Theoretical and empirical analysis of the impact of electricity production by households on the energy market in Wallonia

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Executive summary

The number of households producing their own electricity with solar panels in Wallonia has increased drastically in the very recent years. In this paper we analyse the effect such production may have on the market from an economics point of view. We first present theoretical analysis and predictions for which we later obtain empirical evidences. We distinguish two main impacts the solar panels may have on the market and on which we focus, although we acknowledge that more exist. The first is that households producing electricity will represent a charge on the grid which increases the tariffs proposed by the firms managing it. The second is a reduction of the price of electricity itself through supply and demand mechanisms. The period covered is 2008-2017. Such analysis has just very recently been made possible regarding the number of observations available. Even as of the current time we struggle to gather a sample of sufficient size allowing for proper empirical analysis. We use data of both the federal and regional regulators as well as of the ministry of Economics. Our findings are the followings. According to the current system of incentives in solar panels investments, firms managing the grid have to pay a fee to households connected to their network which produce green energy. We find that the lower the prices such firm proposes for its services, the higher the fee it has to pay is likely to be. A higher fee compensates the fact that the electricity production of the panels will have a lower value due to the lower tariffs of the grid. We find that the value of the said fee may influence the time at which households choose to install solar panels. We estimate the monetary impact of their production on the grid to be 2.8% of the turnover of the firms managing it for 2016, but cannot know how much of it was passed onto the price. We determine however that the price increase corrected for inflation was sufficient to cover the fees in their entirety. Further, we find that the increased supply and lowered demand these households represent for the market result in a price decrease of electricity of approximately 0.2 cents per kilowatt-hour, or 0.76% of the retail price for December 2016. Of the different elements composing the price of electricity the effect is strongest on the charge per kWh with a decrease of 3.8% of its value at the same period. Additionally we find that the strength of the effect should keep on increasing but at a diminishing rate and that it is highly over estimated in the data due to time trends. Overall we conclude that, as of December 2015, if more than 60% of the monetary impact solar panels have on the grid is passed on the price by the firms managing it, the increase will be stronger than the decrease of the price of electricity and the total effect will be an increase of the retail price. We believe it is the case and show evidences for it but find that the trend might reverse in the future. We estimate that if 100% of the effect on the grid were to be compensated for by a price increase, the overall impact of the electrical production of households with photovoltaic panels would represent, for an average standardized consumer and for 2016, a raise of the annual bill of 13.61 EUR, or 1.5% of its value. This result is to be considered as the rooftop value of the monetary impact for consumers in Wallonia.

Le nombre de ménages produisant leur propre électricité au moyen de panneaux solaires à explosé en Wallonie ces dernières années. Dans cet article nous nous intéressons à l'effet que l'arrivée d'une telle production peut avoir sur le marché d'un point de vue économique. Nous développons dans une première étape des modèles théoriques dont nous testons les prédictions empiriquement dans une second partie. Nous distinguons deux effets principaux sur lesquels nous nous concentrons dans cette analyse, bien qu'il apparaisse claire que ce ne soit les seuls. Premièrement, la production électrique des ménages représente une charge pour le réseau de distribution et est répercutée par une augmentation du prix de son utilisation. Deuxièmement,

Word count: 15,326.

que cette production exerce une pression à la baisse sur le prix de l'électricité au moyen de mécanismes d'offres et de demandes. La période couverte est de 2008 à 2017. L'analyse empirique d'un tel sujet n'a que très récemment été rendue possible de par le faible nombre d'observations disponibles et il apparait que même à l'heure actuelle obtenir un échantillon de taille permettant des résultats significatifs reste un vrai défi. Les données utilisées sont celles des régulateurs, tant fédéral que régional, ainsi que celles du SPF Économie. Nos résultats sont les suivants. Le système actuel octroi une prime annuelle aux possesseurs de panneaux solaires, payées par le gestionnaires du réseau auquel ils sont raccordés. Nous trouvons que plus les prix du gestionnaire seront bas, plus la prime qu'il devra payer est susceptible d'être élevée. En effet, une prime plus élevée permettra de compenser le fait que les prix bas du gestionnaire diminuent la valeur de la production des panneaux solaires. Nous trouvons également que la valeur de cette prime pourrait influencer la période à laquelle les ménages installent leurs panneaux. L'impact de cette production sur le réseau est estimé à 2.8% du chiffre d'affaires total des gestionnaires du réseau de distribution pour 2016, sans pouvoir savoir avec exactitude en quelle quantité cela est répercuté sur les prix payés par les consommateurs. Nous déterminons cependant que la hausse des prix proposés par les gestionnaires, corrigée pour l'inflation, apparait suffisante que pour couvrir l'entièreté des primes payées. De plus, nous trouvons que de par l'augmentation de l'offre et la baisse de la demande que la production d'électricité des ménages représente, les prix de l'électricité ont baissés d'environ 0.2 c par kilowattheures, soit 0.76% du prix final, ce pour décembre 2016. Cette pression à la baisse est la plus intense sur la charge par kWh, avec une baisse de 3.8% de sa valeur pour la même période. Nous trouvons également que cet effet devrait continuer à croître dans les années à venir mais de manière dégressive, et que cet effet apparait très largement surestimé dans l'échantillon de données dû à des tendances temporelles. Globalement nous arrivons à la conclusion que, en décembre 2015, si plus de 60% de leur charge sur le réseau a été répercuté sur le prix des gestionnaires, la hausse des tarifs réseau sera supérieure à la baisse du prix de l'électricité et la production des foyers aura résulté en une hausse du prix final payé par les consommateurs. Nous pensons que ça soit le cas mais mettons en évidence des signes que cette tendance pourrait s'inverser à l'avenir. Finalement, il est estimé que si l'entièreté de la charge sur le réseau devait être reportée sur le prix, l'effet total serait, en 2016 pour un consommateur standard, d'une hausse de la facture annuelle de 13.61 euros, soit 1.5% de sa valeur. Ce résultat est à considérer comme la valeur maximale de l'effet sur le marché de la production d'électricité des panneaux solaires des ménages en Wallonie.

Contents

1 Introduction

The Belgian electricity landscape is a complex market which has known tremendous changes these recent years, the Government liberalized it, new companies emerged, our ways of producing energies evolved, the VAT rate on electricity changed twice in less than 2 years, to name a few. But one of the most impactful changes lays in the explosion of the number of self producing consumers on the market. That is, households owning solar panels which will produce electricity for them. Such phenomenon has important consequences for the market and its prices. We will refer these households producing electricity as *prosumers*, in the sense that they are both producers and consumers. The term is notably used in Gautier, Jacqmin, Poudou (2016). This paper focuses on determining these impacts on the electricity market as well as quantifying them. Energy is a good that is consumed by everyone and for which the demand has, below a certain level, a low price elasticity. Consequently its price variations can have meaningful impact on the purchasing power of consumers, especially the ones with lower incomes as it represents a higher share of their wealth. Solar panel production is taking an increasingly large part of the electrical production of the country and the regulators are here confronted with a dilemma. As electricity is an important good of consumption, required for the most basic needs such as heating or lighting which consumption can hardly be reduced, it is their role to control the market in order to protect the consumers. Accordingly any negative effects a phenomenon such as the introduction of prosumers may have on the market, e.g. a price increase, should be reduced if not eliminated. But, it is well known that pollution and climate change are major issues of our society which green electricity production such as solar panels helps reduce. The Government has set important incentives mechanisms for households to invest in the said panels in the high quantity. Where should the limit be drawn between those two, a priori opposite, objectives ? When should the Government stop pushing for a higher share of green energy production in the country in order to avoid harmful consequences for consumers and firms ? This is a delicate topic with arguments for both perspectives and no clear answers. It is our role, as economists, to help create a system such that the negative impacts prosumers may have on the market are minimized while keeping the incentives to invest in solar panels as high as possible. In order to do so one of the primary aspect is to fully understand how households producing electricity really affects the market and the consequences it represents for every agents. As the quantity of electricity produced by households increases, several impacts will appear. We classify them in two categories: those pushing prices down, and those pushing them up. The two mains effects of which are identified as the followings:

Households will produce electricity for their own to consume and to be sent in the grid for other consumers. Overall this will increase the supply of electricity on the market and lower the demand addressed to the firms. As a consequence we should observe a drop in the price and a lower profit for the firms.

Prosumers will inject electricity in the grid which they will later be able to extract back. They will make usage of the grid, but will not pay for it as in Belgium electricity imported and exported by households is value identically due to the metering system. However their usage of the grid still as a cost for the firms managing it, the Distribution Service Operator, or DSO. This cost will most likely be supported by the other consumers instead. Additionally, electricity is produced and consumed by prosumers, where it would have been bought and extracted from the grid otherwise. This is a miss to win for the energy sector. Consequently we should see a rise in the prices proposed.

These are the two mains consequences for the market which can be drawn from the introduction of prosumers, but other exists. For instance, if a higher number of solar panels results in a higher level of price of electricity, becoming a prosumer will be more and more profitable as their number rises, increasing the price furthermore and making it even yet again more profitable to start producing electricity. This would create a loop, which has already been identified by several authors (figure 1). If the total effect of the prosumers on the market were to be a drop of the price, the loop would be identically backward.

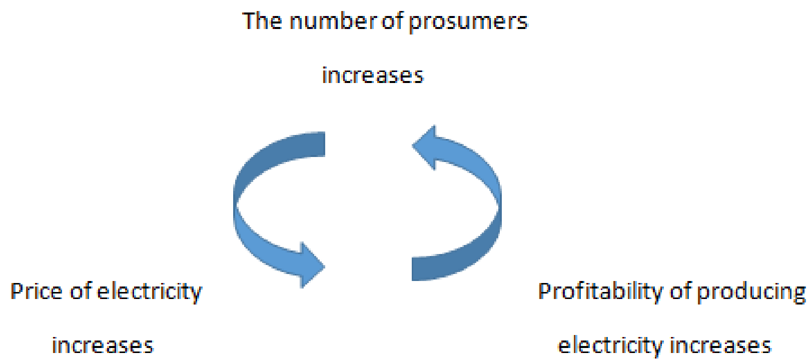

Figure 1: The loop effect of the profitability of solar panels

Another consequence which can be drawn from the introduction of prosumers on the market results from the green certificates (GC) market. Households producing electricity will earn a number of GC proportional to the level of their production. These certificates can later be sold to the firms of the market which are required to purchase a certain amount by the Government. The price of the GC is the consequence of both the level of supply and demand. If the quantity of electricity produced by households increases, so will the quantity of GC. The demand for the later being equal their price will fall, which should result in a drop of the price of electricity.

It appears clear that there do exists multiple forces having different influences on prices and all resulting from a single factor, households producing electricity. But what is the overall effect, and what range of values can it take ? The analysis will be restrained in this paper to the first two effects mentioned above, that is the supply and demand forces and the impact on the grid. We will present them theoretically, define the predicted outcomes and estimate them empirically.

The paper is constructed as follow. A first section presents the Belgian electricity market and its specificities, followed by the review of the literature on the subject. We will then go through the effect on the grid and later the effect from a supply and demand perspective. Finally, we will elaborate an overall conclusion as well as recommendations in order to improve the current system.

2 The Belgian electricity market

The energy market was liberalized in Belgium in 2007. The objectives were the following: to give a fair price to consumers, to promote green energy, to create an European market and to insure access to electricity for all (source: Brugel.be). One of the thought was that competition would bring more efficient firms and lower prices. However due to the nature of the good and the need for a network of distribution only segments of the overall market were liberalized. The segments of the sector are the following: electricity is first produced, in Belgium or elsewhere. It is purchased by providers which will sell it back to their consumers. Electricity is transported and distributed through a network. Consumers are connected to the network and can extract energy from it when desired. Production and sales were liberalized, but the transportation and distribution taking place on the market are still monopolized. This can be explained by the fact that the network cannot be duplicated and having a single firm managing it allow for important economies of scale. The firms managing the network, or grid, are called Distribution Service Operators (DSO). They are responsible for transportation, distribution and location of metering systems. Further, the manage the grid and handle reparations and maintenance. There exists thirteen DSOs in Wallonia, each assigned to a specific geographical area. Each DSO has its own tariffs. A consumer will be able to choose its provider but not its DSO. Such coexistence of monopoly and competition is typical of network industries. The major requirement for such system to be optimal is a high regulation of the monopoly. There exists two regulators competent in Wallonia. One federal, the Creg, and one regional, the Cwape. They are notably charged with the mission of approving the prices of the DSOs. The limitation between the competences of both regulators is unclear, although it appears the the Cwape holds the most power on the monopolies since the reorganisation of the market in 2014.

The final bill of electricity is thus composed of several elements. We divide them in three specific groups. The price of electricity itself and the contribution for green energy through green certificates are represented by the market of the providers which is competitive. We classify those elements as the energy component of the price. There are as well the DSOs tariffs, for transportation and distribution and finally governmental charges with different taxes. Consumers only pay one price which includes all the above elements. The regional regulator estimates the composition of the retail price to be the following, on average in Wallonia for June 2016: distribution 38.8%, transportation 16.4%, electricity 30.2%, green energy contribution 11.9%, and federal and regional taxes 2.6%. The specific price of electricity free of all other components appears to be diminishing. As of June 2016 its value had decreased of 8.5% since 2014 where it represented 38% of the total bill. This indicates that the introduction of competition on this specific segment of the market does seem to effectively reduce its price, which was one of the objectives of the Government. Price of distribution appears to have known a drastic increase of more than 32% over the same period. The biggest increase however comes from the green energy contribution with has grown of 48%. Overall the retail price of electricity shows a clear increasing trend. Let us note that we are here concerned with prices for residential consumers only.

Production of electricity by households has started to reach significant levels in the recent years, mostly due to improvements in technologies allowing to investments in solar panels to be made at affordable prices coupled with incentives programs of the Government. As a consequence of both phenomenons the number of installations and the residential solar panels market have developed tremendously over the last decade. The process is simple and straightforward. A household makes the decision of investing in solar panels. They are purchased and installed. The installation will be connected to the grid in which the excess production will be injected. There exist two metering systems through which such production will be measured, net metering and net billing. The choice is made at the country level. Although the vast majority appears to be net billing, Belgium is equipped with net metering (Gautier, Jacqmin and Poudou, (2016)). The main difference comes from the value the electricity injected in the grid is given. With net metering one meter runs backward while with net billing a second meter registers electricity exports. Consequences of both systems for the consumers and the grid are presented in details later. The energy market is complex. The fact that electricity cannot be stored efficiently, the demand being heterogeneous throughout the years and other factors have to be taken into considerations, ensuing convoluted analysis.

3 Review of the literature

To our knowledge, hardly any empirical analysis of the subject exists. For the specific case of Wallonia even fewer, if any at all. Indeed, as stated above, the market for solar panels installations at residential level has recently emerged and the tariffs of electricity vary at a rate such that data are just only beginning to reach an amount sufficient to allow for proper empirical analysis. At the time this paper is written it still shows to be extremely challenging to gather sufficiently large samples. Theoretical analysis is more proficient. A high number of papers focus on descriptive analysis of electricity prices, its components and their evolutions. The results are mentioned in the above section.

Boccard and Gautier (2015) show in an analysis covering the period 2003-2012 that the Belgian support system to green energies is extremely generous, far more than the neighbouring countries, and that it is especially the case for photovoltaic panels which received more than five time the amount of other means of production. The consequence has been a high cost for carbon emissions avoided. The change of support mechanism for solar panels in 2014 likely results from an effort of the Government to diminish this costs an improve the system.

Several works were also achieved on the comparison of meter systems. Eid, Guillén, Marín and Hakvoort (2014) determine that net metering will result in a loss of incomes for network utilities, consequently increasing the charge per kWh supported by all consumers. Brown and Sappington (2015) show that households should not be paid at the retail price for their production of electricity and that a lower pricing for such production will induce welfare maximization. Interestingly, they show that it is possible for the production of households being valued higher than the retail price to be optimal were the externalities such production entails sufficiently high enough. Similarly Gautier, Jacqmin and Poudou (2016) argue that while net metering shows to be inefficient it is possible for the result to change depending on the value which is given to the environmental externalities the production of households yields. Further, the authors determine that under net metering the number of households switching to become prosumers will be too high and that its first best level is achieved by pricing the electricity produced by solar panels at the cost level. It is also shown that an important objective mechanisms regulating decentralized production of electricity should have is to give incentives for efficient behaviours, namely prosumers synchronizing consumption with production. Overall the literature appears to give the consensus that net metering is less efficient than net billing and that the supports to solar panels are to important.

Although the effect on the grid has already been widely discussed theoretically, few work asses the effect of the prosumers on the providers market. This paper aims to show both theoretical and empirical evidences for the effect of the rise of self-produced electricity on multiple segments of the energy sector, to clearly determine the overall outcome on retail price and the possible evolutions to come.

4 Prosumers - Distribution Service Operators relationship

4.1 Theoretical analysis

The Belgian photovoltaic market has been renewed in 2014. Up to then the system in place was called Solwatt. It was an help for households to invest in solar panels, in an effort to increase the share of green electricity production of the country and to further increase competition on the energy market. The system appeared to be very successful, resulting in an explosion of the number of installations. The number of solar panels in households was such that is was no longer possible for the government to sustain such system, as it was just costing too much (Boccard, Gautier (2016)). A new mechanism was created in 2014, called Qualiwatt. The aim of Qualiwatt is to give a return on investment of about 8 years for citizens who decide to have solar panels. To do so, the system lays on 2 sources of incomes for the owners :

1) The prosumers receive a fee annually paid by the DSO, the price of which is set by the Cwape. There exists different level of fees for each DSO. The fee is composed of a base and a complementary part, and is expressed as a function of the capacity of electrical production of the installation. The complementary part is not applied if the base level of the fee already guarantees an internal return on investment of 6.5% (source: Cwape). This is an additional cost.

2) Secondly, the prosumer can inject the excess electricity he produces in the network, making his metering system run backward and decreasing his electrical bill. A prosumer also consumes part of his electricity production for which he must not pay. This is a shortfall for the DSOs.

The existence of different levels of fees specific to each DSO, instead of a global fee, can be explained by the fact that electricity is not valued identically across Wallonia as DSO's have different prices for transportation and distribution, thus effectively influencing the value, and consequently the return on investment, a household will yield out of the electricity he produces. The point of the different level of fees is to compensate these differences, offering higher compensations to households located in area with lower prices of electricity in order to allow every installation to be identically profitable. Indeed, if we compare the level of the fee of each DSO with the level of there prices, a clear scheme appears where low prices are met with high fees (see appendix A). From a DSO point of view this could show to be troublesome, as a company with lower prices and potentially lower markups will have to pay a much higher fee, up to 22% more for 2017.

Introducing prosumers on the market through the Qualiwatt system thus clearly appears as a financial charge for the DSOs which is likely to be compensated for by a price increase, such firms owning monopolistic power. This is our interest for this section. In the following, we will estimate the total amount of the fees paid by the DSOs since the implementation of the Qualiwatt system in 2014. We will compute as well an estimation of the value of the shortfall for the DSOs due to the free usage of the grid, or its non-usage, by the prosumers. After having obtained a total value of the impact of solar panels installations for the grid managing firms we will try to determine if it was passed on the prices of transportation and distribution. The data are for now insufficient to allow econometric analysis in this matter. The prices of the GRD do not vary enough and the system has been implemented for only a few years, making it impossible to obtain a sample of sufficient size. We will instead develop a methodology of estimation. Although we can only obtain gross estimations, it is interesting to grasp the range of value these variables may take as well as, even more importantly, their evolutions over time and the predictions for their future values. We use the data of the Qualiwatt system given by the Cwape for the number of solar panels installations and for the prices of the fees. The time lapse is march 2014-march 2017. We only account for Wallonia.

4.2 Quantified analysis: estimation of the cost and miss to win for the DSO's

4.2.1 The fee

The price of the fee for each DSO is set by the CWAPE. The prices change every semester. The value of the fee paid to a prosumer is the one corresponding to the semester in which the panels were installed. The fee paid to a prosumer stays a the same value later on and does not follow the price changes of the Cwape. This value can be reassessed after two years, but since our sample is of only 3 years we will consider that it is not the case for ease of computation. The prices of the fees are published by the Cwape well in advance. A household willing to invest in solar panels could thus theoretically delay its installation to be paid a higher level of fee for a minimum of two consecutive years. Indeed, from one semester to another, we can observe changes in prices of over 60 EUR/kWp[1]. If the value of the electricity the installation would have produced during the delay is lower than the differential between the levels of the fees times two years then it is beneficial to do so. It could be interesting to see if we do observe an increase in the amount of solar panel installations at the beginning of semesters providing a higher level of fee with respect to the previous semester.

There are quotas for the number of fees that can be paid by the DSOs through the Qualiwatt system. It is of a maximum of 12.000 annually for the totality of the market. We do not observe yet 12.000 installations benefiting the Qualiwatt program as of march 2017, and so we will not take this quota into considerations. We will however use the repartition of quota among the DSOs to compute a weighted average of the price of the fees each semester. We consider the value of the quota of a DSO to be an image of its weight on the market. Using a weighted mean instead of a simple mean will give us a more accurate estimate. The average capacity of production of a solar panel installation at household level is of 3 kWp (source : Cwape). Moreover, we observe that the rooftop fee (the fee cannot exceed a certain level, regardless of the capacity of production of the installation) that can be paid by a DSO generally corresponds to that of 3 kWp. We will therefore consider that every installation is of a capacity of production of 3 kWp. Such an estimation is not much of an issue in this case. While every installation is most certainly not of 3 kWp, the average capacity installed should approach this value. It is the installations in a whole that matters, the way in which the capacity of production is distributed in itself is of small interest e.g. $10 \cdot 2 + 10 \cdot 4$ and $10 \cdot 3 + 10 \cdot 3$ yield the same result. We multiply the number of cumulated installations of each semesters by the mean value of the fee for 3 kWp at the corresponding period, multiplied by the number of years between the time of installation and 2017, and obtain the following results (figure 2).

The figure summarizes the estimated values of total amount of fees that had to be paid each year by the DSOs. It gives as well the average value for a DSO for both the totality of the period and annually; that is the total value divided by 13 as there are 13 Distribution System Operators

[1]kWp = kilowatt peak, which is a measure of the maximal capacity of production of an installation.

	Base fee	Complementary	Total
2014	1.632.149,39 €	170.519,53 €	1.802.668,92 €
2015	4.850.782,56 €	395.236,68 €	5.246.019,24 €
2016	8.221.971,12 €	395.236,68 €	8.617.207,80 €
Total	14.704.903,07 €	960.992,90 €	**15.665.895,97 €**
Total average per DSO	1.131.146,39 €	73.922,53 €	1.205.068,92 €
Anual average per DSO			401.689,64 €

Figure 2: Totality of the Qualiwatt fees paid by the DSOs in Wallonia

in Wallonia. Therefore it appears that a DSO had to pay, on average, 401,689.64 EUR of fees each year since the implementation of the Qualiwatt system.

The total value of the fees paid is highly increasing every year. Indeed, every semester new households set up solar panels and can claim the fee, but yet the DSOs still have to keep on paying previous prosumers as well. This could certainly be a problem in the future if the trend goes on as the cumulated amount of the fees could reach unsustainable values for the grid managing firms. Tough, this result can be relativized on several aspects. There exists a quota for the total number of fees which can be claimed annually. If every Belgian citizen were to invest in solar panels, the firms would not have to pay everyone of them. We are close to reaching the annual quota of 12.000 fees since we observe 11889 solar panels installations benefiting the Qualiwatt system as of February 2017. There exists as well a rooftop value for the fee that cannot be exceeded, regardless of the capacity of the installation. Additionally, the value of the fee keeps on diminishing over time. For 3 kWp, in 2014, the average price was of 994 EUR annually for the base fee alone. It is of 559 EUR in 2017, almost half as less. We can also add that in our model we do not consider the possibility for a prosumer to retract from the market. It seems quite unlikely that a household would invest in solar panels to stop the production less than 3 years after, but in the long run this is without a doubt a phenomenon that is to take into considerations. As such our results are probably overestimated. The following condition needs to be fulfilled for the cumulated value of the fees paid annually to start diminishing:

$$Leavers \cdot Fee_n > Entries \cdot Fee_t \tag{1}$$

With $Leavers$ the number kWp of installations exiting the market, Fee_n the level of price of fees the later were perceiving, $Entries$ the number of kWp of installations entering the market and Fee_t the present value of the fee. The market seems to be converging toward the above equation as the number of new installations is dropping while the average power installed is constant and the price of the fee is reducing significantly, although we do not have any data of prosumers exiting the market. Assuming the quota is reached, it would just be required for the fee to be below its previous values for the above condition to be true, as $Leavers > Entries$ would then be a necessary condition. We conclude that, everything else being equal, the cumulated price paid annually by the DSOs to the prosumers should keep on increasing until the quota is reached, after what it will decrease.

4.2.2 The shortfall on the grid

In Belgium prosumers are equipped with a net metering system. With such system electricity imported and exported are measured with the same device which runs backwards when electricity is injected in the grid. This has several implications, the major of which being that electricity extracted and injected are valued identically. The prosumers can make usage of the grid as a storage method of electricity they would produce but not consume, and extract it back later at no cost. Two situations will occur. A prosumer will consume electricity he produces instead of purchasing it on the grid and a prosumer will inject electricity in the network, and either lower his electricity bill or extract that energy back later. He will make use of the grid, which represents a cost for the DSO, without paying for it. In both cases it results in a miss to win for the DSO. This section measures this shortfall for the recent years.

If a household produces electricity and consumes it as it is being produced without connecting to the grid, the loss for the DSO is equal to the price-cost margin it would have earned for that quantity of electricity. If the production is instead injected in the grid, the metering system will run backward and the household will be able to extract it later fully and free of charge. The loss for the DSO is thus its full price for that quantity. For ease of computation we will only consider the later case for the entirety of the solar panels production. Such assumption is reasonable in the sense that solar panels only produce energy during day time, when the need for electricity is the lowest, leading us to make the claim that most of the production is injected in the grid. The value of the loss for DSOs is equal to the quantity of electricity produced by prosumers times the price of the grid at the time of the production. We are here confronted with a major issue. The price of a DSO is measured in EUR per kWh, while the capacity of production of solar panels in the available data is given in kVA[2]. It is not possible to convert kVA into kWh. Therefore we cannot simply link the data on the total capacity of solar panels installed with the prices of the grid. We developed two methodologies to tackle this issue.

Firstly, we know as previously cited that an average solar panel installation of a household is about 3 kVp, which is a measure of the capacity of production of the installation. The kVp can be converted in kWh with the following estimated ratio : 1 kVp = 850 kWh a year (source: LineaTrovata.com). We make the unrealistic assumption that electrical production is homogeneous throughout the year and that the same amount of electricity is produced each month, that is for a 3 kVp installation: $(3 \cdot 850)/12 = 212.5$ kWh. We assume that the prosumers of Wallonia each produce an average of 212.5 kWh a month. This is undoubtedly far stretched but we are constraint by limited data and the need to keep relative eases of computations. We can now have a measure of the miss to win for the DSOs with the following formula, With DPU_i (decentralized production unit) the number of solar panel installations producing electricity in Wallonia during month i.

$$Shortfall_i = DPU_i \cdot 212.5 \cdot tariffs\ of\ the\ DSO_i \tag{2}$$

For the second methodology, it appears in the data that the average capacity of production installed[3] has been relatively constant since 2013 and is at a value of 5.3 kVA. According to the regional regulator this average capacity is of 3 kVp. We make the assumption that 5.3 kVA = 3 kVp, or 1 kVA = 40.08 kWh monthly with the ratio of 1 kVp= 212.5 kWh monthly previously mentioned. We obtain the following formula:

[2]Kilovolt ampere.

[3]That is, the cumulated capacity of production divided by the number of installations.

$$Shortfall_i = kVa_i \cdot 40.08 \cdot tariffs\ of\ the\ DSO_i \quad (3)$$

With kVa_i the cumulated capacity of production for that specific month. The first methodology uses the data on number of installations while the second on the capacity of production of the said installations, which we deem more precise. We select the second method of computation. Once again we use a weighted mean based on the quota of fees for the prices of the DSOs. We obtain the following results (figure 3). This amount can be seen as a shortfall. It corresponds to two elements : the price of the usage of the grid that is not being paid by the prosumers and what would have been purchased and paid by the prosumers had they not consume their production. The results obtained with the first methodology are presented in appendix B. All results are corrected for inflation.

Miss to win		Distribution	Transportation	Total
2014	Total	20.632.211,43 €	9.131.091,80 €	29.763.303,23 €
	Per DSO	1.587.093,19 €	702.391,68 €	2.289.484,86 €
2015	Total	26.140.303,15 €	10.390.366,13 €	36.530.669,28 €
	Per DSO	2.010.792,55 €	799.258,93 €	2.810.051,48 €
2016	Total	28.956.561,50 €	10.815.424,13 €	39.771.985,62 €
	Per DSO	2.227.427,81 €	831.955,70 €	3.059.383,51 €
Jan-Feb 2017	Total	5.000.033,32 €	1.799.442,75 €	6.799.476,06 €
	Per DSO	384.617,95 €	138.418,67 €	523.036,62 €
Projection 2017	Total	29.989.529,06 €	10.792.816,18 €	40.782.345,24 €
	Per DSO	2.306.886,85 €	830.216,63 €	3.137.103,48 €
Total 2014-2016	Total	75.729.076,07 €	30.336.882,05 €	83.102.130,96 €
	Per DSO	5.825.313,54 €	2.333.606,31 €	6.392.471,61 €
Average per year per DSO		1.941.771,18 €	777.868,77 €	2.130.823,87 €

Figure 3: Shortfall for the DSOs of Wallonia resulting from prosumers

The shortfall of a DSO is estimated to be approximately 2.13 million EUR a year. We do not have data on the turnover of the DSOs, however we do know that electricity trade generated a turnover of 2.12 billion EUR in 2014, and that the sector had that year an average price-cost margin of 10.9% (source : SPF Economie). The turnover of the DSOs being for the biggest part a cost of the said sector we know as a consequence that it can take a maximum value of 1.889 billion EUR a year[4], that is the total costs of the electricity trade sector for that year. We can

[4] $(1 - 0.109) \cdot 2.120.600.000$.

obtain another measure of the turnover of the DSOs. In 2016, 14.78 TWh were extracted from the grid in Wallonia (Source : Synegrid). Having the average prices of the DSOs at the time, it is possible to compute the part of their turnovers resulting from transportation and distribution for that month. It is of 1,743 million EUR for the totality of the market, or 134 million per DSO on average. This is plausible with the previous results obtained. With this in perspective, the value of the shortfall seems coherent and is estimated to represents on average 2.3% of the turnover of a DSO.

Overall, we distinguish two effects the prosumers and the Qualiwatt system have on the firms managing the grid. An additional costs through the payment of a fee and a loss of revenues. They are estimated at respectively 8.6 million and 39.7 million EUR for 2016 for the whole market, or 2.8% of its turnover. We obtained results that can somehow appear quite lackluster. Indeed, we made a lot of assumptions that do not necessarily reflect reality, regarding the quantity of electricity produced by solar panels, the fact that the production is equal every month, the fact that we used a weighted mean for the prices and so on. Computing those results for each DSOs instead of at the regional level is probably the best path to investigate in order to increase the accuracy of estimations, unfortunately due to the availability of data it is not possible for now. Nonetheless, we were able to put forward values the shortfall may take and compare them to the turnover of the DSOs as well as showing its evolutions and making a clear prediction for the future, which are results less likely to be influenced by the weaknesses of our estimations.

4.3 Is the loss compensated by a price increase ?

We showed that the prosumers represent a miss to win and an additional cost for the firms managing the grid, but how does this influence the prices ? These firms having monopolistic power, it is very likely that to the very least the cost of the fee is partially passed onto the prices, the only factor restraining the DSOs from doing so being the regulation of the Government. In this section we will try to measure the price increase attributed to the prosumers, even though it is difficult to know exactly what a price variation results from.

The DSOs generate benefits from their customers via three different activities. That is, the distribution and transportation of electricity, and the location of metering systems. Each DSO has its own prices, which have to be validated by the Cwape since 2014, by the Creg before that. For a standard client of an annual consumption of 3500 kWh, distribution represented 71% of the price resulting from DSOs services, transportation 26% and the location of the meter 3%. Let us have a look at their recent evolutions over time. We use a fixed base index 100=December 2014. It will allow to compare the evolution of prices of different ranges of value[5]. A weighted mean based on their quota of fees is used for DSOs of Wallonia (figure 4). The prices of distribution has known the biggest increase, close to 15% between 2014 and 2017. It appears as well that the distribution as the highest volatility. Transportation and location of metering systems vary very little over time and have done so only a few times since the beginning of 2014. Their prices seem to have maintained a relatively constant level after a drop in early 2015. Further we know that distribution represents almost three fourth of the total income of DSOs. As a consequence the loss due to prosumers should be compensated with the distribution charges.

With that in mind, we can compare the additional income generated through prices variations with the cost of the fee. For October 2015, 1,377 GWh were extracted from the DSOs network

[5]We start the analysis in December 2014 as we only have one observation for the whole year, 2014 corresponding to the beginning of the Qualiwatt system

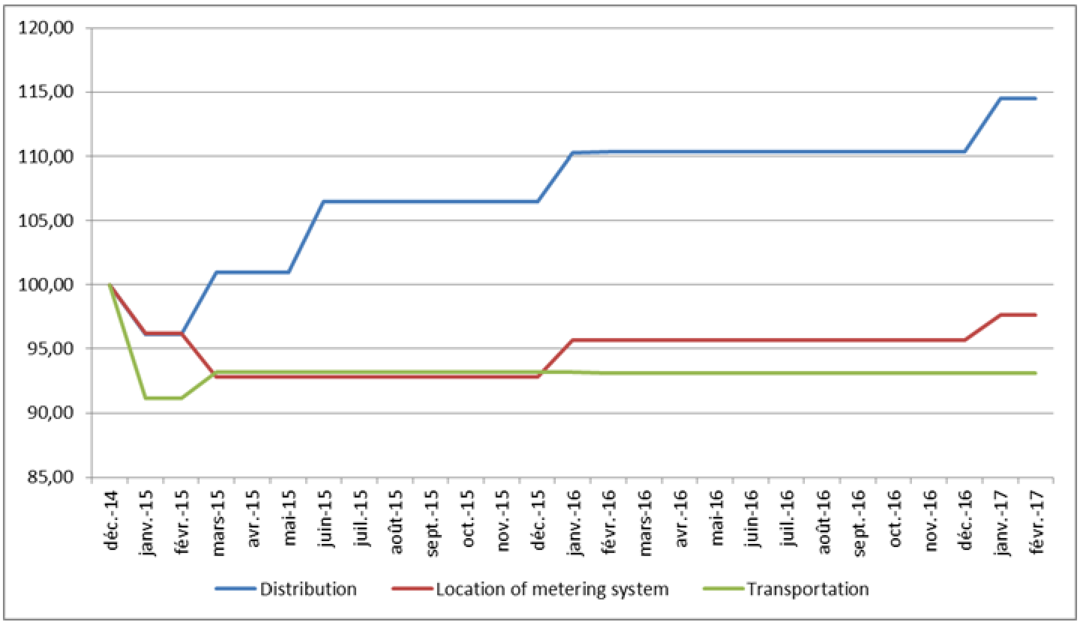

Figure 4: Evolution of the average tariffs of the DSOs in Wallonia, base 100 = December 2014

in Wallonia (source : Synegrid). By comparing the revenue corresponding to this quantity with the prices for December 2014, one year prior, and December 2015 we are able to determine the additional income resulting from price variations. The prices are corrected for inflation. We do not include location of metering system as we do not have data on the number of meters. This is negligible as it hardly makes up for 3% of the total revenue. We have:

Table 1: Revenues generated by DSOs in Wallonia for December 2015 using tariffs of 2014 and 2015[6].

	Service	Service Price (cEUR/kWh)	Quantity (kWh)	Benefit (EUR)
2014	Distribution	7.87	1,377,000,000	108,369,000.00
	Transportation	3.48	1,377,000,000	47,919,000.00
2015	Distribution	8.33	1,377,000,000	114,704,000.00
	Transportation	3.23	1,377,000,000	44,477,000.00
Differences	Distribution	0.46		6,335,000.00
	Transportation	-0.25		-3,442,000.00

The total additional revenue from December 2015 due to prices change for the totality of the DSOs with respect to the prices of December 2014 was of $6,335,000.00 + (-3,442,000.00) = 3,352,000$ EUR. We know that over the same period, the year 2015, the DSOs had to pay approximately a cumulated 5.246 million EUR of fees, which represents a monthly burden of 437,000 EUR while the shortfall for that month was of 3,166,000 EUR, which is a cumulated charge of approximately 3,603,000 million EUR. The prices increase corrected for inflation generated

[6]Corrected for inflation.

an additional monthly revenue which appears sufficient to cover the fee paid to the prosumers but not the totality of the burden they represent on the grid. The later could have been at best compensated for by price variations at the rate of 93%. Although, we cannot make claim at this regard for now. Indeed, we cannot exactly know what the prices variations fully represent, and how much of it account for the effect of solar panels. Further, the prices of DSOs have low volatility and are highly regulated. We proposed a methodology in which the prices variations between December 2014 and December 2015 are chosen purely arbitrarily. Econometrics could certainly help in this mater at a time where a sufficient large sample could be gathered. We will conclude that for December 2015 for the DSOs in Wallonia, the fees paid represented the equivalent of 0.031 cents per kWh while the shortfall was of 0.229 cents per kWh and that the price increase appears sufficient to cover most of this charge but cannot make certain claim as of how much was passed onto the prices paid by the final consumers which depends on the strength of the regulation that is applied to the monopolistic power of DSOs.

5 Prosumers - Providers relationship

In this section we are interested in the interaction of prosumers and electricity providers. Namely the effect the electricity production of households has on the price proposed by the providers. We are particularly interested in this segment of the electricity market as it is competitive since the liberalization in 2007, unlike transportation for instance which is still monopolized. The market being liberalized means that prices result from supply and demand forces and from the intensity of the competition on the market. Prosumers are likely to affect competition and to have an influence on this segment in this regard which is of our greatest interest. We will first analyse this relationship theoretically and determine the outcome it may result in. After which we will test it empirically and draw conclusions from the results.

5.1 Theoretical analysis

The energy component of the electricity price is the price of electricity itself. It is represented by the providers, which either produce it or purchase it to different producers and sell it to consumers. Competition takes place on both production and sale of electricity. In a simplistic view, the price of electricity is the result of the level of supply and demand of different markets all linked to each others (figure 5). We distinguish three specific markets. The materials of production, the production, and the providing. Intensity of competition and supply and demand will adjust the levels of the markups of the firms and the prices on each of the said market, which will result in the final price of electricity itself. In Wallonia, this price is composed of a fixed charge and of a charge per kilowatt hour. The green energy contribution is often added to this price to form the energy component. Providers have to purchase green certificates to green electricity producers as a form of contribution to renewable energies. This costs is then charged back to the consumers at different percentages regarding the provider.

Households producing electricity will be able to inject the share of their production they do not consume into the grid, therefore increasing the quantity supplied on the energy market. When the number of prosumers arises, ceteris paribus, the total quantity of electricity supplied on the market increases, the total demand remains constant and the demand addressed to the providers decreases by the amount of the self-consumption of prosumers. Additionally, the number of green certificates, which are given for green energy production, will increase. Their price being settled by supply and demand mechanisms, competition will take its toll. In both cases supply increases while demand remains constant, we should observe a drop in the prices. We determine that the price of electricity should decrease as the production of households trough solar panels increases. This production is estimated to have reached in 2015 the equivalent of 2% of the quantity of electricity extracted from the grid in Wallonia (Source: Creg, Cwape). This amount may be sufficient to have an observable effect on the level of the prices.

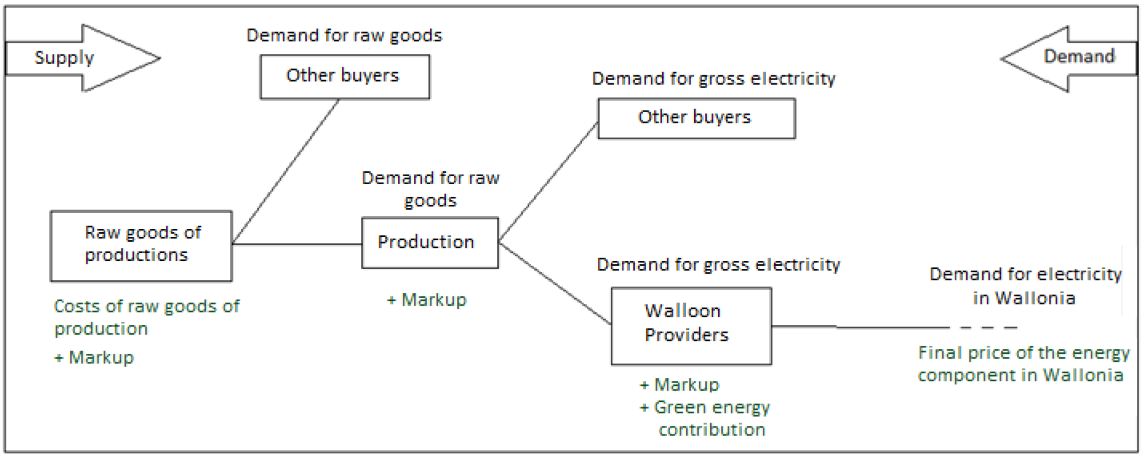

Figure 5: Simplistic view of the energy component market from a demand and supply point of view

5.2 Empirical analysis

The Belgian energy market was liberalized in 2007, making the empirical analysis only relevant since then. Before 2007 the market was monopolized and the solar panel technologies were not well developed. As a result the electricity production of household had close to no impact, if any, on the market from a supply and demand point of view. Due to this factor empirical analysis of this matter has only appeared to be possible since very recently. For our analysis we will use econometrics and consider the period January 2008 to February 2017. That is a temporal panel of 110 monthly observations and a sample of a size allowing significant results. We will first present the econometrical equation we aim to estimate, the results we might expect from it, and the data sample before going over the development of the models.

We are interested in the relationship between the self-production of electricity of households with solar panels and the price of the energy component. To isolate this relationship in the data we will control for other factors influencing the price. Thus the equation we aim to regress is the following:

$$Energyprice = \beta_0 + \beta_1 prodsolarpanel + \sum_{i=1}^{n} \beta_{i+1} x_i \tag{4}$$

With x_i a specific factor influencing the price of electricity which we want to control for. β_0 can be considered as the price of the energy component all other factors controlled for being equal to 0. The coefficient of interest, β_1, will be interpreted as the effect on the price of one additional unit of solar panel production, whatever it may be. We will refer to *Energyprice* as the dependent variable and *prodsolarpanel* as the variable of interest. According to our theoretical analysis, we suppose this relationship negative. If this is verified empirically we should find a value for β_1 that is significantly different from 0 and negative.

Formally:

$$\beta_1 \neq 0$$
$$\beta_1 < 0$$

Meeting the above criterion will show evidences of such negative relationship. Moreover, the value of β_1 will inform us on the strength of this relation. If there do exist a relationship between solar panels production and prices, is it drastic or merely noticeable? We will use as a measure of the level of production of solar panels of households the cumulated monthly capacity of production registered for both the Solwatt (01/2008-08/2014) and Qualiwatt (03/2014-) systems in kilovolt ampere in Wallonia multiplied by the monthly hours of daylight[7] (see equation 5). The data are given by the regional commission of regulation for Wallonia, the Cwape. These data have the advantage of being cumulative over time, unlike, for instance, the average capacity of production. While it is possible to convert the capacity of production of an installation into a level of production, we decide not to. Such conversion is highly approximative as the conversion is an annual estimation. Moreover what does matter the most in this case are the relative monthly values, rather than absolute. The hours of sunlight however appear as an important factor to take into consideration while trying to evaluate the level of production of prosumers. Photovoltaic panels only produce electricity when exposed to the sun and the amount of sunlight varies greatly from a month and a year to another, resulting in different levels of production for an identical installation with respect to the period. We believe such methodology gives, while not exact, the best measure of the monthly electricity production of households. We have to note that the data do not allow for prosumers to leave the market, only allowing the cumulated capacity of production to increase. This should lead to an overestimation of the real capacity of production, although we consider the number of households retracting from the solar panels market to be non-significant.

$$prodsolarpanel_i = (kVa\ Solwatt_i + kVa\ Qualiwatt_i) \cdot sunlighthours_i \tag{5}$$

Regarding the price of the energy component, gathering data as proven to be challenging. We have however managed to obtain three sets of data relatively close the variable we are interested in, i.e. the price of the energy component in Wallonia from 2008 to 2017. The following section of the empirical analysis will consequently be divided in three parts, corresponding to the three sets of data on prices, which we will call regression 1, 2 and 3. That is the average price of the energy component in Belgium since 2008 (1), the price of the energy component in Wallonia from 2012 to 2017 (2), and the prices of the different elements composing the energy component itself since 2010 (3). Each set will be presented in detail below. While selecting these data we focused on three aspects: the period covered, the price being referred to and the region concerned. All sets of data have their flaws for which we hope to compensate by having multiple of them. The three sets we have managed to obtain fulfil the following conditions:

[7]We use the hours of daylight for a representative city of the country, Uccle, given by the national meteorological institute.

Table 2: Definition of the data sets on prices of energy.

	2008-2017	Energy component	Wallonia
Regression 1	Yes	Yes	No
Regression 2	No	Yes	Yes
Regression 3	No	Yes	Yes

As for the control variables, they are other factors impacting the value of the dependent variable. The exact value of the dependent variable at a given time will depend of the values of the control variables at the said time. We include them in the regression in order to isolate the effect of the production of solar panels. We are however greatly limited in their choice by the availability of data. Although we will mostly use identical variables for in each model, we will try adjust the set of controls for every dependent variable. We divide control variables in three categories: Government policies, supply related and demand related. The energy market is highly regulated due to the nature of the market and of the good, thus leaving a important place in the level of prices to Government actions. One of the major being the price freeze of 2012. From April to December 2012 the former Government decided to implement what was called a price freeze, blocking the tariffs proposed by the provider under a threshold and limiting increases in pricing. This measure had an important impact as it deeply influenced the variation of prices during that time period. We include it in the regression under the form of a binary variable, called $pricefreeze$, taking the value of 1 for the month of April to December 2012, 0 else. A second impactful measure the energy market has undergone in the last decade was the VAT rate change. Over the course of little more than a year in 2014 and 2015 the rate has changed twice, going from 21% to 6%, back to 21% in sixteen months. While the VAT rate does not directly affects the price of the energy component, as it is not included in it, it does still have an important influence. Electricity purchase can be seen as a bundle. Regular consumers do not buy component of the price independently, electricity is necessarily purchased with transportation, distribution and so on. The demand for the energy component is dictated by the final price of electricity as it is the one consumers pay, which includes VAT. It is thus only natural that changes in the VAT rate as drastic as a 350% variation will to at least some extend indirectly affect the price of the providers (see appendix C for graphical argument). We include this effect once again via a binary variable, taking the value 6 or 21 corresponding to the level of the VAT rate for that specific month. According to the same reasoning we should include prices of distribution and transportation in the regression. We could, however these prices generally appear to vary very little over time, maintaining their values for long period. Further the data are lackluster. We dismiss these variables for the regression.

Regarding supply related variables, as notably cited by the federal commission of regulation the Creg one of the main determinant of the price of retailed electricity, specially before 2012, are the prices of the gross market, the Belpex. They are the prices paid by the providers and are thus one of their main costs. We compute a monthly average based on the Belpex hourly prices and include it as control variable. And alternative to the Belpex prices if the price of oil. We use the price of the Brent barrel of petrol. The price of oil is known to be a good representative of the energy market and is often used as such. Additionally it can, depending on the means of production, be a cost of electricity production. We consider the variable a representative of the gross market of energy alike the Belpex prices. We do not use both variables simultaneously as we consider they are the reflection of the same forces on prices of electricity and to be equivalent control variables.

For models with prices data for Wallonia, we can include as well the Herfindahl-Hirschman Index (HHI). The HHI is computed as the sum of the square of the market shares of the providers at a given time. It is a measure of the concentration of the market. we deem the concentration to be one of the strongest forces of influence of prices. A low concentration is synonym of a very intensive competition on the market, which will push prices down. On the contrary, firms operating on a market with a structure close to the one of a monopoly shall have the capacity to present price-cost margins far much higher. Besides, we know that the Belgian electricity market was liberalized in 2007, prior to what it was monopolized. Its concentration has been reshaped since then with the entry of new firms an the redistribution of market shares, making the HHI even more relevant to include in the regression. The index is computed with the quarterly shares of the five biggest provider of Wallonia, Electrabel, Luminus, Lampiris, Essent and Eni. We use the market shares based on the number of consumers. Unfortunately, the weakness of this variable is that it is computed quarterly. Its variations are not continuous in the monthly sample unlike data on prices, which can show to be troublesome in some cases. We do not have data available on the market shares at country level and thus can only compute it f or the regional case.

Selecting control variables regarding demand effects on price is the hardest part of the work. Electricity can be use for numerous purpose without any apparent links, such as lightning, heating, electronic utilities, etc. Further, electricity demand has a weak price elasticity. We naturally add the production of solar panels, as it is our variable of interest. We select the monthly hours of sun as additional control variable. It is a representation of the need for lightning and indirectly for heating. Furthermore, it will account for seasonality in the prices, which is an important issue coming to our concern. Demand is far from being constant over the course of a year. Factors such as luminosity or temperature linked with demand for electricity can vary tremendously from a month to another. It is likely that we will observe variation in the demand, and thus in the price, only resulting from a change of season. A substitute method of control for seasonality would be to introduce control variables for seasons, taking the value of 1 if the observations is included in that season, 0 else.

5.2.1 Regression 1

The first data we use as dependent variable are the monthly average price of the energy component in Belgium for the period January 2008 - December 2016. The price are given for the consumption of a standardized household (Dc), 1600 kWh daytime and 1900 kWh nighttime annually. It is computed as a weighted mean of the prices of the five biggest providers of the country, that is Electrabel, Luminus, Lampiris, Essent and Eni. The values are adjusted for inflation based on the level of prices of early 2017[8]. We use as weighting the quarterly market shares of the providers based on the number of consumers in Wallonia. We use data based on Wallonia for the shares are they are the ones with the highest availability. We are forced to make the assumption that the shares are similar at regional and country wide level, though it may be challenged. The raw data are furnished by the Creg for the prices and by the Cwape for the market shares. The weakness of this sample lays in the fact that the prices are at the country level while the production of solar panels is measured regionally. Consequently it is likely that we will underestimate the importance of the relationship in this regression.

Similarly to seasonality, time trends are important problems specific to time series for which we have to control. Variables often follow growing trends over time such that one may believe

[8]We used the consumer price index for computation as given by the ministry of Economics.

having found causal relationship where the correlation is only the result of similar time trends between the variables. We are particularly concerned with this subject as time trend are often common in prices. Further, as mentioned earlier, our data sample on solar panels production do not allow for households to retract from the prosumers market, leaving great room for such issue. We will correct for time trend shall it prove to be problematic in our sample.

Additional general concerns regarding time series are lagged variables. That is when the t-1 value of a variable added in the regression is correlated as well with the dependent variable and is responsible for part of its variations. Adding lags can diminish the size of the sample, as such much care is needed in their selection. While it might seem obvious that value of a price at time t is correlated with its value at time t-1, we do not add a lagged variable of the price of electricity in the regression. We do not believe the relationship is causal. Indeed, it often appears that the prices proposed by a provider can go through huge variations over a short time laps, indicating that prices are not bounded by their previous values. Regarding other control variables, adding their lagged values in the regression is interpreted as the fact that their exist a delay in their effect on price superior to the period between observations i.e. a month in this case. We do not believe it to be the case and overall do not believe there exists a causal relationship between lags and the dependant variable which could justify adding them in the models. Accordingly we do not select lagged values as control variables.

The selected models are the following:

$$Pricebel = \beta_0 + \beta_1 Kvaensoll + \beta_2 Belpexinfla + \beta_3 Pricefreeze + \beta_4 VAT + \beta_5 Sunlight \quad (6)$$

$$Pricebel = \beta_0 + \beta_1 Kvaensoll + \beta_2 Brent + \beta_3 Pricefreeze + \beta_4 VAT + \beta_5 Sunlight \quad (7)$$

We run equation (6) and obtain the results presented in figure 6. The coefficient of $Kvaensoll$ appears negative and significant. This indicates that there do seem to exist a negative relationship between the level of production of electricity of households and the price of the energy component. An increase in the capacity of production of solar panel will result in a drop of the price. This result is coherent with our theoretical analysis. Logically the result for the Belpex prices is positive, an increase in the cost will increase the price. Other results surprisingly appear contradictory to common sense prediction. The Ramsay's RESET test for H_0 = no misspecification gives a p value superior to 0.05, showing that such issue is not a concern. The Breusch-Pagan test gives similar results about heteroskedasticity, which is hence not a concern either.

We check for time trend by adding a control variable taking the value 1 for the first observation of our sample, 2 for the second and so on, and run the model again. We obtain a significant coefficient for the variable t, indicating that time trend is a potential issue. We correct for it by using first difference of the variables potentially subject to a trend. That is: $x'_t = x_t - x_{t-1}$. The presence of a time trend in the variables for the price freeze period or the VAT rate makes no sense. We only correct for both the energy component and the Belpex prices as well as for the production of prosumers. We run the model once more with the adjusted variables and obtain results corrected for time trend. Although the coefficient of $Kvaensoll$ is still negative and significant, it now appears far much smaller, about a tenth of its previous value with $-1.97 \cdot 10^{-9}$. We can interpret this result as the fact that the effect the production of posumers may have on prices is overestimated in our sample due to a time trend.

Source	SS	df	MS
Model	113.897835	5	22.7795669
Residual	35.9322556	102	.352277016
Total	149.83009	107	1.40028122

Number of obs =	108
F(5, 102) =	64.66
Prob > F =	0.0000
R-squared =	0.7602
Adj R-squared =	0.7484
Root MSE =	.59353

Pricebel	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Kvaensoll	-1.79e-08	1.73e-09	-10.36	0.000	-2.13e-08	-1.45e-08
Belpexinfla	.0321316	.0045932	7.00	0.000	.0230211	.0412421
VAT	-.018853	.0122464	-1.54	0.127	-.0431437	.0054376
Pricefreeze	.9797266	.2111739	4.64	0.000	.5608641	1.398589
sunlight	.0063147	.0009725	6.49	0.000	.0043858	.0082435
_cons	7.257828	.4001164	18.14	0.000	6.464199	8.051457

Figure 6: Results of model (6)

Our second concern with times series is serial correlation. That is, correlation among the residuals of different periods. We run two tests to verify if such issue appears in our case, Breush-Godfrey and Durbin-Watson alternative tests. Both show presence of serial correlation. We use a Cochrane-Orcutt regression to correct it for the models presented above. The coefficient of *Kvaensoll* is once more negative, but this time not significant.

We go through the same process with model (7) and obtain similar issues which we solve, leading to the results presented in figure 7. We obtain a negative coefficient for the production of solar panels which shows significance at 10% and which is corrected of both time trend and serial correlation. Overall, we obtain values for the coefficient of the variable of interest *Kvaensoll* ranging from $-1.79 \cdot 10^{-08}$ to $-9.82 \cdot 10^{-10}$, depending on the set of control variables used and the issues corrected for. This value can be interpreted as the effect on the price of the energy component of an additional solar panels installations of a capacity of one kilovolt ampere illuminated for one hour. In December 2016, the installations of the combined Solwatt and Qualiwatt had represented a total of 60,561,551 kVA-hours of illumination[9]. This represents a reduction of the price of between 0.05 and 1.08 cents per kWh of the price of the energy component. The average price at the time being equal to 6.915 c/kWh it is equivalent to 0.74% to 15.68% to its value. If we consider the later result is highly over estimated due to time trends, these values are coherent with our estimation of the production of households representing about 2% of the market.

5.2.2 Regression 2

The second set of prices to be used are the average pondered prices of the energy component in Wallonia from December 2012 to February 2017. The data are given by the Creg which also

[9]That is the cumulated capacity of installation at the time multiplied by the number of hours of light for that month i.e. 60,561,551 kVA illuminated for an hour or one kVa illuminated for 60,561,551 hours.

Cochrane-Orcutt AR(1) regression -- iterated estimates

Source	SS	df	MS		
				Number of obs =	106
				F(5, 100) =	0.76
Model	.072036043	5	.014407209	Prob > F =	0.5800
Residual	1.89309877	100	.018930988	R-squared =	0.0367
				Adj R-squared =	-0.0115
Total	1.96513481	105	.01871557	Root MSE =	.13759

Pricebel_bis	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Kvaensoll_bis	-9.82e-10	5.92e-10	-1.66	0.100	-2.16e-09	1.93e-10
Brentinfla_bis	.0013223	.0135931	0.10	0.923	-.0256459	.0282906
VAT	.0021375	.0040837	0.52	0.602	-.0059645	.0102395
Pricefreeze	.0014451	.0767459	0.02	0.985	-.1508166	.1537067
sunlight	.0004646	.0002916	1.59	0.114	-.0001139	.0010432
_cons	-.132485	.0933162	-1.42	0.159	-.3176217	.0526517
rho	.448412					

Figure 7: Results of model (7) corrected of time trend and serial correlation

computes the mean. While the prices do refer to Wallonia, their availability is very limited. The data, and as such the factors from which they depend, are similar to regression 1. The difference being that we are now only concerned with Wallonia and that events having taken place prior to late 2012 are not to take into considerations. The sample is only composed of 51 observations. This is rather small and will limit the strength of the interpretations. We find that in this case using the price of oil instead of the Belpex prices seems to yield more interesting results.

The model is the following:

$$Pricewall = \beta_0 + \beta_1 Kvaensoll + \beta_2 Brent + \beta_3 Pricefreeze + \beta_4 VAT + \beta_5 sunlight + \beta_6 HHI \tag{8}$$

We obtain results given in figure 8. The coefficient for HHI is positive. This result is coherent. The higher the concentration is, the weaker competition will be. Firms will be stronger and their dominance of the market will allow them to push higher prices. In this model the negative effect of the production of solar panels on prices is much stronger in comparison which what we had obtained in regression 1. Such result seems logical as the level of production of prosumers represents a higher percentage of the market of Wallonia than the one of Beligum and thus have a stronger impact. The Breusch-Godfrey test shows signs of serial correlation for this model. Further, when obtain a significant coefficient for the variable t when adding it to regression, which indicates time trend to be an issue. We correct for both problems through similar methods as presented above and obtain which yields results presented in figure 9.

Source	SS	df	MS
Model	34.6478547	6	5.77464245
Residual	6.01038208	44	.136599593
Total	40.6582368	50	.813164735

Number of obs =	51
F(6, 44) =	42.27
Prob > F =	0.0000
R-squared =	0.8522
Adj R-squared =	0.8320
Root MSE =	.36959

Pricewall	Coef.	Std. Err.	t	P>|t|	[95% Conf. Interval]	
Kvaensoll	-7.01e-08	2.04e-08	-3.45	0.001	-1.11e-07	-2.91e-08
VAT	-.031555	.0079274	-3.98	0.000	-.0475316	-.0155784
Pricefreeze	1.462739	.5251	2.79	0.008	.4044694	2.521009
Brenteur2	-.0464991	.0294659	-1.58	0.122	-.1058838	.0128855
sunlight	.0417355	.0133584	3.12	0.003	.0148134	.0686575
HHI	45.83469	19.30023	2.37	0.022	6.937629	84.73175
_cons	-4.190997	4.903072	-0.85	0.397	-14.07249	5.690496

Figure 8: Results of model (8)

Using first differential reduces the size of the sample, which excludes the variable$Pricefreeze$ from the model. Since our sample begins in December 2012, only the first observation was concerned by the price freeze, observation which is excluded in the above model for the sake of its correction. The regression yields a value of $-3.51 \cdot 10^{-09}$ for β_1. It appears the effect of solar panels production was overestimated by a time trend and serial correlation. The value of the coefficient of the variable of interest in the above model can be interpreted such that, in December 2016, the electricity produced by households had represented a drop in the price of 0.212 cents per kWh, or 3.5% of its value.

5.2.3 Regression 3

For the following regression we use data on the price of the energy component and the elements which compose it computed by the Belgian ministry of Economics. This is probably the most interesting data. Whereas the price of the energy component was previously computed as a percentage of the retail price of electricity, it is in this case computed as the sum of the multiple elements composing it. The data should thus be more accurate. Additionally, this will allow to decompose the effect of electricity production of households and see which part of the price of energy is the most affected. The data are given from January 2010 to February 2017, that is 86 observations. We acknowledge the fact that the size of the sample is small for econometrics purpose, although it is not possible to obtain additional observations for now. The total price of the energy component is computed as the sum of a fixed fee (15%), a charge per kWh (59%), and a green energy contribution (26%). The percentages are given for February 2017.

Let us first simply look at the correlation table between our variable $Kvaensoll$ for the production of households and the price of the energy component and its multiple parts (figure 10). All correlation are relatively strong with a value of above 0.5. The result for the aggregated price appears negative. The correlation of the electricity production of solar panel is negative with the fixed fee and with the price per kWh, and positive with the green energy contribution. The later

Cochrane-Orcutt AR(1) regression -- iterated estimates

Source	SS	df	MS
Model	1.44182611	5	.288365223
Residual	3.98703146	43	.092721662
Total	5.42885758	48	.1131012

Number of obs	= 49
F(5, 43)	= 3.11
Prob > F	= 0.0175
R-squared	= 0.2656
Adj R-squared	= 0.1802
Root MSE	= .3045

Pricewall_bis	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Kvaensoll_bis	-3.51e-09	1.38e-09	-2.54	0.015	-6.30e-09	-7.20e-10
VAT	-.0005836	.0050308	-0.12	0.908	-.0107291	.009562
brent_bis	-.0902783	.0436013	-2.07	0.044	-.1782088	-.0023478
sunlight	-.0001495	.0006387	-0.23	0.816	-.0014376	.0011387
HHI	-2.841734	2.520679	-1.13	0.266	-7.925168	2.2417
_cons	.8573046	.8205772	1.04	0.302	-.797547	2.512156
rho	-.2877092					

Figure 9: Results of model (8) corrected of time trend and serial correlation

result may seem contradictory with one's intuition on the theoretical sign of the relationship. Indeed it would be expected that the price of the green energy contribution drops as the number of green certificates emitted increases.

	Kvaen~ll	Total	Fixedfee	Perkwh	Greenc~b
Kvaensoll	1.0000				
Total	-0.5028	1.0000			
Fixedfee	-0.6722	0.6471	1.0000		
Perkwh	-0.5105	0.9481	0.6199	1.0000	
Greencontrib	0.5844	-0.6785	-0.7503	-0.8408	1.0000

Figure 10: Correlation table of the production of households and the parts of the energy component

We shall run four models for this sections, corresponding to the four sets of prices, one for the aggregated price and three for its components, namely the fixed charge, the price per kWh and the green energy contribution. We decide to use identical control variables sets as those used in regression two for the three first variables as they should be influenced by identical supply and demand factors.

$$Pricetotal = \beta_0 + \beta_1 Kvaensoll + \beta_2 Brent + \beta_3 Pricefreeze + \beta_4 VAT + \beta_5 sunlight + \beta_6 HHI \quad (9)$$

$$Fixedfee = \beta_0 + \beta_1 Kvaensoll + \beta_2 Brent + \beta_3 Pricefreeze + \beta_4 VAT + \beta_5 sunlight + \beta_6 HHI \quad (10)$$

$$Perkwh = \beta_0 + \beta_1 Kvaensoll + \beta_2 Brent + \beta_3 Pricefreeze + \beta_4 VAT + \beta_5 sunlight + \beta_6 HHI \quad (11)$$

We first regress model (9) for the total price of the energy component in Wallonia. A negative and significant coefficient is obtained for β_1 of a value of $-8.36 \cdot 10^{-9}$. The Breusch-Godfrey and Durbin's tests detect the presence of serial correlation, for which we once more correct through a Cochrane-Orcutt regression. The results are presented in figure 11. The value of β_1 is this time much lower with about a third of the previous value obtained. Time trend does not look as an issue to be concerned about in this case as we do not obtain a significant coefficient for the variable t when added in the model. The result for β_1 shown in figure 11 corresponds, for December 2016, to a drop of the price of the energy component of 1.9%. The result obtained is smaller than what was obtained in regression 2. This can be explained by the time period covered by both models. This results includes data from as early as 2010, where the effect of solar panels was weaker. The data of regression 2 begin in 2012. The capacity of production of prosumers was then much more important than two years prior. It is thus understandable that the overall effect they may have on prices was stronger for that period.

Cochrane-Orcutt AR(1) regression -- iterated estimates

Source	SS	df	MS
Model	.341688885	6	.056948147
Residual	2.36461552	78	.030315584
Total	2.70630441	84	.03221791

Number of obs	= 85
F(6, 78)	= 1.88
Prob > F	= 0.0950
R-squared	= 0.1263
Adj R-squared	= 0.0590
Root MSE	= .17411

Total	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Kvaensoll	-2.85e-09	1.41e-09	-2.02	0.047	-5.66e-09	-4.16e-11
VAT	.0054246	.0084981	0.64	0.525	-.0114937	.022343
Pricefreeze	.0377539	.1304501	0.29	0.773	-.2219524	.2974602
Sunlight	.0009756	.0006946	1.40	0.164	-.0004072	.0023585
Brenteur2	.0125206	.0130529	0.96	0.340	-.0134657	.038507
HHI	4.264676	6.393874	0.67	0.507	-8.464549	16.9939
_cons	7.328383	1.754712	4.18	0.000	3.835019	10.82175
rho	.9079382					

Figure 11: Results for model (9) corrected of serial correlation

Regarding the fixed fee and model (10), we do not manage to obtain any sort of significant result once issues such a residual correlation are solved for. For the price per kWh, we run model (11) and find a negative significant relationship for the production of solar panels of $-6.63 \cdot 10^{-09}$. We do not find any presence heteroskedasticity nor time trend in the model. It shows however signs of misspecification and serial correlation. We correct the later and obtain results presented in figure 12. The correlation for $Kvaensoll$ is yet again negative and significant. We find a β_1 of $-3.40 \cdot 10^{-09}$, which correspond for December 2016 to a drop of the price of 0.2 c per kWh, or 3.8% of the price of 5.37 cents per kWh. This is more important than what we had obtain for the total price.

Source	SS	df	MS
Model	.366110112	6	.061018352
Residual	2.39435313	78	.030696835
Total	2.76046324	84	.032862658

Number of obs	85
F(6, 78)	1.99
Prob > F	0.0774
R-squared	0.1326
Adj R-squared	0.0659
Root MSE	.17521

Perkwh	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
Kvaensoll	-3.40e-09	1.41e-09	-2.42	0.018	-6.20e-09	-5.99e-10
VAT	-.000525	.0085578	-0.06	0.951	-.0175623	.0165123
Pricefreeze	.0150836	.1308502	0.12	0.909	-.2454193	.2755864
Sunlight	.0010528	.0006906	1.52	0.131	-.0003221	.0024277
Brenteur2	.0117039	.0140382	0.83	0.407	-.0162442	.0396519
HHI	8.417286	6.744986	1.25	0.216	-5.010949	21.84552
_cons	2.982242	2.002386	1.49	0.140	-1.004201	6.968686
rho	.9367965					

Figure 12: Results for model (11) corrected of serial correlation

As for the green energy contribution, let us first remind how it is calculated. The regulator decides annually of a percentage. This percentage is to be applied to the total quantity of electricity provided to determine the number of GC a provider will have to present, which with the price of a GC sets the total cost it represents. A percentage of that cost is then passed onto the prices. Mathematically:

$$Number\ of\ GC = percentage \cdot kWh \tag{12}$$

$$Total\ cost = number\ of\ GC \cdot P \tag{13}$$

$$Contribution = \frac{Total\ cost \cdot a}{kWh}$$

$$= \frac{percentage \cdot kWh \cdot P \cdot a}{kWh}$$

$$= percentage \cdot P \cdot a \tag{14}$$

With a the percentage of the cost of the GC that is supported by the consumers, P the average price of GC and kWh the total quantity of electricity provided. When the production of households increases, we can expect P and kWh to decrease. The price of the green energy contribution appears as the result of the price of the GC, the percentage of GC imposed by the government, and a which we will interpret as the market power of firms and for which we will use HHI as an image. Luckily we do have data on all the above listed variables and are thus left with the following model in order to test if the production of households does have a causal relationship on the price of the contribution:

$$Contribution = \beta_0 + \beta_1 Kvaensoll + \beta_2 Quota + \beta_3 Pricegc + \beta_4 HHI \tag{15}$$

We do not find a significant relationship between the price of the green contribution and the electrical production of households with the above model, although the coefficient of interest does appears to be positive.

5.3 Conclusion

It has been shown through multiple regressions evidences that the electrical production of households in Wallonia has a negative effect on the prices of the energy component. This result corresponds to the effect predicted theoretically. Furthermore, we show that this effect is strongly overestimated in the data due to time trends. We find that the downward pressure of prosumers is the strongest on the charge per kilowatt hour (-3.8%) and that the impact is lesser on the total price of the energy component (from -0.74% to -3.5%) due to the effect on its other elements being lesser or non-existent. Though we consider the number of households exiting the solar panel market to be insignificant, these values are likely to be slightly overestimated since we do not account for such phenomenon in the data. Throughout the entirety of the work a challenge we were confronted with has been the size of the sample, which often shows to be on the shorter hand of the amount of observations required. Not much can be done in this regard as of now, beside increasing the number of models and confronting the results. We believe to have obtained all available and interesting data regarding the prices of the energy component of electricity. An interesting follow-up would be to run the models again once further data have been gathered.

It now appears that the electrical production of households with solar panels, in the actual Belgian electricity system, has an impact on the price of energy and on the providers market. The effect on the final bill of consumers is relatively small, since as of 2016 it only represented a variation of about 3% of the energy component's price, or 0.76% of the retail price. How will this effect evolve in the future ? What matters is the ratio between the total demand for electricity and the capacity of production of solar panels. If the later grows at a higher rate we should see a stronger negative force on prices occur, everything else being equal. From January 2015 to January 2016 the growth rate of the demand of electricity in Wallonia was of 0.38% (Source: Synergrid) while the growth of the number of kVA installed was close to ten time as much with 3.61%. We can reasonably expect prosumers to have an increasing impact on the market. This trend however is diminishing every year. The number of solar panels installation has undergone a drastic progression in its early stages, with annual growth rates of over 140% in 2012. This growth rate has since then consistently been decreasing to the point where we could expect a reverse of the trend to appear as soon or later.

An additional conclusion can be drawn from this work. Installing solar panels lowers the benefices of doing so, as it lowers the price of the electricity which it will produces, thus making the installation less profitable. That is from the perspective of the price of the energy component to the least.

6 Overall conclusion

Throughout this work it has been shown evidences of two distinguished effects the households producing electricity have on the energy market. A price increase through the payment of a fee they receive and the shortfall they represent, and a reduction of the price of the energy component through supply and demand forces. These results are coherent with the evolutions of the prices of the component of electricity presented in section 2. This is a simplistic view of the reality as prosumers undoubtedly have much more influences on the market. While remaining in the borders of this work we will try do determine the cumulated effect they may have on the final prices. How do these two inverse forces oppose each other on the retail price ? We showed that the fee paid to the prosumers represented an annual cost of about 5.25 millions EUR in 2015, or 437,168 EUR monthly. For the month of December 2015, 1,377 GWh were extracted from the grid of the DSOs in Wallonia (source: Synegrid). We concluded that the fee thus represented a cost of 0.032 cents per kWh. Identically, the annual shortfall estimated at 36.5 million EUR for 2015, or 3.04 million monthly is the equivalent of 0.229 c per kWh. Further, through the results obtained in the section on the analysis of the providers market, we compute that as of December 2015 the electrical production of households in Wallonia represented on average a reduction of the energy component price of 0.157 cents per kWh[10]. Consequently we conclude that, for 2015, if more than 60% of the total monetary effect prosumers have on grid managing firms was compensated for by a price increase, the overall effect will be a price raise[11]. If less than 60% was passed onto the prices, the reduction of the energy component charge will be stronger and the cumulated effect will be a price decrease. The value of this percentage is far lower as of today. Indeed, from December 2015 to January 2017, the number of kVA installed under the Qualiwatt system has more than double. Further, DSOs have monopolistic power. As a result households producing electricity are likely to be increasing the retail price. We believe this trend could reverse at some point however, as we have shown that the total cost of the fees will not increase much more and is thought to decrease in an upcoming future, while the providers market should keep on becoming more and more competitive, enhanced by the increasing capacity of production of prosumers, and thus effectively further reducing the price of the energy component.

[10] Using results of regression 3.

[11] $0.157/(0.229 + 0.032) = 0.6$.

For a standardized consumption of 3500 kWh annually, if the fees and the loss of income were to be fully compensated for by a price increase of the tariffs of the DSOs, as of December 2015 the prosumers of the Walloon market had represented an additional annual cost of $3500 \cdot (0.229 + 0.0317 - 0.157) = 1361$ cents, or 13.61 EUR. The average annual price of such consumption being for 2015 of 897.18 EUR (source: Creg), this represents 1.5% of the total price. Although this value is certainly overestimated and is the result of numerous estimations, it allows to obtain a range of values in which prosumers may affect the final bill of a consumer, which was the purpose of the paper.

7 Recommendations

The problem of the actual system is that energy has a very low price elasticity. Its consumption can hardly be reduced below a certain threshold for most households. Indeed, everyone needs lightning, heating systems, or other basic electricity powered utilities. We have shown that the overall effect of prosumers appear to be an increase of the final price of electricity through the tariffs of the DSOs. As such when the number of prosumers arises so should the prices. The price increase is identical for every consumer[12] and each will see his bill raised by the same share. The demand for energy will barely adjust to the new price as it is a mostly inelastic good, and consumer will not have any possibility of avoiding this price raise has the DSO is attributed an mandatory to a specific area. The poorer households will be the most penalised, loosing the biggest share of their income to the price increase. The dilemma being to either allow an increase of the DSOs prices, punishing consumers, or to reduce incentives to invest in solar panels, reducing the share of green electricity production of the country. In order to avoid such choice, or to the least diminish the negative consequences it implies, and to improve the actual system we propose the two following suggestions :

- The fee should be paid by the Governement rather than by the DSOs.
With the actual system, the fee represents a charge for the DSOs that is compensated for by a price increase for all consumers, therefore pushing on everyone of them the same contribution. If, instead, the Government were to pay the fees to the prosumers by means of its budget, households would still contribute, but with a share proportional to their incomes through taxes. This change would solve the problem of the price increase without punishing the prosumers. Part of the total charge would be passed from the poorest to richest households. A negative consequence of such change would be that, as the price of electricity is lowered, so will the value of the production of prosumers. Although such loss should not be of much of a concern, considering that Belgium is already very generous with solar panels owners (Boccard and Gautier (2015)), the decrease in the value of their production could be compensated for, for instance, by the payment of a higher fee. The increase could be allowed by the shift from DSOs to Government in the payment of the said fee, as its amount would have much less of an impact on DSOs and poorer consumers. To what extend should the fees be increased relies on the above presented dilemma.

- The net metering system should be change to a net billing system.
Net metering values exportations and importations of electricity on the grid identically, making part of its usage free of charges for prosumers. With a net billing system, two meters register the different flows. Exportations should be valued lower than importations. With this in place, part of the cost of the grid usage would fall back from the DSO's, and ultimately from the other consumers, to the prosumers. As a possible compensation for prosumers and in an effort to

[12]Except consumers benefiting social programs.

maintain the incentives of solar panels investments, the fees could, here also, increase. Further, with net billing, it is more profitable for prosumers to consume the self-produced electricity rather than sending it in the network. As such net billing increases incentives to synchronise consumption with production for prosumers, effectively reducing their usage of the grid. This phenomenon has been presented and demonstrated by Brown, D. and Sappington, D., (2015) where the show evidences of the welfare superiority of net billing.

8 References

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9 Appendix

9.1 Appendix A

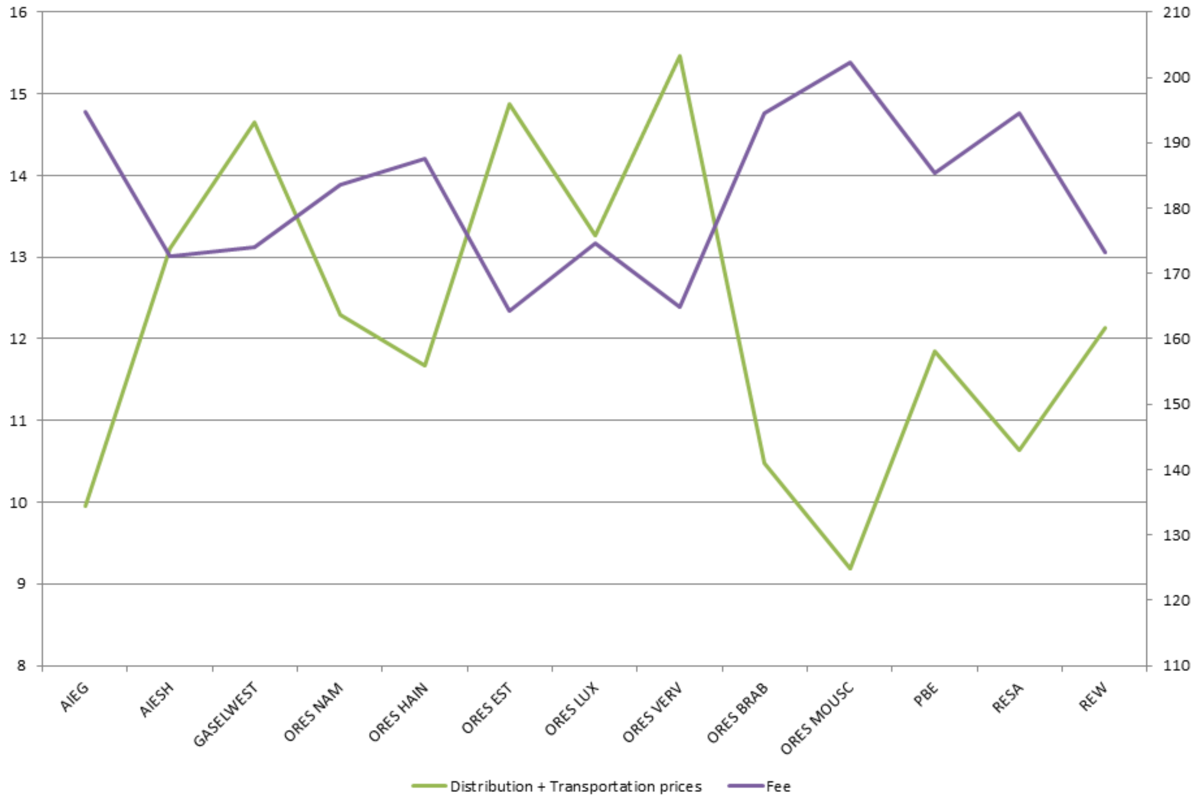

Figure 13: Correlation between the level of prices of the DSO in Wallonia (left axis, in c per kWh, and the level of the fee of the Qualiwatt system, right axis, in euro per kWp. For 2017).

9.2 Appendix B

Miss to win		Distribution	Transportation	Total
2014	Total	20.380.441,61 €	9.019.667,32 €	29.400.108,94 €
	Per DSO	1.567.726,28 €	693.820,56 €	2.261.546,84 €
2015	Total	25.807.630,17 €	10.258.255,58 €	36.065.885,75 €
	Per DSO	1.985.202,32 €	789.096,58 €	2.774.298,90 €
2016	Total	28.525.782,07 €	10.654.527,47 €	39.180.309,55 €
	Per DSO	2.194.290,93 €	819.579,04 €	3.013.869,97 €
Jan-Feb	Total	4.918.617,28 €	1.770.142,24 €	6.688.759,52 €
2017	Per DSO	378.355,18 €	136.164,79 €	514.519,96 €
Projection	Total	29.501.960,69 €	10.617.347,08 €	40.119.307,77 €
2017	Per DSO	2.269.381,59 €	816.719,01 €	3.086.100,60 €
Total	Total	74.713.853,86 €	29.932.450,37 €	81.934.954,81 €
2014-2016	Per DSO	5.747.219,53 €	2.302.496,18 €	6.302.688,83 €
Annual average per DSO		1.915.739,84 €	767.498,73 €	2.100.896,28 €

Figure 14: Results for section 3.2.2 with the first methodology

9.3 Appendix C

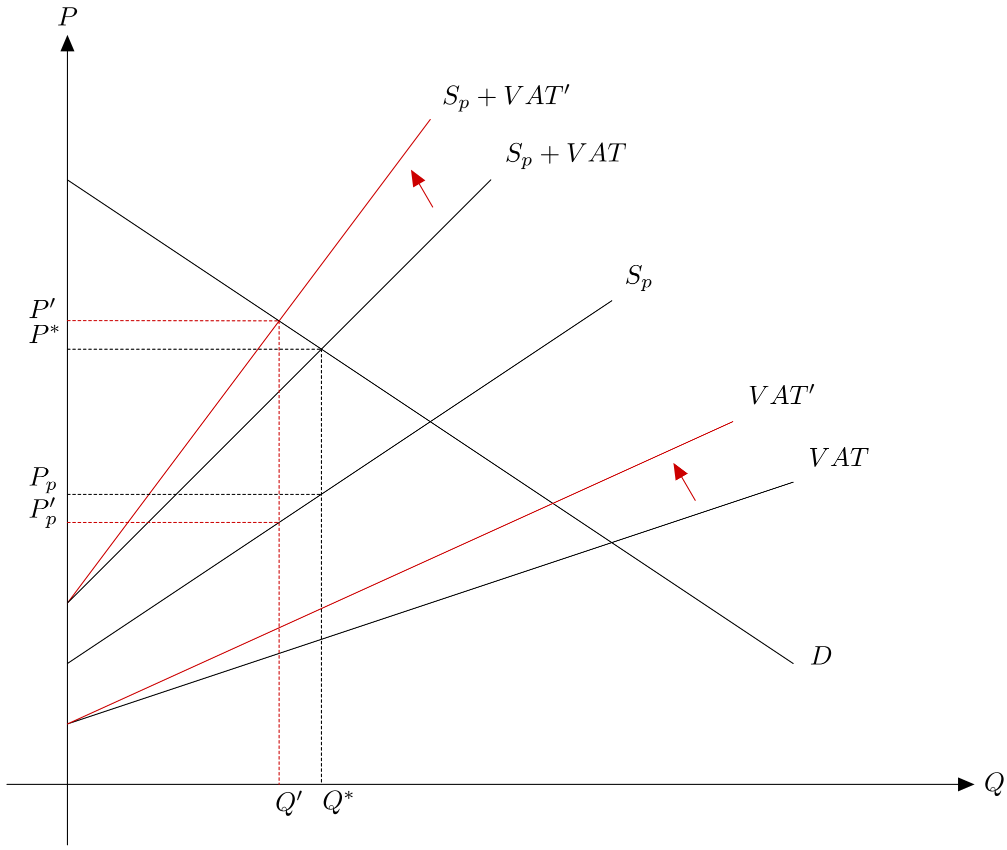

Figure 15: Graphical argument for the effect of VAT on the prices of providers.

In a simplistic view were we only consider the VAT and the providers price. With Sp the supply of providers and Pp the equilibrium price of providers. When the VAT rates goes from VAT to VAT', the price of the providers drops of Pp-Pp'.