PV DEVELOPMENT AS PROSUMERS: THE ROLE AND CHALLENGES ASSOCIATED TO PRODUCING AND SELF-CONSUMING PV ELECTRICITY

Ir. Gaëtan Masson - IEA PVPS, France, g.masson@iea-pvps.org
Sinead Orlandi - Becquerel Institute, Belgium, s.orlandi@becquerelinstitute.org
Kristian Petrick - IEA-RETD, Spain, kristian.petrick@allgreenenergies.org
Valerick Cassagne – Total SA, France valerick.cassagne@total.com
José Ignacio Briano - Eclareon, Spain jib@eclareon.com
Maria Jesus Baez Morandi - Eclareon, Spain mjb@eclareon.com
Robert Margolis – NREL, USA, Robert.Margolis@nrel.gov
Wilson Rickerson - MCG, USA, wilson.rickerson@mc-group.com

ABSTRACT: Direct compensation mechanisms are based on the idea that PV electricity can be used first for local consumption and that this electricity shouldn't be bought to utilities. The part of the bill that can be compensated depends on several options that are used differently depending on countries or regions; this receives various names depending on policy options, from self-consumption schemes to net-metering or net-billing schemes.

But all these schemes refer to the same underlying idea: PV producers who consume a part of the electricity produced should be considered as "prosumers": consumers who are also producers of their own electricity.

While prosumers are not linked to a particular technology, PV systems represents today the majority technology that is used.

This paper summarizes two parallel studies focusing on the development of PV prosumers through self-consumption mechanisms: one currently developed by the IEA-RETD Implementing Agreement of the International Energy Agency and a second one developed by the PVPS implementing agreement of the International Energy Agency (to be published Q4 2014). This summary will be augmented with additional information regarding the impact of self-consumption on possible business models for PV development with reduced financial support.

1 Structure of the work

1.1 Prosumers under self-consumption of PV electricity: generalities & definitions

Traditionally, the same wording is used for compensation schemes with different definitions. In order to clarify the misuse of concepts such as "net-metering", "net-billing" and "self-consumption", we will use the following ones in this paper.

Self-consumption: the possibility for any electricity consumer to install a PV system with a capacity corresponding to his consumption in order to self-consume part of the PV electricity generation, and receive a compensation for the excess PV generation fed to the grid. A self-consumption scheme is a real-time compensation mechanism (e.g. per 15 minutes[1]). The wording "self-use" is similar.

Net-metering: a simple billing arrangement that ensures consumers who operate PV systems receive one for one credit for any electricity their systems generate in excess of the amount consumed within a billing period. In this case, production and consumption are compensated over a longer period (up to one year) than under a self-consumption scheme. Under net-metering, all kWh of PV generation are equally valorised.

Net-billing: an arrangement by which the consumer receives one-for-one monetary credits for every kWh of excess PV generation he injects into the grid. Every kWh is valorised at its corresponding price, depending on when it was exported. Credits are awarded over a determined time-frame, typically one year. It is equivalent to a net-metering scheme but with monetary compensation instead of energy compensation.

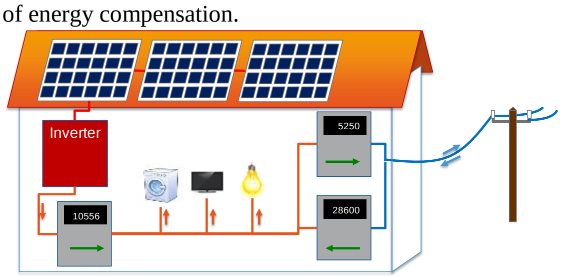

Figure 1: self-consumption energies flows

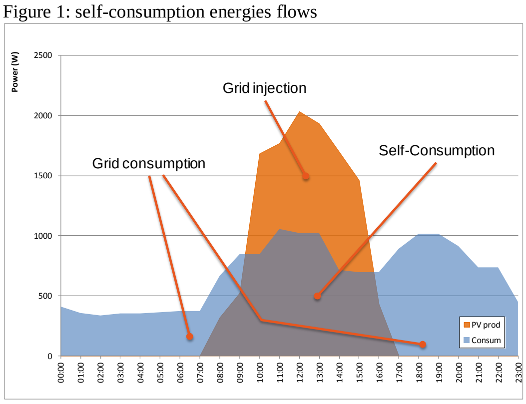

Figure 2: comparison of production and consumption profiles

[1] The unitary balancing period is typically 15 minutes, but can be longer in some countries.

1.2 Description of categories of self-consumption schemes

The existing business models that are being implemented worldwide vary depending on several parameters. The following classification aims at defining building blocks that will characterize compensation schemes according to the specifics.

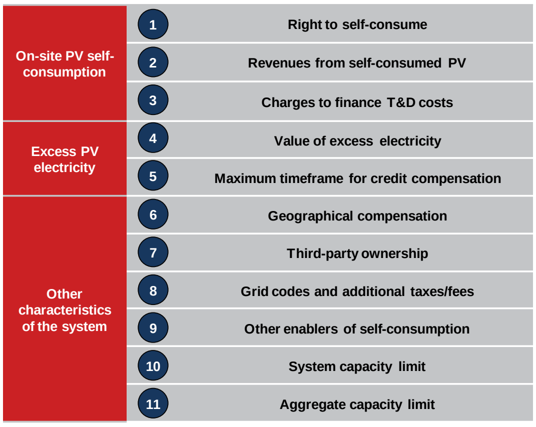

Figure 3: Main parameters defining a self-consumption scheme

These parameters will be used to analyse the current situation in different markets and to define the most common range of self-consumption incentives. Each parameter is described below:

- Right to self-consume

- Does the electricity consumer have the legal right to connect a PV system to the grid and self-consume a part of its PV-generated electricity?

- Revenues from self-consumed PV

- What are the revenues from each kWh of on-site self-consumed PV? (e.g. bill savings from the displaced electricity from the grid, or bill savings plus additional inflows such as a self-consumption bonus and green certificates[2]).

- Charges to finance T&D costs

- Does the self-consumer have to pay additional taxes or fees that an electricity consumer normally does not have to pay? (e.g. specific fees per kW of installed solar or per kWh of PV self-consumption).

- Value of excess electricity

- What is the value of the excess electricity (PV electricity not consumed on-site) fed into the grid? Examples include:

- Credits to compensate the bill through a net-billing scheme (economic credits) or through a net-metering scheme (energy credits).

- Payment through traditional support schemes such as feed-in tariff (FiT) and green certificates (GC).

- Market price through some regulated or market tariff.

- No value

- Electricity is injected into the grid but not remunerated
- Electricity is not injected into the grid (and lost).
- Maximum timeframe for credit compensation

- If applicable, what is the maximum timeframe during which compensation is permitted? (e.g. real-time, 15 minutes, a day, a month, a year, or indefinitely).

- Geographical compensation

- Are consumption and generation allowed to be compensated under other mechanisms apart from purely on site? (e.g. “Virtual net-Metering”, “Meter Aggregation”, and “Peer to Peer”).

- Regulatory scheme duration

- For how long are the conditions (net-metering, FiT, etc.) of the regulatory scheme guaranteed for?

- Third-party ownership

- Are there laws permitting total ownership of the generation asset by a third-party? (e.g. through structures such as leases and PPAs).

- Grid codes and additional taxes/fees of self-consumption

- Are there additional costs and requirements to consider when installing a PV system for self-consumption? (e.g. grid code requirements such as phase balancing, frequency-based power reduction, reactive power control, voltage dips, inverter reconnection conditions, output power control, among others, or taxes/fees such as a specific tax on PV generation).

- Other enablers of self-consumption

- Are there additional supports to self-consumption such as a storage bonus, demand side management, or electricity rates with TOU/tiers[3]?

- System capacity limit

- Which is the eligible capacity limit (and consumer segment, if applicable) under the incentive?

- Aggregate capacity limit

- Is there any maximum PV generating capacity allowed? If so, which one?

Having defined the most relevant parameters of support schemes, the following Figure summarizes the main characteristics of the compensation schemes under study: self-consumption, net metering, and net billing:

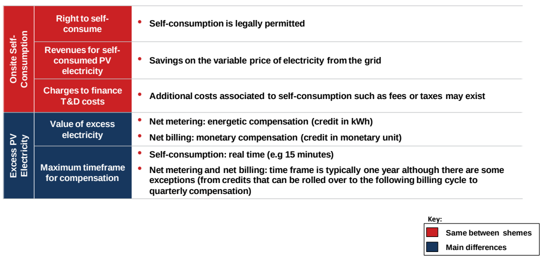

Figure 4: Main parameters defining excess electricity and on-site self-consumption

As shown above, the main differences between these schemes are associated to the compensation of excess PV generation. While under self-consumption the balancing period is in real time, under net billing and net metering

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[2] Green certificates not only compensate on-site self-consumed PV but also the excess electricity injected into the grid.

[3] PV production usually takes place during peak hours, therefore TOU rates may allow for a higher saving/revenue (at least as long as the amount of PV-generated electricity does not depress mid-day market prices). Tiered rates also result in higher savings, as self-consumed PV electricity replaces electricity from the grid values at a higher price.

the prosumer receives credits (monetary and energetic, respectively) as compensation for each kWh of excess PV.

1.3 Analysis of existing self-consumption schemes

From the Table 1 here below, 5 cases will be described in more detail with the aim of clarifying the range of existing schemes.

Spain

• In Spain, PV self-consumption is legally permitted (i.e. any electricity consumer can invest in a PV system for self-consumption).

- However, there is neither a feed-in tariff scheme nor a net-metering (or comparable) mechanism in place, to compensate self-consumers for their excess PV generation. In addition procedures are complex and costly.

• There are two main categories of grid-connected PV systems for self-consumption:

- Systems for consumers connected to the grid but without energy injections to the grid, which can exceed 100 kW.

- System with energy injections where prosumers can sell the excess

- Electricity in the spot market through a market representative[4].The required administrative procedures depend on the installed capacity (below or over 100 kW) and the voltage level (low to high voltage).

• The latest law proposal (July 2013) for the self-consumption market totally de-motivates the installation of these PV systems. The measures designed by the Government, which could go into effect this year, include:

- No compensation for the excess PV generation fed into the grid.

- A fee charged for every kWh of PV self-consumption.

Germany

• In Germany, self-consumption is legally permitted under the Renewable Energy Act (EEG, acronym in German).

• Germany's EEG FiT program has been recently modified, eliminating the former self-consumption bonus.

- Historically, PV owners were encouraged to self-consume PV-generated electricity with a premium paid for each kWh of self-consumed PV electricity.

• Instead, a "market integration model" is in place, which restricts the percentage of the yearly power production entitled to receive the tariff.

- For installations with a capacity of 10 – 1,000 kWp only 90% of the yearly-generated electricity will receive the tariff, the remaining energy should be either self-consumed or sold at market value.

• Although the self-consumption premium was eliminated, FiT levels make feeding PV electricity into the grid less attractive than self-consumption since FiT for small-scale systems are currently lower than the retail electricity price.

• Recently, a grid charge on self-consumption (a percentage of the EEG) has been introduced.

Germany has introduced an energy storage incentive program that provides owners of systems up to 30 kW with a 30% rebate and low interest loans from KfW (German development bank).

Italy

• The Conto Energia (FiT scheme) and the self-consumption premium were stopped on July 2013, as the set budget was reached. The Scambio Sul Posto (SSP) net-billing mechanism remains the only incentive for self-consumption.

• The SSP allows users with PV systems under 200 kW to obtain credits used to offset their electricity bill for each PV kWh fed into the grid.

- The amount of the SSP grant includes an "Energy Quota" that varies with the value of energy exchanged and a "Service Quota", updated regularly, that depends on the cost of services and the energy exchanged.

- Net-billing is only possible when the owner of the PV system and the self-consumer are the same entity (i.e. it is not possible to have net-metering when the plant's owner is a third party).

- It should be noted that this mechanism is currently under discussion among Italian regulators.

• Moreover, the new law on PPA (SEU, Sistema Efficiente di Utenza) allows the direct sale of electricity to the final consumer in the residential and commercial sector, although in most cases the excess PV electricity will be fed to the grid and receive a much lower price than the retail price of electricity.

Mexico

• A net-metering mechanism (Medición Neta) was created in 2007 for renewable energy based systems under 500 kW.

- It allows the users to feed into the grid part of their electricity and to receive credits (in kWh) for it, used to offset their electricity bill.

• Since 2012, net metering is also available to multi-family housing.

- Each tenant will pay the difference between its individual consumption from the grid and the specific PV-generated electricity allocated by the CFE to that tenant's utility account, according to a pre-arranged share.

• For non-residential consumers, there is the incentive of an accelerated depreciation of the investment.

• For larger installations, a reduced and distance-independent transmission fee allows users to "self-consume" electricity generated by a PV installation that can be located thousands of kilometres away from the energy consumer.

USA

• In the USA, depending on the state there are different regulatory policies for self-consumption.

- The most popular scheme is net-metering, since 43 states have adopted it already, although the characteristics of each regulation differ (some States such as Arizona and Idaho charge a monthly fixed fee, others allow remote or aggregated net-metering).

- A small number of cities or jurisdictions have adopted FiT or "Value of Solar" tariff in their service territories.

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[4] In most cases this option is not economically viable for residential consumers.

- Certain markets allow PV systems to sell into the wholesale market.

Country	Scheme type	Comments	SC incentive?[5]
Australia	Feed-in-tariff	The FiT is lower than the retail electricity price.	□
Belgium	Net-metering	Brussels and Wallonia also have Green Certificates.	□
Brazil	Net-metering	Virtual net-metering is available.	□
Canada (Ontario)	Net-metering and FiT	Also a FiT scheme, with a compensation higher than retail electricity price.	□
Chile	Net-billing (expected)	The technical note is pending.	□
China	Feed-in-tariff	FiT equal to the wholesale electricity price plus a bonus.	□
Denmark	Feed-in-tariff	The FiT is lower than the retail electricity price.	□
France	Feed-in-tariff	FiT above retail electricity price. Self-consumption is not being incentivized.	□
Germany	Feed-in-tariff	The FiT is lower than the retail electricity price.	□
Israel	Net-metering	T&D costs are subtracted from the credits.	□
Italy	Net-billing	Quarterly compensation.	□
Japan	Feed-in-tariff	FiT above retail electricity price. Self-consumption is not being incentivized.	□
Mexico	Net-metering	Virtual net-metering is available.	□
Spain	Self-consumption	PV excesses are not compensated but are charged to cover T&D costs	□
Switzerland	Feed-in-tariff	The FiT is lower than the retail electricity price.	□
The Netherlands	Net-metering	For up to 5 MW/h per year.	□
United Kingdom	Generation + Export tariff	A generation tariff remunerates PV generation and an export tariff is added to electricity exported to the grid.	□
USA (California)	Net-metering	Positive balances at the end of each year can be either cashed in or rolled over.	□

Table 1: Summary of analysed self-consumption schemes

[5] A "tick" refers to the situations where the prosumer is better off by consuming PV electricity onsite rather than by exporting the electricity to the grid (and receive a compensation for that electricity).

1.4 Self-consumption ratios and the optimization of PV system size

The two main ratios that can describe a self-consumption operation are:

- PV production self-consumed (PSC): it corresponds to the PV energy produced which is consumed locally divided by the total PV production. The complement to this ratio is the energy which injected to the grid divided by total production.
- The consumption coverage (CC): it is the ratio between the PV energy produced which is consumed locally and the total consumption of the site.

The link between these energy amounts can be completed by these equations:

Total PV production = PV energy produced which is consumed locally + PV energy produced which is injected to the grid

Total site consumption = PV energy produced which is consumed locally + energy drawn from the grid

These calculations are done usually on a full year base as both PV production and site consumption are seasonally periodical. These ratios will of course be dependent of

- consumption profiles linked to
  - o Type of activity: large/small family household, industry, supermarket, etc.
  - o Local climate: cold (electrical heating), hot (air conditioning)
  - o Consumption behavior: cheap energy (strong consumption) or strict energy savings
- PV production profile parameter by
  - o Size of the PV system: the main element, a twice bigger system will generate a twice higher profile
  - o Location: the irradiance profile reflect the local climate
  - o The orientation will both affect the level of power and the bumps shifts

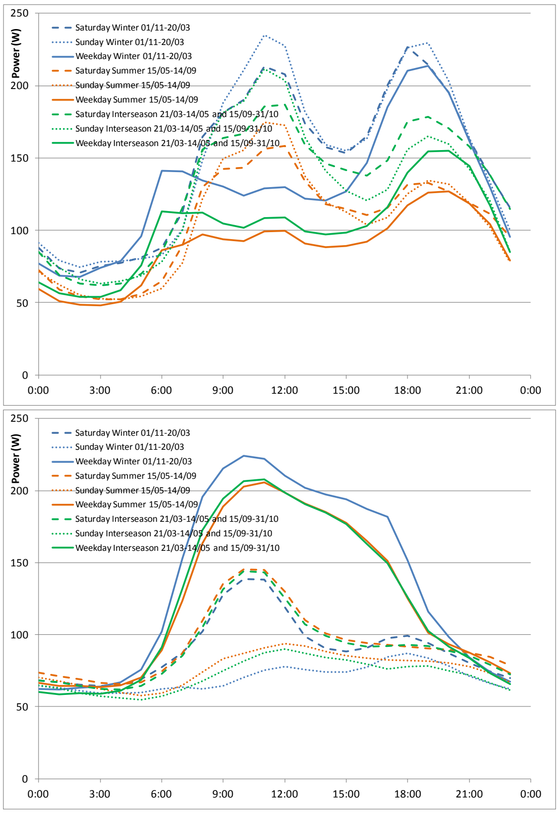

Figure 5: Consumption profiles of household and commercial activity in Germany (source E-On)

The ratios can be calculated as a function of the PV size (figure 2). For small PV system, the PSC is high, all (small) power produced is instantly locally consumed, on the other hand as the amount of energy is small, the CC ratio is small too: it covers a negligible part of the total consumption. In our case, we can notice a plateau of 100% PSC until 700Wp PV system size. Then when PV system is growing the consumption coverage increases but in parallel PSC starts decreasing, more and more energy is injected to the grid and the system produces more the consumption more and more frequently. On CC curve, a change of slope can be noticed around 3kWp, an increase of PV size doesn't bring a significant improvement of self-consumption: there is a saturation of consumption profile. Further, we can notice that there is a asymptote on CC: whatever if PV system size, the night consumption will never be covered directly by PV.

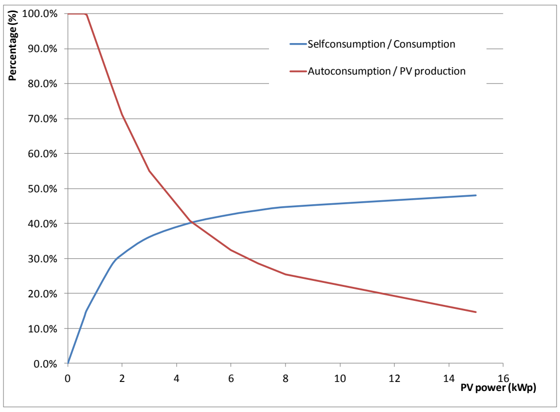

Figure 6: PSC and CC ratios for a residential case in Germany (consumption 4.5 MWH/year)

In this case, we can measure that for a typical 6 KWp system, 35% of produced electricity will be self-consumed (so 65% injected into the grid) and so it will cover about 45% of the total consumption.

The optimization of the system size (annual production and consumption equalized) and the use of demand side management tools, such as heat-pumps or decentralized storage system could increase the ratio to levels that depend on several factors. For example, moving loads to production peak (around noon) like washing machines or dish washer, increases CC by about absolute 5%. Reaching higher levels could require long term local storage. These relatively low levels can be explained by the low consumption during week days in the summer and high consumption in the winter at times when PV produces less electricity.

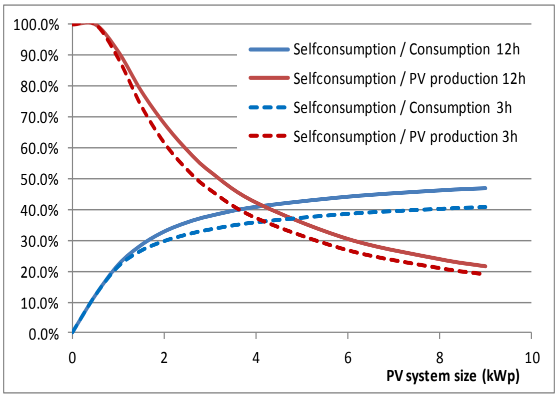

Figure 7: effect of moving washing machine or dish washer from night to noon on self-consumption ratios

On commercial or industrial rooftops, the self-consumption rates (PSC and CC) can be expected to be higher due to the better correlation between consumption and production: they are daytime activities and often using air conditioning. As commercial companies can have very different size, we then use the metric kWp installed by MWh consumed as variable to study the PV system size effect. The curves in figures 5 shows the higher self-consumption rates compared to residential.

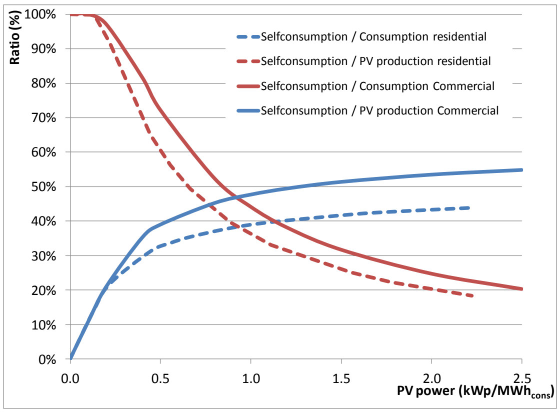

Figure 8: Self-consumption ratios comparing residential and commercial application in Germany

High self-consumption rates are thus technically feasible, under conditions of size limitation for instance and could therefore be considered as equivalent to net-metering schemes.

1.4 Analysis of self-consumption business cases

Among the business models analyzed, only 5 will be contrasted from an economic point of view. These cases by no means represent all possible alternatives, but intend to reflect the range of existing support variants, from a less attractive alternative for the prosumer to a more attractive one. The business models considered are defined next:

A. No compensation: Self-consumption without grid injections, and therefore no compensation for PV excesses.

B. FiT: Real-time self-consumption with a compensation (FiT) for the excess PV energy, which is below the retail rate of electricity (equal to the value of the wholesale electricity price), and TOU rates.

C. Net-billing: Net-billing mechanism, with quarterly compensation, and a remuneration for the remaining excesses after every 1-year period.

D. Net-metering: Net-metering, with annual compensation, and TOU rates.

E. Generation + FiT: Includes a generation tariff over self-consumed PV and excess PV, where the latter also receives an export tariff (while the former saves on the retail prices of electricity).

The implications of each Case regarding the cash flows associated to on-site PV self-consumption, excess PV generation, and consumption from the grid are illustrated below:

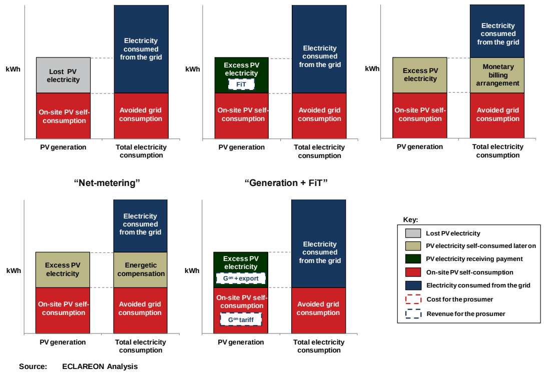

Figure 9: Illustration of annual PV generation and electricity consumption per Business Case

A financial model was created to estimate the economic impact of each Case on the prosumer. All the cases are analyzed assuming identical economic and environmental conditions, so as to isolate the effect of the regulatory framework for self-consumption on the economics of the investment (see table 2 in page 7).

With this aim, the following Base Case was set:

Parameter	Unit	Value	Comments
Retail rate with taxes			
Peak	*EUR/kWh*	*0.23*	-
Off peak	*EUR/kWh*	*0.19*	-
Standard	*EUR/kWh*	*0.22*	-
Estimated annual price increase of grid electricity	*%*	*2%*	Conservative estimate (the higher the price increase, the better the profitability of the investment for the prosumer)
Annual solar irradiation	*kWh/m2/yr*	*1,611*	Irradiation in Rome
Performance Ratio (PR)	*%*	*80%*	-
Size	*kW*	*3*	-
Turnkey cost	*EUR/Wp*	*2*	-
Annual degradation rate	*%*	*0.5%*	-
Lifetime of the investment	*Years*	*30*	-
Operating costs	*EUR/(kWp.yr)*	*20*	Includes annual O&M and insurance costs (5 EUR/kWp per year)
CPI	*%*	*2%*	It is assumed that operating costs grow according to the CPI
Inverter replacement	*EUR/W*	*0.26*	The inverter is replaced once during the lifetime of the PV system
Financing			
Leverage	*%*	*50%*	-
Interest rate	*%*	*7%*	A loan of 10 years is assumed
Discount rate	*%*	*7%*	
kWp/kW ratio	-	*1.15*	-

Table 2: Parameters used in the analysis

The results of the analysis are based only on this specific set of assumptions. To the extent that these parameters change under a specific reality, the actual results will be different from the ones presented here. Therefore, these results cannot be generalized to apply to other cases (instead, a case-by-case analysis is required).

To assess the attractiveness of a PV investment from the point of view of the prosumer under the 5 different states of the world under study, the following metrics were used:

- Net Present Value (NPV): a positive (negative) NPV indicates that the project is profitable (unprofitable).
- Simple payback period: all else being equal, a project is more (less) attractive if the payback period is lower (higher) than a particular desired term[6].

The following Figure shows the results for each business case:

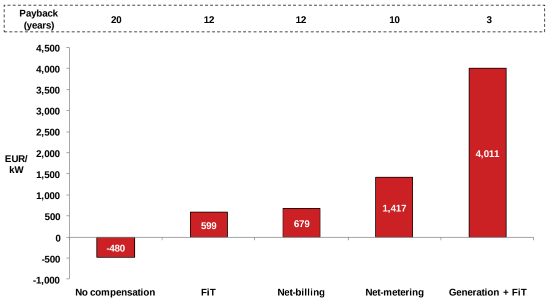

Figure 10: NPV per installed kW (30 years) for the prosumer per Business Case

The above results were to be expected, for the following reasons:

F. "No compensation" Case is unprofitable: the prosumer does not inject generation excesses into the grid and does not receive any compensation whatsoever for them. The only revenues (savings) the consumer achieves are those associated to the reduction of consumption from the grid, due to on-site PV self-consumption. Considering the period under analysis, such savings do not compensate for the investment in the PV system.

G. "FiT" Case is economically viable: for each kWh of PV on-site self-consumption, the prosumer saves on the full variable cost of electricity from the grid (plus taxes), and excess PV generation exported to the grid is valued at a price that is lower than the retail price of electricity.

H. "Net-billing" Case is economically viable: same as "FiT" Case but PV excesses are valued at a higher rate under net-billing.

I. "Net-metering" Case is attractive[7]: for each kWh of PV on-site self-consumption, the prosumer saves on the full variable cost of electricity from the grid (plus taxes), and excess PV generation exported to the grid is valued at a price that is equal to the retail price of electricity.

J. "Generation + FiT" Case represents a very attractive investment: for each kWh of PV on-site self-consumption, the prosumer not only saves on the full variable cost of electricity from the grid (plus taxes) but also receives an additional payment (the generation tariff). Moreover, excess PV generation exported to the grid is valued at a price that is higher than the retail price of electricity.

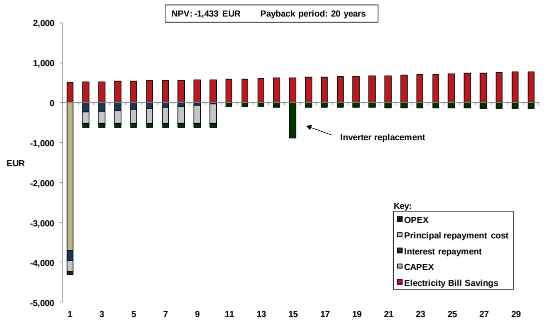

Figure 11: Annual cash flows for the prosumer under "No compensation

Under "No compensation", the prosumer receives no value for its generation excesses.

In contrast, within "Generation + FiT", not only there is a remuneration for generation excesses, but also there is a revenue, on top of the savings, associated to on-site PV consumption:

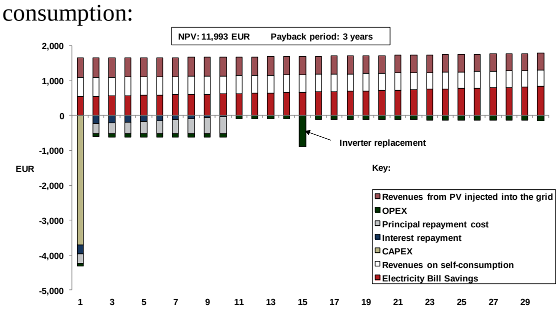

Figure 12: Annual cash flows for the prosumer under "Generation + FiT"

Under the specific assumptions made (mainly, current costs of PV and retail rates), the following conclusions can be extracted:

- The economic analysis from the perspective of the prosumer shows that "No compensation" is the only scenario where PV for self-consumption is an unprofitable investment.
  - This means that the number of PV installations generated under "No compensation" would be insignificant, as opposed to those under the other cases analysed.
- Even if the support scheme compensates for PV excesses injected to the grid at a value below the retail rate (e.g. "FiT" and "Net-billing"), the investment is still profitable for the prosumer.

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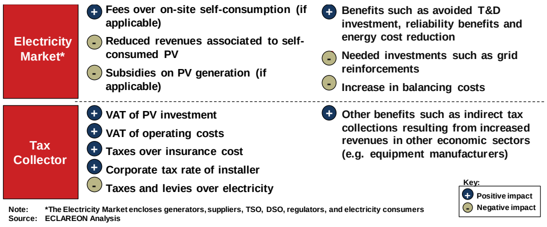
[6] This indicator should be used only in conjunction with other metric.

[7] For the sake of the analysis, an investment with a payback period lower than 10 years is regarded as attractive.

It should be noted that to fairly assess the economic sustainability of each Case, the impact on other stakeholders (chiefly, the Electricity Market and the Tax Collector) should also be acknowledged. The following Figure presents some of the differential cash flow components associated to PV self-consumption that can affect the electricity market and the tax collector.



1.5 Self-consumption market share

The following figure[8] illustrates the penetration of compensations schemes with regard to the current market development. The percentages are rather low compared to other incentives and especially Feed-in Tariffs. It must be noted that in this case, only markets where the compensation schemes have driven the market are considered. If we take the case of the residential market in Wallonia (Belgium), the net-metering system is complemented with green certificates which value makes harder to identify which of the net-metering and the certificates really drives the market.

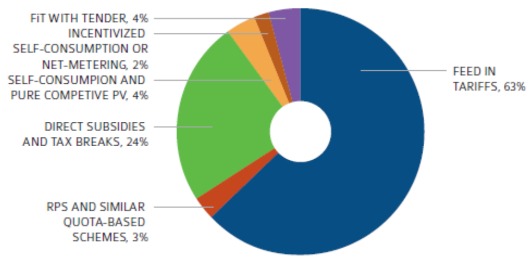


Figure 14: Long term trend in terms of main driving forces in the PV market.

It is worth highlighting that the reduced revenues of the Electricity Market (in particular, T&D) from the PV electricity that is self-consumed on-site could be equated to an energy conservation measure.

T&D and energy supply activities are obliged by the Energy Efficiency Directive (EED) to comply with certain yearly efficiency gains:

- DSO's must reduce losses (EED Article 15).
- Energy suppliers should achieve a 1.5% yearly reduction in total energy sales to their consumers (EED Article 7).

In this context, distributed generation would contribute to the fulfilment of their energy efficiency obligations.

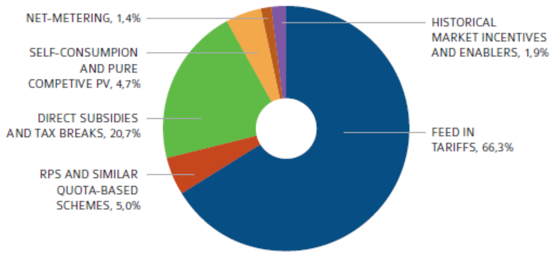


Figure 15: 2013 Trend in terms of main driving forces in the PV market.

The same situation occurs in several countries. Meanwhile some countries are using compensation schemes will small additional incentives in such a way they can be seen as secondary to the compensation scheme to drive the market. Self-consumption drives the market in some markets segments in Germany where the price of PV is lower than the retail price of electricity. Self-consumption is completed by a Feed-in Tariff for the excess PV electricity but it can be considered that a very large part of the rooftop segments in Germany are driven by self-consumption.

Net-metering and similar compensation schemes are driving the market in Denmark, the Netherlands, as we have seen in a part of Belgium and in Italy, for a part of the market. In the USA, more than 43 states plus the District of Columbia and Puerto Rico have implemented net-metering policies[9].It is uneasy to identify if the net-metering policies are the main driver op PV development in the rooftop segments in the USA, but for sure, they are contributing to its development.

The following table identifies driving market forces and the market size they represented in 2013.

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[8] IEA PVPS, Trends in Photovoltaic Applications 1992-2013 – September 2014 – Brussels, Belgium.

[9] IEA PVPS, National Survey Report of PV Applications in the USA - 2013

MW(DC)	Self-consumption without incentives	Net-metering and net-billing	Self-consumption with other incentives	Net-metering with other incentives	Other drivers
Australia			810,98		
Belgium		78,84		157,68	
Canada					444,51
China			800		12120
Denmark		155,6			
France					643,1
Germany	1222,85				2082,2
Israel				4	240,36
Italy		430		650	539,7
Japan			1366		5601,5
Korea			38		407
Netherlands		360,05			
Sweden	19,07				
UK			1020		526
Ukraine					290,2
USA				1911	2840
RoW					5300

Table 3: Driving market forces and the market size they represented in 2013

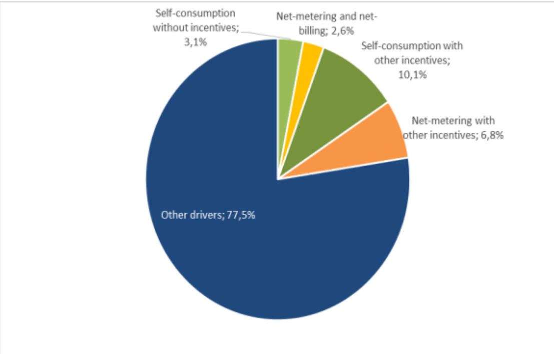

Figure 16: Different types of Self-consumption schemes

In a nutshell, 77% of the market in 2013 was driven by other support schemes than compensation ones. The share of PV installations driven by self-consumption, with or without incentives amounts to around 14% of the world market while net-metering (or net-billing) schemes can be considered as having driven more than 9% of the market. This can even be refined by considering that most large-scale PV installations inject 100% of their production on the grid. According to IEA-PVPS, the share of distributed PV in 2013 corresponded to around41% of the PV market (or 16 GW). The previous figure can then be interpreted in a different way that would say that compensation schemes represent in 2013 more than 55% of the decentralized PV market or in other words, more than half of the rooftop market all over the world.

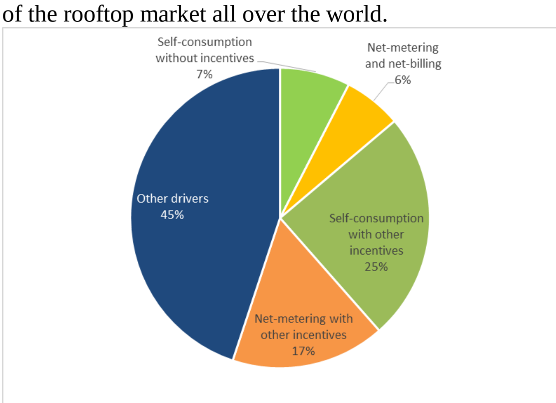

Figure 17: Different types of Self-consumption schemes

It is foreseeable that this trend will continue in a near future with many countries discussing about compensations schemes in order to replace or complement their current policies. Canada, France, Spain, and others will influence more and more the evolution of the drivers of PV in the decentralized PV segments.

1.6 Quantitative analysis of large-scale prosumers development and main challenges associated to such development, including grid and market impacts.

In the following the impact of a large-scale uptake of prosumers on grid financing and the cost for utilities in general will be discussed. Finally, a number of strategic pathways for policy makers will be proposed.

Widespread onsite power production will shift electricity system revenues away from electric infrastructure service providers such as utilities and other owners of generation, transmission and/or distribution systems (which can be regulated or unregulated entities) to new market actors such as residential prosumers. IEA-RETD 2014 (RE-PROSUMERS) groups the financial challenges that incumbents face as follows:

- Lowered profitability due to reduced sales: Infrastructure providers often recover their fixed infrastructure costs through volumetric charges (i.e. $/kWh), resulting in an interest in selling higher amounts of electricity. As self-consumption of prosumers – similarly to other energy efficiency related measures – decrease sales volumes, infrastructure providers may not be able to recover their costs. There are a number of options though on how the traditional regulatory framework can mitigate these challenges, e.g. through alternative rate designs (e.g. stand-by charges) or new approaches to ratemaking allowing regulated utilities different to recover their costs.
- Reduced profitability due to wholesale market price suppression: In several markets with high renewable penetration
- (Most notably Germany), large amounts of low-marginal-cost renewable generation injected into the bulk power market have led 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. Sustained reductions in wholesale energy market prices may lead existing generators to cease operation or scale back expansion plans.
- Reduced earnings opportunities due to lower capital investments: Capital investment in electric system infrastructure is driven in many instances – especially in case of regulated, vertically integrated entities– by load growth (or replacement). By dampening load growth, prosumers may reduce the opportunities for new investments in electric infrastructure by incumbents, thus reducing earnings through regulated rate-of-return on those investments.

Utilities and consumer groups in regions with growing presence of distributed solar have already begun to express concerns about the potential rate impacts, questioning whether owners of distributed generation are paying their fair share of fixed infrastructure costs, and evoking 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).

But not only incumbents, also local, state and national governments may experience erosion of revenues as a result of the growth of prosumers: This is the case when they have embedded taxes in retail electricity rates; in countries where FIT revenues are taxed as income, governments may also experience revenue loss as result of the transition from FITs to self-consumption.

Although prosumers pose new and particular financial challenges, it should also be noted that these 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.

In addition to the financial challenges, increased prosumer growth can cause a number of technical challenges in distribution systems, particularly in rural areas or in areas with weaker grid infrastructure, such as over-voltage and congestion issues, back-feeding, inverter tripping, and more complicated net load forecasting and long-term system planning. However, most of these issues can be overcome by a) utility-led solutions like grid enforcement, voltage control for HV/MV transformers, network reconfiguration, advanced forecasting, etc., b) prosumer-led solutions, e.g. on-site storage, greater self-consumption, PV orientation and smart inverters or c) interactive solutions such as demand response via local or market price signals. Prosumers themselves may gradually need to become increasingly "smart", taking 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.

While the above mentioned challenges are in no way dismissible, it is crucial to recognize that prosumers can also lead to a number of opportunities and benefits. Next to the general benefits of solar power (like long-term energy availability and affordability, innovation and industrial development, emissions reductions, etc.) distributed PV provides additional benefits and services compared to large-scale solar power plants, such as avoided system losses, deferred or avoided distribution and transmission capacity, increased resilience in the event of grid disruptions, local economic benefits and price hedging opportunities. In more general terms, it can be even claimed that prosumers may be necessary to trigger structural change required in the electricity industry to achieve sustainability. Prosumers stand for an active and direct participation of citizens in the energy market, increasing competition in the electricity industry.

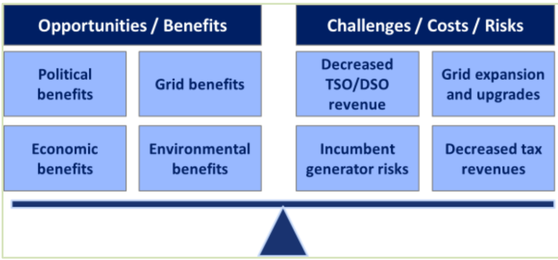

Figure 18: Cost Benefit Analysis

Therefore, prior to trying to find solutions that may primarily help incumbents to retain their current business models, policy makers should take a holistic approach considering the full picture:

The economic, behavioural and technological drivers for the different stakeholder groups as well as the specific national conditions (insolation, policies in place, grid infrastructure, etc.) are the foundation for prosumer policymaking. Mapping prosumer drivers can provide a useful framework for understanding the complex forces acting upon the energy system.

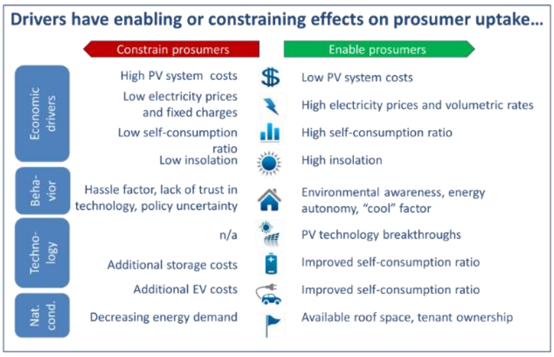

Figure 19: Drivers have enabling or constraining effects on prosumer uptake

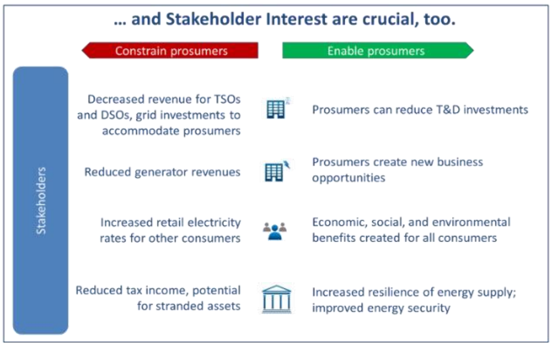

Figure 20 : Drivers have enabling or constraining effects on prosumer uptake and Stakeholder Interest are crucial, too

Policy makers should then identify and articulate the benefits and costs created by prosumers, weighting risks and opportunities, in order to determine whether encouraging the growth of prosumerscan be a national policy objective.

Once drivers are understood and policy objectives are defined, policy makers can develop strategies based on

these objectives. IEA-RETD RE-PROSUMERS suggest three different pathways:
1. Constraining prosumers, e.g. by actively penalizing prosumer development through the creation of new taxes or fines. But this approach creates the risk that prosumers could emerge anyway at some point in the future in an unanticipated manner which would be difficult to govern.
2. Enabling prosumers, including, for instance, the introduction of incentives and interconnection standards. However, this pathway can lead to a prosumer scale-up which may threaten the economic viability of existing utility systems and infrastructure in ways that existing regulatory paradigms cannot mitigate.
3. A third potential pathway "transition to prosumers" supports prosumer scale-up while at the same time introduces legal and regulatory reforms that encourage "prosumer friendly" structural shifts in current business models. Two types of transition approaches can be distinguished:
a. 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.
b. Structural approaches include policies that fundamentally alter the structure of the electricity market or utility sector, or that implicate significantly different utility business models. Policy makers faced "structural" decisions of similar magnitude when contemplating the restructuring and liberalisation of monopoly electricity markets. However, currently there are not yet strong examples of structural approaches to prosumer transition and no roadmap for structural transition yet exists.

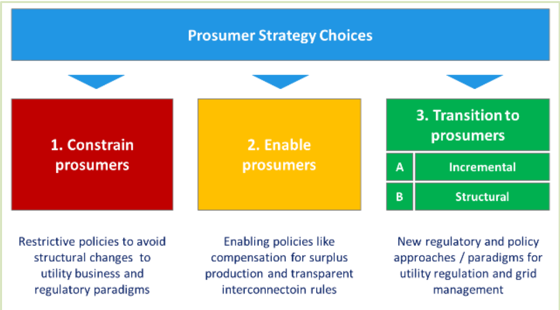

Figure 21: Prosumer Strategy Choices

As the conditions for PV prosumers are likely to continue to improve at the global level, it is recommended that policy makers initiate efforts to develop comprehensive prosumer strategies in the near-term, considering not only costs and risk but also benefits and opportunities.

Conclusion

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. The current evolution towards self-consumption and prosumers friendly strategies is therefore more constraintedthan desired. 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.
These two reports provided by IEA-PVPS and IEA-RETD aim 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.

References

IEA-PVPS, Trends in PV Applications, 1992-2013 – September 2014, Brussels, Belgium.
IEA-PVPS, National Survey Reports of PV Applications, 2013 – August, September 2014
IEA-RETD, Residential Prosumers - Drivers and Policy Options (RE-Prosumers) – June 2014