EVALUATING THE FACTORS AFFECTING THE BREAK-EVEN COST OF ON-SITE PV GENERATION AT INDUSTRIAL UNITS

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ABSTRACT: This paper studies the way in which the regulatory framework and market rules affect the feasibility of on-site PV generation for large industrial units. In most European markets net metering and feed-in tariffs for self-consumed electricity are not possible or are being phased out, providing an incentive to the industry for becoming more flexible in the way electricity is consumed in order to maximise the percentage of the variable electricity generated on-site that is self-consumed. The electricity cost for the industry is the benchmark for PV or any other on-site generation technology and in general on-site solar energy is competitive with that. However, as the regulation develops further, the exemptions of paying the regulated charges for the electricity that is self-consumed are phased out. Also the cost of flexibility required to self-consume all variable on-site generation has to be added to the LCOE of solar electricity, moving it further away from the competitiveness benchmark. Still, as the LCOE of solar electricity reduces continuously mostly due to the reduction of PV system costs, it becomes competitive for more and more users in more and more target markets.

Keywords: Economic Analysis, Funding and Incentives, Grid Integration, On-site generation, Self-generation, Flexibility, Regulatory framework

1 INTRODUCTION

Currently energy policy in Europe is in a transition and faces fundamental choices. Among others, the following two topics have been at the top of the agenda: (a) The cost-effective integration of variable renewable electricity into the power systems of Europe; (b) The rising cost of electricity and its effects on the competitiveness of the European Industry.

On-site generation through PV when combined with flexible self-consumption minimises excess electricity exported to the grid. This facilitates further growth and integration of variable renewable energy, while it can reduce the industrial electricity costs. Thus, on-site generation through PV combined with flexible self-consumption can help addressing at the same time both issues at the top of the European energy policy agenda.

The European rules suggested in 2014 regarding renewable energy support schemes, foresee increased market exposure and balancing responsibilities for renewable energy [1]: *"The following conditions apply from 1 January 2016 to all new aid schemes and measures: (a) Aid is granted as a premium in addition to the market price (premium) whereby the generators sell its electricity directly in the market; (b) Beneficiaries are subject to standard balancing responsibilities, unless no liquid intra-day markets exist; (c) Measures are put in place to ensure that generators have no incentive to generate electricity under negative prices."*

This trend, leads also the renewable energy generator to look for applications like on-site generation with flexible consumption, where there is no dependence from subsidies.

This study focuses specifically on the issue of on-site generation for the industrial sector. It is relevant to examine separately this sector as its access to resources, demand flexibility and large roof spaces make it ideal candidate for self-generation; however the low energy prices that the industries have access to, make it less attractive to adopt this new trend and the market design issues become more critical.

2 METHODOLOGY

That paper highlights the regulatory and market elements affecting the feasibility of on-site renewable energy generation for industrial users, aiming to enable wider adoption of on-site generation through regulatory adjustments and the use of business models that maximise returns under certain conditions.

As part of the IndustRE project [2], we performed a systematic analysis of the regulatory framework and the market rules in main European markets (Belgium, France, Germany, Italy, Spain and the UK), assessing the impact they have on the feasibility of on-site generation and consumption [3]. This analysis is presented in sections 3.1 and 3.2. Then, we reviewed the cost of electricity for small, medium and large industrial users, in our effort to define the benchmark that on-site generation levelised cost of electricity (LCOE) has to meet for becoming competitive. This work was performed as part of the RED Heat-to-Power project [4] and is presented in section 3.3. Finally, the demand flexibility emerges as a key factor affecting the feasibility of on-site generation and therefore section 3.4 was added addressing this issue.

The work focused on the markets in Belgium, France, Germany, Italy, Spain and the UK. These countries have important industrial production and together they represent more than 65% of the EU population and almost 80% of all the installed wind and PV capacity. These figures allow us to balance between a manageable effort of working with six target countries and still having an important impact on a European level.

3 RESULTS AND DISCUSSION

3.1 Electricity procurement and self-generation options

Traditional business models are defined as industrial electricity users signing a contract with a supplier, who in turn charges them for the consumed energy. Usually the supplier also charges them the network charges, other regulated charges and taxes according to options provided by the existing regulation and the agreed conditions.

However, large industrial consumers that are connected to the medium or high voltage grid can choose to follow an alternative process and purchase energy directly from the wholesale electricity market or through bilateral contracts with generators. In that case they pay separately the use of system charges, or network charges, other regulated charges, and taxes as defined by the regulation according to their level of voltage and power/energy consumed.

Own generation behind the consumer's meter, is allowed in all target countries under certain circumstances. The way that the self-consumed and the excess energy fed into the grid are treated, follow one (or a combination) of the three approaches listed below:

a) A feed-in-tariff/premium approach on all instantly self-consumed and/or excess energy injected into the grid.

b) Net metering approach, which is a billing system by which the excess electricity injected into the grid can be used to offset net consumption, not instantly but cumulatively throughout a whole billing period, e.g. a month or a year.

c) Market value approach, by which the electricity that is not self-consumed but injected (instantly) into the grid would be rewarded at the market price of the time of injection.

Consumers under any of these schemes may be exempted from, or asked to contribute to the network and other regulated charges on self-generated energy/power.

In section 3.2 more details are provided regarding the way that self-generation is regulated in the six target countries.

3.2 Target country review

The analysis of the situation in the target countries [3] did take into account the good overview included in the relevant Commission Staff Working Document [5], which accompanied the Communication of the European Commission on 2015 about the new energy market design [6]. This analysis is presented next for the target countries/markets.

Belgium: Consumers with renewable energy installations under 10 kW can benefit from a net metering system. This system entails that the amount of renewable electricity produced annually is deducted directly from the general electricity bill of the consumer, while there is no other remuneration for the part of the electricity injected in the grid. For renewable energy installations over 10 kW, typically two meters are installed: (i) A meter which measures the renewable generation, which is used to calculate the subsidy. (ii) A bi-directional grid connection meter: typically there is still a single grid connection but with separate meter readings for injection and consumption. Consumption and injection are subject to different grid costs and additional charges.

This regulation creates an incentive for medium sized companies to become more flexible in the way the use electricity, following the generation patterns and minimizing the exchange of electricity with the grid.

It has to be noted though, that from July 2015, in the Flemish region, a specific tariff for prosumers was launched to make prosumers contribute to the distribution network costs. This tariff ranges from 67 to 106 €/kW installed.

France: Self-consumption is allowed in France [7]. This foresees the option to consume on-site all self-generated electricity and to be exempted from paying a series of taxes, such as VAT, the Renewable and Social surcharge (CSPE) and the Municipal tax (TICFE). This regulation encourages self-consumption, but it is still possible to feed any excess generation into the grid and be remunerated under the feed-in tariff scheme if the user complies with the terms established in the feed-in tariff policy.

Germany: The review of the German Renewable Energy Act (EEG) in 2012 has introduced a limiting factor for grid injection which is favouring direct consumption. For the excess energy injected into the grid, the consumer is paid the market price. Regarding grid tariffs and other charges, since 01/08/2014, self-consumed energy is totally exempted if < 10 kWp and < 10 MWh/year. Above these levels, a reduced renewable energy surcharge is applied on self-consumption. This surcharge increased gradually, representing always just a fraction of the total surcharge: 30% by 2015, 35% by 2016 and 40% by 2017.

Italy: For generation units < 500 kWp owned by the consumer, a net-billing system in used as an alternative to net metering. According to this system, the value of the excess energy injected into the network is calculated at the wholesale price. This can be used as credit for subsequent periods or is paid to the customer. For larger renewable energy systems, up to 20 MW, there is a scheme in place called SEU20 ("Sistemi Efficienti di Utenza"), by which large consumers can self-consume or sell the excess energy at a market price. Since 2014, under the SEU scheme, industries with on-site generation are exempted from paying 95% of the volumetric part of the general system charges on the self-consumed electricity, encouraging self-consumption. SEU requires a private connection between a VRE plant and a single industrial consumer.

Spain: Self-consumption is allowed in Spain and is regulated by the Real Decreto 900/2015 of 10th October 2015. According to this regulation, there are two potential self-generation types of consumers: i) consumers with on-site renewable energy generation capacity under 100 kWp for self-consumption, where any excess energy fed into the grid is not remunerated; ii) consumers with officially registered generation facilities for self-consumption, who could optionally receive economic remuneration for the energy injections to the grid, according to the specific regulation in place for the generation technology in question. In any case, installed generation capacity must be below the consumption contracted capacity. Under both modalities, the consumer with self-consumption must pay for a series of regulated charges, such as: (i) Network access tariffs, including a volumetric charge and a capacity charge, applied respectively on the hourly net demand supplied from the grid and on the contracted capacity. (ii) Charges associated to the electricity system regulated costs, applied on hourly consumption, i.e. the electricity withdrawn from the grid plus the self-consumed energy. (iii) Charges for other services of the system, or "support charge", which is a specific charge determined by the Ministry of Industry and energy aimed at recovering the costs incurred by the system to support the connection of self-consumption, which would not be necessary if the prosumer were not connected to the grid. This charge would be applied on hourly self-consumed energy. There is a transitional period until the charges associated to the electricity system regulated costs are defined, after which the full charges mentioned above will be introduced.

United Kingdom: A feed-in-tariff approach is implemented in the UK, by which small-scale PV and wind systems (<50 kWp) eligible to receive a feed-in-tariff are given not only a generation tariff for the energy production (that is self-consumed), but also a bonus for up to 50% of the excess electricity fed into the grid. For an installed capacity > 50 kWp and < 5 MWp, there is only a feed-in-tariff paid to the energy generation. Regarding grid and system costs, prosumers are exempted from paying any of them for the part of the electricity that is self-consumed, incentivizing self-consumption among industrial consumers. The tariff structure further incentivizes industries to self-consume, so they will try to forecast peak demand periods and manage their injection/withdrawals during those hours (either by using on site generation or by reducing their consumption).

We can see that only Belgium among the target countries actually presents a net metering policy, but it is limited to very small units (below 10 kW), so large industrial consumers cannot benefit from this policy.

It can also be observed that, in most cases self-consumption is incentivized to some extent for large industrial consumers. This is done by exempting them from paying certain regulated charges on the self-consumed energy, such as a series of taxes (e.g. in France), part of the network charges (e.g., the exemption to pay for 95% of the volumetric part of the system charges under the SEU scheme in Italy, and in Germany the requirement to pay only for a RES-surcharge on self-consumed energy that corresponds to a reduction of the normal grid tariff and other regulated rates) or any grid and system charges at all, as in the UK and Belgium. This creates an important incentive for self-consumption from on-site generation. This is also an incentive for flexibility in order to maximise the percentage of the on-site generated electricity that is self-consumed.

Overall, as the net metering and the feed-in tariffs for self-generated electricity are phased out, the price that the prosumer pays for electricity supply from the grid becomes the benchmark for the cost of the renewable electricity generated on-site. Therefore, in section 3.3 we review the industrial electricity prices.

On the contrary, grid tariff exemptions on self-consumed electricity are gradually being cut down or eliminated in other places, e.g. in Spain prosumers are required to pay the network access tariffs on the net consumption plus an additional charge for grid and system costs on the self-consumed electricity and in the Flemish region of Belgium a specific distribution network tariff for prosumers was launched in July 2015. These developments make self-consumption a less attractive option, as the benchmark LCOE for on-site generation moves lower.

3.3 Industrial electricity prices

In some countries favourable prices are available, especially for large industrial sites with annual electricity consumption of over 70 GWh. The electricity prices (including all taxies and levies) for small/medium and for large industrial sites for the period 2012-2016 are given in Fig. 1 for some representative EU Member States, according to 2016 data from Eurostat [8].

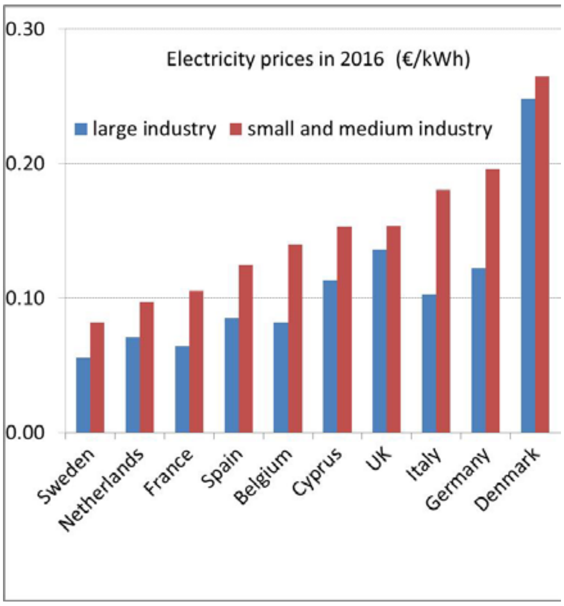

Figure 1: Electricity prices for small/medium and for large industrial sites in EU countries for the year 2016 (Eurostat data)

Average electricity prices for small/medium industrial sites are about 0.15 €/kWh, reducing to 0.10 €/kWh for large ones. Most countries are not too far from the average European prices, while Denmark is an exception as it has much higher prices and Sweden, Netherlands and France have lower prices.

In case large industries procure electricity from the wholesale market, the prices vary in time and are generally lower. An example is provided in Fig. 2 from the German/Austrian energy market for the period June 2016-June 2017 [9].

There are moments with negative prices (in total 3 days during the last year), due to overproduction of electricity. However, there are even more moments with electricity price over 0.05 €/kWh, which for the last year were about 40 days (10 days during December 2016, and from 10th January up to 10th February 2017). On the other hand, similar market prices for France according to EEX data [9] are shown in Fig. 3 for the same duration.

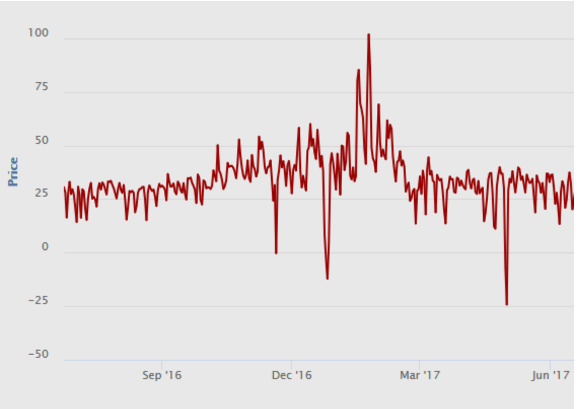

Figure 2: Wholesale electricity prices in the German/Austrian market for the period June 2016-June 2017, price in €/MWh (EEX data)

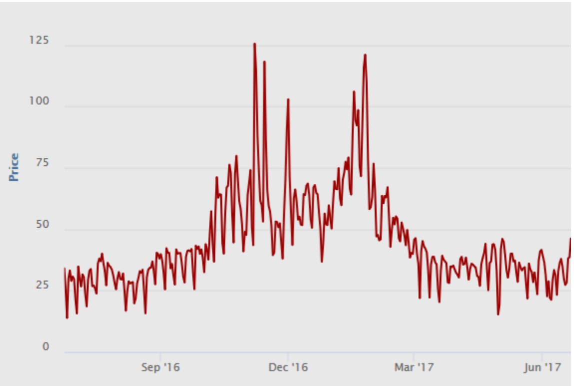

Figure 3: Wholesale electricity prices in the French market for the period June 2016-June 2017, price in €/MWh (EEX data)

In France the prices of the wholesale market are more variable and we observe a longer period with prices over 0.05 €/MWh (about 4 months, October 2016-January 2017).

Overall we have seen that the prices that small and medium industry pays for electricity in most European countries are in the region of 0.10 to 0.20 €/kWh. On the other hand the levelised cost of electricity of on-site solar energy ranges between 0.05 to 0.14 €/kWh according to the latest data [10]. The very wide range of LCOEs in that study stems from the fact that the systems considered range from very small (5 kWp) to large rooftop systems (1 MWp), while different climates are also considered. Still, in all cases, the overall conclusion is that on-site PV generation can be competitive.

The benchmark for large industry is lower, especially if they have access to wholesale electricity prices. However, the solar energy costs can still be competitive and as the solar energy costs decrease further, they will become even more competitive; offering also cost stability, as opposed to the price fluctuations of the wholesale energy market.

Finally, according to the available data, electricity prices for industrial users have experienced a small increase about 2-3% in average in EU during the last decade [8], revealing the potential of introducing promising energy measures in industries.

3.4 Industrial demand flexibility

The price that the industry pays for electricity is a benchmark only if the industry can consume all electricity generated on-site. This is the case if the capacity of the on-site renewable energy system is small compared to the industrial demand. If we want to accommodate larger systems, the flexibility of the on-site generation and/or consumption becomes of interest. In the case of solar energy, the generation becomes more flexible by adding a battery, which increases also the electricity costs. The flexibility of the industrial demand on the other hand can be an interesting case, which we discuss in section 3.4.

Having flexibility to shift electricity demand over time can be beneficial as this can be used to increase the percentage of the self-generated electricity that is self-consumed. The amount of flexibility that is available to be activated by industrial users varies depending on the kind of industrial activity, the technical installations, the production processes and the objective perceptions, preferences and requirements of the industrial plant owner. In order to quantify the available flexibility, the research group of VITO has developed a process called Demand Response Audit (DRA) as part of the IndustRE project [11]. This process was further developed as part of the IndustRE project and it was applied to several case studies. The main conclusion was that there is often more flexibility available than the plant operators think. However, the cost of activating this flexibility is case specific and can be determined only by the industrial plant owners/operators.

4 CONCLUSIONS

We have seen that in most of the European markets studied (Belgium, Germany, Italy, Spain, France and the UK) net metering and feed-in tariffs for self-consumed electricity are not possible or are being phased out. This provides an incentive to the industry for becoming more flexible in the way electricity is consumed in order to maximise the percentage of the variable electricity generated on-site that is self-consumed.

The electricity cost for the industry is the benchmark for PV or any other on-site generation technology. This consists of the cost of energy (market-based price), the network charges and any other taxes, levies and surcharges that may apply (regulated costs). In the vast majority of cases (considering size of systems, solar irradiation and tariffs available to the end-user) the LCOE of solar energy is already competitive. However, as the regulation develops further, the exemptions of paying the regulated charges for the electricity that is self-consumed are phased out. This lowers the benchmark, taking some of the large energy users that have access to low energy tariffs out of the zone of on-site solar energy competitiveness, especially in countries where solar irradiation is not so high. For, the cases where the industry changes its consumption patterns in order to self-consume all electricity generated on-site, the cost for activating this flexibility has to be added to the LCOE of solar energy, moving it further away from the competitiveness benchmark. Still, as the LCOE of solar energy reduces continuously, it becomes competitive for more and more users in more and more target markets.

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