households (Ong et al., 2012). Overall, it is difficult to generalize about the value of time of use rates to PV prosumers since the economic outcomes can vary based on factors such as rate design, system size, and onsite demand profile (Dargouth et al., 2010).

It is also suggested that time-based pricing is important for prosumers because it sends price signals that allow them to adapt their household energy systems. Real time pricing under "smart grid" scenarios, for example, can help prosumers determine whether they should inject or store their power, and whether they should increase or decrease their onsite load (Shandurkova et al., 2012). As discussed above, however, real time pricing links retail electricity prices directly to the wholesale market. It has been observed in countries such as Germany that large-scale penetrations of renewable energy can suppress wholesale market prices – partially because PV generation "steals" the peak during the day when power is most expensive (Channell et al., 2013). This dynamic creates the risk for prosumers that real time pricing would link PV compensation to wholesale rates just when PV output is causing wholesale rates to crash. In other words, PV output could effectively undermine the economic case for PV investment (Masson et al., 2013). Based on these complex dynamics, it remains unclear whether time-based pricing is – or is not – advantageous for PV prosumers.

2.2.2.4 Subsidies and rate regulation

Retail electricity prices in some countries may be kept artificially low as a result of subsidies or rate caps. Countries around the world cap the amount that utilities are able to charge on a $/kWh basis at a rate below the utility's cost of service. In order to keep the utility financially viable, government budgets must be utilized to close the gap. These types of subsidies insulate electricity ratepayers from retail rate increases. However, they also mute the price signal for potential PV prosumers. Even in countries that generally allow utility rate increases, the pace of these increases may not fully reflect market conditions. Some countries, for example, regulate the rate that utilities can charge for generation, transmission, and/or distribution service and only allow these rates to be revisited on a

periodic basis (once every 2-5 years). To the extent that rates are not adjusted in a manner that keeps pace with changing market conditions, this may similarly decrease or delay price signals that might otherwise encourage PV prosumers.

2.2.3 Self-Consumption Ratio: Matching PV Output and Onsite Demand

A low self-consumption ratio decreases the economic case for PV prosumers. The self-consumption ratio refers to the match between a prosumer's pattern of onsite energy use and the pattern of PV system output. If a prosumer is not home during the day, for example, then PV output may be greater than home demand. As can be seen in Figure 10 below, the amount of time that PV output matches onsite load at the residential level varies from country to country. In the south of Spain, for example, a PV system sized to meet the entirety of a home's annual consumption will directly serve load only 29% of the time, on average.

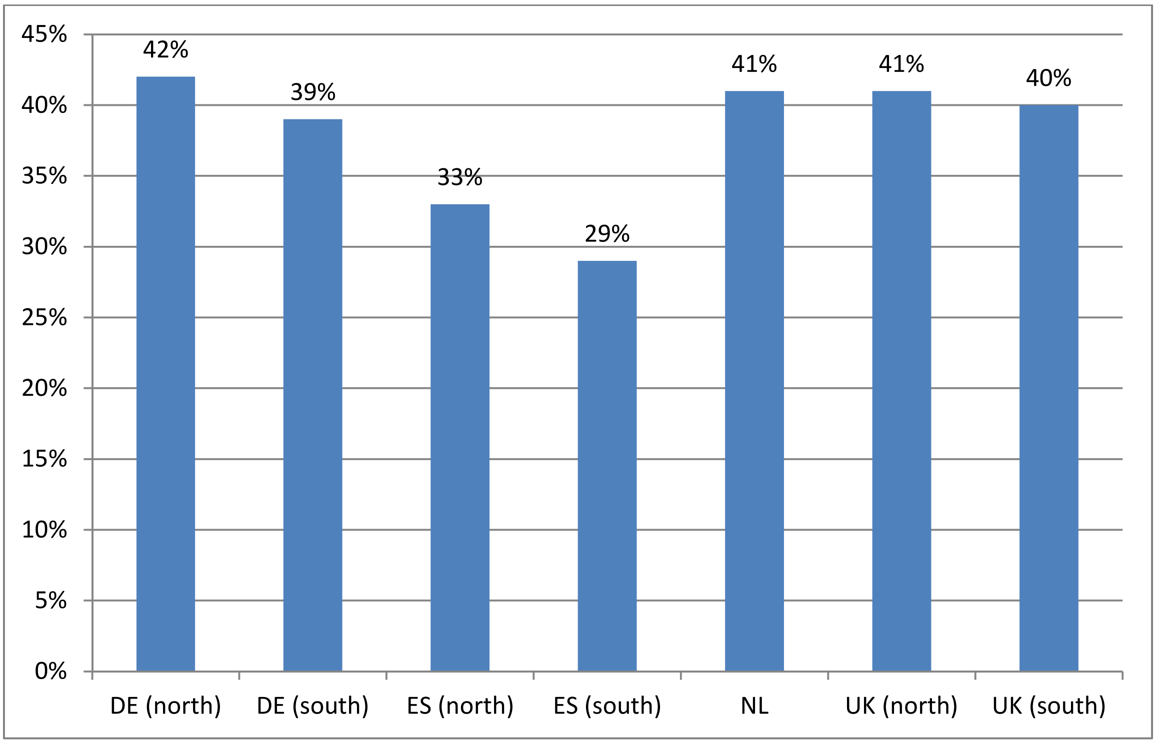

Figure 10: Theoretical self-consumption ratios in European countries
Source: Adapted from Latour (2013) and PV PARITY project data. Assumption: PV system sized to serve a 5,000 kWh annual onsite residential demand (i.e. 5,000 kWh ouput).

The self-consumption ratio is a critical driver for the economic case for PV. If prosumers cannot capture the full value of their system output, then the return on investment significantly decreases. There are both policy and technological solutions to improving the self-consumption ratio which are discussed in subsequent sections, including sizing the PV system small enough to never exceed

minimum household load[17], storage, and strategies to increase or dispatch onsite demand (Section 3.3.2.2).

2.2.4 Insolation

Insolation refers to solar resource quality, and is often expressed as the average amount of sunlight striking a square meter of surface area in a day. **Higher insolation increases PV system output and improves system economic performance**. As can be seen in Figure 11, average insolation in the inhabited countries of the world ranges from 2.0-2.5 kWh/m^2/day in the Nordic countries, to 6.5-7.0 kWh/m^2/day in countries in Africa. A 1 kW PV system in Namibia can have a capacity factor of ~23% and produce close to 2,000 kWh per year, whereas a 1 kW PV system located in northern Norway would have a capacity factor closer to 11% and produce less than 1,000 kWh per year.[18]

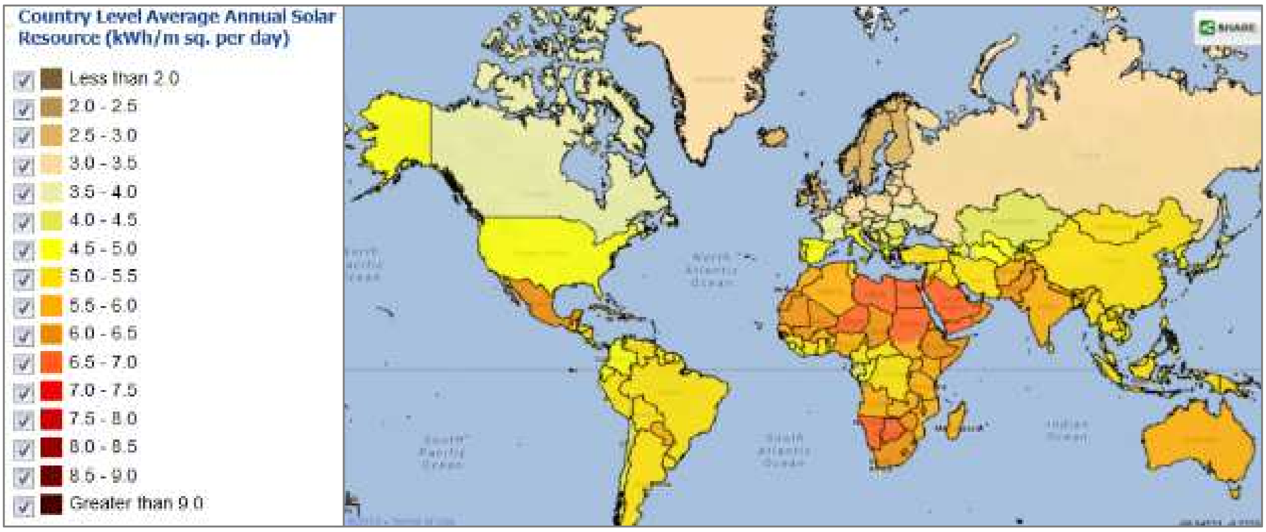

Figure 11: Country level average annual solar resource (kWh/m^2/day)
Source: Clean Energy Solutions Center (2014)

Insolation can also vary significantly within countries. The insolation in southern France, for example, is 25% higher than the insolation in northern France.[19]

[17] Most buildings have a constant base load that is consuming electricity even when the residents are not at home. On the one hand PV systems can be sized to meet this minimum load and therefore increase the self-consumption ratio. On the other hand, baseload power demand in some houses may be so small that sizing PV systems to serve them may be impractical.

[18] Based on calculations using RETScreen software, assuming optimally sited systems tilted at latitude and facing due south (in Norway) or due North (in Namibia), and 10% losses due to inverter efficiency and other miscellaneous losses.

[19] Based on data for Rouen and Toulouse from RETScreen

2.3 BEHAVIOURAL DRIVERS

Behavioural drivers can include a range of non-financial motivations and vary by stakeholder type.[20] This section focuses primarily on the motivations of consumers to become prosumers. A compelling return on investment is not necessarily an indicator of consumer willingness to adopt PV – and vice versa. Cost savings are an important driver for PV adoption, but do not take into account factors such as consumer awareness or consumer attitudes, values, and beliefs. Some consumers have invested in PV systems or even gone fully "off the grid" when it is not financially advantageous to do so (Tatum, 1991).

Although the current (and future) impact of non-financial drivers is difficult to predict, they have generally accelerated consumer PV adoption rather than hindered it. However, non-financial factors have not yet proved sufficient on their own to drive prosumer scale-up in the absence of a compelling economic case. In general, PV enjoys significant support according to public opinion research across countries. This translates into public support for the concept of PV prosumers - even among citizens who are not PV prosumers themselves. PV prosumers are also emerging as an important (and increasingly organized) interest group in countries where this constituency is expanding.

Figure 12 below captures some of the factors that may motivate electricity consumers to become PV prosumers (Boughen et al., 2013; Bremdal, 2011; Farhar & Buhrmann, 1998).

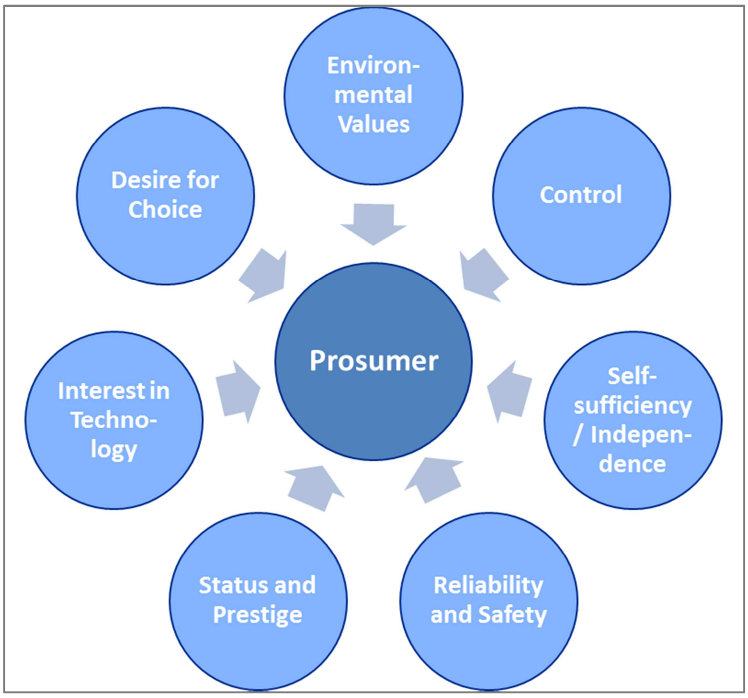

Figure 12: Examples of factors that may influence PV prosumer adoption behaviour
Source: IEA-RETD research

[20] For example, corporate actors may choose to take action to "green their bottom line" in a manner that does not generate returns in the traditional sense but that builds brand, reflects corporate values, and/or that demonstrates corporate responsibility.

- Environmental values. Environmental values encompass a range of potential motivations for PV adoption, including the impacts of fossil fuels on air and water pollution, concerns about climate change, a desire to preserve the environment for future generations, and specific environmental disasters (e.g. Fukushima).
- Control. Some consumers value the freedom to directly control all aspects of energy usage - not only the amount of energy that they consume, but also the manner in which the energy is produced.
- Self-sufficiency. Self-sufficiency refers to consumers that value the ability to sustain themselves without having to purchase commodities from a third-party (e.g. a utility).
- Reliability and safety. Onsite PV can be used in concert with storage as an uninterruptible power supply. Some customers may adopt PV in order to "keep the lights on." In most OECD countries black-outs may not be a frequent issue but in emerging and developing countries they can make daily life difficult.
- Status and prestige. Some consumers value the prestige of being perceived as owners of advanced technology by others.
- Interest in technology. Early adopters and others may be motivated primarily by the "newness" of PV technology and/or interested in the physics behind photovoltaic electricity.
- Desire for choice. Consumers may feel that they have the right to make their own choices about electricity, rather than having those choices dictated to them (e.g. by a monopoly utility). As a result, some choose to assert this right by purchasing PV systems.

At the other end of the spectrum, some consumers may not adopt PV even when it would be profitable to do so. The drivers for non-adoption can include, for example, a lack of awareness, a lack of trust in the technology and its economic performance, uncertainty as to how to best purchase PV, inconvenience (i.e. the "hassle factor"), among others.

Figure 13 below presents a generic framework for thinking about how innovations, such as PV, are adopted and diffuse through the market. As can be seen in the graphic, a certain percentage of a given addressable market can be thought of as innovators and early adopters – they are limited in number, but they will adopt new technologies before the majority of consumers do.

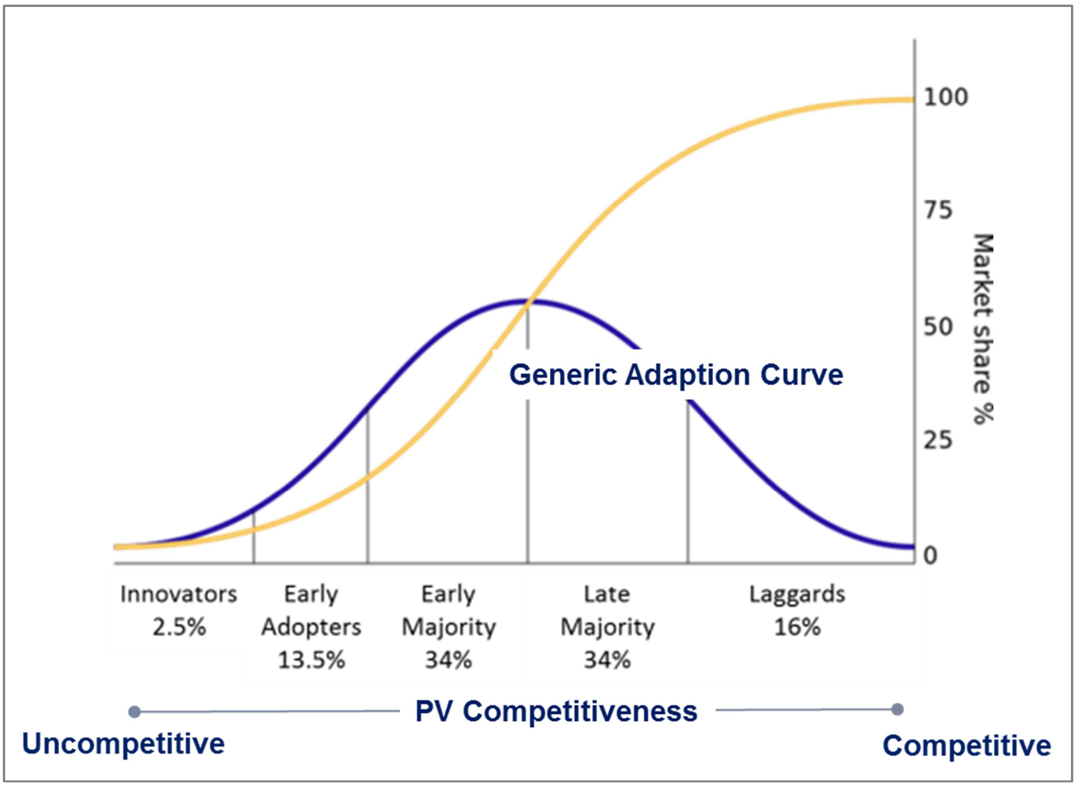

Figure 13: Technology Adaptation Curve and relation to PV competitiveness
Source: Adapted from Rogers (1962)

In thinking through PV diffusion, it can be helpful to consider the different types of adopters according to their relationship to PV competitiveness. The line at the bottom of Figure 13 loosely aligns PV competitiveness with types of adopters. Innovators and early adopters, for example, may be willing to adopt PV before it is economically competitive because their non-financial motivations (e.g. technology interest, energy independence, environmental awareness, etc.) drive their decision making. The early majority may not adopt PV, however, until it becomes more economically attractive (either because it becomes competitive or because they receive sufficient incentives).

Historically, PV market growth among residential prosumers has been rapid in jurisdictions where strong enabling incentives and enabling policies for PV prosumers have been put in place. Conversely, market growth has been limited in jurisdictions where enabling polices for PV prosumers have not been put in place. As discussed in Section 1.3, this study assumes that the large-scale emergence of PV prosumers will be closely linked with the policy environment in the near term and that enabling policy will be required to support and sustain prosumer development. In the mid- to long-term, PV prosumers may emerge independently under different models (e.g. grid defection) as prices continue to fall.

But what if drivers beyond cost savings play a greater role than anticipated? Could PV prosumers adopt storage or even go “off grid” in large numbers before the point of competitiveness is reached? According to innovation diffusion theory, adoption can eventually reach a “critical mass” after which the market diffusion will become self-sustaining. This occurs for innovations that do not have a “payback” in the conventional financial sense (e.g. plasma TVs) and some analysts suggest that this could also occur for PV prosumers.

Figure 14 below summarizes two "pathways" along which prosumers might scale up rapidly. The pathway on the left assumes that prosumers make decisions on a purely economic basis, in which case the correct mix of financial conditions will need to be in place to achieve scale-up. The pathway on the right assumes that non-financial drivers are sufficient for PV adoption and that policy and economic considerations are secondary. In both cases, enabling policy is necessary to allow prosumer scale-up.

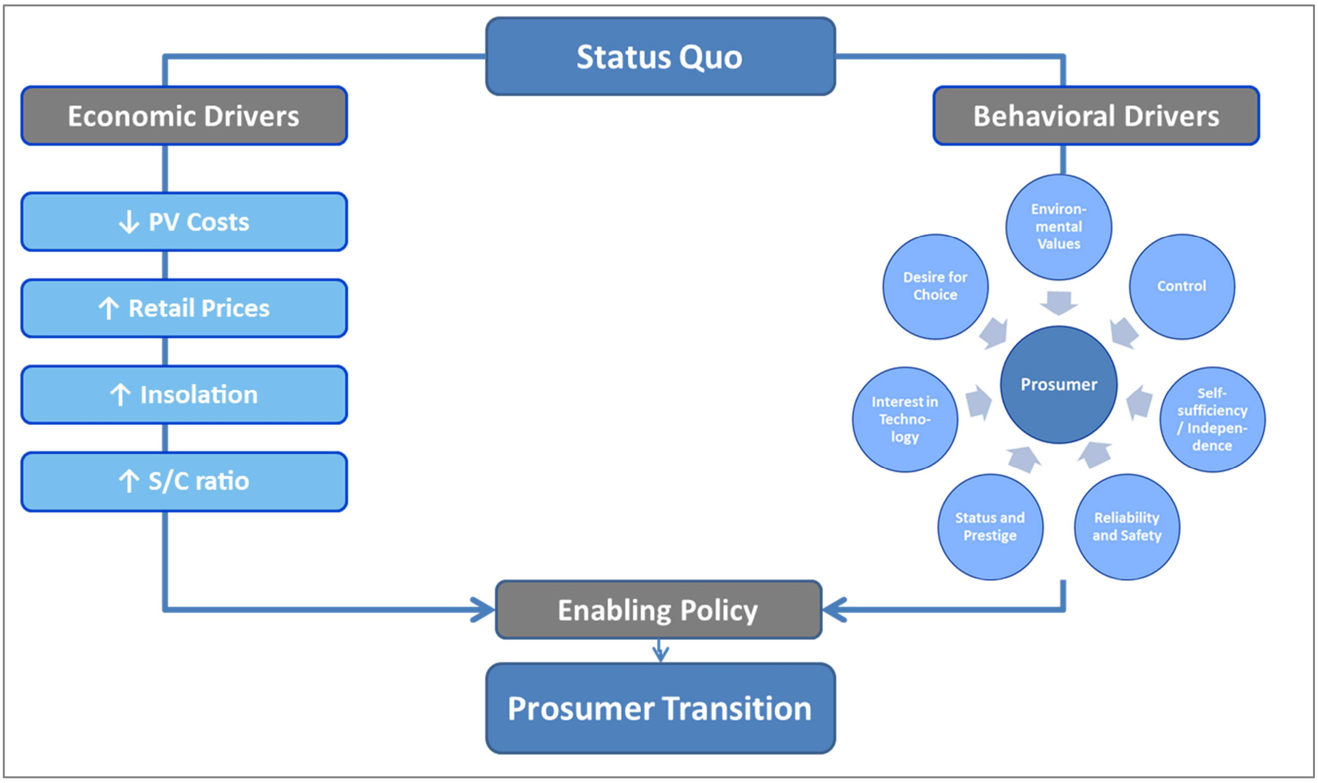

Figure 14: Potential pathways for prosumer scale-up
Source: IEA-RETD research

It is highly likely that reality exists somewhere in between these two extremes. On the one hand, it is unlikely that PV prosumers will scale up in the near term without the right mix of national conditions and policy support. On the other hand, policy makers and other stakeholders should not assume that the emergence of PV prosumers can be fully predicted, managed, or contained given the possibility that non-economic drivers might push the market to a "tipping point."

In Germany, for example, there is increasing interest in the emergence of unregistered[21], micro-scale systems that are installed by the homeowners themselves, typically by simply plugging the PV system directly into the outlets in the wall. The PV systems are then placed on the roof or even hung out of the window. These systems are not used by the homeowner to gain the feed-in tariff rate and are instead used simply to offset a portion of onsite demand. The emergence of these micro-scale systems both in Germany and in other European countries (e.g. Spain) is being driven anecdotally by the perception of cost savings, but also by environmental motivations and by the desire to avoid specific taxes and surcharges that are under consideration for registered PV systems. The precise

[21] Germany requires that PV system owners register their systems

number of these systems is currently unclear, but the issue is prominent enough that the German solar energy industry association has issued a position paper on safety issue for micro-scale solar (BSW, 2013a). Even if micro-scale, self-installed solar systems do not emerge as a massive new "movement," they are illustrative of the type of unexpected developments that could result from non-financial drivers. Another example of prosumer scale-up without traditional incentives is currently occurring in the Canadian province of Alberta. Text Box I. below discusses the experience to date in Alberta.

Text Box I. Solar prosumers emerge in Alberta, Canada

In 2008, the Government of Alberta passed its Micro-Generation Regulation, which enables consumers to generate their own electricity using alternative or renewable technologies, including solar PV systems.[22] The regulation makes it easier for consumers to generate their own electricity from these sources by reducing regulatory and administrative barriers. As of April 2014, Alberta had nearly 1,000 installed micro-generation sites, with a total capacity of 4.85MW. Over 90 per cent of these micro-generators are solar PV.

Alberta's Micro-Generation Regulation is designed to allow individuals to self-supply their electricity needs, rather than export large volumes of excess energy to the system. Systems must be sized no larger than required to meet all or a portion of their onsite electricity needs, and smaller than 1MW. When daily generation is greater than load, the regulation allows solar PV systems to export to the grid for a credit. Micro-generators need bi-directional meters to measure energy flows from and to the grid and the regulation requires the micro-generator's distribution wire owner to pay for and install this meter. The regulation also requires the retailer to interact with the electricity market on behalf of their micro-generating customers. Any credits the micro-generator receives for exported energy can be rolled over on a monthly basis up to one year.

What is noteworthy about prosumer development in Alberta is that net metering on its own does not create a significant incentive for PV development. PV growth has instead been driven by consumers' interest – be it their desire to reduce their environmental impact from electricity consumption, their desire to reduce their utility bills, or their desire to become more independent – rather than direct government subsidies.[23]

In light of recent uptake, solar prosumer development appears poised for continued growth in Alberta. In its 2014 Speech from the Throne, the Government of Alberta announced that it would develop an alternative and renewable energy framework to further diversify its generation mix and increase choice within the electricity system.[24] This is likely to involve examining how the current Micro-Generation Regulation can further enable solar, as well as other alternative and renewable, prosumer development in the Province.[25]

Consumer attitudes and values could also delay, rather than accelerate, prosumer scale-up. In countries where early prosumers have had negative experiences with market participation, the decisions of subsequent consumers could be negatively impacted. The inconvenience of PV adoption could also increase. For example, PV adoption in the future may require consumers to also adopt additional "smart grid" infrastructure, such as in-home smart meters, remotely controllable

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[22] *See* http://www.qp.alberta.ca/1266.cfm?page=2008_027.cfm&leg_type=Regs&isbncln=9780779745371
[23] Personal Communication, Electricity and Sustainable Energy Division, Department of Energy, Alberta, March 11, 2014.
[24] *See* http://alberta.ca/thronespeech.cfm
[25] Personal Communication, Electricity and Sustainable Energy Division, Department of Energy, Alberta, March 11, 2014.

appliances, and demand response technology. The additional equipment and the potential for required changes in behaviour could also slow or discourage mainstream adoption. Nevertheless, **this report assumes that consumer attitudes and interests will generally accelerate PV prosumer scale-up.**

2.4 TECHNOLOGY DRIVERS

In addition to the economic and behavioural drivers described in the previous sections, policy makers also need to remain apprised of technology developments, trends, and policies that could impact PV prosumers. There are a number of parallel technology innovations that are often discussed in concert with PV. A picture is frequently painted of a future electricity system where each building has an electric vehicle parked in front of it, a PV system on the rooftop, and a battery storage system – all interconnected through an intelligent grid that communicates with smart appliances and onsite demand response. While such visions are compelling, they often do not articulate that each of these technologies will require its own technical, policy, and regulatory innovations in order to be realized. This is not to say that policy makers should not strive for a clean, smart, and highly-integrated energy system. At present, however, these innovations are at different stages of development and are moving at different speeds in different countries and they may be difficult to coordinate. In some countries, for example, PV markets have grown dramatically with little development of potentially related technologies. Other technologies will effectively have to catch up to and fit into the established PV market. Other countries have invested heavily in smart grid infrastructure (for example), but have not yet begun to see significant PV development. In this case, PV may have to "fit in" to the smart grid paradigm if and when markets begin to accelerate.

The topic of how PV and related technologies could be (or should be) integrated in the future is broad and would merit a separate report. This section focuses narrowly on these technology trends from the perspective of near-term PV prosumer development and PV competitiveness. In other words, this section assumes that PV prosumer development is a policy objective and is already underway and asks how other technology drivers will impact current trends. This section provides a brief overview of PV technology development, batteries, electric vehicles, energy efficiency, load management, and smart grid technology.

- **PV technology improvements.** PV has experienced a historical learning rate of approximately 20% as a result of continuous improvements in PV technology and manufacturing processes. A recent 2014 industry roadmap projects that there are additional opportunities to reduce module costs through improved manufacturing efficiencies, more efficient uses of resources, and improvements in module output power. These improvements could result in module prices of $0.45/watt by 2018 and $0.33/watt by 2024 (Forstner et al., 2014). There are also a broad range of improvements that can be made to non-module components (NREL, 2012). In addition to incremental improvements in conventional PV technologies (e.g. both silicon and non-silicon semiconductors), there are also potential breakthroughs that could occur with technologies that draw from nanotechnology and nano-materials (e.g. quantum dots). However, these technological advances are not anticipated until the near- or long-term (Frankl et al., 2010). It is projected that continued advances in technology will continue to improve the competitive position of PV during the next ten years (Kost et al, 2013).

- Batteries. As discussed in Section 2.2.3, concerns about PV self-consumption ratios can be addressed through policies such as net metering, or through onsite storage technologies. Batteries are the most cost-effective onsite storage technology *for electricity* available commercially and they may be adopted widely for onsite PV in the future. Lithium-ion and lead-acid batteries are the two technologies which will likely be dominant during the next decade, although other technologies may emerge. Prices for lithium-ion batteries are projected to fall from $700/kWh in 2013 to $300/kWh in 2020-2025 (Bronski et al., 2014). Current commercially available battery systems could improve the self-consumption ratio to 60-80%. Batteries could unlock "grid defection" scenarios, but they represent additional cost. As discussed above, defection scenarios are unlikely to happen in most countries in the near-term, but could become a possibility for an increasing number of jurisdictions during the 2020-2030 timeframe.[26]

- Electric vehicles (EVs). The IEA projects that the number of electric vehicles could increase from 180,000 today to 20 million (or 2% of world vehicle fleets) by 2020 (Trigg & Telleen, 2013). These projections are supported not only by current sales and diffusion trends, but by national commitments. EVs charged with renewable energy have been advocated for as a solution to simultaneously decarbonize the electricity and the transportation sector. Variable resources such as solar could charge vehicle fleets, which could then potentially be dispatched during periods of low generation output in order to serve load (IEA, 2014; IEA-RETD, 2010). For prosumers, the storage function of EVs could improve the self-consumption ratio in addition to providing additional services (e.g. mobility). However, EVs would also incur additional costs similar to batteries. The presence of an EV would mean that PV systems might need to be sized larger than standard household systems, and additional control infrastructure for charging, dispatch, etc. might also add additional costs. EVs will provide prosumers with greater flexibility and could form part of a broader and integrated prosumer strategy, but they will not accelerate the emergence of prosumers in the near term.

- Energy efficiency trends. Many countries are increasing their commitments to energy efficiency even as PV is scaling up, which can create both opportunities and challenges. Energy efficiency can be targeted to reduce onsite loads – which could be both a negative and a positive for prosumers. On the one hand, a reduced onsite load could further reduce the self-consumption ratio for PV systems and erode prosumer competitiveness if the measures are installed after the PV system is sized and installed or if net metering is not in place. On the other hand, the reduction in onsite peak load through energy efficiency would allow for smaller-sized (and therefore cheaper) batteries. This would accelerate the cost-competitiveness of PV systems with battery storage and could enable grid defection scenarios to occur several years earlier than otherwise projected. Energy efficiency measures could also improve the match between onsite demand and PV output.

- Load management. As an alternative to storage or net metering, demand management technologies can be deployed to improve the self-consumption ratio for PV. This can include, for

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[26] It is important to note, however, that some countries such as Germany may not experience significant rates of grid defection because the significant seasonal variation in available sunlight at northern latitudes makes year-round grid independence technically challenging.

example, shifting loads to periods when PV output is at its highest (e.g. dishwashers, clothes dryers, and pool pumps, etc.) or increasing loads to absorb excess PV demand. This could include, for example, the use of "heat dumps" that can be used to convert excess electricity to heat that can be stored. IEA (2014b) finds that demand side integration via thermal energy storage to be the most cost effective solution. Other research presented to the IEA under the DSM Implementing Agreement concluded that load shifting using technologies such as heat pumps and electric vehicles can "contribute substantially to integration of intermittent renewables (Nieuwenhout, 2008)."

- "Smart grid" infrastructure. As described in many recent reports, "smart grid" can encompass a broad range of different concepts, ranging from advanced meter infrastructure, greater communication between utilities and consumer loads, remote control of onsite demand response, etc. Smart grid infrastructure is often mentioned as an enabler of onsite generation and storage technologies, such as PV. In countries with high penetrations of PV, prosumers may be constrained by the technical limitations of the grid (e.g. reliability concerns). As will be described in Section 3.3.2, smart grid strategies can form the basis for interactive solutions in which customer and utility assets cooperate to alleviate technical concerns. Smart grid infrastructure may also disadvantage PV prosumers, however: if smart grid integration links PV prosumer savings and revenues to wholesale prices as discussed in Section 1.3.3, for example, this may weaken the economic case for PV.

2.5 NATIONAL CONDITIONS

In addition to the primary drivers described in the preceding section, policy makers may also need to take into account additional national conditions that may accelerate or constrain prosumer development. These include, for example:

- Available roof space. The number of PV prosumers in a given jurisdiction may ultimately be limited by available roof tops[27]. Not all residences have suitable roof space as a result of roof orientation, shading, etc. The number of potential prosumer host sites, however, is significant. Studies of technical potential in Europe and the United States, for example, have consistently found that rooftop PV could supply 20-40%+ of total national electricity demand – although a large percentage of this roof space is non-residential (Chaudhari et al., 2005; EPIA & Greenpeace, 2011; IEA PVPS, 2002; Lopez et al., 2012). On a national level, this technical potential is significantly above current PV penetration levels and will likely not be reached in the near term – although specific regions may reach these limits sooner.
- Share of rental property. Different countries have different levels of home ownership. Property renters are less likely to become prosumers since they often do not have an incentive to make long-term investments in property improvements such as PV. Similarly, landlords do not have an

[27] As the scope of this report is about residential prosumers, the term "roof top" refers mainly to single or multi-family homes. Nevertheless, if the commercial and other sectors are considered, roof tops would refer to all types of buildings.

incentive to install PV since they generally do not pay electricity bills.[28] In the EU-28, the share of the population that owns their homes is 70%, whereas 65% own their homes in the United States (Eurostat, 2014; Harvard Joint Center for Housing Studies, 2013).

- Existing and planned renewable energy development. Prosumer adoption typically occurs in parallel with the development of large, central-station renewable energy plants and with small, distributed systems that are not owned by prosumers but are instead owned by utilities or third-party developers. On the one hand, the development of non-prosumer PV can help drive down the costs for prosumer-owned PV as well. On the other hand, non-prosumer renewable energy generation can have significant impacts on electricity markets, on the electricity grid, and on the availability of quantity-limited renewable energy policies (e.g. renewable portfolio standard targets). If non-prosumer renewable energy generation penetrations are high (or are projected to be high), this may limit the potential of prosumer development. To the extent that prosumers and non-prosumers compete, policy makers will need to determine which development models to prioritize.
- National energy demand. It is projected that electricity demand is likely to increase in non-OECD countries during the coming decades. In some OECD countries, however, electricity demand is projected to remain flat or even decrease. Flat or decreasing demand puts prosumers more directly in competition with existing generators and may increase the potential for conflict. Increasing demand, by contrast, creates more opportunity for new prosumers to generate electricity alongside existing generators.
- Connection to energy infrastructure. Islands and remote areas face greater grid integration challenges than do non-remote areas. They are also likely to have higher retail electricity costs than "mainland" communities.[29] As a result, they are likely to experience pressure for prosumer scale-up earlier than other jurisdictions and may also face a different set of grid integration challenges than larger, and more interconnected jurisdictions.

2.6 STAKEHOLDERS

As with the introduction of any new business model, the emergence of prosumers creates winners and losers, depending on how the incentives of different stakeholders are aligned. The alignment (or conflict) of stakeholder interests can most readily be influenced through policy and regulation as will be discussed throughout this report. However, policy makers will likely face conflicting political pressures from different stakeholders as they attempt to determine the most appropriate prosumer strategy. Political pressure could have a countervailing impact on the emergence of PV prosumers even when other economic conditions are favourable.

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[28] Landlords have rather an incentive to install PV on their rooftops when PV remuneration is disconnected from onsite load – e.g. under feed-in tariffs when PV rooftop PV systems export 100% of their power to the grid. However, in Germany there are already models where landlords include self-generated electricity as part of the rental contract.

[29] For more information on this topic, see IEA-RETD (2012) REMOTE.

- Prosumers. During the past decade, the number of residential prosumers has expanded dramatically. Prosumers now represent an increasingly significant political constituency in countries such as Germany and Australia (Section 1.1). There is also broad support for the ability of consumers to install and operate PV on their own property. Efforts to constrain prosumers may meet with political counter pressure not only from prosumers themselves, but from the broader public as well.

- Governments. Government policy makers must balance and mediate the interests of different stakeholder groups when articulating national policy objectives and crafting energy regulations. Government decisions that constrain or enable prosumers could have significant financial implications for different stakeholders and technical implications for the electricity grid. To the extent that government tax revenues are also linked to electricity sales volumes, government could also reduce its spending power to the extent that prosumers consume less electricity.

- Transmission and distribution grid operators. Prosumers reduce the amount of power purchased from the grid, which can reduce the revenue grid operators earn for power that flows through the transmission and distribution system (Section 3.2.1.1). Large penetrations of PV prosumers may also pose challenges to grid reliability which is one of the core services that utilities or system operators provide (often by law) (Section 3.3). At the same time, PV prosumers can generate savings for system operators when their systems are appropriately situated at congested areas within the grid.

- Incumbent generators. Prosumers compete with incumbent generators and can reduce the revenue that they are able to earn. At the same time, the emergence of prosumers can create new business opportunities for generation companies. A recent survey found that 94% of utilities expect “complete transformation or important changes to the power utility business model” and 82% “see distributed power generation as an ‘opportunity’ versus only 18% rating it as a ‘threat’” (PwC, 2013).

- Supply Chain – Technology Providers. The scale-up of prosumers can significantly benefit technology providers in the PV industry. Depending on how the prosumer market evolves, technology providers beyond PV could also see increased demand for their products. These include, for example, storage, demand response, heat pump, electric vehicle, and companies that manufacture components that enable both PV grid integration and smart grid capabilities. In the future, such companies may create new industrial clusters that would profit from greater connectivity while also lobbying jointly on behalf of electricity industry transition.

- Consumers. As the number of PV prosumers scales up, electricity consumers that do not own PV may increasingly be impacted. Some of these impacts may be negative. If prosumers purchase less electricity from the grid, for example, then other consumers may be charged more so that the costs to support the transmission and distribution system can be recovered (Section 3.2.2). Similarly, the cost of grid upgrades to accommodate increases in distributed generation may be recovered from other ratepayers. Despite the broad political support for PV, electricity ratepayers may resist upward pressure on their electricity rates. On the other hand, prosumers unlock values related to the grid, and environmental and economic benefits that consumers can take advantage of (Section 3.1.1). Depending on how the values are calculated, the emergence of prosumers may be a net gain for other consumers.

2.7 SUMMARY OF MAIN DRIVERS AND STAKEHOLDERS

Figure 15 below provides a summary of the most important prosumer drivers depicted in this section. It attempts to capture the complexity of the policy making landscape by reflecting not only the diversity of drivers, but also the fact that many of the drivers can both enable or constrain PV.

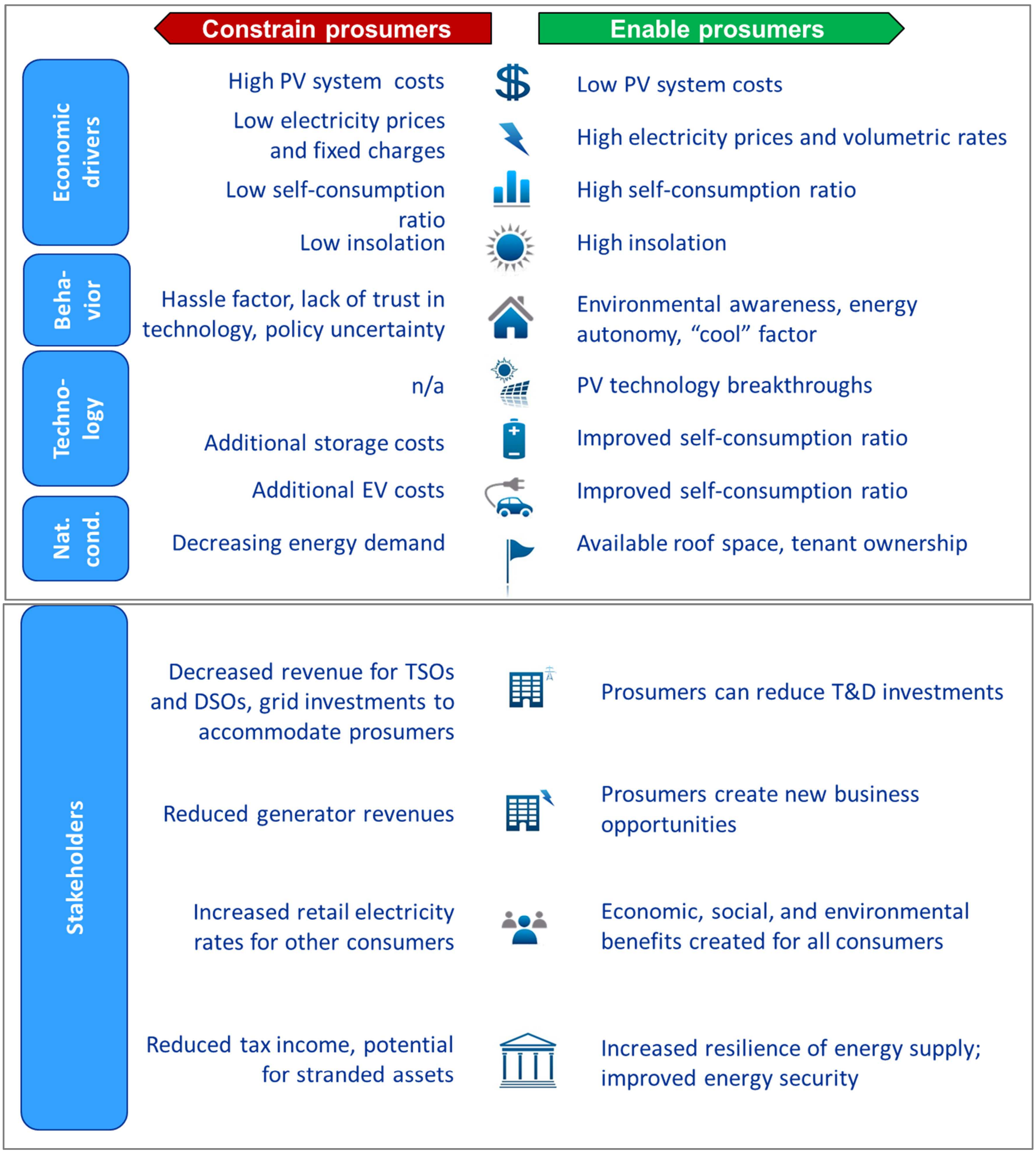
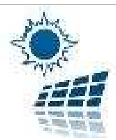


Figure 15: Main drivers and stakeholders that enable or constrain residential PV prosumers
Source: IEA-RETD research

The following Table 1 provides a legend which briefly explains the icons of the different drivers:

Table 1: Main drivers and stakeholders – brief explanation

Legend	Description
	PV system costs. Low PV hardware, installation, and financing costs make PV more competitive and prosumers more likely (Section 2.2.1). Countries with large and mature PV markets are more likely to have lower PV system costs than countries with smaller or newer markets.
	Electricity prices. High electricity prices at the retail and wholesale level make PV more competitive and prosumers more likely. Retail prices vary widely around the world. The structure of electricity rates can also influence prosumer economics (Section 2.2.2.1).
	Onsite demand. The timing of PV system output may not be matched to the timing of onsite demand, which may impact optimal PV system output and system economics (Section 2.2.3). PV systems where output matches onsite demand are said to have a high "self-consumption ratio" whereas systems where output and demand do not match are said to have low self-consumption ratios.
	Insolation. A strong incoming solar radiation, or "insolation" makes PV more competitive and prosumers more likely. The solar resource varies widely from country to country as well as within countries (Section 2.2.4)
	Prosumer behaviour. Consumers may be motivated to adopt PV for reasons that are harder to measure, such as environmental awareness, a desire for greater energy autonomy, energy security and resilience, or a desire for increased prestige (Section 3.1.1).
	PV technology. Although PV technology has improved steadily since the 1950s, there are opportunities for additional technology breakthroughs that could improve PV competitiveness, such as new PV silicon production processes or organic photovoltaics.
	Storage. Storage technology can enable prosumers to capture and utilize the electricity generated by their PV systems more effectively by decoupling time of generation and consumption. Battery costs have declined significantly, but batteries add additional costs to PV systems which have to be calculated against the value of an increased self-consumption.
	Electric vehicles. Electric vehicles may emerge as an important complement to PV for prosumers since they can serve as another source of storage for PV output. Like batteries, however, they represent an additional cost which could delay PV prosumer emergence if they are to be a prerequisite for system competitiveness.
	National conditions. Available roof space, a low share of rental property and rather high or increasing national energy demand drive prosumer development. Islands and remote areas with few interconnections face specific integration issues but can provide good prosumer conditions.
	Transmission and distribution grid operators. Prosumers reduce the amount of power purchased from the grid, which can reduce the revenue of grid operators (Section 3.2.1.1). As the amount of prosumers increases, the grid may require upgrades to maintain safety and reliability (Section 3.3). At the same time, prosumer systems can create benefits when situated in congested grid areas, e.g. by reducing losses or the need for new grid capacity / transmission lines (Section 3.1.2).

Legend	Description
	**Incumbent generators.** Prosumers compete with incumbent generators and can reduce the revenue that they are able to earn. At the same time, the emergence of prosumers can create new business opportunities for generation companies.
	**Consumers.** If prosumers purchase less electricity from the grid, then other consumers may be charged more so that transmission and distribution system costs can be recovered (Section 3.2.2). On the other hand, prosumers unlock values related to the grid, and environmental and economic benefits that consumers can take advantage of (Section 3.1.3).
	**Governments.** Governments must balance the interests of different stakeholder groups and constituents. Revenues on taxes and other levies could be to the extent that prosumers consume less electricity. Governments could become responsible for stranded assets in the future, but they could have increased resilience and improved energy security.

SECTION 3

EVALUATING PV PROSUMER OPPORTUNITIES AND CHALLENGES

The complexity of the drivers influencing prosumer emergence can make it difficult for policy makers to find a clear pathway forward. The convergence and alignment of prosumer drivers could result in rapid and unexpected PV growth – but the inevitability and timing of such an event is uncertain and difficult to predict. The emergence of prosumers on a large scale currently remains a policy choice (at least for now). Policy makers can elect to constrain, enable, or transition towards prosumers.

But what guides policy maker decision making? Why would governments either want to support or block prosumer development? In order to establish a prosumer strategy, policy makers should identify and weigh the opportunities and challenges posed by prosumer development. This section reviews some of these opportunities and challenges in greater detail.

3.1 PROSUMER OPPORTUNITIES AND BENEFITS

3.1.1 Benefits of Solar Power

The benefits of solar power in general have been documented and described in many documents and reports during the past several decades (e.g., Edenhofer et al., 2011), and have been explored by the IEA in a series of reports related to deploying renewable energy (IEA 2008, IEA 2011a, IEA 2011b). At a high level, these benefits as catalogued by IEA include:

- Energy availability. Energy availability means that there is sufficient energy supply to meet demand at all times, as well as the infrastructure needed to transport the resource to final use. As an inexhaustible and inherently local resource, solar power can help assure energy supply availability during periods of fuel supply disruption or geopolitical instability – particularly for countries that are energy importers.
- Energy affordability. Solar energy can help deliver affordable energy in several ways. First, solar energy is already a competitive alternative to conventional generation in islands and remote areas with diesel-dominated grids. Solar energy can also serve as a hedge against both price volatility (i.e. the amount that prices will diverge from an average) and price uncertainty (i.e. the amount that average prices will be different than expected over time). The integration of solar energy into national energy systems can diversify the generation portfolio and help insulate national economies from changes in conventional fuel prices. Solar power can also shave system peak demand and can reduce market prices as a result (which is a benefit for other consumers and the economy as well because the input of expensive fuels is reduced).
- Energy supply sustainability. The amount of fossil fuels that can be extracted will eventually be capped either by regulatory constraints (e.g. greenhouse gas regulation) or by resource exhaustion. Renewable energy will be able to continue to supply power if and when fossil fuels are no longer available or accepted.
- Green growth. Solar energy development can create new and direct domestic jobs in the manufacturing, installation, and service industries, as well as indirect and induced jobs in the broader economy. Solar power can also create the foundation for a longer-term economic

development strategy that can "decouple growth from natural capital depletion" in the face of environmental stress and a decrease in reliance on fossil fuel industries.

- Innovation and industrial development. Along with new jobs, countries may also pursue solar power development in order to develop new industrial clusters that can develop intellectual property (i.e. patents) and be positioned for export.
- Rural development. PV can provide modern energy services to isolated areas that do not have a reliable power supply or that lack energy access entirely. Energy access can significantly improve livelihoods by creating new economic opportunities and improving health.
- Carbon dioxide emissions reductions. PV can displace generation from fossil fuel technologies and thereby reduce emissions, thus mitigating climate change. PV systems also have lower lifecycle CO_2 emissions associated with their manufacture than conventional power plants.
- Air quality improvements. By displacing fossil fuels, PV also reduces the emission of sulphur dioxide, nitrous oxides, particulate matter, mercury, and other air pollutants that are hazardous to human health and to the environment.
- Water consumption. Conventional power plants often require a large amount of water to sustain operations. In the United States, for example, power plants account for 40% of freshwater withdrawals (Rogers et al., 2013). With droughts on the rise in many parts of the world as a result of climate change, the conventional energy supply will increasingly be at risk as it competes for scarce water resources with other critical sectors. PV generation does not require water to operate.
- Land use. Conventional power plants can use a significant amount of land for both operation, but also for waste disposal (e.g. coal and nuclear). PV can be readily integrated into existing infrastructure (e.g. building rooftops, parking lots, etc.) and avoid significant land use impacts, depending on how it is designed.

Benefits such as these have served as the justification for the premium incentive policies that have supported solar market growth. When combined with the revenues that PV electricity can command in conventional electricity markets[30], the total value of these benefits has been estimated to be higher than the levelized cost of PV (e.g. $0.15-$0.41/kWh in the U.S.) both in recent research efforts (Hansen et al., 2013; Perez et al., 2011) and in formal regulatory proceedings (e.g. VTPSD, 2013).[31] Under these circumstances, it can be argued that PV system owners actually cross-subsidize other ratepayers when the value that they create is above the remuneration rate they receive (Bird et al., 2013).

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[30] e.g. the markets for electricity, for capacity, and for ancillary services

[31] There is a large body of research in the United States on the value of solar that supports ongoing policy implementation efforts. In some cases, these "value of solar" calculations are being used to set the rates at which utilities must purchase PV output. The state of Minnesota, for example, developed a methodology for setting a rate based on the value of solar which will be used to develop a tariff rate in 2014 (Minnesota Department of Commerce, 2014). A value of solar tariff has previously been developed by the municipal utility in Austin, Texas for residential PV (Rábago et al., 2012). Value of solar tariffs are similar to value-based feed-in tariffs that have been adopted in countries such as Portugal.

Many of these benefits, however, can arguably be achieved through the deployment of central-station renewable power plants, rather than through distributed prosumers. Some would argue, for example, that a 400 MW PV generating station is superior to installing 80,000 five kilowatt systems because similar greenhouse gas benefits can be recognized at a lower cost.

3.1.2 Specific Benefits of Distributed Solar Power

Distributed PV, however, provides benefits and services that low-cost but large-scale power plants cannot. As a result, policy makers may choose to support prosumers in order to achieve specific objectives or realize specific benefits. These prosumer benefits can include, for example:

3.1.2.1 Benefits for the energy system

- Avoided system losses. By generating power onsite, distributed PV avoids the energy that is lost due to inefficiencies in delivering energy to the customer via the transmission and distribution (T&D) system. Most countries in North America and Europe experience T&D losses of 4-8%.
- Deferred or avoided distribution and transmission capacity. Generating power onsite can also avoid or delay the need for investments in transmission and distribution capacity by relieving upstream constraints or avoiding the need for system expansion, especially in countries with summer peak loads. This can create significant savings for utility systems. PV prosumers can also serve as an alternative to transmission system expansion. In countries with sparse populations spread over large land areas, supporting local prosumer development may be a cheaper alternative than extending transmission system lines. Even in countries where transmission is feasible from a cost perspective, it may not be feasible from a political perspective. Citizens may resist transmission expansion based on either environmental or aesthetic grounds and prevent their construction.
- Resilience. Prosumers who own PV systems with storage can configure their systems to provide back-up power in the event of grid disruptions. This can prevent not only economic loss for the prosumer, but can also reduce the burden of utilities attempting to restore power to blacked out areas.

3.1.2.2 Benefits for local economies

- Local economic benefit. Prosumers who own their own systems can capture the full value of the system for themselves, which can have a greater local economic multiplier effect than systems which are owned and operated by non-local developers.
- Price hedging. Onsite PV systems have very little operational and no fuel costs, so they can effectively "lock in" the price of prosumer electricity purchases over the long-term. This price certainty can serve as a hedge for the prosumer against the volatility of other fuels (e.g. electricity or diesel) and has quantifiable financial value.

3.1.3 Broader Considerations about Distributed Solar Power

Beyond these specific benefits, there are also broader schools of thought or philosophies which may drive policy decision making related to prosumers. These include, for example:

- *Prosumers may be necessary to affect structural change required in the electricity industry to achieve sustainability*. Some analysts argue that the current centralized system of energy generation and supply is structurally incapable of achieving the stabilization of greenhouse gas emissions in the atmosphere. The current system would also be unable to create the distributed architecture required to withstand the extreme conditions associated with climate change. Instead, it is argued that control of the power system must be devolved to distributed networks that can make the necessary investments in low carbon and resilient energy. This philosophy is consistent with the "soft path" energy argument originally articulated in the late 1970s (Lovins, 1979; Lovins, 1976).
- *Citizens should actively and directly participate in and profit from the energy industry*, rather than being passive recipients of regulated commodities. This thinking is often captured loosely under term "energy democracy," and is utilized to refer to individual or community ownership of energy assets as an alternative to utility ownership. The drivers for energy democracy can include creating new economic opportunities at the local level, creating a sense of shared ownership of, and responsibility for, the energy system among energy consumers, and transferring market power in the energy industry from large corporations to a broader spectrum of the population.
- *Prosumers increase competition in the electricity market:* One of the main goals of market liberalisation has been to foster competition among generators. Prosumers can challenge incumbents' business models and add a greater number of players to the market, potentially many more than had been foreseen at the beginning of electricity market reforms.
- *Prosumers are inevitable* given current market trends and must be engaged so that they can be managed. Under this line of thinking, the conditions that enable PV prosumers will continue to align as described in Section 1, and PV prosumers will eventually emerge – even under conditions where policy makers work to restrain them. As a result, there is value in proactively supporting the emergence of prosumers in order to gain experience with new market and planning paradigms – rather than reacting once prosumers begin introducing new and unanticipated business models and market dynamics.
- *Politics also plays an important role in prosumer decision making*. Solar power consistently receives high approval and enthusiastic support in public opinion polls across many countries. This broad public support has encouraged decision makers to support prosumer policies in the past with incentives. This "first generation" of incentivised prosumers, however, has increasingly emerged as a political force of its own. As discussed above, the large numbers of prosumers that already exist in countries such as Australia and Germany constitute a new and growing political constituency within the energy industry. Rather than dealing with a few large generation companies, policy makers are now faced with the prospect of dealing with millions of households that own solar energy assets and may feel compelled to vote accordingly. Efforts to change course on solar policy in Germany, for example, have consistently been met with strong political counter-currents at the local, regional and national levels. Prosumer politics are also beginning to manifest

themselves in unexpected ways in other countries as well. In the United States, for example, efforts to constrain prosumers in traditionally conservative states such as Arizona and Georgia have faced resistance from libertarian conservative groups who support the right of individuals to own their own power systems, rather than having to purchase power from monopoly utilities (Horsey, 2014; Martin, 2013b). Going forward, this relatively new political dynamic could continue to change the political calculus around energy policy. It may further encourage policy makers to "go further" with prosumers, and it may also limit the ability of policy makers to restrict or constrain prosumers growth.

3.2 FINANCIAL CHALLENGES AND RISKS

In addition to creating opportunities, as described in Section 3.1, the emergence of prosumers will also pose challenges to the current model of governing, managing, and operating the electricity sector. The prospect of competitive PV and the rapid scale-up of prosumers has therefore been controversial in some countries. Some electricity industry stakeholders have characterized the rise of prosumers as a needlessly disruptive threat to established business models, to grid reliability and financing, to energy affordability, and to safety. Moreover, the rise of widespread distributed generation could undermine the ability to conduct long-term planning and forecasting. As is already being seen in markets like Germany, the deterioration of a clear planning horizon for major investments such as power plants and transmission lines is beginning to have impacts on traditional utilities' ability to raise capital, to decide on future investments, and to forecast future sales and profits. This uncertainty can be seen as a disruptive force in a sector accustomed to 30-40 year planning horizons. In contrast, other stakeholders have argued that these challenges must be addressed and overcome because prosumers represent a natural, healthy, and necessary evolution of the electricity industry. This section reviews these challenges and groups them into two broad categories: financial (e.g. utility revenue erosion) and technical (e.g. grid stability).

3.2.1 Financial Challenges for Incumbents

Conventional electricity market and regulatory structures have successfully created reliable electricity systems in many parts of the world. These structures have allowed generation, transmission and distribution asset owners to profitably produce and deliver electricity to meet consumer demand and to make long-term investments required for anticipated future electricity system needs. While a number of notable regulatory and market failures have led to significant system disruptions (e.g., the 2001/2002 California electricity crisis), the general global growth of reliable electricity systems is, in part, due to the development of carefully balanced market and regulatory environments that allow electricity system asset owners to make investments with reasonable expectations of future returns.

Significant growth of prosumers may create financial challenges for the market and regulatory frameworks (see Table 2).

Table 2: Potential financial challenges posed by prosumers

Entity	Possible Financial Challenge
Owners of electric system infrastructure	• Lower profitability due to reduced sales • Reduced earnings opportunities due to lower capital investments • Increased integration costs
Electricity consumers	• Rate increases/cost-shifting
Taxing authorities	• Revenue loss from reduced retail sales • Revenue loss on income tax from transition from FITs to self-consumption

Widespread onsite power production will shift electricity system revenues (or savings) away from certain market actors and towards others. Importantly, the financial challenges posed by prosumers are not without historical precedent and contemporary analogues. **Most notably, many of these challenges are similar in many ways to those that arise as a result of energy efficiency programs in the electric sector.** Both PV prosumers and energy efficiency reduce electricity sales, resulting in revenue erosion among incumbent owners of electricity infrastructure, reduced profitability, and possible increases in electricity rates as fixed costs are spread across fewer units of electricity sold.

The implications of these similarities for policy makers are two-fold. First, policy makers have the opportunity to draw upon a relatively broader base of experience with managing the financial challenges associated with a growth of energy efficiency. These comparisons may help to calibrate their assessment of the impacts of prosumers and to inform their strategies for managing those impacts. Second, given the continuing emphasis on energy efficiency in many countries for meeting economic and environmental objectives, policy makers may wish to consider integrated or holistic approaches to managing the financial challenges posed by energy efficiency and PV prosumers, given their compounding and interactive effects on electric industry participants.

3.2.1.1 Utilities or other incumbent owners of electric system infrastructure

In order to remain terminologically neutral, this section generically refers in the following discussion to "owners of electric system infrastructure", with the understanding that this term refers to owners of generation, transmission, and/or distribution systems, and includes both regulated and unregulated entities, unless otherwise specified. As shorthand, the term "utilities" is sometimes used instead.

Great variations in electricity industry structure exist among countries, in terms of the entities responsible for ownership and operation of electricity system infrastructure and the regulation of those entities. Under the traditional model, vertically-integrated utilities own and operate all elements of the electricity production and delivery system (i.e., generation, transmission, and distribution), and are granted monopoly franchise service territories subject to "cost-of-service" or "rate-of-return" regulation. In contrast, many countries have undertaken some form of restructuring or liberalisation, whereby certain functions have been divested or unbundled, and are provided through competitive

service providers. Even in restructured markets, however, elements of the electricity delivery system (i.e., transmission and distribution networks) typically continue to operate as regulated monopolies under cost-of-service pricing.

As discussed below, the growth of prosumers may impose several distinct financial challenges on utilities and other incumbent electric infrastructure service providers. To some extent, these challenges are dependent upon the particular market organization, but in general, they derive from fairly fundamental features of electricity systems and apply broadly across countries.

3.2.1.2 Lowered profitability due to reduced sales

Current systems for producing and delivering electricity are characterized by large fixed infrastructure costs for generation, transmission and distribution networks, and for metering and communication systems. Electricity consumers, however, are often charged for their service based primarily on their quantity of usage (i.e., through volumetric charges), with relatively small fixed monthly charges and/or demand-based charges. Infrastructure owners thus typically recover some portion, if not the majority, of their fixed infrastructure costs through volumetric charges.

As a result of this disconnect between the underlying cost and revenue structure, the profitability of infrastructure owners is highly dependent on their volume of sales. This is particularly true – though not exclusively so – within cost-of-service regulatory environments (e.g., for vertically integrated utilities in traditionally regulated markets and distribution service providers in restructured markets). The prices charged by these entities for their services are often established through periodic rate adjustments and set at a level to allow the regulated entity to receive a specified rate-of-return. If, in between rate cases, costs grow faster than sales, the regulated entity will fail to recover its authorized return and shareholders will see their profits eroded. These revenue risks may also erode the company's credit quality, increasing its cost of capital and driving up the cost of system investments.

Regulated owners of electric system infrastructure therefore have a strong financial incentive to encourage increased consumption and to discourage efforts to reduce consumption. The potential for prosumers to undermine fixed-cost recovery is thus especially pronounced if occurring in conjunction with other conditions that also are curtailing load growth, such as aggressive energy efficiency initiatives. Over the long-term, systematic under-recovery of fixed costs could lead to stranded assets and deter regulated entities from undertaking infrastructure investments necessary to ensure reliable and efficient service. As discussed below, however, various options exist within the traditional cost-of-service regulatory framework to mitigate these challenges.

3.2.1.3 Reduced profitability due to wholesale market price suppression

Prosumers represent a threat to the profitability of central-station generation owners, though the particular nature of that threat depends on the market structure and prosumer configuration. In traditionally regulated markets, it is the impact of prosumers on retail electricity sales that most directly undermines the ability of incumbent generation owners to recover their fixed investment costs, as discussed above. In restructured electricity markets with competitive generation service providers, erosion of generator profitability may instead occur by virtue of the combined impact of prosumers and central-station renewable generators on wholesale energy market prices. As has already been witnessed in several markets with high renewable penetration (most notably Germany), large amounts of low-marginal-cost renewable generation injected into the bulk power market can

lead to substantial reductions in market clearing prices. These impacts have been especially pronounced during mid-day periods when PV generators are producing at maximum output – and when thermal generators would otherwise receive a disproportionate share of their revenues. A rapid expansion of prosumers with onsite PV generation could further compound the effects.

Although conventional generation owners may bear the immediate impacts of falling wholesale prices in terms of reduced profitability and reduced credit quality[32], the effects have broader implications. Sustained reductions in wholesale energy market prices may, in the near-term, lead existing generators to cease operation if wholesale market revenues are insufficient to cover operating expenses, while over the longer term, generation developers may scale back expansion plans, leading to unsustainably low reserve margins. Wholesale market price suppression may also impact the economic viability of both central-station and distributed renewable power (especially solar PV), and with it, the attainment of associated environmental goals. Central-station renewable generators often rely, either directly or indirectly, on wholesale power markets as a revenue source, and thus their economic value may be eroded if mid-day market prices remain depressed. Similarly, the economic viability of prosumers could become compromised if compensation were provided through time-varying retail electricity rates (e.g., net metering with time-of-use or real-time pricing rates) or through direct sales into the wholesale market.

3.2.1.4 Reduced earnings opportunities due to lower capital investments

Capital investment in electric system infrastructure is driven in many instances by load growth (or replacement). By dampening load growth, prosumers may therefore reduce the opportunities for new investments in electric infrastructure by incumbents (as does energy efficiency). These earnings impacts are potentially most significant for regulated entities – i.e., vertically integrated utilities and regulated transmission or distribution service providers – where earnings are generated primarily by deploying capital and receiving a regulated rate-of-return on those investments.

Naturally, the severity of these impacts depends not only on the amount of distributed PV deployed but on its ability to defer or avoid new capital investments. At the distribution system level, that deferral value is often highly idiosyncratic, depending on the conditions of an individual distribution circuit, and current distribution system planning practices in this area are evolving. At the bulk power level, reduced load growth may delay the need for conventional generation and/or transmission network upgrades required for local reliability and resource adequacy. In general, the ability of prosumers to defer new electric infrastructure capacity depends on the coincidence between distributed PV output and peak load on the particular infrastructure element considered. With increasing PV penetration on the grid, this peak coincidence tends to decline. Daytime prices in Germany, for example, are now frequently lower than overnight prices. Thus, the ability of prosumers to defer new capital investments, and the associated earnings erosion suffered by incumbent providers, is likely to be most pronounced in the early stages of prosumer expansion, but would recede at later stages of market development.

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[32] Generators may also enter into 1-3 year contracts with suppliers at fixed costs. If wholesale prices drop in the meantime, the generator is insulated from the shift and the economic loss instead accrues to the to the supplier (this has happened in Germany in recent years)

In cases where prosumers substitute directly for central-station renewable generation, the prospect for earnings erosion takes on an entirely different form. In such cases, prosumers represent a direct threat to the earnings potential of large-scale renewable generation developers (as well as earnings opportunities of transmission developers seeking to construct long-distance transmission to transmit remote renewable resources to load centres). These threats may be even more severe than the potential earnings erosion faced by conventional generation owners, both because renewable generation is typically more capital-intensive than conventional generation and because the capacity-deferral value of distributed PV would generally be much higher when substituting for central-station renewable generation than when substituting for conventional generation.

Regardless of what entity or entities are impacted, the potential erosion of earnings opportunities for electric system infrastructure providers caused by prosumers need not be viewed as a "social problem" requiring a policy solution, per se. **These reduced investment opportunities are, after all, the flip-side of cost savings.** However, incumbent electric system infrastructure providers are a political constituency, and may be an important set of partners in the expansion of prosumers. As such, policy makers may seek to explore strategies for aligning the financial interests of these entities by creating positive earnings opportunities associated with prosumer growth, as discussed further in the section below.

3.2.2 Financial Risks for Electricity Consumers and Ratepayers

As discussed above, the reduction in retail electricity sales associated with an expansion of prosumers can lead to under-recovery of fixed costs if the tariff structure is not adjusted, particularly for those infrastructure assets provided as a regulated service. In the short-term, those impacts are borne by the regulated service provider, in the form of reduced profitability. Over the longer-term, however, the service provider would in most cases be allowed to raise its prices to the level necessary to recover its fixed costs along with its authorized rate of return. Put simply, fixed costs would spread across a smaller volume of sales. All else being equal, this would put upward pressure on retail electricity costs for consumers. At the same time, distributed PV reduces the costs borne by electric service providers, such as by reducing fuel and operating expenses and by deferring the need for new infrastructure (Section 3.1.2).

Whether and to what extent an expansion of prosumers would lead to a net increase or decrease in retail electricity rates therefore depends on the magnitude of those avoided costs *relative* to the magnitude of the revenue erosion caused by reduced sales. Great debate exists about the size and nature of the benefits of distributed solar, and thus **significant uncertainty surrounds the question of whether rates would ultimately increase or decrease with an expansion of prosumers.** Utilities and consumer groups in regions with growing presence of distributed solar have already begun to express concerns about the potential rate impacts, often sounding the alarm of the "utility death spiral" (i.e., the cycle in which departure of load via self-generation leads to rate increases, which causes greater amounts of self-generation, then further rates increases, further increases in self-generation, and so on) (Denning, 2013; Kind, 2013). In contrast to these utility concerns, some policy makers have stressed that the "death spiral" concept is exaggerated and could be readily addressed through modest changes in rate structure (Section 4.3.3), or through changes in utility business models (McMahon, 2014; Trabish, 2014). Some utilities have also indicated new strategic directions in

response to challenges posed by prosumers. RWE in Germany, for example, has stated that is pursuing a new prosumer-oriented business model (Lacey, 2013).

Text Box II: COST-SHIFTING BETWEEN PROSUMERS AND OTHER RATEPAYERS:

Concerns about rate increases are often framed in terms of potential cost-shifting between prosumers and other customers, and in terms of questions about whether owners of distributed generation are paying their fair share of fixed infrastructure costs. Ultimately, however, the size (and directionality) of any cost-shifting among ratepayers depends on the value that distributed solar provides to the electric system, which remains an area of substantial research and debate. Prosumers may also produce broader societal benefits – e.g., through reduced air pollutant emissions or local economic development – that accrue to ratepayers at large and may be considered within the calculus of cost-shifting.

It is also worth noting that debates about cost-shifting are, to some extent, fuelled by the perception that distributed PV is financially accessible to only a small segment of the population. A future with significant expansion of prosumers presupposes that distributed PV becomes widely accessible, in which case concerns about cost-shifting may become moot as the ratio of "haves" to "have-nots" becomes more politically palatable. Returning again to the analogue with energy efficiency, it is perhaps because energy efficiency is viewed as being broadly available to all customers that it has generally been less of a lightning rod for concerns about cost-shifting.

Finally, rate increases attributed to PV prosumers should be put in perspective with rate increases attributable to other sectors. Many countries, for example, provide subsidized electricity rates to strategic manufacturing industries (e.g. aluminium and automobile manufacturing), which other ratepayer classes must absorb through higher rates. Such industrial cost shifting can significantly outweigh the magnitude of cost shifting attributable to residential prosumers.

3.2.3 Financial Risks for Taxing Authorities

Local, state and national governments may experience erosion of tax revenues as a result of the growth of prosumers. Governments in some countries embed taxes in retail electricity rates, allocating these revenues to either the general fund or to specific programs and purposes. The revenue generated through these taxes is a direct function of the volume of retail electricity sales. To the extent that the growth of prosumers reduces retail sales, it will also reduce government revenues through these tax mechanisms. Governments may also experience revenue loss as result of the transition from FITs to self-consumption. In some countries, FIT revenues are taxed as income. As FIT rates decrease below the retail rate and generators may migrate to self-consumption (or as FIT rates are simply phased out), the associated tax revenues will decline.

3.3 TECHNICAL CHALLENGES AND RISKS

The integration of variable renewable energy generation (e.g. wind and solar) into power grid can create a range of technical challenges and create electricity system reliability issues. The significant scale-up of PV prosumers can also contribute to these challenges, particularly at the distribution grid level – although it is important to note that these challenges are not typically attributable to PV alone.

The rapid growth of PV prosumers is already presenting technical issues in some parts of the world. In Australia, some utilities are putting a halt to the integration of new distributed generation in certain locations as solutions are sought (Noone, 2013). Meanwhile, in jurisdictions like Hawaii, the rapid rise of distributed PV has already led to overloading on certain feeders and to restrictions in the approval of new solar PV projects (Wesoff, 2014). Solar PV in certain Hawaiian neighbourhoods has led to power back-feeding into the circuit, causing voltage increases and other power quality issues. Some countries are already moving to address technical challenges posed by PV. Advanced inverters, for example, can provide a wide range of functionalities to support network stability, such as voltage control. A parallel process of upgrading inverters and increasing the ability of distribution grid operators to remotely control and monitor them is beginning to emerge in a number of countries, such as Germany and the Czech Republic. Germany has also required that inverters on an estimated 315,000 PV systems be retrofitted in an effort to improve electricity system reliability and prevent potential instability issues.

These and other examples point to the need for policy makers to proactively plan for a future in which more consumers will be increasingly motivated to become prosumers. Given practical considerations related to grid stability, electricity systems that do not proactively plan for increased prosumer penetration will likely be forced to either limit distributed generation interconnections or adopt reactive policies and standards when grid stability issues result from unanticipated (or poorly managed) prosumer growth.

A growing body of literature exists highlighting technical issues of integrating distributed solar into existing low-voltage distribution systems (EPIA, 2012; Mateo et al., 2014, IEA 2014b). National and international studies have been completed in Europe, North America, and Australia, among others, and the IEA is actively convening global experts to discuss the topic through its PVPS Task 14 activities.[33] **The consensus of this work is that there are limits to the ability of distribution networks to accommodate variable renewable energy generation given current grid configurations, but that new grid integration strategies and technologies could overcome these limitations.** As Sandia National Laboratory research concludes, "There are no absolute technical limits to PV penetration" (Broderick, 2012).

For policy makers, the **key question then becomes one of cost and regulation – rather than technical feasibility**. Integration costs for high penetrations of PV can vary significantly, depending on the distribution grid system. Policy makers need to determine the extent to which the costs of grid integration should be incurred and also how these costs should be allocated. Some countries have socialized the cost of PV grid integration by recovering it from other ratepayers, whereas other

[33] See, e.g., http://iea-pvps.org/index.php?id=58

countries are exploring whether and how to recover the cost of PV integration from the PV generators themselves. This latter strategy would delay the competitiveness of PV prosumers.

Policy makers also need to remain aware of new technological developments that support grid integration and whether distribution system operators have the technical capability and regulatory authority to deploy these solutions. As will discussed in Section 3.3.2 below, integration solutions can include new grid technologies, new approaches for prosumers to manage their energy consumption and output onsite (rather than exporting electricity to the grid), and new ways for the grid and prosumer PV systems to interact in "smart" ways. Even though these solutions are readily available, utilities may need to be given new permission (or regulatory incentives) to deploy them. This section provides a high-level overview of challenges, as well as a suite of solutions that are available - or are under development.

3.3.1 Technical Limitations to Prosumer Integration

Existing grid infrastructure has technical capacity limits to integrating renewable energy, including distributed PV. High concentrations of PV can cause a number of challenges in distribution systems, particularly in rural areas or, more generally, in areas with weaker grid infrastructure. While a full discussion of these engineering issues is beyond the scope of this report, several of the most prominent potential issues are discussed below:

- Over-voltage conditions caused e.g. by sudden fluctuations in PV power output: Electricity output from distributed solar systems increases the voltage in the network at the point of interconnection. As PV output fluctuates over the course of the day, this causes voltage fluctuations in the distribution lines that deliver power to homes and businesses (Noone et al., 2013). If the distributed PV system is large enough, it can raise the voltage level above the recommended operating limit. Utilities are required to provide power to customers within a specified voltage range. Traditionally, utilities and distribution operators have used a range of solutions, including load tap changers in the substation, as well as line regulators and capacitors to deal with these challenges (SDG&E, 2013). Line regulators are used to adjust the voltage up or down; line capacitors are used to inject reactive power onto distribution lines, increasing voltage. However, as distributed solar has grown, the magnitude and frequency of voltage fluctuations is becoming difficult to manage with the existing electromechanical equipment. Frequent voltage swings caused by distributed solar can also increase wear-and-tear, leading to higher maintenance costs and earlier replacement of certain components.
- Congestion issues caused by excess power export on certain nodes in the system: The growth of solar PV in certain areas has led to congestion on certain feeders, which results when there is insufficient grid capacity to wheel power. Congestion can occur both at the transmission and the distribution levels, and is a driver of network investments for most utilities and TSOs. A common response to congestion is to expand the capacity of the lines (EURELECTRIC, 2013).
- Back-feeding into the circuit and two-way power flows. When solar PV output on distribution lines exceeds the instantaneous load (i.e. demand) on that feeder, it can cause power to back-flow between the low-voltage and medium-voltage lines, or in certain cases, between the medium and the high-voltage lines. In many cases, due to cost reasons, power distribution systems were only

designed to allow power to flow in one direction. In jurisdictions with older grids (e.g. the United States), the power system infrastructure may be ill equipped to deal with two-way power flows, which can lead to unpredictable power flows on the lines and reliability issues.

- Stability issues related to inverter tripping because of grid voltage or frequency fluctuations. This can occur, for instance, when a fast-moving cloud passes over a solar array. The sudden change in voltage can trip the inverters, causing the temporary islanding of the PV system. Inverters are designed to trip at specified voltage levels, partly in order to isolate the generator quickly, and to limit the risks of unplanned islanding. Tripping the PV system offline, however, results in a loss of supply to the network, which can worsen the instability in the network. There can be a cascading effect at low voltage level in areas with high residential PV concentration due to simultaneous tripping of inverters.
- Transmission operator challenges in forecasting net loads and ensuring appropriate available capacity. The rise of distributed solar PV in recent years has reduced the load that needs to be supplied in distribution grids. Forecasting these fluctuations in net load, and in the concomitant supply requirements from elsewhere in the transmission and distribution system, has proved challenging.
- Long-term system planning challenges for both transmission and distribution operators given rapid distributed generation project timelines and unpredictable technology adoption trends. The rise of PV prosumers, combined with the adoption of new technologies like electric vehicles, has made it much more difficult to predict distribution system needs.

Taken together, these issues present challenges to traditional utilities and or other incumbent owners of electric system infrastructure. Many of the challenges are common across regions, although the precise nature of these challenges may vary depending on factors such as local grid configuration, climate, and consumer behaviour.

3.3.2 Solutions to Grid Limitations

A number of solutions are being explored by researchers and deployed by utilities in order to increase the capability of the grid to accommodate a growing number of distributed PV prosumers on the system. In order to clearly identify and categorize the various solutions, they are broken down into three basic categories:

1. Utility-led Solutions
2. Prosumer-led Solutions
3. Interactive Solutions.

These categories were developed through recent work by the PV GRID initiative:[34]

[34] For more information, see : http://www.pvgrid.eu/results-and-publications.html

3.3.2.1 Utility- and System Owner-led Solutions

Several technical solutions are available to deal with a growing share of distributed PV. Some of these are more incremental, such as installing on-load tap changers or booster transformers, while others, such as network reconfiguration are more structural. Which solution is most appropriate in each context will require detailed system analysis and will need to anticipate the evolution of future supply and demand patterns on the network in that area. Distribution system operators will also need to consider which option is most appropriate from a cost, as well as a practical, perspective (Vandenbergh et al., 2013). Text Box III below provides an overview of the new approaches that may be required of distribution system operators.

Text Box III: More Active and Responsive Distribution System Management

Effectively integrating high concentrations of PV into distribution systems will require new distribution system operations models that include advanced monitoring, flexible infrastructure and new cost recovery models. EURELECTRIC has developed a comprehensive framework that describes the evolution of system operators from todays "passive network" to "re-active network management" and finally to "active system management" (EURELECTRIC, 2013):

- Under the current passive network paradigm, system operators largely take a "fit-and-forget" approach to system operations with most system performance parameters established during the system design phase. These systems have limited real-time information and control over their low voltage assets and have limited ability to integrate distributed resources.
- "Re-active networks" are more advanced than passive networks and have limited ability to interact with generator on the distribution system in order to manage sub-optimal conditions. EURELECTRIC characterizes some European system operator territories as re-active networks given their ability to dynamically adjust voltage and curtail some distributed generation assets.
- Active system management, the most advanced stage of system operation, integrates new technologies and strategies including market-based procurement of ancillary services provided by distributed generation resources and advanced system planning efforts. This system operations paradigm would take full advantage of advanced PV system inverter capabilities to support power quality and grid stability requirements. Implementing this new grid management approach will require deployment of both new technologies and development of new market models and regulatory regimes that incentive system operators to change current business practices.

- Grid reinforcement: Reinforcing existing distribution networks is one of the traditional solutions used to ensure continued compliance with voltage and other regulatory requirements. In some cases, it can be less expensive to build a new feeder, or a new substation connecting medium and low voltage grids, rather than reinforcing an existing line.
- Install on-load tap changer: On-load tap changers (OLTC) are used to adjust the lower voltage value of an energized transformer, helping support grid stability during periods of voltage irregularities (Sonvilla et al., 2013). They are most commonly used in HV/MV transformers, but are becoming available for lower voltage levels, and can help significantly in stabilizing overall voltage patterns.
- Advanced voltage control for HV/MW transformers: Using new control methods, it is possible to combine the operation of the OLTC with a more advanced voltage regulation system involving

direct measurement of the real-time status of LV and MV grids. This can improve power system control upstream at higher voltage levels.

- Installing static volt ampere reactive (VAR) control: Introducing a static VAR control mechanisms can help provide immediate reactive power to the system when it is needed. These are typically used at higher voltage levels, and can help regulate voltage, power factor, harmonics, and other aspects essential to grid stability.
- Adopting storage controlled by the distribution grid operator: Storage systems can be installed at various parts of the grid system in order to support the grid in various ways. This may include providing ancillary services, load shifting, and providing backup in case of grid failure.
- Installing a booster transformer: A booster transformer helps provide voltage support along a feeder. They are commonly used on long feeders, such as in rural areas, to keep voltage within the regulated range.
- Network reconfiguration: In certain cases, reconfiguring the architecture of the distribution grid can be used to solve certain problems related to shifting load and supply patterns. Network configurations are generally optimized for a specified range of network conditions – if these conditions change due to the introduction of distributed PV systems, reconfiguration can help maintain voltage within regulated thresholds and alleviate congestion.
- Advanced closed-loop operation: This configuration consists of allowing two different feeders to be jointly operated. It is quite rare at lower voltage levels, but has been used in a limited number of cases in Germany for instance, and in a few urban areas. It typically requires smart grid infrastructure with bi-directional communication as well as remote control capabilities.
- Improved Data and Forecasting: In many parts of the world, both transmission and distribution system operators have limited visibility into the behaviour of generators integrated into the low voltage distribution system. This information gap can include both real-time information about system production and information about total installed PV capacity at the feeder level. Access to this type of information is critical to TSOs as it is integral to their ability to accurately forecast net system loads and appropriately schedule generators and ancillary service providers. Additionally, more granular information about generation assets on the distribution system would allow system operators to produce more refined power forecasts that take into account local phenomenon that affect PV output such as cloud cover. As has been documented by a number of organizations (EPIA, NERC, IEA) electricity system operators have an extensive track record of dealing with demand and supply variability, but effectively dealing with the increased system variability resulting from high prosumer penetration will require new forecasting methods and better information about distribution system conditions and distributed generator production.

Depending on utility regulatory structure, upgrades to existing grid infrastructure such as those described above can be borne by prosumers or socialized across the utility's rate base. Various models for compensating distribution grid operators for infrastructure costs have developed around the world and issues surrounding prosumer/consumer equity, effects of infrastructure upgrade costs on PV parity and upgrade requirements will be a major consideration for policy makers going forward as distributed generation increases (EPIA, 2012; Mateo et al., 2014).

3.3.2.2 Prosumer-led solutions

- Incentivize prosumer storage: The decentralized adoption of onsite storage can contribute to reducing the peaks of PV power output, particularly during the day when loads are quite small. Distributed storage can help reduce local voltage fluctuations as well as congestion problems and back-feeding. Distributed storage is currently expensive. A program is currently underway in Germany to subsidize up to 30% of the cost of distributed PV storage system (KfW, 2013). However, prosumer storage systems could also be adopted on a neighbourhood or community basis, thereby reducing the cost-per-kWh and allowing individual regions to integrate higher volumes of distributed, prosumer-driven PV (GPPEP, 2014).

- Encourage greater self-consumption via price incentives: Reducing power exports through self-consumption will reduce both voltage-related and congestion related grid challenges. Advanced self-consumption strategies can include smart home loads--such as heat pumps—that are designed to operate during periods of highest PV production or battery backup-systems that store excess power instead of injecting it into the grid (EPIA, 2013). Another potential option for increasing storage and self-consumption is coordinated charging of electric vehicles during periods of excess home PV system production (EPIA, 2012). By offering a lower tariff for power exports to the grid during certain parts of the day, for instance, utility regulation could help create an incentive for prosumers to consume more of their power onsite. Alternatively, some jurisdictions have opted to encourage onsite consumption by offering a small premium above the regulated export-oriented feed-in tariff to encourage self-consumption. This approach relies either on automated home energy management systems (e.g. to dispatch electric heating/cooling systems, water pumps, washer/dryer units, etc.) or on individual prosumer response to price signals. If sufficiently high, price-based incentives could begin to increase the engagement of prosumers in managing their own consumption in a way that is more optimal for the grid, deferring or avoiding altogether the need for upgrades and investments.

- Curtail solar PV power output: A more heavy-handed response to distributed PV deployment is to introduce boundary conditions beyond which prosumer output will be curtailed, either for safety reasons or to ensure grid reliability. In Germany's current solar regulations, PV output is limited at 70% of the installed nominal capacity (kWp) for PV systems under 30kW in size. This applies only to PV systems that cannot be remote-controlled by the grid operator. This typically reduces electricity generation by 3.5% to 5%. This kind of capacity based regulation can also be used to encourage prosumers to dimension their PV system sizes based on onsite load, as is done in many U.S. net metering policies (Barnes et al., 2013). However, note that introducing the prospect of uncompensated PV curtailment, even if curtailment events are relatively rare, can have negative impacts on the PV prosumer economics and can increase investor risk.

- PV orientation: In certain markets, some PV system developers have also started to install PV systems with a western orientation, in order to increase output during the later hours of the day when market prices can be higher. While this may seem sub-optimal from the production standpoint as it decreases total kWh output, it has advantageous system benefits, as it helps smooth out the generation profile of solar PV systems over the course of the day, potentially reducing congestion and easing system integration.

- Adoption of advanced or "smart" PV inverters: In many European countries, it is already common to introduce higher standards on solar PV inverters. Advanced inverters can provide a wide range of valuable services to the system:
    - Low-voltage ride through capabilities: This can enable the solar system to remain connected to the grid and produce power under a wider range of voltage conditions. This can help avoid load shedding and help stabilize the grid during critical periods. Current international standards (IEEE 1547) have been deemed to be conservative, as they force generators to trip off-line quickly when system circumstances change. New standards in countries like Germany and the Czech Republic increasingly work in the opposite direction, mandating an increased ability to ride-through low voltage disruptions and allowing inverters to continue functioning under a wider range of operating conditions.
    - Two-way communication functions: "Smart" inverters can interact directly with grid operators, enabling inverter data to be remotely accessed, and programmed to interact more intelligently with the system. This functionality becomes increasingly important as distribution grids reach high levels of PV penetration. Moreover, while many inverters now have these functionalities, they are not always activated.
    - Frequency control: Most new inverters are programmed to provide frequency control via active power control. This can be important in maintaining frequencies within the narrow range required for proper grid functioning.
    - Dynamic reactive support: Smart inverters can provide reactive power to help control and mitigate voltage rises.
    - Dynamic grid support: Smart inverters can also provide direct support to the grid, for instance to prevent disconnection of the system during disturbances, as well as voltage recovery during post-fault conditions.

Many of these inverter functionalities are already part of new inverter designs. New regulations have recently been drafted in California to encourage the adoption of these new standards, while in Germany the industry guidelines proposed by the BDEW have effectively become mandatory as they are now required by many distribution grid operators in order to connect distributed PV systems to the grid (SDG&E, 2013).

3.3.2.3 Interactive Solutions

There is a wide range of solutions that distribution network operators can introduce to help integrate a growing share of prosumers into the network that make use of interactive technologies. Emerging innovations in smart grid devices and in ICT have made it possible to tap into a higher level of interactivity and network intelligence than was possible even a few years ago. This section provides a brief overview of some of these interactive solutions:

- Demand response via local price signals: Local price signals can be provided either by grid operators or by aggregators based on network information and generation/demand forecasts. These price signals can be used to establish thresholds or triggers beyond which specific demand response measures are activated. Adopting this solution requires the integration of a smart meter

interface between the prosumer and the grid operator, as well as an energy management system with customized preferences and system behaviours.

- Demand response via market price signals: Market price signals can also be used in a way similar to local price signals to incentivize certain kinds of behaviours or responses from prosumers. This can include reducing load during peak times, and shifting it earlier or later in the day to off-peak times, based on the wholesale market price. Like the first option, this requires the installation of a smart meter interface. Control can range from full, automatic control via pre-set smart meter configurations to a fully engaged, real-time prosumer control.
- SCADA-based techniques: A SCADA (Supervisory Control and Data Acquisition) system can be adopted at the distribution level by the system operator or energy aggregator in order to improve a number of system interactions. For instance, it could be used to connect various loads in an interactive way to reduce strain on the system, or to remotely control inverter behaviour based on system needs. This could be done to manage a large number of individual loads simultaneously or to control the provision of active and reactive power by PV systems.
- Voltage and VAR control technologies: This includes a wide number of potential technologies, including on-load tap-changers (OLTCs), distribution capacitor banks, voltage regulators, as well as a number of related smart grid technologies such as sensors that require a moderate-to-high level of interaction of between prosumers and the grid system.

3.3.3 The "Smart" Prosumer of the Future

Broadly, all of these interactive and prosumer measures involve a profound shift in the nature of traditional electricity customers, and may eventually become integral to what it is to be a "prosumer". It may not be sufficient simply to produce and consume in a business-as-usual way, irrespective of supply, demand, and grid behaviour, and prosumers themselves may gradually need to become increasingly "smart". "Smart" prosumers refers to those that take an active role in managing both their energy production and consumption – either on their own or within the context of a smarter and more responsive grid infrastructure. Prosumer operating strategies and technology choices can have a substantial effect on total potential grid capacity. Some of these strategies will require coordinated approaches that involve grid operators and other energy market actors while others could be adopted with limited required grid operator involvement. Many of these strategies can be implemented as part of an integrated approach to limiting prosumer grid impacts and increasing utility system distributed generation integration capacity.

The rapid growth of PV prosumers has attracted the attention of a range of stakeholders across the world. Many countries and regions have active ongoing discussions related to this issue that include regulatory authorities, standard-setting organizations, utility system operators, inverter manufacturers and others to proactively consider and address the technical challenges related to prosumer growth. Moreover, in light of the significant changes triggered by the rapid decrease in the cost of PV, current and future prosumers will need to consider the possibility that regulatory frameworks will change over the course of the life of their solar systems. Prosumers may have to adapt to technological changes (e.g. installing new inverters, as required for some systems in Germany), to the introduction of new means of communication between solar PV systems and local (or onsite) loads, as well as to

the real-time behaviour of the distribution grid as a whole. If future regulatory changes occur in an erratic manner, or are too onerous or restrictive, this could impact the financial attractiveness of distributed solar and increase regulatory and political risks for prosumers. It could also have the effect of encouraging prosumers to establish distributed local systems or micro-grids that use advanced control and communication technologies to integrate DERs and coordinate it in real-time with local and regional demand (Pérez-Arriaga et al., 2013). In such a configuration, local management of energy resources could enable prosumers to interact in increasingly network-responsive ways, activating or ramping down a wide range of appliances, heating/cooling units, irrigation pumps, electric vehicle chargers, as well as various storage devices to optimize energy use on a local or regional basis.

That said, many of the solutions that will allow increased distribution system prosumer capacity will require policy makers and legislators to develop and implement new regulatory frameworks that encourage regulated entities to make the operational and infrastructure changes necessary to increase grid prosumer capacity. Deciding how to distribute the costs and benefits of this new grid paradigm will be a major challenge for regulators and policy makers in the years to come.

3.4 SUMMARY OF OPPORTUNITIES AND CHALLENGES

The benefits and challenges of prosumer development are often discussed – but their complexity makes it difficult to discuss them in an integrated manner. This section has presented a broad overview of prosumer tradeoffs, see Figure 16.

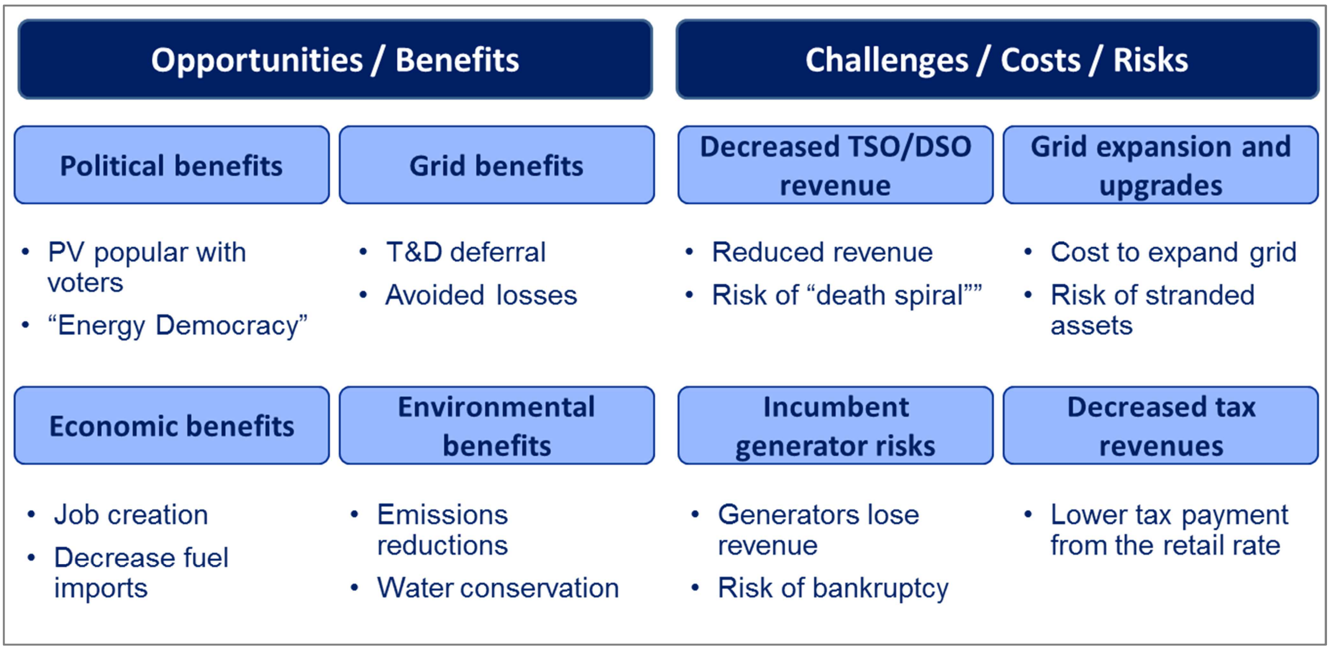


Figure 16: Opportunities and challenges of prosumer uptake

Prosumers can potentially create significant economic, social, and environmental benefits. These include both the benefits generally associated with any renewable energy development, as well as

benefits that accrue specifically because prosumer systems are installed on consumer property (e.g. avoided losses and distribution upgrade deferral). On the other hand, prosumer development also poses financial and technical challenges for incumbent energy industry stakeholders (e.g. revenue erosion) and to the infrastructure of the electrical grid.

Policy makers must evaluate the pros and cons of prosumer development against the challenges created for the existing system. Aside from technical and financial issues, there are also political realities – as prosumers continue to expand, they also grow as a potential political constituency that may have increasing input with regard to how the public interest should be defined. The speed and breadth with which policy makers choose to address prosumer expansion will implicate different technical and regulatory solution sets. The next section provides an overview of the policy options that can be employed to manage prosumer scale-up.

SECTION 4

LAYING OUT PROSUMER POLICY STRATEGIES

4.1 DEVELOPING PROSUMER POLICY STRATEGIES

While policy makers may not have direct control over many of the prosumer drivers described above, they can attempt to guide and govern prosumer development through the use of targeted policy. At present, policy is one of the most important drivers for prosumer development and can provide consumers with a supportive environment to adopt PV.

This can include supporting (or preventing) prosumers through rules to connect to and sell power into the grid. This can also include more structural reforms, such as creating new regulatory frameworks that allow utilities to develop new business models and new grid technology as prosumers scale-up. In order to determine the most appropriate PV prosumer engagement approach, policy makers can adopt a step-by-step approach to assessing their current situation and laying out preferred strategies.

Step 1. Assessing near-term and mid-term drivers.

The drivers described in SECTION 2 are the foundation for prosumer policymaking. Policy makers can assess the magnitude and impact of different drivers on prosumers (i.e. whether the drivers will enable or constrain prosumer development) and how prosumer drivers may interact with other national conditions. These drivers can be assessed both for the present as well as in the near- and mid-term. Mapping prosumer drivers is an imperfect science, but can provide a useful framework for understanding the complex forces acting upon the energy system and to better determine if the conditions required to support prosumer scale-up are in place or are a distant consideration. Figure 17 below shows an illustrative example of how the impact of different drivers can be qualitatively visualized.

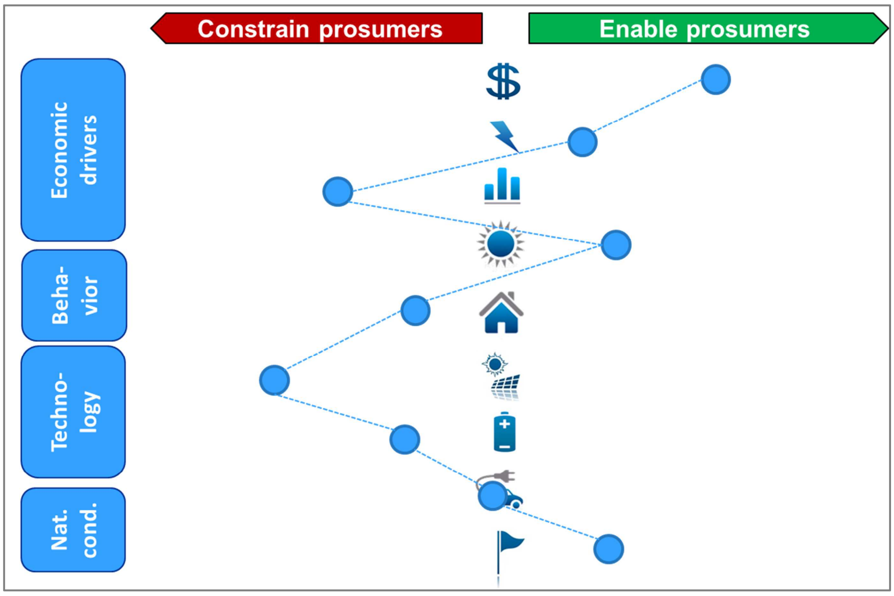


Figure 17: Example of PV prosumer driver assessment
Source: IEA-RETD research

Step 2. Weighing the pros and cons of prosumer development.

As discussed above, prosumers can create significant economic, environmental, and social opportunities, but may also introduce additional costs related to introducing new regulatory, business, and grid models. In order to develop coherent prosumer strategies, policy makers should identify and articulate the benefits and costs created by prosumers. Given the trade-offs, policy makers should then clearly establish whether encouraging the growth of prosumers is a national policy objective. Figure 18 below contains a representative example of the PV prosumer costs and benefits that policy makers may wish to consider.

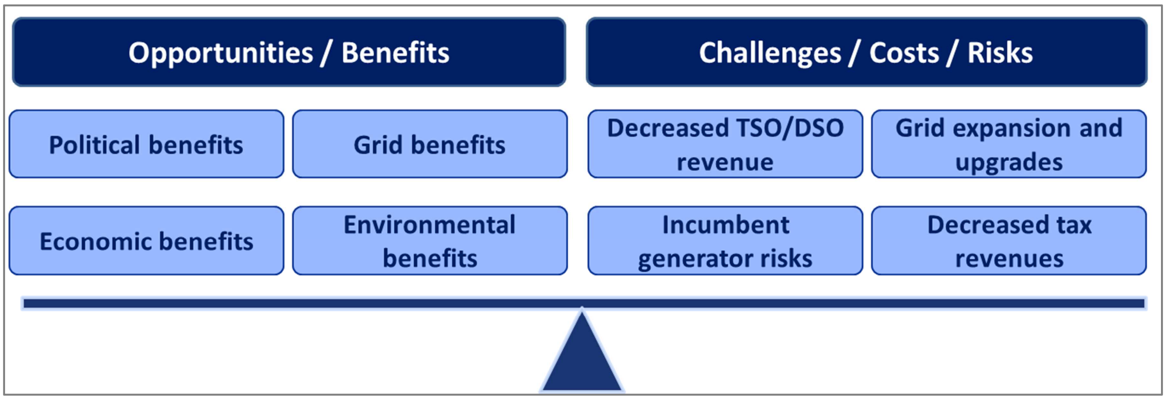


Figure 18: Weighing the benefits and costs of PV prosumer development
Source: IEA-RETD research

Step 3. Developing and implementing a prosumer strategy

Once the drivers are understood (and to the extent they can be understood), and the objectives for engaging with prosumers have been clarified, policy makers can then develop strategies based on these objectives. Figure 19 contains examples of several strategic pathways that policy makers may choose.

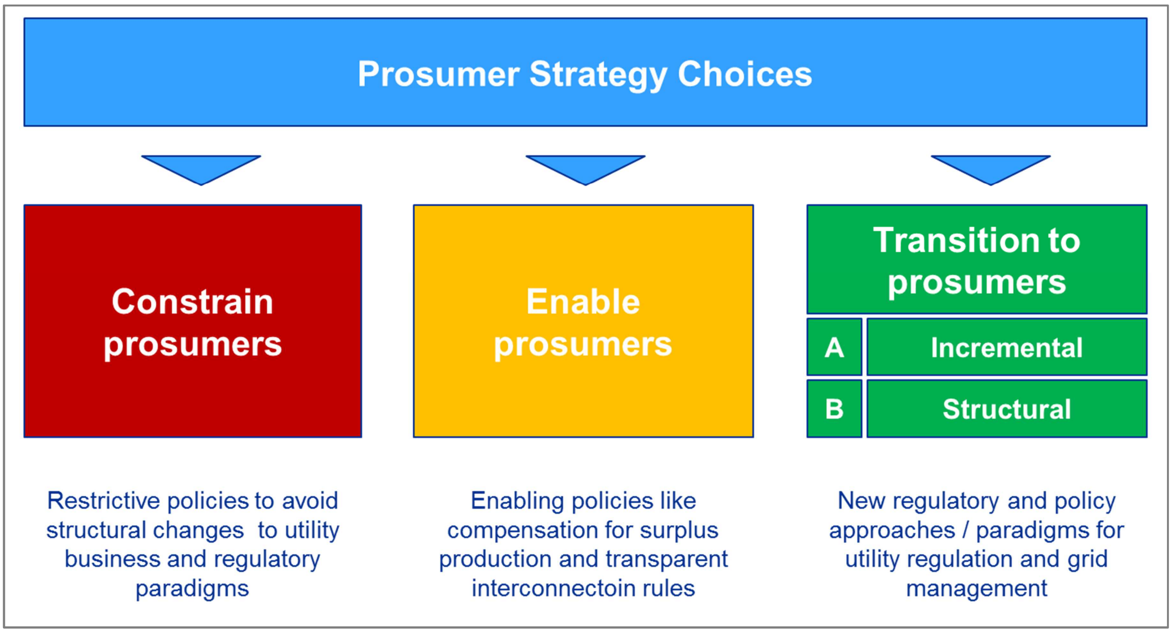


Figure 19: Prosumer policy strategy approaches
Source: IEA-RETD research

Each pathway is accompanied by its own opportunities and risks:

- Some policy makers may act to **constrain prosumer development**. This could include, for example, actively resisting the establishment of policies that enable prosumers, removing or weakening existing enabling policies, or actively penalizing prosumer development (e.g. through the creation of new taxes or fines). This pathway, however, creates the risk that prosumers could emerge anyway at some point in the future in an unanticipated manner which would be difficult to govern. This report does not focus in depth on policies to constrain prosumer development because in most cases constraining policies can be identified as the opposite of the enabling policies discussion in section 4.2**¡Error! No se encuentra el origen de la referencia.**.

- Other policy makers may wish to put policies in place to **enable the introduction of prosumers**. This creates the risk, however, that prosumer scale-up may threaten the economic viability of existing utility systems and infrastructure in ways that existing regulatory paradigms cannot mitigate. Section 4.2 below focuses on the "enable prosumers" strategy and reviews the current generation of policies that support prosumer development (e.g. incentives and interconnection standards).

- A third potential pathway **"transition to prosumers"** is for policy makers to support prosumer scale-up while at the same time introducing legal and regulatory reforms that encourage "prosumer friendly" structural shifts in current business models. This third pathway is consistent with many of the "utility of the future" initiatives currently underway around the world. The risk with this pathway is that the regulatory template for the transition it implicates does not yet exist and will need to be created as markets evolve. Sections 4.3 and 4.4 focus on this strategy, distinguishing between two types of policy approaches:
    - **Incremental approaches** include adjustments to existing policy and regulatory frameworks that attempt to, for example, minimize revenue loss in the utility sector or recover transition costs directly from prosumers. As discussed below, some incremental approaches may serve to constrain prosumers, depending on how they are implemented.
    - **Structural approaches** include, for example, policies that fundamentally alter the structure of the electricity market or utility sector, or that implicate significantly different utility business models.[35] Policy makers faced similar "structural" decisions of similar magnitude when contemplating the restructuring and liberalisation of monopoly electricity markets.

Countries are pursuing different approaches to prosumers and there is evidence of all three strategies (constrain, enable, and transition) internationally. This report does not make recommendations regarding which strategy is most appropriate. **A key finding, however, is that there are not yet strong examples of structural approaches to prosumer transition and no roadmap for structural transition yet exists.**

Following the exploration of policies and transition approaches, SECTION 6 provides a high level framework for describing different countries based on the national conditions and drivers they

[35] Depending on the planning horizons, policy makers may also wish to think through and evaluate structural strategies even at lower PV prosumer penetrations.

experience, the enabling (or constraining) policies they adopt, and the transition approaches that they pursue. This "prosumer scenarios" framework is intended to allow policy makers to readily characterize their own countries or countries they wish to use as benchmarks.

4.2 POLICIES FOR ENABLING PROSUMERS

Enabling policies govern prosumer activity and can include, for example, legal definitions of prosumers, procedures for connecting to the grid, rules governing the treatment of excess electricity, and efforts to reduce soft costs. This section briefly reviews the policies that support PV prosumers in a "non-incentivized" environment. Countries that adopt "prosumer-friendly" policies such as the ones below lay the foundation for the emergence of prosumers. Countries that do not adopt these policies are less likely to see prosumers emerge in the near term – even when compelling economic conditions and high consumer interest are otherwise in place.

4.2.1 Connecting to the Grid

Although some PV prosumers may wish to disconnect fully from the grid, it is expected that the vast majority will prefer to remain connected to the electricity grid in the near term in order to ensure reliability. In other words, most prosumers will want to have the option to draw power from the grid when not producing power from their PV system – or to draw power from both simultaneously. In order to allow this type of flexibility at the lowest cost, PV systems typically need to be interconnected in parallel with the electricity grid. The rules and regulations that govern interconnection can have a significant impact on the economic case for PV prosumers. Policy design issues related to interconnection can include:

- Permission to interconnect. The legal authority to interconnect a PV system is an important threshold issue for prosumers. Residential PV systems are not allowed to be interconnected to the grid in some countries. To enable prosumers, policy makers can grant PV owners the legal right to connect to the grid. In some countries, such as Germany, PV prosumers have been *guaranteed* the right to interconnection.
- Interconnection rules. Defining interconnection procedures can help support the development of prosumers. In some counties, there are no specific rules for residential PV interconnection and so PV systems are subjected to in-depth evaluations on a case-by-case basis. In contrast, countries that support prosumers have typically developed standard interconnection rules that are streamlined to allow small residential systems to be quickly reviewed and connected to the grid if they meet certain technical criteria.
- Interconnection application and review fees. Minimizing the fees to apply for interconnection and to review interconnection applications can support the development of prosumers. In some countries, utilities have charged high interconnection application and review fees which have served as a barrier to residential prosumers. Other countries have capped interconnection application and review fees at an amount that is reasonable for both the prosumer and the administrator – or have eliminated the fees entirely.

- Interconnection cost recovery. Interconnection costs can include both the costs to physically connect the PV system to the grid, as well as the cost to upgrade the grid to accommodate the extra PV generation injected into the grid. Some countries require that PV generators be responsible for all of these costs. Countries that have enabled prosumers have frequently allocated at least some of these costs (e.g. the cost of grid upgrades) to other parties. Since grid upgrades can benefit other customers, for example, some countries allocate the cost of grid upgrades to all ratepayers.

- Interconnection transparency. As discussed in Section 3.3, there are currently limitations to the amount of PV that most distribution grids can absorb without experiencing reliability challenges. Policy makers can support prosumer decision making by providing greater transparency as to where PV can be most readily interconnected as PV markets scale up, such as distribution system maps that reflect levels of PV penetration. Figure 20 below, for example, contains a map of Hawaii's locational value map for PV that shows the percentage of daytime minimum load on different circuits supplied by distributed generation.

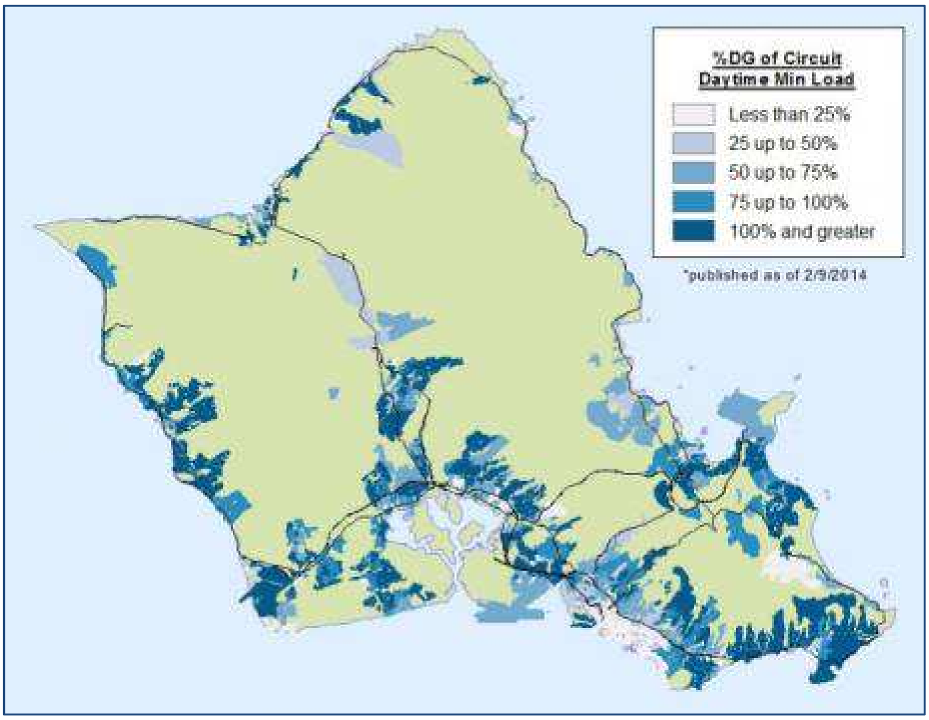


Figure 20: Hawaii's locational value map for PV
Source: Hawaiian Electric Company, Inc. (2014). Accessed at:
http://www.heco.com/portal/site/heco/lvmsearch

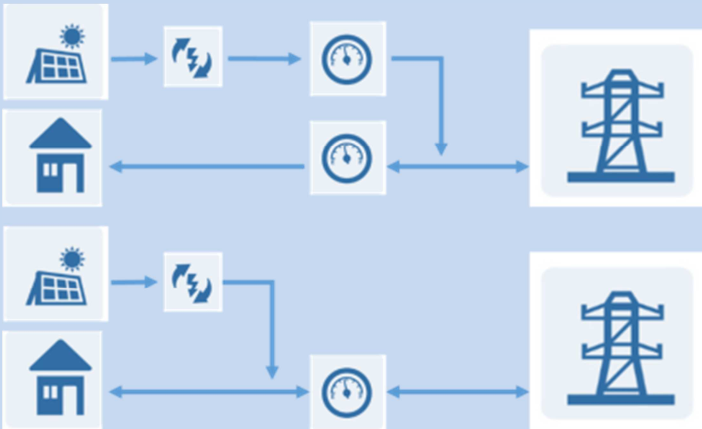
4.2.2 Feeding into the Grid

Even if PV prosumers can interconnect and operate their PV system in parallel with the grid, they may not legally be allowed to feed power back to the grid that they do not consume. This was the case in

Colombia, for example, where onsite PV generators are allowed to connect to the grid, but could not feed excess power back into the grid.[36] In other countries, onsite generators are guaranteed the right to feed electricity into the grid. As discussed in Section 2.2.3, residential PV systems sized to meet a significant proportion of annual onsite load will face the issue of low self-consumption ratios in most countries. The ability to feed power into the grid is therefore a key indicator for whether a policy environment is structured to support residential PV prosumers or not. A related issue is whether the PV generators are configured to feed only some or all of its power into the grid. This issue is discussed in greater detail in Text Box IV.

Text Box IV. Grid connection configurations

When connecting to the grid, onsite PV generators can either be connected "behind" or "in front of" the meter (Figure 20). Systems that are connected in front of the meter bypass onsite load entirely and feed 100% of the power into the grid. Systems that are connected behind the meter, by contrast, are configured to first supply power to the host site and will only feed power back into the grid if system output exceeds onsite load. [37] Behind the meter configurations have been traditionally associated with net metering policies whereas in front of the meter configurations have been traditionally associated with feed-in tariff policies.



From the prosumer perspective, the primary difference is the level of compensation that different configurations will entail and the economic case they create, as discussed in Section 4.2.3 below. Some analysts also assert that

[36] In December 2013, Law 278 was passed and would have allowed other types of onsite generators to feed power back into the grid. The Law was not signed by the President. However, a new version of the bill was passed and signed in May 2014 as Act 1715 of 2014. Regulations for the law are still under development. The Act can be found online at:

http://wsp.presidencia.gov.co/Normativa/Leyes/Documents/LEY%201715%20DEL%2013%20DE%20MAYO%20DE%202014.pdf

[37] The distinctions between net metering and feed-in tariffs policies have increasingly blurred over time as the policies have diffused internationally. In Grenada, for example, the prosumers that take advantage of the net billing policy actually feed 100% of their power into the grid – which is more consistent with feed-in tariff policies. In Australia, by contrast, some state-level feed-in tariffs require that generators be configured to serve onsite load – which is generally more consistent with net metering policies (e.g., Tasmanian Government, 2013). Given policy evolutions such as these, this report generally attempts to avoid using terms such as "net metering" or "feed-in tariffs" to broadly describe policy types and instead attempts to differentiate according to specific design issues.

behind the meter configurations are psychologically important for prosumers since they enable more direct control of their PV electricity and they create a direct link between energy consumption and production and therefore create behavioural incentives for energy conservation. There is little empirical evidence to support these claims at present.

From the utility perspective, behind the meter systems decrease the volume of electricity that is sold in a manner similar to energy efficiency. Behind the meter systems can therefore decrease the revenue earned by incumbent generation, transmission, and distribution owners under traditional utility business and regulatory models. Systems connected in front of the meter, by contrast, do not reduce utility sales since consumers sell 100% of their PV output. This configuration effectively turns residential PV generators into wholesale power producers that are in competition with existing power plants – but it does not reduce the revenue earned by T&D operators to pass electricity through the system. These revenue issues are discussed in greater detail in Section 3.2.1.

There is debate as to whether consumers that sell 100% of their power into the grid can technically be considered "prosumers" or whether they should instead be considered distributed power producers. This study takes both types of connection configurations into account, but focuses primarily on behind-the-meter configurations.

4.2.3 Compensation for Electricity Fed into the Grid

If electricity is allowed to be fed into the grid, the two major policy design considerations are the amount that will be compensated and the level at which it is compensated.

4.2.3.1 Amount that will be compensated

Given the mismatch between PV output and onsite load discussed in Section 2.2.3, **policies that allow prosumers to be compensated for all of the power that they feed into the grid provide onsite generators with the greatest investment security and flexibility**. Historically, European feed-in tariffs have allowed generators to feed 100% of their output into the grid with the guarantee that it would be purchased.[38] Net metering laws, such as those used across the United States, enable generators to export power that is not consumed onsite – but the total amount that is compensated is typically limited by the amount of onsite consumption. In some states, for example, excess generation can be applied to consumption at any point during the year but no credit is given for output above and beyond annual consumption. In other states, excess generation can only be applied within the month it was generated. Finally, some states allow excess generation to be carried forward indefinitely (IREC, 2009). In Denmark, the current version of net metering only allows excess from one hour to be applied to the next hour – which is one of the most limited net metering carryover provisions in the world. From the prosumer standpoint, limiting the amount that will be compensated will generally incentivize prosumers to decrease the size of their PV systems in order to optimize economic performance. Text Box V below provides a discussion of flexible net metering policy development in the Northwest Territories of Canada.

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[38] More recently, however, some European countries have begun to introduce alternative rules for export. Germany's 2012 feed-in tariff law, for example, allows PV generators between 10 kW and 1000 kW in capacity to sell only 90% of their power at the feed-in tariff rate and requires that the rest be either consumed onsite or sold into the wholesale market.

4.2.3.2 Compensation level

PV prosumers can be compensated for their excess output above, below, or at the same retail rate – or some hybrid of these. The precise compensation levels will depend on the regulations in place. Examples of the approach taken in different jurisdictions are presented in Table 3 below. **Prosumers should be indifferent to whether the level of compensation is at, below, or equal to the retail rate as long as the compensation level is sufficient to meet their economic performance criteria**. This report considers compensation either at or below the retail rate as "non-incentivized," although this does not mean that prosumers will be able to economically install PV without other enabling policies as discussed throughout this section.

Table 3: Different approaches regarding compensation levels

Compensation level	Jurisdiction/Policy
Above the retail rate	• Ontario (CAN) FIT. The FIT in Canada is currently set at CAD ~$0.33-$0.40/kWh for 20-year contracts. The average residential retail rate in Ontario is approximately CAD 0.14/kWh • Japan FIT (current). The FIT in Japan for systems below 10 kW is currently ¥36.0 (US$0.35). The average residential rate in Japan is under $0.30/kWh.
At the retail rate	• Tasmania (AUS) FIT • Net metering policies in many North American states and provinces
Below the retail rate	• Germany FIT. The German FIT rate for residential generators is currently €0.131/kWh. The average retail electricity rate in Germany is currently ~€0.29/kWh.

Text Box V. Solar Prosumers Take Root in the Far North

The Northwest Territories (NWT), one of three territories in northern Canada, procures most of its power from hydroelectric projects and diesel generators. The current population of the Territory is approximately 42,000. In some of the most remote communities, the fully bundled cost of electrical service is over CAD $2.00/kWh. In order to mitigate these high energy costs, the Government of the Northwest Territories currently subsidizes the cost of electricity by up to CAD $0.44/kWh on the first 1000kWh of demand during the winter months, and on the first 600kWh during the summer months (Government of the Northwest Territories (GNWT), 2013).[39] This subsidy has amounted to CAD $34 Million for the Territorial government over four years. This creates a considerable opportunity for both the government and for individual residences and businesses to save money from onsite, prosumer-driven PV development.

The GNWT introduced a Solar Energy Strategy in 2012 to promote the use of solar energy technologies (NWT DENR, 2012). Partly in response, in January 2014 the Public Utilities Board (PUB) of the NWT issued a net metering decision in order to enable residents to install onsite solar PV systems and export their surplus to the network (PUB NWT 2014). The decision targets systems up to 5kW in size, and includes a capacity limit of 20% solar PV on any individual grid system. The Board notes in its decision, however, that both the individual system

[39] The *Energy Action Plan* of the Government of the Northwest Territories (GNWT) has identified five main support measures for electricity: (i) bulk fuel transport subsidy ($2.4M in 2012-13); (ii) electricity for social housing (7.8M in 2012-13); (iii) Territorial power subsidy program ($5.2M in 2012-13); (iv) electricity rate zone subsidy ($34M for 2012-2016); and (v) the government facility electricity premium ($5.2M in 2012-13).

threshold as well as the capacity limit will be flexibly enforced, allowing individual systems and regions to surpass the thresholds on a case-by-case basis.

The net metering decision currently allows excess generation to be carried forward up to the end of March every year, at which point any excess credits are retired. This is designed to help encourage PV system owners to dimension their systems based on onsite needs, and to mitigate the negative impacts to local utility operators.

Despite the significantly higher installed costs and the limited availability of solar PV suppliers in the NWT, the establishment of the new five year Strategy and net metering decision could attract significant prosumers and could drive PV development in the years ahead. If successful, utilities in the NWT could gradually evolve into a series of hybridized micro grids using a combination of solar, hydroelectric, and diesel power and could provide an interesting example for other regions around the world, particularly in countries seeking to boost rural electrification using renewable energy technologies.

4.2.3.3 Certainty of compensation level

Revenue certainty is an important component of renewable energy investment decisions for both commercial investors and for homeowners (DBCCA, 2009). **Prosumers are more likely to adopt PV systems if the system can generate a stable and predictable stream of benefits in the future.** Different compensation models can provide prosumers with different levels of certainty. Several examples of these are summarized below in order of decreasing certainty:

- **Fixed contracts.** Prosumers are guaranteed a fixed price payment for all of their production (or just their excess production) under contract. This model provides prosumers with the greatest amount of certainty. Most FITs include a contract for a fixed price. Historically, this contract was above the retail price, whereas PV prosumers can increasingly develop PV with contracted prices set at below the retail price.
- **Retail compensation.** Prosumers are compensated at the retail rate (or at a value pegged to the retail rate).[40] Although retail rates are not as volatile as wholesale spot market prices or fossil fuel commodity prices, they can still be subject to change. The retail rate itself can adjust upwards or downwards over time, and the rate structure can also be subject to change.[41] Policies governing retail compensation (e.g. net metering) can also be modified or removed by policy makers. Since the prosumer in some cases is not compensated under contract, the savings or revenue generated from their PV system may fluctuate based on these and other factors.
- **Wholesale compensation.** Prosumers can also be compensated for their excess power at a rate based on wholesale prices. Depending on how the wholesale price benchmark is defined, prosumers could face significant price volatility. Wholesale spot market prices can swing significantly and the market could produce significant upside for PV prosumers during price spikes. As discussed earlier, however, renewable energy could also suppress wholesale market prices in a way that could negatively impact PV system economics – but that is difficult to predict

[40] Time-based rates are discussed in Section 2.2.2.3.

[41] For example, if retail rate structures are based on different levels of consumption, a prosumer that significantly reduces or adds to onsite load may move into a different class of retail electricity pricing – which could negatively or positively impact system economics.

at least at lower PV penetrations. The uncertainties related to the potential impact of renewable energy scale-up in wholesale market prices are reflected in a recent analysis of Italy and Spain, which found that the point at which PV will become competitive at the wholesale level could vary by up to 20 years (e.g. 2017 to 2040 in Italy, and 2021 to 2040+ in Spain) (Lettner & Auer, 2012).

4.2.4 Efforts to Reduce Soft Costs

As discussed in Section 2.2.1, soft costs include non-hardware costs of PV. These costs can include:

- Labour costs to install the hardware and electrical components of the PV system
- Fees and costs associated with PV system permitting, interconnection, and inspection (e.g. time and fees to prepare and submit paperwork)
- Customer acquisition costs
- Installer overhead and profit on labour and hardware

Prior to 2010, PV modules were the single largest cost component, accounting for more than 50% of system cost, whereas soft costs accounted for 20-30% (BNEF, 2012). Soft costs declines have not kept pace with the dramatic decreases in module and inverter prices in recent years, however. As a result, soft costs are now higher than the hardware costs in some countries. The PV LEGAL project in Europe, for example, has identified significant differences across EU countries in terms of both the magnitude of soft costs, and the amount of time that it takes to develop a PV project. It takes 227 hours to comply with legal and administrative procedures for residential PV development in Bulgaria, for example, but only 4 hours in the UK and Germany (Garbe et al., 2012). In the United States, soft costs for residential systems now account for over 50% of total system costs and were estimated to be $3.34/watt in 2011 – compared to $0.62/watt in Germany (Seel et al., 2013). Some of the discrepancy between the United States and Germany can be attributed to the fact that the German market is much larger and has naturally become more streamlined and efficient. A large part of the discrepancy, however, is attributable to lengthier and more expensive legal and administrative procedures in the United States.

Recognizing the significance of soft costs, some national governments are making a concerted effort to lower costs through targeted programs – which in turn reduce the installed cost of PV and improve PV competitiveness. These include efforts to remove or reduce cumbersome bureaucratic procedures, reduce or eliminate fees and costs, and support PV marketing efforts in order to reduce installer acquisition costs. In some countries, these programs are undertaken at the national level. However, soft costs may ultimately derive from requirements imposed by regional or local governments. Under such cases, subnational governments must lead soft cost reduction efforts or national governments must create incentives for them to do so. In the United States, the Department of Energy's (DOE) SunShot Initiative[42] is a multi-year nationwide program to reduce the cost of PV, which includes significant outreach to municipal government to reduce soft costs (DOE, 2010).

[42] *See* http://www1.eere.energy.gov/solar/sunshot/index.html

4.3 INCREMENTAL APPROACHES FOR PROSUMER TRANSITION

As PV becomes more competitive and the need for financial incentives decreases, the policy cost burden will decrease – but so too will the ability to use incentive availability as a control mechanism. This could mean that markets may experience PV scale-up unexpectedly as PV prices cross certain thresholds. In other words, PV policies that were designed to be ancillary support to "cornerstone" incentive programs may become sufficient to support PV scale-up on their own. Policy makers in many countries have engineered their enabling policies with this possibility in mind – i.e. with the thought that PV would one day no longer need incentives. The key question that emerges from increasing PV competitiveness, however, is how the policy environment might need to change once the scale-up inflection point is reached.

Even without incentives, policy makers can still exercise a number of strategies (beyond incentive level adjustments) to control or guide the emergence of PV prosumers in a non-incentivised environment. This section focuses specifically on "transition" policies that take the next steps after prosumers have been enabled and have begun to scale up. These strategies are grouped into "incremental" approaches that make adjustments to existing regulatory structures and "structural" approaches that implicate broader change (4.4). In both cases, these transition strategies respond to the prosumer challenges defined in Section 3.2. As previously discussed, there does not appear to be a well-articulated template for prosumer structural transitions in existence. As a result, the discussion of structural strategies is limited.

A variety of incremental or "evolutionary" approaches – to be distinguished from more far-reaching structural or "revolutionary" or structural approaches – could be pursued within existing market and regulatory paradigms to address some of the financial challenges associated with prosumer growth. These approaches typically are specific to the challenges associated with a particular entity (i.e., infrastructure providers, ratepayers, or taxing authorities), though some approaches address multiple challenges.

In some cases, incremental approaches to prosumer policy making can effectively "claw back" the economic case for PV and make it more difficult for PV prosumers to compete. Incremental approaches also often involve other kinds of trade-offs, either between the competing interests of different stakeholders (e.g., between utilities and ratepayers) or between competing policy or social objectives.

4.3.1 Modifying Prosumer Enabling Policies

The economic challenges discussed in Section 3.2.1 occur when prosumers install PV behind-the-meter to offset self-consumption and are most severe when 100% of the PV production can offset onsite load, regardless of its output profile relative to the customer's consumption profile (e.g. with full net metering or storage). Many of the financial challenges described above can therefore be mitigated by limiting access to enabling policies (e.g., through limits on eligibility or program participation caps) or by limiting the amount of excess generation that can be compensated (e.g.

limiting the ability of customers to roll-over credits from one billing period to the next under net metering). These kinds of modifications serve to limit the exposure of the utility (or other regulated infrastructure service provider) to revenue erosion, and the potential for rate increases and cost-shifting that would otherwise be required in order to ensure recovery of fixed costs. At the same time, these modifications can restrict or halt PV development and may be politically untenable.

Alternatively, PV compensation may occur via **buy-all/sell-all mechanisms**, instead of through net metering. These arrangements come in many varieties and by many names, including FITs, value-of-solar tariffs, or two-way tariffs. Hybrid mechanisms are also possible, where the customer offsets its consumption with contemporaneous PV generation, but is compensated at tariffed rate for PV generation exported to the grid. Such approaches substantially reduce the utility's revenue erosion relative to full net metering, and if payments for PV generation are passed-through in full, then the utility may be made whole without any direct impact on its profitability. These trade-offs are currently being considered in both Europe and the United States (Text Box VI). Whether or not the rate impacts of prosumers are mitigated, however, depends entirely on how the price paid for PV generation compares to retail electricity rates.

Text Box VI. Onsite consumption in the United States and Europe

Europe pioneered the use of feed-in tariffs for PV when municipal utilities in Germany (e.g. Hammelburg and Aachen) first offered long-term premium contracts in the 1990s (Solarenergie-Förderverein, 1994). Under the German PV FIT model, residential consumers continued to purchase 100% of their electricity needs from the grid while selling 100% of their output under the FIT contract. This model became the dominant form of PV procurement in Europe (and beyond) for the next twenty years. As PV prices have continued to decline and as the penetration of PV in the distribution grids of some regions has dramatically expanded, policy makers and the PV industry have increasingly begun to encourage onsite consumption (EPIA, 2013). These include net metering polices in Belgium, Denmark, and the Netherlands, and policies to encourage self-consumption in Italy and Germany.[43] The shift to encourage onsite consumption has been in part driven by concerns about grid integration costs of excess PV power fed into the grid.

In the United States, states such as Minnesota and Massachusetts first introduced net metering policies to encourage onsite consumption in the 1980s (Stoutenborough & Beverlin, 2008). Net metering policies are now in place in 43 of 50 states. The majority of US PV systems are net metered and the rapid expansion of the US market in the past several years has raised questions in major solar markets as to whether net metering is the optimal policy framework for supporting PV at higher penetrations. In particular, issues of revenue erosion for transmission and distribution operators have been raised as a concern in several recent high-profile regulatory proceedings. So-called "dual rate" polices under which consumers purchase 100% of their power from the grid and sell 100% of their PV output have been adopted in some US jurisdictions and are currently under consideration in others as a strategy for reducing utility revenue erosion under net metering. In practice, these

[43] The German FIT included an incentive for self-consumption from 2009 to 2012. Under this regulation, owners of solar PV projects up to 30 kW could directly consume the electricity they generate and receive a reduced feed-in tariff. Either the operator of the installation or a third party in the immediate vicinity of the plant had to consume the power. The revised 2012 FIT law allows only 90% of PV output to be sold to the grid. The remainder must be consumed onsite or sold into the wholesale market. This effectively creates an incentive for self-consumption.

policies would be similar to European FITs in terms of how electricity is transacted. There continues to be significant debate in the United States, however, whether dual-rate policies are politically acceptable (e.g. Colthrope, 2014).

These recent developments in Europe and the United States indicate that additional dialogue on these issues could be fruitful given recent interest on each side of the Atlantic in policy models that have been pioneered on the other side.

In general, changes to prosumer compensation mechanisms are a zero-sum game: any changes that reduce the financial impacts on any of the three players (utilities, ratepayers or prosumers) will have a negative impact on at least one of the others. In addition, although these kinds of policies would not typically be implemented for the purpose of benefitting tax authorities, those entities may gain if any of the above mechanisms results in an increase in taxable transactions (e.g., increased retail electricity sales or payments for exported generation).

4.3.2 Retail Rate Design

Where prosumers are compensated for PV production by offsetting their electricity consumption, the value of that reduced consumption is dependent upon the underlying retail electricity rate structure. As noted in Section 2.2.2.2, retail rate designs that rely largely upon volumetric charges provide a relatively high value to the prosumer, but correspondingly leave the utility susceptible to revenue erosion and other ratepayers susceptible to potential rate increases and cost-shifting. Alternative rate designs that rely upon larger fixed customer charges or demand-based charges will directly mitigate those impacts, simultaneously eroding prosumer economics. Movement towards these kinds of rate designs would also erode the customer's financial incentive for energy efficiency, and for that reason, they are sometimes looked upon unfavourably. Alternatively, utilities may institute standby tariffs: rates specific to customers with onsite generation that impose charges on the customer to recover costs associated with providing back-up and supplementary power. Standby rates would yield the same kinds of impacts on utilities, ratepayers, and prosumers as would movement to retail rates with higher customer charges or demand charges.[44]

As discussed in Section 2.2.2.3, retail rate designs may also vary in terms of the temporal structure of the volumetric charges. Rather than a flat volumetric rate, retail electricity tariffs may incorporate time-varying pricing, such as time-of-use (TOU) rates or hourly real-time pricing. Prosumers taking service under such a rate would therefore be compensated for their electricity production at a rate that better reflects its value to the system. In principle, such rate designs are intended to reduce cross-subsidies among rate classes. In practice, however, time-based pricing may exacerbate utility revenue erosion caused by prosumers, given the coincidence between PV generation and peak pricing periods. Thus, time-varying pricing may not be an effective policy in the short run for mitigating the financial challenges imposed by prosumers. Over the longer-term, however, rising

[44] Customer charges refer to standard fixed charges that utilities may charge a customer in order to maintain an account – i.e. a charge that must be paid even if no kilowatt-hours are consumed. Demand charges refer to charges that are assessed based on the peak onsite demand (i.e. $/kilowatt) that a customer experiences during a month. These are separate from the $/kWh charge.

renewable penetration levels will cause peak pricing periods to shift to times that are less-coincident with PV production, at which point time-varying retail electricity pricing for prosumers may serve to reduce revenue erosion by regulated utilities.

4.3.3 Ratemaking

Retail rate design refers specifically to how the retail rate that customers pay is structured (flat, inclining, etc.). Ratemaking, by contrast, refers to the broader process used to determine how utilities are allowed to recover their costs. This includes aspects such as whether the utility is allowed to achieve financial break-even, or obtain a return on investment, and if the latter, how that return on investment can be earned (i.e. via new capital investments, on which a guaranteed rate of return is granted, or via achieving certain performance targets such as reductions in load growth, or in utility overhead costs). More specifically, various ratemaking reforms have been instituted to mute the impact of energy efficiency on the profitability of regulated utilities – many of these could be directly applied in a prosumer context as well.

Decoupling is one such option. Many variants of decoupling have been instituted, but the underlying concept is to sever the relationship between the volume of retail sales and the utility's earnings and profit, thereby eliminating the utility's financial disincentive towards energy efficiency (or, in this case, prosumers). The intent of a lost revenue adjustment mechanism (LRAM) is similar, but it functions instead by effectively reimbursing the utility for revenues lost through energy efficiency program savings. Depending upon their design, these kinds of mechanisms can largely eliminate any erosion of utility profitability caused by energy efficiency or PV prosumers. These mechanisms are not without their criticisms, however; for example, consumer advocates often fear that decoupling shifts risks from utilities to ratepayers, and mutes the utility's incentive for cost control.

Somewhat bolder ratemaking reforms have also been considered in relationship to energy efficiency, and could potentially apply to PV prosumers. Different kinds of shareholder incentive mechanisms have been tested, whereby utilities are given the opportunity to earn profits on investments in customer energy efficiency. Similarly, performance-based ratemaking (PBR) refers to a fairly fundamental shift in ratemaking principles, where utilities' profits and earnings are tied to achievement of specific performance benchmarks, which might, in theory, include benchmarks related to the facilitation of PV prosumers. Shareholder incentive mechanisms and PBR go one step further than decoupling and LRAM, by not simply eliminating the financial disincentive of utilities towards energy efficiency or prosumers, but by providing a positive incentive (i.e., a profit opportunity). These additional profits, however, are funded by ratepayers, and thus these mechanisms entail a basic trade-off between the financial interests of utility shareholders and ratepayers.

4.3.4 Market Reforms

The challenges created by wholesale market price reductions from renewable generation are most acute in "energy-only" markets, where generators are wholly or primarily dependent upon revenue from energy market sales in order to recover fixed investment costs. Changes to wholesale electricity markets may be instituted to mitigate those impacts and ensure sufficient long-term investments needed for reliability, by creating other revenue models that are compatible with high penetrations of

variable generation. One option, currently employed in several markets, is a forward capacity market that provides a separate revenue stream for generators that provide dependable capacity. Other reforms could be considered to create markets specifically for the kinds of flexible, fast-ramping generation that is needed specifically for integrating variable renewables. To be sure, such reforms may or may not address the challenges faced by all incumbent generation (e.g., baseload generators). Depending on design, this could keep inflexible capacity on the grid, prolonging price depression and undermining the value of PV. In any case, it is likely that such reforms will impact the business case for prosumers as they will influence market prices.

4.3.5 Tax Reforms

Tax reforms can either serve to enable or to constrain prosumers. For instance, many jurisdictions exempt certain solar PV components from value added tax (VAT) in order to make it more attractive for homeowners and businesses to invest in solar systems. Others have introduced a wide range of tax incentives such as accelerated depreciation, or investment tax credits to support the development of the sector. These kinds of tax policies can also help support the rise of prosumers by making the distributed supply of electricity more economically attractive.

However, a number of other jurisdictions are moving in the other direction, or even in both directions at the same time, encouraging solar PV development through net metering or FIT policies while simultaneously attempting to increase taxes on self-consumed power (e.g. Germany and Arizona).

Where taxing authorities are dependent on tax revenues from retail electricity sales or from FITs that are being phased out/degressed, they may seek to shift tax collection to other sources of income. As highlighted above, some jurisdictions have considered (or implemented) taxes on renewable generators. In Spain, there has been a recent proposal to levy a tax on PV prosumers on a €/kWh basis – even for the power consumed onsite. This policy discussion is summarized in Text Box VII below. As discussed in the case studies in SECTION 6, Germany also is also considering levying a surcharge on self-consumed electricity in order recover the costs of its renewable energy law[45].

Increasing the taxes on self-consumed power, or reforming the tax system in other ways that serve to constrain the growth of prosumers, could significantly undermine the economics of prosumers, and make it harder to obtain financing for self-consumption. (Note that these types of taxation schemes are distinct from – but related to - the standby tariffs and fixed charges discussed in Section 4.3.2, and both mechanisms represent an attempt to shift or recover costs within a quickly evolving economic and regulatory landscape).

Ultimately, policymakers need to decide whether the tax reforms they introduce serve to constrain or to enable prosumers. However, this simple binary approach may be too simplistic in certain cases: it could be argued that some degree of tax reform will be necessary at some stage in order to accommodate a wider shift toward prosumers. Indeed, with declining electricity sales and the potential growth in fixed system costs, certain tax reforms could be seen as necessary to manage the transition toward an increasingly decentralized and interactive electricity system. As such a transition

[45] At time of publishing of this report the decision was still outstanding.

takes place in different jurisdictions around the world, tax policy may need to be adjusted simply to adapt to the emergence of new business models and to the rapid changes taking place across the industry.

This notwithstanding, policymakers should be mindful of potential negative consequences or even prosumer backlash, as disproportionately high taxation, for instance, could have the result of accelerating grid defection – thus creating more challenges in the process.

Text Box VII: Spain considers taxes to slow prosumers

In recent years, the Government of Spain has introduced a host of measures to restrict or scale-back renewable energy development. Most of these measures, however, have been aimed primarily at larger renewable energy projects, particularly large solar PV and CSP projects. This has begun to change within the last year, as Spain has sought to restrict the development of small residential and commercial PV projects as well.

Although there is no net metering framework in Spain and it is expressly forbidden to compensate prosumers for excess generation, individual residences and businesses are legally allowed to engage in "instantaneous" self-consumption ("autoconsumo instantáneo"). This involves consuming one's own solar or wind power behind the meter rather than importing it from the grid. The growing interest in self-consumption in Spain stems from a wide range of factors:

1. The continued rise of retail electricity prices, as the country seeks to reduce its electricity system deficit;
2. The rapidly decreasing costs of solar PV, which have helped bring PV generation costs below retail prices across the country (i.e. "socket parity");
3. The fact that self-consumed electricity is not subject to value-added tax (at 21%); and
4. Recent government policy measures, including the suspension of feed-in tariffs in early 2012, that have all-but-closed other avenues for solar PV project development.

In response to these changes, a number of solar promoters in Spain have begun to develop new products tailored specifically to residential and commercial prosumers. In the absence of net metering, feed-in tariffs, or other forms of incentive, the economic case for these emerging prosumers is based primarily on the savings generated from reducing their power bills (Viúdez, 2013b).

As a result of shrinking revenues and reduced tax receipts, the government in Madrid feared that the rapid rise of prosumers could strand the high costs of the electricity system with shrinking per-kWh sales. In an attempt to avert this outcome, the government contemplated a levy on the share of electricity that is self-consumed onsite. This idea was widely denounced as a "tax on the sun" by renewable energy advocates; many also argued that increasing the share of solar PV on the distribution system has the same load-reducing effects as energy efficiency, which remains a top priority of European energy policy. On this basis, the solar industry argued that it was discriminatory to single out self-consumed solar PV for a special tax (Viúdez, 2013b). In contrast, the leading electric utility industry association in the country, UNESA, took a supportive stance, praising the government for closing what it called a "covert tax haven".

The future of prosumers and renewable energy in general in Spain remains uncertain: A regulation on self-consumption as demanded by Royal Decree 1699/2011 still has not been defined; there are several law suits against the government pending at the European level; and although a new Royal Decree regulating renewable energy production was finally approved by the Parliament (RD 413/2014 from 6 June 2014), it is likely that it will be appealed by the renewable sector.

4.3.6 Summary of Incremental Approaches

Table 4 summarizes the incremental approaches discussed in this section. The first column describes the approach, and the second and third columns summarize the impacts that the approach would have on PV prosumer competitiveness. Some approaches related to rate and decoupling can be implemented without negatively impacting PV prosumers. As can be seen in the table, however, some of the incremental transition approaches serve to decrease PV competitiveness.

Table 4: Incremental approaches for mitigating prosumer financial impacts

Incremental strategy approach	Constrain prosumers	Enable prosumers
Prosumer compensation mechanisms	• Restrictions on net metering or onsite consumption • Restrictive roll-over policies for excess generation (i.e. how long can excess power be banked?)	• Buy-all/sell-all arrangements or hybrids with net metering[46] • Net excess generation purchased at full retail rate, or (in islands) at, or near, the avoided cost rate
Rate Design	• Increased customer charges or demand charges • Standby charges for onsite generation	• Time-varying prices (this could be positive or negative, depending on the jurisdiction and level of PV penetration) • Pure volumetric tariffs ($/kWh), i.e. without fixed charges
Ratemaking		• Decoupling utility revenues from power sales (this would blunt the effect of reduced power sales) • Lost revenue adjustment mechanisms
Market Reforms	• Regulations prohibiting onsite generation, or grid connection • Rules prohibiting onsite storage	• Allowing peer-to-peer power sharing • Encouraging new business models and prosumer-friendly shifts in the industry
Tax Reforms	• Tax on self-consumed generation • Tax on solar system components	• Shift electricity sales tax to other income sources • Tax incentives or credits for solar system components, or investments

[46] Buy-all/sell all arrangements can reduce the revenue erosion experienced by utilities, while at the same time allowing PV to be profitably developed. Depending on the regulatory process, however, the rate can be set too low for PV to be viably developed. Some solar industry companies in the United States have organized campaigns against value of solar tariffs based on this perceived risk (*see* e.g. http://stopfeedintaxes.com).

For countries that do not desire PV prosumer development, these types of approaches can be implemented in a way that slows or halts PV adoption. Other countries may wish to find a balance between halting PV growth and eroding grid operator revenues. In these cases, there may exist policy "midpoints" that balance prosumer and grid operator interests. For example, a fixed charge for prosumers could be introduced that lowers PV prosumer returns but still permits profitable project development – and at the same time compensates grid operators for lost revenues. The precise level at which such fixed charges could be set is currently under debate in a number of jurisdictions and remains contentious (e.g., Martin, 2013a).

There are many parallel and ongoing efforts around the world to identify and implement incremental transition approaches. A key challenge with incremental approaches, however, is that they sustain the fundamentals of current regulatory paradigms, which place PV prosumers in conflict with incumbent business models. A number of jurisdictions are beginning to explore models that more closely align utility and PV prosumer interests through the implementation of new or alternative regulatory structures. A high level review of some of these "structural" transition concepts is contained in the next section.

4.4 STRUCTURAL APPROACHES FOR PROSUMER TRANSITION

Many of the incremental approaches discussed in the previous section are being implemented in different jurisdictions around the world or are under consideration. As discussed above, these approaches typically involve trade-offs between the interests of prosumer and those of incumbent stakeholders and are sometimes cast as a struggle that one side or the other must ultimately lose. The interests of prosumers and the interests of the entities that manage the electricity grid do not necessarily have to be in conflict.

A growing body of research focuses on future business models that could enable existing utilities to adapt to profit from inherently "smarter" and more distributed industry infrastructure (Small & Frantzis, 2010). This research tends to focus on similar and interrelated themes, such as:

- Innovative business models. Utilities would shift from generating, transmitting, and distributing power in the conventional manner and would instead become neutral managers of grid infrastructure, brokers of new customer relationships, partners with prosumer service providers, or even financiers of prosumer infrastructure (Bird et al.,2013; Newcomb et al., 2013).[47]

[47] This could involve, for instance, a move toward business models such as "aggregators". These new business models transcend traditional notions of utility service area and operate instead by purchasing electricity from a wide range of sources, including the wholesale market, from independent power producers, from utilities, or from individual prosumers, and re-distributing it to a geographically dispersed network of customers. As a result, aggregators can operate in a more streamlined (i.e. less capital-intensive) fashion than traditional suppliers, as they do not need to own electric infrastructure such as transmission lines or power plants. They purchase power from a wide range of places, pay distribution and

- New product and service offerings. Instead of selling electricity as a universal bulk commodity, utilities could make differentiated offerings based on individual requirements and preferences. Some customers, for example, could elect to pay for higher levels of reliability, whereas other customers would elect not to do so. Along similar lines, utilities could orient their business models away from selling electricity and toward selling specific "services" such as light, heat, or load management – which would include not only the energy but the installation of the associated infrastructure as well (Fox-Penner, 2010; Future Grid Forum, 2013).
- New operational models. The evolution toward more decentralized business models may require strengthened and more sophisticated grid operators in order to ensure the near-term and long-term reliability of the bulk power system throughout all future system configurations. As the number of prosumers increases, distribution grids may need to adapt many of the management mechanisms of transmission grids, including locational pricing and price signals, forecasting, and real time visibility into grid operations (EPRI, 2014). The requirement for more sophisticated granular approaches to distribution grid management would require significant investments in not only technology but in human capital and workforce capabilities.
- Emerging technologies (e.g. smart grid infrastructure) that will reconfigure the utility-customer relationship to be more integrated, interactive, and price responsive. Utilities will have more visibility and control at the distribution level, whereas customers will benefit from greater transparency and opportunities to react to (or participate in) the electricity market.

Unlike the incremental approaches, however, there are currently few full-scale examples of structural approaches that have been implemented by utilities. Part of the reason for this is that there are a wide range of potentially different paths that could be pursued and there are no business model roadmaps that clearly chart the best way forward. A closely related driver is that the regulatory framework for supporting fundamental business model changes is not in place. Although the liberalisation of the electricity sector is often associated with deregulation, the utility industry remains heavily regulated in many parts of the world and these regulations tend to favour the status quo.

The regulation that has governed monopoly utilities – and transmission and distribution operators in liberalised markets – has historically rewarded them for minimizing costs while maximizing electricity sales. This regulatory posture creates barriers to energy efficiency and distributed generation, but also to utility business model innovation more broadly. While approaches such as decoupling can remove some utility disincentive for prosumer technologies, such policies do not create the conditions for utilities to make transformative investments in new business models or services. Some utilities have recently made announcements that they are repositioning their businesses in order to support prosumers (Lacey, 2013), but it remains unclear how they will profitably realize these ambitions under current regulatory structures.

Recent studies have pointed to the UK's *Revenue set to deliver strong Incentives, Innovation and Output (RIIO)* model as an example of a regulatory framework that could enable transition from commodity- to prosumer-oriented models. The RIIO creates incentives for utilities to achieve specific

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transmission charges for access to the network, and distribute electricity to end-users in a variety of different packages based on customer preferences.

objectives beyond electricity sales, while also creating mechanisms for utilities to not only capture savings from efficient operations, but to share savings with customers as well (Malkin & Centolella, 2013). The RIIO likely needs more time to operate before conclusions can be drawn about its function or its applicability to prosumer scale-up scenarios. However, it will likely serve as a useful mile marker as other countries contemplate new regulatory models.

Text Box VIII below outlines another example of an innovative approach to regulatory reform.

Text Box VIII: New York: Transitioning to prosumers?

In April 2014, the New York State energy regulator, the Public Service Commission (PSC), launched a regulatory proceeding (Case 14-M-0101 - *Proceeding on Motion of the Commission in Regard to Reforming the Energy Vision (REV)*) to reform the state's energy industry and regulatory practices with "the objective to make energy efficiency and other distributed resources a primary tool in the planning and operation of an interconnected modernized power grid" (NYPSC, 2014; NYDPS, 2014). The proceeding will continue through the first quarter of 2015, at which point the Commission's policy decisions will begin to be implemented by individual utilities.[48] In order to frame the proceeding, the New York Department of Public Service (DPS) published a proposal to "transform New York's electric industry … with the objective of creating market based, sustainable products and services that drive an increasingly efficient, clean, reliable, and customer-oriented industry" (NYDPS, 2014). Although the proceeding was only recently launched, it appears likely that the Commission will consider a range of structural regulatory and policy approaches that would have direct relevance to PV prosumers.

The state has been a leader in the adoption and scaling up of renewable energy in the US and has supported both centralized and prosumer-based renewable energy development. The state Renewable Portfolio Standard policy targets 29% by 2015 and includes a specific target for customer-sited development. The state had only installed 271 MW of PV by the end of 2013, but Governor Andrew Cuomo committed to a new program in January 2014 to spend $1 billion to promote the solar deployment during the next 10 years – and new incentive programs are currently being initiated (Cuomo, 2014; SEIA, 2014). These commitments, combined with parallel programs in energy efficiency, net metering, revenue decoupling in the utility sector, demand response programs, and the state's Green Bank, have set the stage for prosumer growth. At the same time, electricity consumption has decreased below its peak in 2007 and this has resulted in idle electricity infrastructure capacity - which has raised concerns about current utility business models in the state.

Case 14-M-0101 will take these trends into account in two separate regulatory tracks:

- A collaborative process to examine the role of distribution utilities in enabling market-based deployment of distributed energy resources to promote load management and greater system efficiency, including peak load reductions.
- An examination of changes in current regulatory, tariff, and market designs and incentive structures to better align utility interests with achieving the Commission's policy objectives.

The DPS proposal supports the development of a new "Distributed System Platform Provider" utility model with the goal of improving overall efficiency and reliability and increased responsiveness to customers. The Distributed System Platform Provider would be responsible for developing the communications infrastructure

48 Case 14-M-0101 is moving forward in parallel with Case 07-M-0548, which considers a Clean Energy Fund (CEF) to address the expiration of the renewable portfolio standard and energy efficiency portfolio standard in 2015. It is envisioned that the CEF would be in place from 2015-2020 while the REV is being implemented.

(i.e. the "smart grid"), integrating energy efficiency programs, pricing structures, and other services. To realize the creation of this new utility model, the DPS (2014) staff proposed that reforms could include:

- Ratemaking changes: a transition to multi-year rate plans; shifting towards a results-based model from the current input based ratemaking; implementing symmetrical versus one-way incentives; and focusing on incentives related to capital and operating expenditures;
- Rate design changes: a further focus on rates that are based on time-sensitive pricing, sensitivity to energy efficiency goals, etc.;
- A "Small bets" approach: A more flexible regulatory approach that would allow utilities to spread the risk of investments and learn from any mistakes that may be made;
- Standby tariffs: Consideration of whether to include charges to balance the needs and expectations of non-prosumers ratepayers with the benefits accumulated by prosumers.

The DPS staff proposal explicitly takes international models such as the UK RIIO into account, as well as the ongoing work of New York State stakeholders such as the Advanced Energy Economy (AEE) Working Group (AEE & MIT, 2013). In advance of the DPS proposal, the AEE Working Group convened to gather input from utilities and electricity industry leaders on options for industry transition (AEE, 2014). The Working Group focused on structural changes that might be required to accommodate the emergence of distributed generation, energy efficiency and other technologies with the goals of better aligning the state's utility regulatory framework with the state's energy, environmental, and economic policy objectives; and successfully addressing the underlying technology and market forces shaping the "utility of the future." The Working Group identified "three pillars" for supporting new utility models, including new customer products and services, new network infrastructure and operational models, and new regulatory frameworks.

Together, the Public Service Commission's proceeding, the DPS proposal, and the work of stakeholder organizations such as the AEE Working Group should create a useful international benchmark on how to approach the structural policy changes that may be implicated by prosumers.

At present, there remains a knowledge gap about how to move from current utility and regulatory models to models that better accommodate prosumers. Analysts have articulated the current challenges and have also articulated possible future scenarios (e.g. new utility business models). However, there have been few efforts to articulate how policy makers can support a transition to electricity industry business models that are more profitably aligned with high penetrations of prosumers – i.e. where prosumers can continue to develop PV systems, national energy policy objectives can be achieved, grid operators can remain profitable, and electricity consumers can access appropriate and affordable energy services.

While some analysts have noted that "new business models … will likely need to evolve in a step-wise fashion, allowing time for new service provider business models to evolve and for customers to learn and adapt to new rates and rules (Newcomb et al., 2013)," others have concluded that changes in the electricity market have outpaced the ability of the industry to change and that this trend will continue with prosumers. The necessity, substance, sequence, and pace of future structural reforms will therefore be a critical challenge for policy makers in the coming years if current prosumer trends continue.

4.5 SUMMARY OF PROSUMER POLICY STRATEGIES

Table 5 below summarizes the PV prosumer drivers, enabling policies, and transition approaches described and organizes them according to whether they support prosumer emergence or whether they constrain it. Table 6 then presents several generic categorizations for the different types of prosumer scenarios or strategies that are currently in evidence around the world or could arise in the near-future. These "scenarios" represent an initial and illustrative attempt at characterization and it is recommended that additional research focus on exploring each country's prosumer narrative in greater detail.

Table 5: Summary of Factors Impacting Prosumer Development

Drivers	Policies	Strategies
Enabling drivers in place?	Enabling policy in place?	Strategies to manage prosumer challenges?
✔ Yes	✔ Yes	✔ Yes
• Low installed costs • High retail rates • High insolation • High consumer interest • Market growth in enabling technologies (e.g. batteries)	• Interconnection standards • Rules to feed into the grid • Rules for compensation • Targeted soft cost programs	• Incremental transition strategies deployed • Structural transition strategies under development or deployed to maximize societal value
🚫 No	🚫 No	🚫 No
• High installed costs • Low retail rates • Low insolation • Low consumer interest • Low market growth in enabling technologies	• No interconnection standards • No rules to feed into the grid • No rules for compensation • No soft cost programs	• No incremental strategies deployed • No structural strategies

Each of these factors can be used to characterize generic prosumer scenarios, based on whether countries have enabling drivers, policies, and strategies in place to support prosumer development. Table 6 below provides examples of scenarios, and the last column of the Table provides a more detailed description of the scenario and relates it to international experience, where applicable. This categorization is basic, but provides a high-level framework for situating different international jurisdictions in terms of their engagement with prosumers

Table 6: Scenarios for Prosumer Development

<table>
<tr><th>Prosumer Scenario</th><th>Drivers</th><th>Policies</th><th>Strategies</th></tr>
<tr><td>No Prosumers</td><td>🚫</td><td>🚫</td><td>🚫</td></tr>
<tr><td colspan="4">• Weak conditions for prosumers. These can include, for example, low retail electricity prices and a lack of consumer uptake of onsite energy technologies
• No policies or rules permitting interconnection, feeding into the grid, or compensation for onsite power
• No regulatory or policy strategies for addressing challenges that prosumers may introduce into the system
• The Gulf Cooperation Council member states are examples of countries that have historically had no prosumers. They have low, subsidized retail electricity rates and few policies to enable prosumers development.</td></tr>
<tr><td>Constrain Prosumers</td><td>✓</td><td>🚫</td><td>🚫</td></tr>
<tr><td colspan="4">• Good conditions for prosumers, such as high retail prices and low installed costs
• No policies or rules permitting interconnection, feeding into the grid, or compensation for onsite power
• Policies or laws that specifically prevent prosumers or that penalize prosumer development through fines or taxes may be in place
• No regulatory or policy strategies for addressing challenges that prosumers may introduce into the system
• Some Latin American and Caribbean (LAC) countries have relatively good conditions for supporting prosumers (e.g. high retail prices), but have not adopted enabling policies. Module prices in the LAC region are currently lower than in many other areas of the world (Jones, 2013), for example, and retail prices in many countries are high – particularly in the Caribbean. In other countries such as Spain, governments have acted to introduce new charges on self-consumption, which will have the impact of slowing prosumer development.</td></tr>
<tr><td>Enable Prosumers</td><td>✓</td><td>✓</td><td>🚫</td></tr>
<tr><td colspan="4">• The conditions are in place to create a competitive environment for prosumers
• A suite of enabling policies is in place that allows prosumers to rapidly emerge on a non-incentivised basis.
• Policy makers and utilities do not anticipate, plan for, or react to the challenges introduced by prosumers. Prosumer development conflicts with incumbent business models and encounters technical constraints, which results in a range of negative financial, technical, and/or political impacts.
• European countries that experienced unanticipated PV booms during the past 5-10 years are examples of this dynamic. Some of these countries have attempted to effectively halt PV prosumer development through the imposition of caps, fixed charges, or retroactive fees and taxes, whereas other countries are on track to achieve high national PV penetrations, but without an evident plan for transitioning to alternative business models.</td></tr>
<tr><td>Prosumer Transition – Incremental and Structural Approaches</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td colspan="4">• The conditions are in place to create a competitive environment for prosumers
• A suite of enabling policies is in place that allows prosumers to rapidly emerge on a non-incentivised basis.
• Policy makers have identified clear objectives for supporting prosumers, have identified the near-term financial and technical boundaries of prosumer development (e.g. grid integration challenges and financial vulnerabilities of utilities), have set goals for prosumer scale-up, and have identified regulatory and policy pathways to make the required grid infrastructure investments and support the development of alternative utility business models.</td></tr>
</table>

Prosumer Scenario	Drivers	Policies	Strategies
• Some jurisdictions have implemented incremental transition approaches. At present, no jurisdictions have articulated and executed a structural prosumer transition strategy. Jurisdictions are developing components that could support a transition, e.g. the UK has introduced RIIO regulation and Hawaii is working to develop grid solutions to manage 10%+ PV penetrations. However, no countries have yet to articulate an integrated roadmap for prosumer scale-up.			

SECTION 5

CONCLUSIONS AND NEXT STEPS

5.1 CONCLUSIONS

The prosumer revolution is not yet here. Widespread grid defection will not likely occur in near-term in most major PV markets, and governments remain able to control the development of customer-sited PV systems at the residential level with the existing suite of policy tools. However, there is a complex landscape of economic, behavioural, technological and political trends relevant to prosumers that could outpace standard policy making processes. The most significant and potentially disruptive of these trends – continuing PV cost declines, rapid PV market growth rates, and the inherent decentralisation of PV systems – will persist for the years to come as the global PV market continues to expand.

Internationally, different countries and policymakers have adopted different strategic postures towards PV prosumers. Although it is possible to significantly slow down the prosumer development at the national level, the conditions for PV prosumers are likely to continue to improve at the global level. Even policymakers that are acting to constrain PV prosumers in the near-term are likely to confront the prospect of increasingly competitive (and/or increasingly popular) PV in the coming years.

It is recommended that policy makers with active PV markets initiate efforts to develop comprehensive prosumer strategies in the near-term. This report has provided a basic framework for such strategies that includes:

1. **Assess specific national conditions and drivers that may influence prosumer development.** These vary by jurisdiction and could include economic factors such as electricity rates, behavioural factors such as environmental values, and technical factors such as the rate of PV technology innovation. Prosumer development can also be impacted by national conditions such as the number of available rooftops and the parallel growth of non-prosumer renewable energy.

2. **Weigh the pros and cons of prosumer development as they relate to national objectives.** Prosumers can create economic, social, and environmental benefits both for society at large as well as for the prosumers themselves. At the same time, prosumers may create financial challenges for incumbent energy industry stakeholders and may also pose technical challenges to the electricity grid. These challenges are not insurmountable, but they may require policy makers to explore and implement new policies and regulations for governing the utility industry.

3. **Make strategic choices about the policy approach to prosumers.** In order to manage the scale-up of prosumers, policy makers can choose to adopt different several different strategic postures, depending on the extent to which prosumers are viewed as a policy priority. These could involve enacting policies to constrain prosumers, developing policies to support PV prosumers, and/or pursuing incremental or structural approaches to managing prosumer growth.

The prosumer strategies adopted in different countries will vary substantially based on status of the PV market, the political climate, the current state of energy system infrastructure, the market power of the incumbent utility sector, etc. As can be seen in the case studies, the question of how best to manage and accommodate PV prosumer growth is an ongoing discussion and there is no clear template for best practice. The strategies being formulated in frontrunner PV markets will be important for policy makers in other countries to continue to watch in order to determine whether

new "standard" approaches can be developed in a timely and efficient manner that can keep pace with the "revolution of millions of individual steps" imagined by Hermann Scheer.

5.2 PROPOSED AREAS OF FURTHER ANALYSIS

The discussion of PV prosumers in this report should be viewed as an initial effort. Many of the issues identified in this document are emerging and will evolve significantly in the coming years as policy makers attempt to shape and react to current trends. IEA-RETD and its partner entities will have an opportunity to build on the work completed under RE-PROSUMERS to continue to support international stakeholders to navigate the opportunities and challenges created by the continued growth of PV markets. This section contains an overview of near-term next steps for additional research and dialogue.

Commercial prosumer characterization. Although this report focuses exclusively on residential prosumers, commercial entities may emerge as a more significant class of prosumers in the future since they control a greater share of real estate and of electrical load than residences do in some countries. Commercial prosumers may also emerge ahead of residential prosumers because they have higher self-consumption ratios (e.g. 70-100%) and because they are able to install larger PV systems at lower costs. On the other hand, commercial prosumers may face headwinds in some countries because of paying lower retail electricity rates, paying a higher share of their electricity bills as fixed charges, and by having a lower tolerance for longer-payback investments than residential consumers. It would be useful to conduct a quantitative analysis of certain classes of commercial customers in order to get a better sense of their competitiveness as compared to residential prosumers. A clearer understanding of the potential for commercial prosumers would help policy makers better calibrate their enabling policies and forward-looking prosumer strategies.

Multi-family prosumer research. Multi-family properties can vary by ownership structure (e.g. owner occupied vs. rental), the number of units (e.g. 3 vs. 300), metering strategy (e.g. master metering vs. submeters), economic composition (e.g. luxury apartments vs. mixed-income units), and structure (e.g. high rise vs. low rise). As a result, it is challenging to identify a standard model for multi-family PV development and will likewise be challenging to predict prosumer behaviour. A characterization of multi-family prosumers would be a useful accompaniment to additional prosumer research. The multi-family focus would also raise questions as to whether and how innovative ownership and policy structures such as community solar gardens, virtual net metering, and meter aggregation might support prosumer development under new models.

Additional technology research. This report has focused narrowly on PV, but prosumer issues extend to other technologies as well. Additional research could be conducted with regard to other onsite generation technologies, such as combined heat-and-power and small wind. It would also be useful to merge this research with ongoing research related to energy efficiency regulation and with emerging "smart" technologies in order to capture the broader innovation landscape in which PV prosumers are currently operating.

Prosumer behaviour. As discussed in the sections dealing with behavioural drivers, prosumers may adopt PV for a range of non-financial reasons. In the past, a comparatively small number of adopters

have chosen to purchase PV – or entirely defect from the grid – even when the payback was not attractive in standard economic terms. Now that PV is both a more economically attractive and better known commodity, there is the chance that PV could diffuse for reasons other than cost savings (e.g. resilience or utility independence). At present, however, PV prosumer behaviour is poorly understood in many countries aside from limited anecdotal evidence. It would be useful for policy makers to better understand prosumer behaviour with regard to PV adoption and the factors that may drive PV prosumer emergence in unexpected ways.

Collaboration to set up enabling policies. There is now a robust conversation about how to structure enabling policies for PV prosumers in countries around the world. As discussed in Section 4.3.1, Europe is now exploring net metering and self-consumption policies as an alternative to feed-in tariff policies – partially in order to address grid and market integration concerns. At the same time, other jurisdictions are exploring feed-in tariffs as an alternative to net metering in order to avoid utility revenue erosion. There is a real opportunity for international joint fact finding and targeted exchange to discuss the comparative pros and cons of different prosumer policy models and how they are each evolving (or being hybridized) in different jurisdictions. A facilitated dialogue that integrates stakeholders from multiple sectors (e.g. the solar industry and grid operators) as well as from multiple continents could help establish which policies could best be deployed in which circumstances.

Additional national research. This paper was necessarily limited in the number of national case studies that could be conducted. Additional research, however, should focus both on characterizing the prosumer landscape in a broader number of countries, as well as delving more deeply and comparatively into specific countries. There is an important opportunity for stakeholders in different countries to understand which issues are rising to the forefront of national conversations in other countries and why. This would help establish a more common understanding of current practice in a rapidly evolving field, as well as assist countries to identify gaps in (or alternatives to) their current prosumer strategies.

Value of solar calculations. The quantitative value of solar is under discussion in numerous jurisdictions and is being calculated for different purposes. It is being used, for example, to set value-based feed-in tariff rates in some jurisdictions, in order to justify net metering in other jurisdictions, and to contest whether and how new charges should be levied on PV self-consumption. Although there are many concurrent solar valuation efforts, there is not a harmonized approach to these calculations across countries – or even within individual countries. There is an opportunity to conduct comparative research as to how these valuations are being done across countries and continents.

Incremental strategy quantification. There is currently controversy over efforts in some countries to increase fixed charges or levy taxes on prosumers for their self-consumption. Grid operator business and financial models are not well understood by policy makers outside of regulatory bodies. It can therefore be challenging for policy makers to evaluate whether utility claims of revenue erosion are accurate, the degree to which PV prosumers are responsible, and the magnitude of the revenue "cure" required. It would be useful to develop high-level models of utility financials that could be used to transparently evaluate the impact that different penetrations of prosumers might have on utility financial performance, the amount that would be need to be recovered through fixed charges in order to avoid significant cost-shifting to other ratepayers, and the impact that such fixed charges might have on PV system economics. With such calculations, it may be possible to identify

"midpoints" where PV systems can be profitably developed and utilities can avoid unnecessary cost shifts – or to identify that expectations of such midpoints are unrealistic.

Policies for structural utility reforms. Stakeholders are gaining a more thorough understanding of incremental prosumer strategies as different jurisdictions around the world experiment with them. Policy makers are also familiar with strategies to constrain or halt prosumer development. At the other end of the spectrum, however, there are a significant number of efforts that are attempting to identify and categorize the "utility of the future" – but there are few articulated pathways for countries to move beyond incremental strategies and actually realize the future utility structures envisioned. There is a near-term opportunity to share best practices and current experiences across those jurisdictions that are exploring structural strategies (e.g. the UK and New York State) to address both financial and technical challenges. There is also an opportunity for IEA-RETD and its partner entities to help unify the utility of the future discussions and work to create a toolkit for prosumer transition. It is likely that multiple roadmaps will need to be developed in order to accommodate multiple visions of future utility structure.

Remote community research. The IEA-RETD REMOTE study laid out initial considerations for renewable energy policymaking in remote areas and surveyed remote communities that have achieved high renewable energy penetrations for lessons learned. There is an opportunity to integrate the next steps of the REMOTE and PROSUMERS activities in order to support remote communities as they think through prosumer regulation in greater detail. Islands and remote areas will encounter the financial and technical challenges posed by prosumers on an accelerated timeline than will non-remote areas because PV prosumers are already highly competitive and because their grids are small. There is an opportunity to provide targeted support to regulators and utilities in islands and remote areas as to how to think through and pursue structural prosumer transitions. There is also an opportunity for mainland communities to learn from islands that have already embraced high penetrations of renewable energy how their transitions were specifically managed.

SECTION 6

CASE STUDIES IN KEY JURISDICTIONS

6.1 CASE STUDY OVERVIEW

This report has compiled an inventory of policy considerations related to PV prosumer development. As discussed in Section 1, there are complex economic, technological, and behavioural drivers that might influence the emergence of prosumers and these drivers may manifest themselves differently across countries. In order to illustrate the similarities and divergences of prosumer trends in different countries, this section provides high level case studies of Australia, France, and Germany after first discussing representative prosumer scenarios.

The case studies were selected after consultation with IEA-RETD and reflect a diversity of national conditions and national approaches. The case studies are organized to draw on the themes described throughout this report, but do not cover all topics introduced in this report in the interest of brevity. Generally, however, the case studies are organized around presenting drivers, enabling policies, and transition strategies. Brief and high-level summaries of the case studies are included below in order to provide orientation, but readers are encouraged to conduct their own more detailed cross comparisons.

- Australia. Australia's retail rates have gone up significantly in recent years, driven by a combination of rising grid investments and fossil fuel prices. Australia has enabled prosumers through state-level polices that combine elements of feed-in tariffs and net metering, paying a fixed rate for excess power sold to the grid. Rising retail rates and a strong solar resource, combined with the recent decline in solar module costs, have made becoming a prosumer an increasingly attractive opportunity for residential customers. At the time of writing, approximately 12% of households now have solar PV systems installed on their roofs, a trend that is raising concerns about revenue erosion from the incumbent utility sector, as well as concerns about stranded assets. The market continues to expand despite reductions in incentives, signaling that Australia may well be in the process of making the shift to a purely non-incentivized solar market.
- France. Compared to most other European countries, France has relatively low retail electricity rates (currently at €0.147/kWh). Despite a solar boom in France in 2011, development in the last few years has slowed due to changes in the policy framework and the impacts of the financial crisis on France's economy. Due to the relatively low retail rates in relation to slightly higher installed PV costs in France, and the fact that residential electricity bills have a fixed charge component irrespective of consumption, prosumer development has been modest. However, it has not gone unnoticed: in recent months, France has initiated a national conversation on the future of prosumer development, engaging a wide range of stakeholders in order to chart a clearer future for the sector.
- Germany. Germany currently has the highest retail rates of the three case studies, at approximately €0.29/kWh for residential ratepayers. These rates, combined with the continuing degression of feed-in tariffs offered to solar PV, have made self-consumption an increasingly attractive option for system owners in Germany. However, as the number of self-consuming prosumers grows, concerns are growing that they are no longer contributing sufficiently to support fixed grid costs (which are currently recovered volumetrically through rates). There are also concerns that self-consuming prosumers are no longer paying a sufficient share of electricity

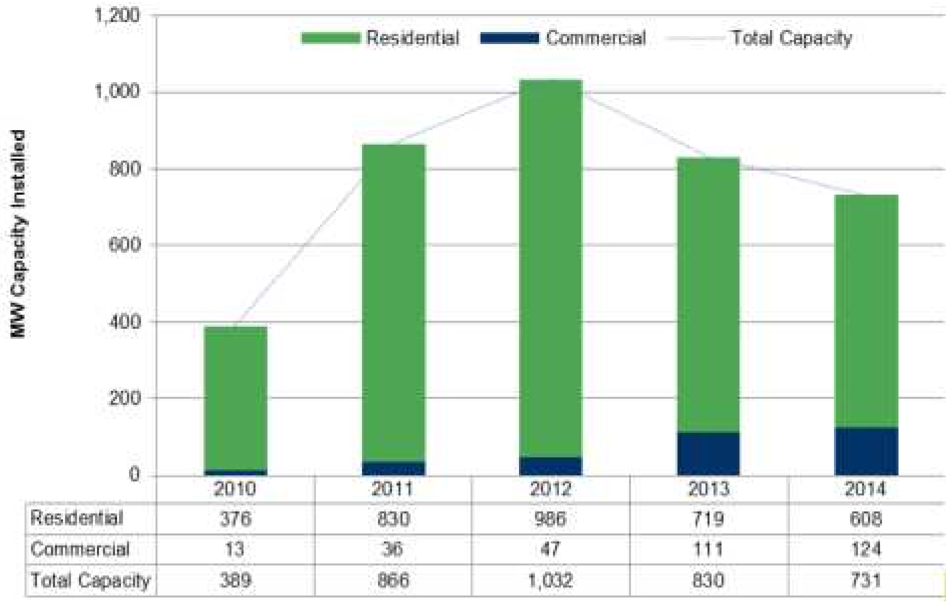
system taxes, including the renewable energy surcharge, from which self-consumed power is currently exempt. Although the government has recently tabled proposals that would have required PV prosumers to pay a share of the renewable energy surcharge for the power they consumed onsite (i.e. 50% of the EEG surcharge of €6.24/kWh), there is not a clearly articulated strategy to deal with the rise of prosumers. Policy makers are currently looking for alternatives to incentive-based support mechanisms (e.g. the feed-in tariff program) while at the same time exploring avenues to contain and limit prosumerism.

6.2 AUSTRALIA

Australia	Data

PV Statistics

- Solar PV generation in 2013 represented around 1.5% (3,340 GWh) of total net electricity consumption in Australia (220 TWh). On a capacity basis (3.1GW), it represents approximately 5% of total installed capacity.
- There are over 1.1 million individual solar PV rooftop installations under 9kW in Australia, with an average system size of approximately 2.9kW.
- Systems under 9kW represent more than 95% of total installed solar capacity in the country, but the market for commercial installations is growing.



Source: Brazalle (2014)

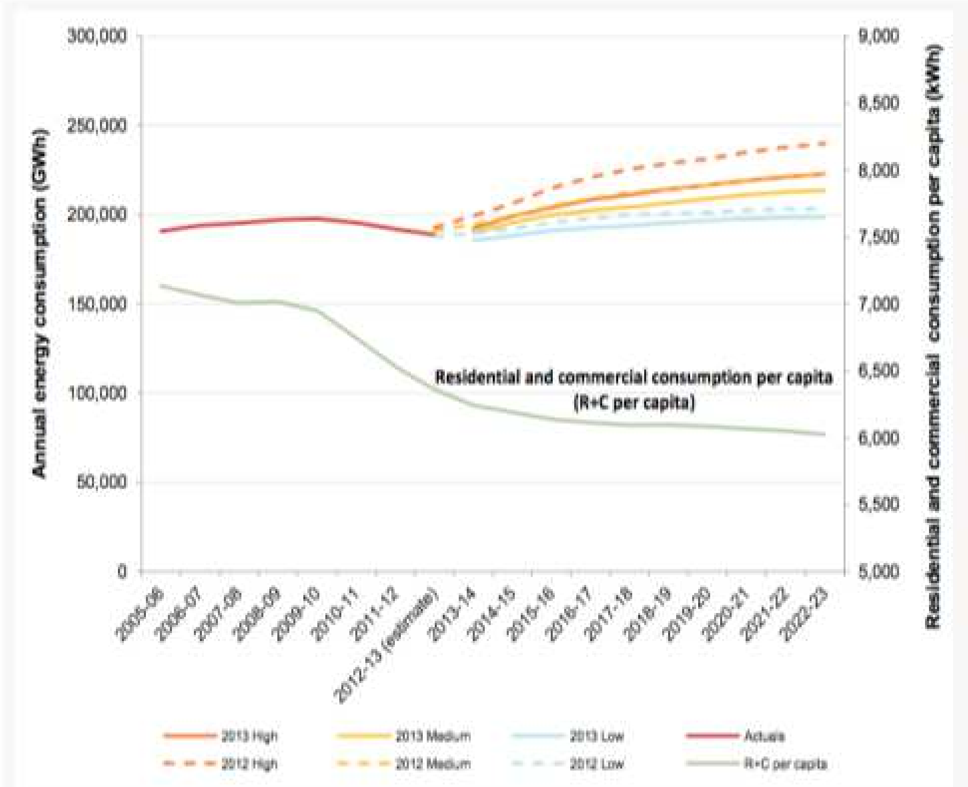
Solar install forecast per year

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Systems (000s)	63	203	360	343	241	172	103	138	155	172	172	172
kW per system	1.3	1.9	2.4	2.8	2.9	2.9	2.9	2.9	2.9	2.9	2.9	2.9
MW installed	84	379	873	955	700	500	300	400	450	500	500	500
Commercial					100	100	100	130	140	160	160	160
Cumulative systems (000s)	63	266	626	969	1210	1382	1486	1624	1779	1951	2124	2296
% total households	0.6%	2.6%	6.1%	9.5%	11.9%	13.6%	14.6%	15.9%	17.4%	19.1%	20.8%	22.5%
Cumulative MW	84	463	1336	2291	3091	3691	4091	4621	5211	5871	6531	7191
Electricity produced TWh		0.3	1.1	2.3	3.4	4.3	4.9	5.5	6.2	7.0	7.9	8.7

Source: UBS (2014)

Demand projections

- Due to a mix of falling industrial capacity, energy efficiency improvements, and solar PV, demand from the grid has declined since 2009.
- Electricity demand is, however, projected to grow 1.3 per cent per annum out to 2020, as forecast by the Australian Energy Market Operator for the National Electricity Market (which

<table>
<tr><th>Australia</th><th colspan="2">Data</th></tr>
<tr><td></td><td colspan="2">operates the grid in the eastern seaboard)
<u>National Energy Market total annual energy (GWh)</u>


Source: AEMO, (2013)</td></tr>
<tr><td>Technical rooftop potential</td><td colspan="2">
• It is estimated by AEMO, the market operator for the National Electricity Market (NEM), that the total amount of rooftop area available for solar in all of Australia is around 20 GW.
• At current rates of around 650MW of installations per year, rooftop solar will reach 14GW by 2030. The AEMO has included forecasts of between 12-18GW by 2030, while the Australian Photovoltaic Institute suggests that at growth rates of 15%, total installed solar PV capacity could reach 38GW by 2030.</td></tr>
<tr><td>Adoption behaviour</td><td colspan="2">
• Support for renewable energy, and for solar PV in particular, remains strong in Australia. A recent poll by Crosby Textor, on behalf of the Clean Energy Council, found that 82% of Australians favor the continued development of rooftop solar.
• Current PV development in Australia is driven primarily by the Federal Government small-scale renewable energy scheme (part of the renewable energy target), which allocates a certificate (per MWh) equivalent to 15 years deemed output. Government set feed-in tariffs have been reduced significantly in recent year to reflect little more than the wholesale price for electricity for exports back into the grid. Australia's feed-in tariffs are closer in design to traditional net metering, with a payment offered only for excess generation.</td></tr>
<tr><td>Avg. residential installed cost (2013)</td><td>€/watt</td><td>Between $A1.60 -$A2.60/W (€1.09 – 1.77/W) installed, depending of the state, according to Solar Choice, a local installer.</td></tr>
</table>

<table>
<tr><th>Australia</th><th colspan="2">Data</th></tr>
<tr><td rowspan="4">Electricity retail rates</td><td>Average electricity retail price</td><td>Approx. A$0.30/kWh (approximately €0.20/kWh), although prices vary between states and tariff schemes. Average tariffs have increased 80% over the last five years, mostly as the result of large investments in network infrastructure. The forecast is for these increases to moderate and for average electricity bill increases to remain below inflation (around 3%) in the years ahead, although this depends on the state. In Western Australia and large parts of Queensland state, the retail electricity price is heavily subsidized by the state governments – efforts are underway to wind back these subsidies and to create deregulated pricing markets, which until this year (2014) only existed in the state of Victoria.</td></tr>
<tr><td>Are there fixed (i.e. non-volumetric) charges?</td><td>Yes. Residential tariffs in Australia include a fixed charge set by state-based pricing regulators, these range from $A0.50/day (€0.34) to more than $A1.00 (€0.68) per day. There is discussion about adapting these fixed charges from flat rates to the size of the connection, or to onsite peak demand.
<u>National residential electricity price trends from 2011/12 to 2014/15</u>


<table>
<tr><th></th><th>2011/12</th><th>2012/13</th><th>2013/14</th><th>2014/15</th></tr>
<tr><td>State Schemes</td><td>0.4</td><td>0.3</td><td>0.3</td><td>0.3</td></tr>
<tr><td>Small Scale Renewable Energy Scheme</td><td>0.6</td><td>0.5</td><td>0.2</td><td>0.2</td></tr>
<tr><td>Large Scale Renewable Energy Target</td><td>0.4</td><td>0.5</td><td>0.6</td><td>0.6</td></tr>
<tr><td>Retail Margin</td><td>1.3</td><td>1.6</td><td>1.6</td><td>1.6</td></tr>
<tr><td>Retail</td><td>1.7</td><td>2.1</td><td>2.2</td><td>2.3</td></tr>
<tr><td>Feed-in Tariffs</td><td>0.1</td><td>0.7</td><td>0.7</td><td>0.7</td></tr>
<tr><td>Distribution</td><td>9.8</td><td>10.4</td><td>11.1</td><td>11.7</td></tr>
<tr><td>Transmission</td><td>1.9</td><td>2.4</td><td>2.6</td><td>2.8</td></tr>
<tr><td>Carbon costs</td><td>0.0</td><td>2.1</td><td>2.2</td><td>2.2</td></tr>
<tr><td>Wholesale</td><td>9.7</td><td>9.0</td><td>8.5</td><td>8.8</td></tr>
</table>
Source: AEMC, (2013)</td></tr>
<tr><td>Applicable self-consumption taxes</td><td>There is currently no tax on electricity self-consumption in Australia.</td></tr>
<tr><td>Time-of-Use tariffs</td><td>Time-of-use tariffs are used widely in deregulated markets in Victoria, and less widely in other markets. The tariffs are designed to reduce consumption at times of peak demand on a day-to-day basis rather than by season.</td></tr>
</table>

<table>
<tr><th>Australia</th><th colspan="2">Data</th></tr>
<tr><td>Insolation</td><td>5.75 – 6.3 kWh/m²/day)</td><td>The Australian continent has the highest solar radiation per square metre of any continent and consequently some of the best solar energy resource in the world. The regions with the highest solar radiation are the desert regions in the northwest and centre of the continent. The annual solar radiation falling on Australia is approximately 58 million petajoules (PJ), approximately 10 000 times Australia's annual energy consumption. The daily irradiation is approximately twice the average in Europe.

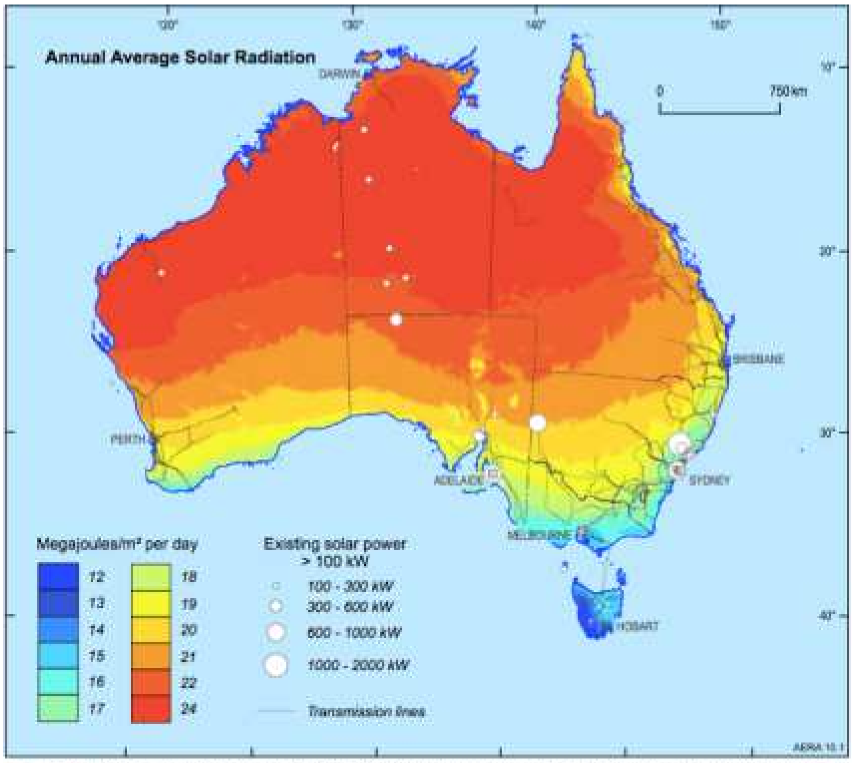


Figure 10.1 Annual average solar radiation (in MJ/m²) and currently installed solar power stations with a capacity of more than 10 kW

Source: Bureau of Meteorology 2009; Geoscience Australia

Source: Geoscience Australia and ABARE (2010)</td></tr>
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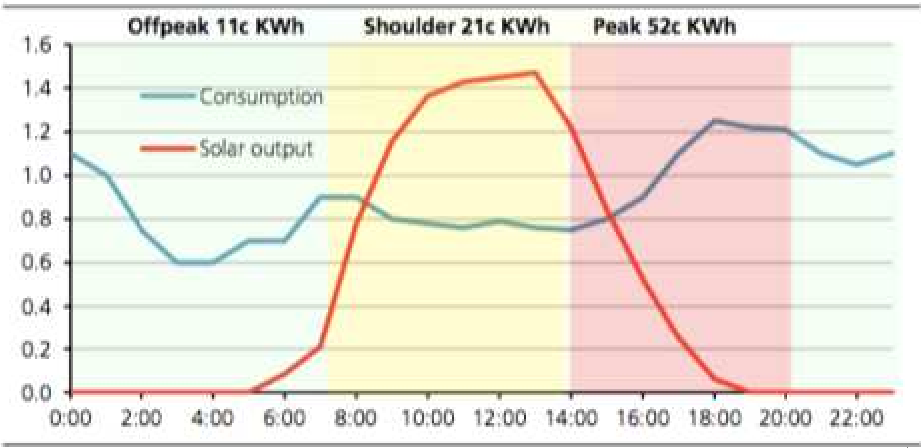
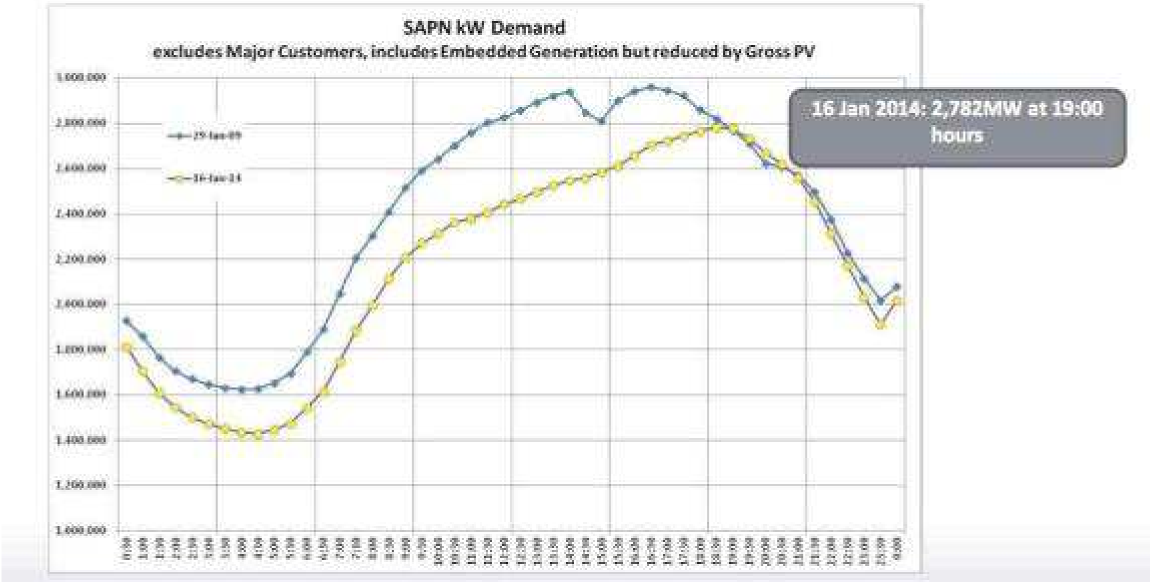
Australia	Data	
Self-consumption profile		The graph below shows an overview of a typical household's solar PV output in relation to electricity consumption. Household consumption compared to solar output  Source: UBS (2014)
Residential PV Policies	Inter-connection	Solar PV systems are allowed to connect to the network once they receive the required permits and regulatory approvals.
	Feed-in of onsite generation	Rules and rates vary from state to state. In NSW and parts of Queensland, tariffs are voluntary, but the recommended rate ranges from $A0.06-$A0.08/kWh (€0.04 – 0.06/kWh) for exports, even at times of peak rates. Higher gross feed-in tariffs offered in previous years to customers in NSW and Victoria are scheduled to expire in 2016.
	Treatment of excess generation	In some states, commercial systems are now required to install technologies that prevent exports back into the grid.
Status of other technological developments that could facilitate prosumers:	• Demand response. There is a growing number of demand response initiatives in Australia, but utilities and network operators are calling for tariff and regulatory reform that could accelerate that development. Part of the issue is addressing the surges in peak demand in Australia - it is estimated that 25% of retail electricity costs is accounted for by peak demand that occurs for less than 40 hours per year (less than 0.5% of the year). However, apart from the South-West Interconnected Grid in Western Australia, the development of demand response in the eastern seaboard has been slow. In the most populous stage of NSW, transmission operator Transgrid delivered 48MW of peak demand reduction in 2012/13, when peak loads could exceed 10,000MW. There is, however, growing use of demand controls of individual appliances. • Battery and storage technologies. A number of network operators are piloting battery storage technologies at the residential and network level, including "mobile" facilities that could respond to areas of peak demand. In Western Australia, regional utility Horizon Power has called for tenders for up to 2MW of solar and 1400kWh of storage options to take some remote towns off grid. A storage facility is being introduced on King Island, and on Magnetic Island to reduce the amount of diesel consumed in the former, and to remove the need for a larger cable connecting to the mainland in the latter. Anecdotally, solar installers are reporting increased inquiry about battery storage, and installation by some "early adopters" and	

Australia	Data
	"hobbyists". UBS said in a recent report that solar plus storage could be cost competitive for average households in Australia by 2018. • Electric vehicles. Electric vehicle usage has not developed quickly in Australia, although some EVs are available, the Tesla and the BMW EVSs are soon to be introduced, and utilities are investing in some car charging stations. Utilities have suggested that EV adoption be encouraged by government policy. It is seen by some utilities as a potential antidote for declining demand, and as a potential option to retain customer loyalty. The Energy Supply Association of Australia has called for tax concessions, new infrastructure and capital options, electricity tariff reforms and on-road privileges such as use of transit lanes, to encourage EVs, noting that it could reduce transport costs, lower emissions, and reduce Australia's reliance on imported liquid fuels (ESAA, 2013).
Opportunities for Prosumers	Public support for renewable energy in general, and solar PV in particular, remains very strong in Australia. Already in some states, more than one in four households have installed rooftop solar, and there is considerable potential for an increased localization of the electricity system, particularly in regional areas, where network operators concede that localized generation and storage will be a cheaper option (for consumers and operators) than maintenance of an extended grid. In Queensland, Ergon Energy has said this could occur by 2020, in South Australia, SA Power Networks has said local communities could find this attractive within a few years. A Future Grid report led by CSIRO including all major utility players suggested that in some scenarios, more than 50% of electricity could ultimately be generated on site, while in other scenarios one third of consumers could leave the grid completely.
Challenges for other actors	• The rapid growth of renewable energy projects (both large-scale and prosumer-driven) poses challenges to the existing electricity industry in Australia. • Fossil fuel generators, particularly coal and gas-fired generation, are experiencing reduced loads and revenues due to the growing share of renewables, and of rooftop solar in particular, which has grabbed market share during the day-time peaks, and has also shifted the peaks in some states, particularly South Australia, from around 5pm to 7pm in the summer (see yellow demand curve from 2014 compared to blue curve from 2009 in graph below). • The rising cost of gas-fired generation is also causing baseload gas generation capacity to be either mothballed, or re-purposed to intermediate or peaking plants. • Electricity retailers in Australia experience high "churn" rates – up to 30 per cent in some states in Victoria – as consumers seek to reduce their bill burden. Despite the removal of most subsidies and incentives, more than 15,000 households are installing rooftop solar each month. Network providers increasingly recognize the challenge that this is putting on the current network infrastructure, but more particularly onto long-standing business models. They are seeking regulatory and tariff changes to respond to the challenge.

Australia	Data
	 Source: Spark Infrastructure (2014)
Current Government Strategy and Future Outlook	• Electricity prices are a major social and political issue in Australia; the current conservative federal government has used them as a justification for introducing legislation to repeal the carbon price, and to review Australia's renewable energy target. State governments have used the issue to reduce solar feed-in tariffs, although there has been little public and political focus on network costs, and issues such as the proliferation of air-conditioners that underpinned much of recent cost increases, triggered by network investments. • Australian regulators are conducting numerous reviews of tariff and network investment policies, and the renewable energy target review is due to be delivered in July. The renewables industry is fearful of changes that will reduce incentives and targets, although most private forecasts suggest that in the medium to long term, rooftop solar and possibly storage will remain attractive because of falling technology costs and high retail electricity prices. The federal government is preparing another Energy White Paper to help guide policy in coming decades. The white paper is due to be delivered by the end of the year.

6.3 FRANCE

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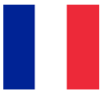
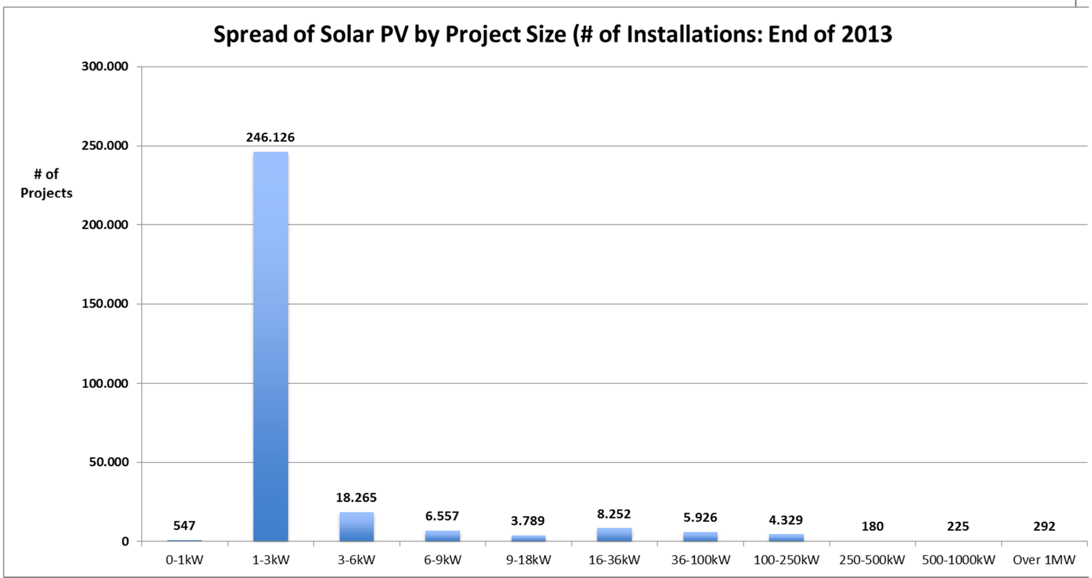
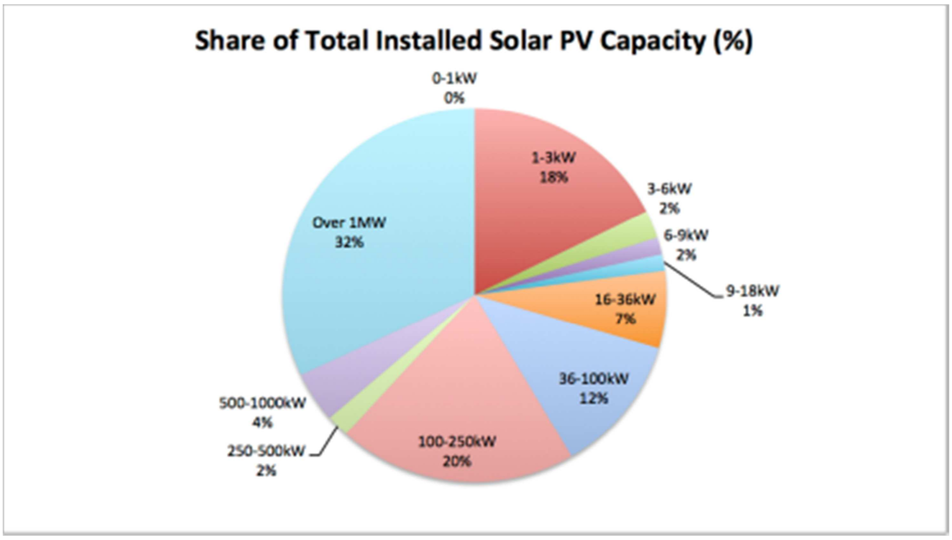
<tr><th>France</th><th>Data</th></tr>
<tr><td></td><td>

- Current solar PV generation represents 1% (4.450 GWh) of total net electricity consumption in France (437TWh) (Chabot, 2014; MEDDE, 2014)
- On a capacity basis, there was 4,330 MW installed as of December 31 2013, or approximately 3% of total installed capacity (ERDF, 2014).
- There are over 271,000 individual solar PV rooftop installations under 9kW in France, with an average system size of approximately 3kW. The majority of installed systems (84%) range from 1-3kW.
- Systems under 9kW represent approximately 21% of total installed solar capacity in the country (ERDF, 2014)

</td></tr>
<tr><td>PV Statistics</td><td>





Source: ERDF (2014)

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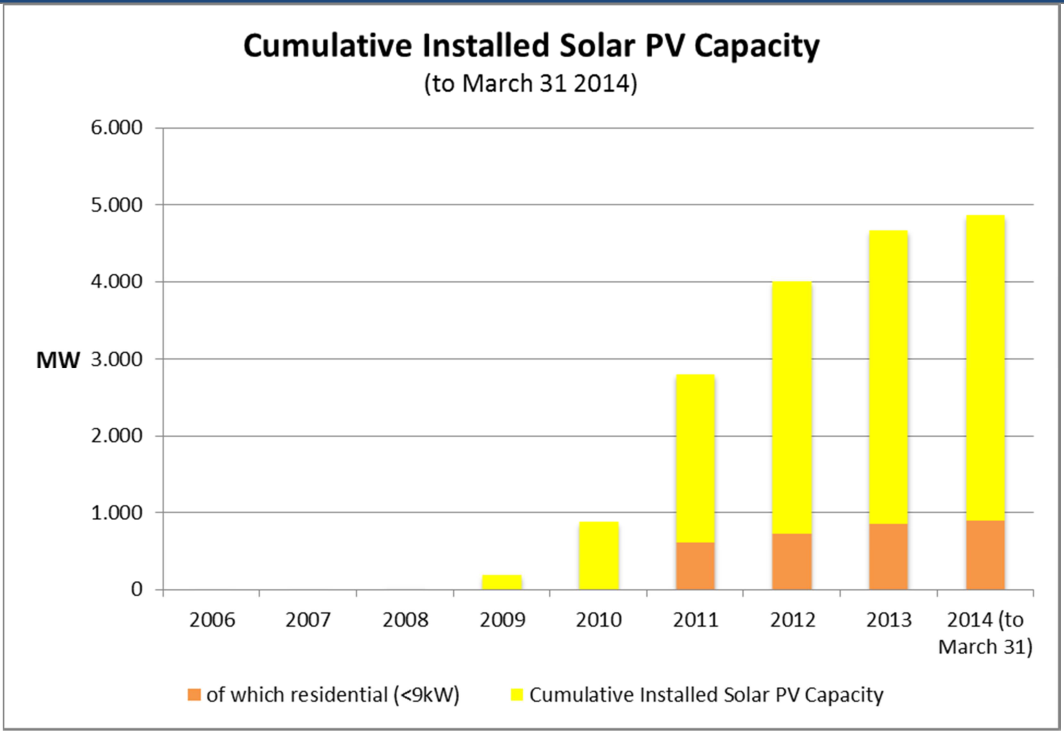
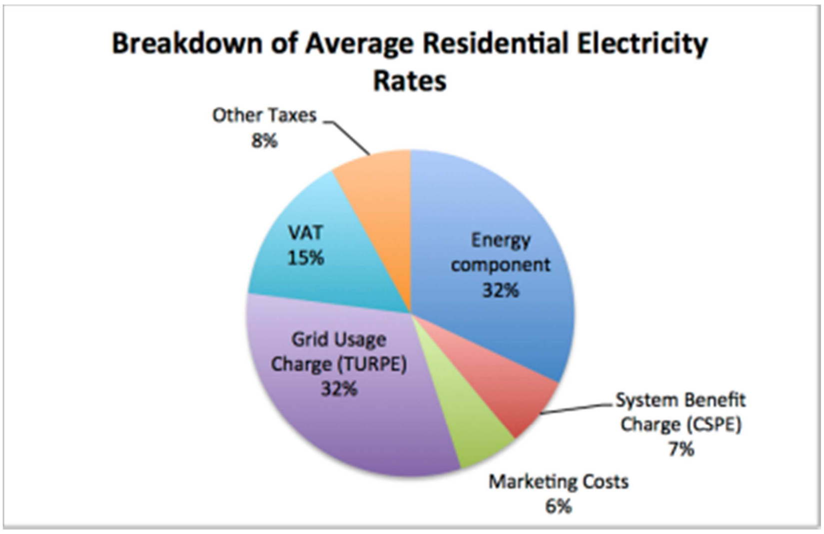


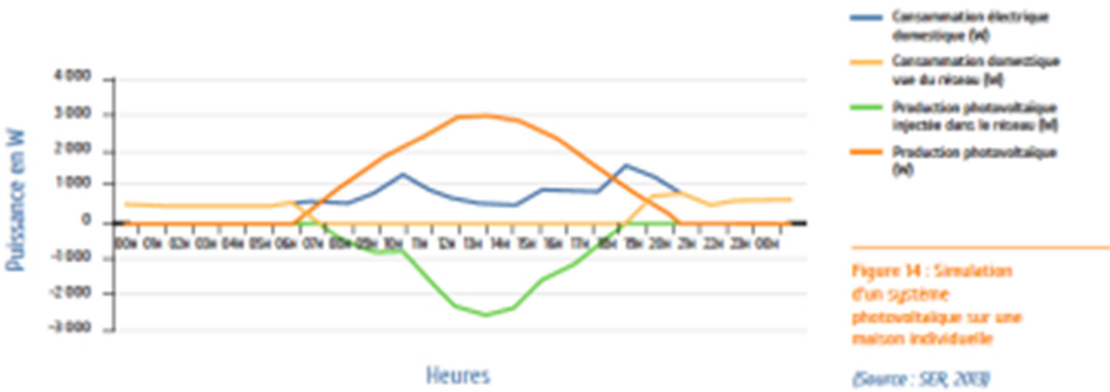
The share of residential systems is shown for the years 2011-2014 . It should be noted that “residential” in this case refers to all systems under 9 kW. France does not track which systems under 9 kW are residential and which are small commercial.
Sources: (ERDF, 2014; RTE, 2014), http://www.statistiques.developpement-durable.gouv.fr/energie-climat/r/energies-renouvelables.html?cHash=6c2aadbcba0d657fa4b7d4aa4ee6377d&tx_ttnews[tt_news]=21169
</td></tr>
<tr><td>Demand projections</td><td colspan="2">Due in part to energy efficiency improvements and broader economic circumstances, gross electricity demand in France has been flat since 2011 at approximately 476TWh/year.
Electricity demand is, however, projected to increase by roughly 0.6% per year between 2014 and 2030 to around 550 TWh per year (RTE, 2012).</td></tr>
<tr><td>Technical rooftop potential</td><td colspan="2">It is estimated by ADEME, a leading government research institute, that the total rooftop PV potential in France is approximate 45GW, or approximately 35% of total potential PV capacity. Annually, this would represent more than of 45TWh per year, or approximately 9% of current electricity demand (ADEME, 2011).</td></tr>
<tr><td>Adoption behaviour</td><td colspan="2">Support for renewable energy, and for solar PV in particular, remains strong in France with almost 90% of residents supportive of solar PV, and 92% in favour of the continued development of renewable energy sources, according to a 2013 survey (Ipsos, 2013).
Current PV development in France is driven primarily by the support policy (FIT + purchase obligation), which remains in place for small renewable energy projects.</td></tr>
<tr><td>Avg. residential installed cost (2013)</td><td>€/Watt</td><td>Between €2.20 – 3.00/W Installed (SER and SOLER, 2013)</td></tr>
<tr><td>Electricity retail rates</td><td>Average electricity retail price</td><td>Approximately €0.147/kWh. This represents an increase of approximately 4% over 2013; a further tariff increase of approximately 5% is expected in August of 2014 (Fournisseurs-électricité, 2014b; MEDDE, 2013).</td></tr>
</table>

France		Data
		• Projections regarding future rate increases remains uncertain, but are estimated at between 2% and 6% per year through 2017 (Fournisseurs-électricité, 2014a). However, due to the important role of the government in allowing or suppressing rate increases, any forecast of future electricity rates in France remains speculative.
	Are there fixed (i.e. non-volumetric) charges?	Yes. Residential tariffs in France include a fixed charge set by the government that represents the cost of connecting to the network ("frais d'abonnement") (MEDDE, 2013). This charge varies depending on the size of the connection to the network (e.g. 3kVA costs approximately €65/year, 6kVA costs €78/year, etc.) (Jechange.fr, 2014).  Source: (MEDDE, 2013)
	Applicable self-consumption taxes	There is currently no tax on electricity self-consumption in France.
	Time-of-Use tariffs	There is currently a time-of-use tariff option offered by EDF to residential customers aimed at peak shaving ("effacement de demande"), but it is focused on flattening seasonal rather than hourly variations in demand. A higher tariff is charged during a specified number of days (22) between November 1st and March 31st of each year (EDF, 2014). Customers are notified via email or SMS a day or two in advance when the next higher cost day will occur.
Insolation	3.12 kWh/m^2/day (Average daily output for 2013) Up to 4.27 kWh/m^2/day in the Rhône-Alps Region (Chabot, 2014)[49]	Insolation rates in France are average by global standards, but in southern regions, they are stronger than in neighboring markets such as Germany and the Netherlands.

[49] *See also* http://maps.nrel.gov/global_re_opportunity

<table>
<tr><th>France</th><th colspan="2">Data</th></tr>
<tr><td>Self-consumption profile</td><td colspan="2">A study conducted by SER, one of the leading unions representing the renewable energy industry in France, shows that the average self-consumption ratio could range from 20-40% depending on the region, usage patterns, and the installation type (SER and SOLER, 2013).

Stylized Self-Consumption Profile (Model) for an individual Household


</td></tr>
<tr><td rowspan="3">Residential PV Policies</td><td>Interconnection</td><td>Solar PV systems are allowed to connect to the network once they receive the required permits and regulatory approvals.</td></tr>
<tr><td>Feed-in of onsite generation</td><td>France offers a purchase obligation for solar PV generation and guarantees the right to feed electricity into the grid; producers must comply with the terms established in the country's FIT policy.</td></tr>
<tr><td>Treatment of excess generation</td><td>• The tariff is paid to 100% of output from the system. France FIT policy includes a schedule of tariff degression according to which the price paid for the solar output of systems declines on a quarterly basis based on the attainment of targets during the previous quarter. If the governmental targets are achieved, tariff degression of up to 10% is automatically applied (MEDDE, 2013). For reference, a FIT of €0.285/kWh was offered to building-integrated solar PV projects under 9kW up to March 31 2014 (Photovoltaique.info, 2014a).
• France has a unique policy framework governing solar PV systems, with different tariffs for fully integrated, simply integrated, and ground-mounted systems. The highest tariffs are offered for installations that meet the fully building-integrated system criteria under which the solar modules themselves must fully replace the roof or wall structure, the installation as a whole must meet the criteria of water- and air-tightness ('étanchéité'), and the installation itself must be located on fully enclosed buildings. Slightly lower tariffs are offered to PV projects that adopt the simplified building integration approach, where the solar PV system can be place on and above the roof or wall structure. Eligible simplified systems must also be in the same plane as the roof structure and must not exceed specific height thresholds designated for a wide range of specific building materials (CEIAB, 2014). A significantly lower tariff is also offered for ground-mounted or freestanding systems.</td></tr>
</table>

France	Data
Status of other technological developments that could facilitate prosumers:	• **Demand response**. There is a growing number of demand response initiatives currently underway in France (EDF, 2013; Nekrassov, 2010). In the spring of 2013, one demand response provider mobilized 550MW of capacity from larger industrial and commercial customers, helping stabilize the grid in response to fluctuations caused by sudden temperature changes (Roux Dit Riche, 2013). Currently, the majority of demand response efforts are focused on the commercial and industrial sectors. • **Battery and storage technologies.** Different storage pilot projects are ongoing in France, particularly on the country's overseas territories (MEDDE, 2013). Due to a 30% limit imposed on the share of variable renewables in the island territories such as Reunion Island, Martinique and Guadeloupe, future RE projects on these islands are for the moment largely ground-mounted and have been required to be equipped with storage solutions. • **Electric vehicles.** There are efforts to boost the adoption of electric vehicles in France, particularly in urban areas such as Paris. As of August 1 2012, France offers a number of cash grants depending on the vehicle type and model. Fully electric vehicles are offered a cash grant of up to €7.000 per vehicle, up to a maximum of 30% of the cost of the vehicle (Avere-France, 2014). A new car-sharing platform is also in place in Paris called 'Autolib', modeled on the successful bike-renting program 'Vélib'. It offers a subscription based service providing access to electric vehicles in the city, which can picked up at over 5.000 individual charging stations (Autolib, 2014). In addition, it is possible to plug one's own electric vehicle for free in at a growing number of designated parking sites.
Opportunities for Prosumers	Public support for renewable energy in general, and solar PV in particular, remains very strong in France (Ipsos, 2013). There is considerable potential for an increased localization of the electricity system, driven by distributed technologies like solar PV and leadership at the local level. In recent years, local regions in France have begun developing more autonomy over their energy infrastructure, including renewable energy. A recent analysis of regional renewable energy strategies found that the sum of RE capacity potential assessed by the various regional authorities totaled 15.500MW by 2020 (including residential, commercial, as well as large ground-mounted systems), or almost three times more than currently envisaged by the national strategy (Photovoltaique.info, 2014b). Based on the current breakdown of projects, this would suggest approximately 4.000MW of residential solar PV uptake. This indicates significant local and regional potential for the development of renewable energy technologies and may play an important role in driving future prosumer growth.
Challenges for other actors	The rapid growth of renewable energy projects (both prosumer and non-prosumer driven) poses challenges to the existing electricity industry in France. These challenges can be broken down into four key themes: 1) France's electricity mix remains dominated by nuclear power, which currently represents approximately 75% of total electricity supply. Compared to other generation technologies such as hydropower or natural gas, nuclear power plants are relatively inflexible, having difficulty adjusting their output rapidly and efficiently in response to shifting demand patterns. While this arguably does not pose a major challenge at the moment, it could make integrating higher volumes of variable renewable energy such as solar PV more challenging in the years ahead, particularly as the latter's share continues to grow. 2) Electricity demand in France is highly dependent on temperature patterns. This means that power demand peaks during the winter months, and overall when solar PV output is substantially lower. This increases the challenges of integrating large volumes of PV

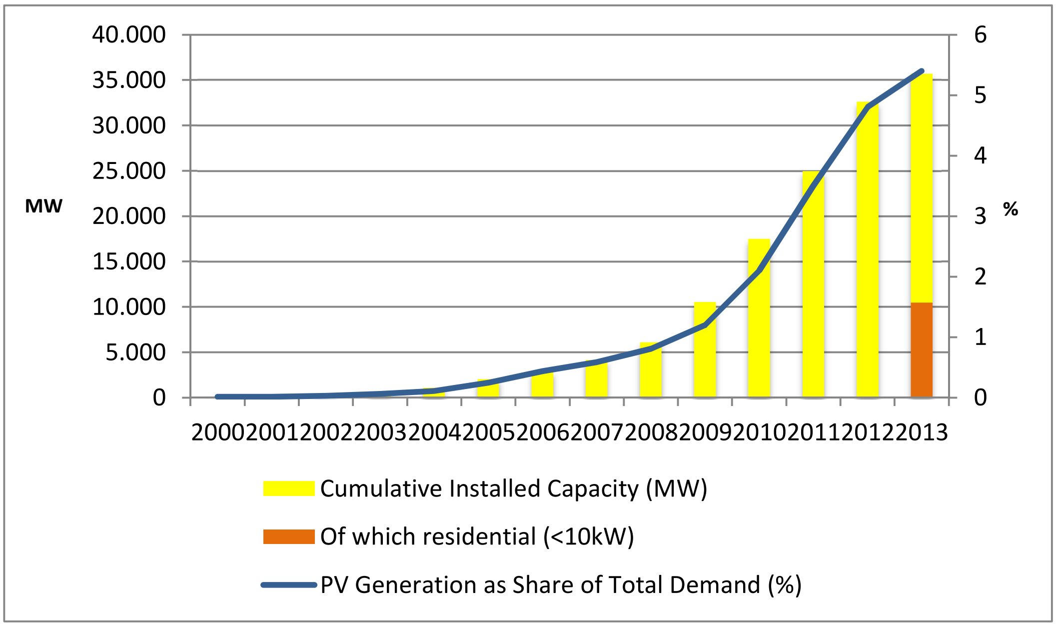
France	Data
	into the grid during the summer months, when PV output is at its highest, and demand is at its lowest. 3) Despite European Commission efforts to encourage liberalization of European power markets, France's electricity market remains largely dominated by EDF. Significant prosumer development could translate into a loss of revenues for EDF, ceteris paribus, due a decrease in electricity sales. In addition, mainland residential electricity tariffs are among the most profitable, which could increase the resistance to any further erosion of demand in this customer category. 4) Peak electricity demand in France is generally in the early evening (between 19:00 and 20:00), when solar output is on the decline. This negatively impacts the self-consumption ratio, and in turn, the economics of prosumers in France.
Current Government Strategy and Future Outlook	• In light of comparatively low residential retail prices, there is little risk of large-scale prosumer growth in the near term. However, the government has launched a multi-stakeholder taskforce, piloted by the General Directorate of Energy and Climate Change (DGEC), to understand the opportunities and risks associated with the emergence of prosumers. First results are expected in the summer of 2014. • The establishment of a stakeholder Task Force demonstrates that France is making a concerted effort to develop a coherent strategy for the future evolution of prosumers in the country. • According to one of the leading industry groups taking part in the Task Force, a new and more conducive regulatory framework will be required in order for the prosumer sector to scale-up (SER and SOLER, 2013).

6.4 GERMANY

<table>
<tr><th>Germany</th><th>Data</th></tr>
<tr><td>
PV Statistics</td><td>

- Solar PV represented 4.5% of total electricity demand in 2013 (AG Energiebilanzen, 2013).
- In 2013 alone, about 500 MW of solar PV under 10kW were installed (more than 80,000 projects). In total, there are more than 1.4 million solar PV producers in Germany. Total installed solar PV capacity is more than 35 GW) and 29% (or 10.5 GW) is below 10 kW (Wirth, 2014)

Accumulated Installed PV Capacity in Germany (MW); Share of Total Electricity Demand



</td></tr>
<tr><td>Demand projections</td><td>Due in part to energy efficiency and conservation, electricity demand in Germany is stable or slightly declining. Official (non-binding) targets aim for a 10% reduction in total electricity demand between 2010 and 2020 (Scheuer, 2011). Currently, the total installed generation capacity in Germany stands at 175 GW, approximately 36GW (21%) of which is solar PV. Peak demand in Germany is roughly 85 GW.</td></tr>
<tr><td>Technical rooftop potential</td><td>The technical potential for roof mounted solar PV systems in Germany is estimated at about 161 GW (Lödl et al., 2010).</td></tr>
<tr><td>Adoption Behavior</td><td>

- National polls consistently show very high support for renewable energy: 93% support an increasing share of renewables, while 47% of Germans have expressed a clear willingness to pay more for the transformation of the energy system (the 'Energiewende').[50]
- While the market has historically been almost exclusively driven by the national feed-in tariff, there have been signs of "guerrilla" PV in certain regions: homeowners installing small, behind-the-meter solar PV arrays in order to displace daytime loads. The

</td></tr>
</table>

[50] *See, e.g.*, https://www.erneuerbare-jetzt.de/aktionen/akzeptanzumfrage/

Germany	Data	
	economics of doing so can be attractive, as homeowners erase daytime power needs, which cost approximately €0.29/kWh to supply with onsite PV that can be produced for approximately €0.14/kWh.	
Avg. residential installed cost (2013)	€/watt	• 7-kW-System: 1300 - 1480 €/kW • 2-kW-System: 1600 - 2060 €/kW Note that these numbers have declined slightly since 2013 (Quaschning, 2013).
Electricity retail rates	Average electricity retail price	Approximately €0.29/kWh This rate includes the following taxes and surcharges: • Eco Tax of 2.05 €cent/kWh • Value Added Tax of 19% on lump sum electricity price: 4.6 €cent/kWh • EEG surcharge ('Umlage'): 6,24 €cent/kWh • Surcharge for CHP support: 0,115 €cent/kWh • Grid usage fee correction surcharge: 0,337€cent/kWh • Surcharge for wind offshore liability (in the case of belayed grid connection): 0,25 €cent/kWh
	Are there fixed (i.e. non-volumetric) charges?	• For the residential sector, grid usage fees ('Netzentgelte') amounted to 6.52 €cent/kWh as of 2013 (Statista, 2014). About 21% of those costs are fixed. Concession fees (Konzessionsabgaben) depend of the size of each community and amount up to 2.39 €cent/kWh. • Additional fixed charges can also be included in the rate structure of each supply company (retail competition)
	Applicable Self-Consumption Taxes	As of May 2014, there is no tax on self-consumed solar power in Germany. However, in the proposed amendments to the Renewable Energy Sources Act, a charge has been included that would require individual prosumers with projects larger than 10kW to pay 50% of the EEG surcharge (Umlage) on the self-consumed electricity, which currently stands at €6.24 cents/kWh. In May 2014, the Bundesrat ("Federal Council" – Upper House of the Parliament) proposed to limit the EEG surcharge on self-consumed electricity to 15% (approximately 1 €cent/kWh). Although the provision has yet to be formally passed into law, the current draft suggests that prosumers under 10kW will remain exempt.
	Time-of-Use Tariffs	There are currently only pilot projects for time-of-use tariffs for residential households in Germany.
Insolation	3.10 kWh/m²/d (Saxony)[51]	Insolation rates in Germany are below average by global standards.
Self-consumption		• Self-consumption ratios depend on demand patterns and system size. For larger-scale systems (6kW-systems) 30% of self-consumption is feasible without any adjustments to demand patterns. For smaller scale

[51] *See* http://maps.nrel.gov/global_re_opportunity

<table>
<tr><th>Germany</th><th colspan="2">Data</th></tr>
<tr><td>profile</td><td></td><td>systems (2kW) self-consumption rates of 50% are feasible.
• Higher self-consumption rates can be achieved by combining PV systems with battery system (Quaschning et al., 2014).</td></tr>
<tr><td rowspan="3">Residential Policies</td><td>Interconnection</td><td>Guaranteed and priority interconnection for renewable energy projects, with grid upgrade costs recovered from ratepayers (rather than generators).</td></tr>
<tr><td>Feed-in of onsite generation</td><td>Germany offers priority purchase and dispatch of solar PV generation based on the German Renewable Energy Sources Act (the EEG).</td></tr>
<tr><td>Treatment of excess generation</td><td>• Excess generation can be sold under FIT regime (100% for all systems smaller 10 kW, 90% of excess electricity for systems between 10 kW and 1000 kW). The current government proposal foresees that in the future all excess electricity can be sold to the grid again.
• Under current rules, it can also be self-consumed, sold directly into the wholesale market, or sold bilaterally to aggregators or others.
• It is worth noting that current FIT rates (13.28 €cent/kWh as of April 2014 for systems smaller 10 kW) are considerably below retail rates, which average 29 €cent/kWh (Bundesnetzagentur, 2014).</td></tr>
<tr><td>Status of parallel technological developments that could facilitate prosumers:</td><td colspan="2">• Demand response. There are a few pilots underway at regional level. However, there has not yet been a large-scale role out of smart meters and German costumers tend to be critical because of privacy-related concerns.
• Batteries. In May 2013, Germany started a market-incentive program to store solar PV electricity. Producers receive up to 600 €/kWp for battery storage with a maximum of 2000 € per installation (BSW, 2013b). Also, many communities in Germany as well as local municipal utilities are beginning to experiment with small-scale battery systems in order to help smooth out fluctuations in solar output (EnBW, 2014).
• Electric vehicles. The market is currently small (about 13,000 electric vehicles in Germany) but there is an ambitious Government objective of 1 Million electric cars by 2020 and 6 million cars by 2030.</td></tr>
<tr><td>Opportunities for prosumers</td><td colspan="2">• High retail prices combined with low installed costs (and constantly falling FIT payment levels) create an opportunity for non-incentivized solar PV on residential homes. Currently, small-scale systems (e.g. 2 kW) are considered to be economically viable without feeding excess electricity into the grid – in other words, a positive return on investment can be achieved simply by consuming one's own on-site PV generation during the daytime instead of purchasing power from the grid. In fact, the feed-in tariff rates are now so low in Germany that system profitability can be significantly improved by consuming a portion of power onsite.
• Historically, small-scale and citizen-owned renewable energy producers have been at the heart of the German energy transition. About 50% of all renewable energy installations are owned and financed by small-scale power producers, community cooperatives, and private citizens. Some researchers have argued that citizen engagement (in particular</td></tr>
</table>

Germany	Data
	citizen *financial* engagement) is an important component of maintaining public support for the energy transition (Jacobs et al., 2013). In the absence of supportive policy frameworks at the national level, prosumer-driven PV could become one of the primary ways through which citizens contribute to the energy transition in the years ahead. • Certain communities and villages in Germany are serving all of their own needs at the distribution level. However, these so-called "100% regions" are still connected to the bulk power grid. Nonetheless, these local initiatives could become a supportive factor in the years ahead, as communities seek to become increasingly self-sufficient, either individually, or in cooperation with their municipal utilities.
Challenges for other actors	• **Electricity producers.** Existing power plants are facing lower revenues from spot market sales – partly due to an increase of renewable energy sources and partly due to increasing over-capacity in the German and European electricity market. These factors have depressed wholesale market prices, a trend that shows no signs of abating. • **Consumers (non-prosumers).** One of the major challenges for politicians in Germany is the establishment of a fair and transparent cost-sharing methodology for the energy transition. A central part of this debate as it relates to prosumers has been the proposal to require prosumers to pay a portion of the EEG surcharge. The current draft of the EEG 2014 would require prosumers to pay approximately 70% of the EEG surcharge (4.4 €cent/kWh for all installations larger than 10 kW or for residences whose self-consumption exceeds 10 MWh per year). • **Cost shifting.** Currently, approximately € 20 billion needs to be refinanced annually via the EEG surcharge. A major concern is that as the number of consumers who are exempt from paying the surcharge grows (e.g. energy-intensive industries), and a growing number of customers reduce their demand through energy efficiency, or via self-consumption (e.g. prosumers), the higher the surcharge will have to be for remaining consumers. This has pushed the government to look for ways to broaden the base of ratepayers contributing to the surcharge, partly by reducing the number of exempt industrial customers, and partly by requiring prosumers to contribute directly. If the draft law passes in its current form, this would negatively impact the economics of PV prosumers. From a legal perspective, however, it is not yet clear whether it is constitutional for policy makers to require prosumers to pay surcharges on self-consumed electricity. This issue will likely be debated in the courts in the coming years.
Current Government Strategy and Future Outlook	The current government's plan aims to discontinue FITs for solar PV when a total of 52 GW of installed PV capacity is reached. In the meantime, a soft cap of 2.5GW per year has been introduced and remains linked to a responsive degression framework, which sees the FIT payment decline on a monthly basis (DBCCA, 2012). The government is also planning a number of other changes in order to manage the rise of PV prosumers in Germany (BMWi 2014): • **Increasing fixed charges for grid usage fees.** Grid usage fees will very likely include higher non-volumetric payments (based on the maximum power demand of one household); this will require a reform to the structure of electricity rates. Currently, grid usage fees are paid on a per kWh basis (i.e. volumetrically), which encourages self-consumption. • **Develop a new support framework.** The current policy design for solar PV (the feed-in

Germany	Data
	tariff mechanism) is scheduled to be discontinued when 52 GW of PV have been installed. This target will likely be met in 2016 or shortly thereafter. It is not yet clear what conditions will govern the sale of excess electricity generation from PV systems after this point. Other than small-scale prosumers up to 10 kW in size, there is increasing interest for self-consumption of solar PV in the commercial and industrial sector. Especially for medium scale industrial consumers (which face retail electricity prices of approximately 15 €cent/kWh), self-consumption of solar PV is increasingly financially attractive (Solarpraxis, 2013). It remains to be seen how policies to adapt to the rise of prosumers at the household level will impact those governing industrial and commercial self-consumption.

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APPENDIX

The following table gives an example of how stakeholder - driver analysis could be carried out.

Drivers / Stakeholders	Positive/negative	Prosumers	PV Supply Sector	Governments	Utilities	TSOs
Economic	+	Save money	Make (more) money	Bring down costs of elec supply	Grow through new business models	Save on grid extension costs
	+		Propose the creation of new jobs	Seek the creation of new jobs		
	+			Seek security of supply		
	+ / -	Self consumption ratio				
	+ / -	Own home fit for PV				
	+ / -	Own insolation level				
	-			Avoid costs of (keeping) incentives schemes	Avoid cannibalising existing business models	Avoid increased costs
	-			Avoid losing taxes revenues		Avoid lower revenues
	-					
Behaviour	+	Perceicve PV as "cool"		Action against climate change	Green its bottom line	Green its bottom line
	+	Increase sense of independence				
	+	Show status and prestige				
	+ / -	Trust in local policies		Capture political return (1 rooftop equals >1,5 votes)	Openness to change	Openness to change
	-	Perceive as hassle/unsafe to install/maintain				
	-					
	-					
Techno-logy	+	Possibility of doing it oneself	Differentiate through more competitive offers	Take leadership position	Take leadership position	Take leadership position
	+	Interest for technology	Put techn breakthroughs on the market (PV, smart grids, storage…)			
	+					
	+ / -					
	-			Address safety concerns	Address supply concerns	Address supply concerns
	-					Address grid safety concerns
	-					
National Conditions	+ / -	Administrative burden	Lobbying power	Existing regulatory framework	Supply obligations	Supply obligations
		Residential buildings fit for PV		Residential buildings fit for PV	Degree of concentration	Degree of concentration
	+ / -				Compensation structure	Compensation structure
	+ / -				Fit of existing infrastructure	Fit of existing infrastructure