The impact of Net-Metering on Cross Subsidies between Network Users

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1 Introduction

Residential electricity consumers are increasingly motivated to install distributed generation (DG) units due to supportive renewable policies and decreasing system costs for DG. For instance, Europe's residential and commercial sector already had 36.6 GWp of solar photovaics (PV) panels installed in 2012. Likewise, large amounts of DG installations are noticed in The United States (US) within the states of California, Arizona and Hawaii (Greentech Media & Solar Energy Industries Association, 2013).

The owners of DG units are frequently rewarded for the electricity fed-back into the grid through net-metering. Net-metering is a practice by which owners of DG units may offset electricity consumed against their production during a certain period of time. Net-metering is positively perceived for these DG-owners due to the fact that it leads to reduced cost of customers' final electricity bills and therefore incentivizes DG installation (Darghouth, Barbose, & Wiser, 2011). Indirectly this DG installation has further positive effects on carbon emission reduction targets due to the fact that DG units mostly operate from renewable energy sources like solar and wind (Alanne & Saari, 2006; Darby, Strömbäck, & Wilks, 2013).

However, contrary to the DG-owner and sustainable policy perspective, the issue of net-metering and DG penetration is not positively perceived by European electricity network operators and US Public Service Utilities (Cohen, 2013; The Electricity Journal, 2013). Both types of utilities are operating under economies of scale and net-metering causes those utilities to miss part of their financial incomes while remaining providers of transport and reliability services (California Public Utilities Commission, 2013; Cohen, 2013; Lipman, Edwards, & Kammen, 2002; The Electricity Journal, 2013). More specifically regarding the network related issues of net-metering, unbundled network operators in Europe like the Distribution Service Operators (DSOs) perceive net-metering as jeopardizing their cost recovery for their substantial stranded costs. In order to make up for this cost gap, DSOs incrementally increase network charges. As a consequence, both DG owners and non-DG owners are required to pay higher prices for network usage. This issue of increased network tariffs results in cross subsidies for non-DG owners due to the fact that non-DG owners subsidize network costs that DG-owners avoided to pay.

As a result, an interesting issue remains the impact of differently applied net-metering schemes with different types of tariff designs on the cost recovery of the network operator. The authors of this paper aim to provide insight for policy in those dynamics which affects not only to cost recovery of the network operator but also to cross subsidies between network users and policy objectives. This study focuses on the European case of net-metering, where the effects are mostly announced by the unbundled DSO. However, due to the fact that the nature of the US related public service utility is largely related to that of the European network operator, the results of this study are interesting for both the European and US net-metering case.

2 Method

The network user considered here is a DG-owning household which also feeds-in electricity in the grid. In order to do this, this study takes into account different physical metering alternatives (uni-directional, and bi-directional metering) and different accounting methods (solely consumption charging or separate charging for both consumption and production). Furthermore, the study takes into account different types of rolling credit time frames and tariff design options.

The consumption and production of such a household is obtained from the Spanish System operator, based on the average consumption load profile from low voltage (Red Eléctrica de España, 2013). The hourly production data from the PV panel is calculated with the online tool from NREL for a solar PV unit of 2 kW size located in Madrid (NREL, 2006).

2.1 Analyzed (Net-) metering alternatives

Table 1 presents the analyzed alternatives with the combinations of physical metering and accounting possibilities. Herein, the first number presents the physical metering option applied and the subsequent number after the “M” indicates whether there is solely consumption charging (option 1) or both consumption and production charging applied (option 2). An additional letter shows which type of rolling credit is used (“h” for hourly, “d” for daily, “m” for monthly and “y” for yearly).

In table 1, it is visible that the combinations 1M2 and 3M2 are not analyzed. This is the case due to the physical impossibility of the alternative (option 1M2) and due to the fact that the option already presents a second best solution for the net-metering case, which is not the aim of this study (option 3M2). The aim of the study solely is to provide insights in the dynamics that are caused by net-metering through differently applied rolling credit timeframes and tariff designs.

The basic metering alternative 1M1, is uni-directional metering with solely a consumption charge applied. This type of metering and accounting does not involve production metering and a production charge and therefore is referring to the network user as an electricity consumer solely. This type of metering and accounting is appropriate in an electricity system with solely central production instead of distributed generation.

The second option, 2M1, involves separate metering of consumption and production, however with solely a consumption charge applied. This option is similar to the previous option 1M1, but presents a solely accounting of the consumption behavior and not of the production. Therefore the outcomes of this option are exactly the same to option 1M1 and therefore option 2M1 is not separately presented in this paper.

Thirdly, option 2M2 presents metering and accounting for both consumption and production separately. Due to the fact that electricity that is fed-back into the grid is monitored separately and not subtracted from consumption, this option is called the *no-net-metering* alternative.

Fourthly, option 3M1 presents separate metering with a rolling credit. This means that the excess production over consumption can be used within one timeframe. This timeframe is analyzed on an hourly, daily, monthly and yearly basis. Therefore option 3M1 is actually referring to 4 different alternatives within that option. For an overview of the different alternatives, see also table 1.

Physical Metering ↓ / **Accounting →**	1. Solely Consumption Charge	2. Separate Consumption and Production charge
1M: Uni-directional metering of consumption	Uni-directional metering but only consumption charge **(1M1)**	Not Possible, *Not Analyzed* **(1M2)**
2M: Separate metering of consumption and production	Separate metering but only consumption charging (similar to 1M1) **(2M1)**	Separate metering with separate charging, **2M2**) *No-Net-Metering*
3M: Separate metering of consumption and production with rolling credit	Separate metering with **rolling credit** but only consumption charge **(3M1)**	Separate metering with rolling credit and separate charging for DG **(3M2**) *Not Analyzed*

Table 1: Analyzed alternatives

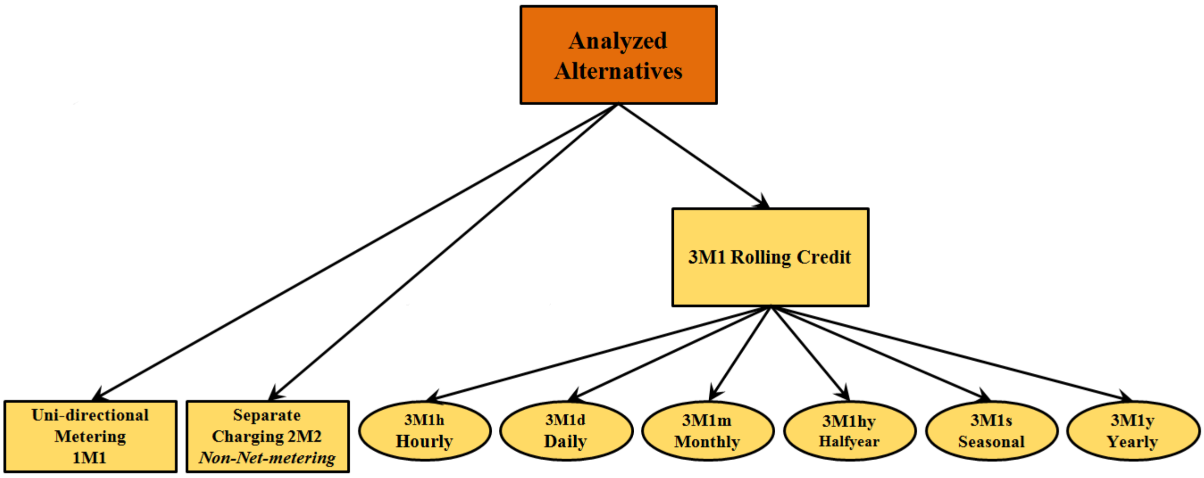


Figure 4: Analyzed alternatives

3 Results

3.1 Measured and accounted kWh and kW

For the analyzed Madrid-based household the total yearly consumption is found to be 2508 kWh. For the PV panel total production was 2570 kWh. Table 2 presents the measured kWh for each of the alternatives, taking into account the households' self-consumption of the DG production. Herein, net-consumption is the registered grid consumption and net production is the registered grid feed-in of electricity. Self-consumption refers to the households' consumption of the electricity produced by the DG unit.

	kWh measured per year		**kWh measured per year**
Uni-directional metering (1M1&2M1)		***Monthly* rolling credit (3M1)**	
Consumption	1528	Net-Consumption	352
		Net-Production	413
Separate metering (No-net-metering) (2M2)		***Seasonal rolling credit(3M1)***	
Net-Consumption	1528	Net-Consumption	311
Self-Consumption	980		
Net-production	1589	Net-Production	372
Total Production	2570		
***Hourly* rolling credit (3M1)**		***6 Monthly rolling credit (3M1)***	
Net-Consumption	1528	Net-Consumption	14
Net-production	62	Net-Production	76
***Daily* rolling credit (3M1)**		***Yearly* rolling credit (3M1)**	
Net-Consumption	471	Net-Consumption	0
Net-Production	532	Net-Production	62

Table 2: Yearly metered kWh

As can be seen in table 2, uni-directional metering provides a reflective value for consumption levels from the grid solely. However, the no-net-metering option (2M2) provides reflective consumption and production measurements because production and consumption are both real time measured and accounted for. Due to self-consumption of the household, the feed-in of electricity is lower than the total electricity produced by the DG unit. Furthermore, it is visible that when a rolling credit is applied, the network user is able to utilize its DG production as a credit over consumption within a set timeframe. Therefore, as can be seen in the table, options with a rolling credit display a decreasing number of kWh measured with increasing size of the timeframe. Finally, a yearly credit shows a measured number of zero kWh due to the fact that total yearly DG production is able to compensate for the entire yearly electricity consumption of the household.

However, regarding observed capacity metering, observations are very different from the previous one. Capacity values for each of the alternatives are exactly equal in the situation without the use of storage. This observed maximum capacity was found to be 0.62 kW for consumption and 1.62 kW for production. The reason for this absence of difference is the fact that peak consumption and DG production do not occur simultaneously in Spain. Therefore the maximum observed capacity remains the same. As shown in graph 1, Spanish peak consumption normally takes place around 23.00, while at 13.00 peak solar PV production occurs.

Due to the fact that the most accurate value of consumption and production data was hourly based, there was no difference presented between the measured kWh for hourly and unidirectional metering

(See table 2). However, in real life, with smaller based measuring intervals, the hourly kWh values could be slightly different (expecting to be lower) than of the unidirectional billing alternative.

3.2 Network billing per alternative

The measured and accounted energy (kWh) and capacity (kW) provide a possible basis for cost reflective billing of the individual network user. However, the amount that is billed to the individual customer largely depends on the tariff design that is applied. The following sections present the outcomes if an energy tariff (section 4.2.1), capacity tariff (section 4.2.2) or fixed tariff (section 4.2.3) would be applied.

3.2.1 **Energy tariff**

If an energy network tariff is applied, this means that a charge per kWh is billed for the network usage. The price of the costs in this study are related to the access tariff for a Spanish household, which is € 38,04 for capacity (kW) and € 0,044 for energy (kWh). In this study we assume that those values, if based on cost causation, are sufficient to ensure cost recovery for the Spanish network operators.

Table 4 presents the outcomes regarding billed network costs for each of the net-metering methods with an energy network charge of €0,04. Due to the fact that traditional metering solely charges consumption, only consumption values are provided for the options. However, only for the option of separate metering we calculated also a production charge, which we have used the Spanish feed-in cost of 0,50 euro per MWh. In theory DG production would be charged if DG production rises above local network consumption (Li & Tolley, 2007). However, for this study we are mainly interested in the effects of potential decreased DSO incomes and cross subsidies due to net-metering. Therefore the dynamics related to DG penetration are not of main interest and therefore we assumed that DG penetration will not decrease or increase network cost necessarily, but these costs remain the same for the DSO.

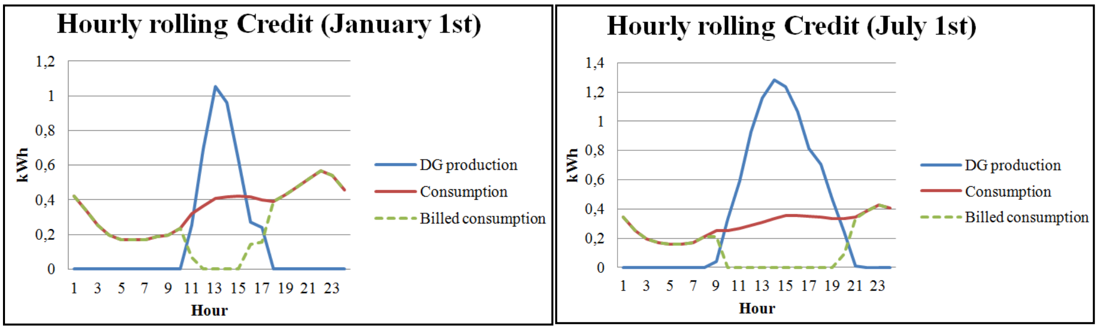
	Network Cost billed per year (€)		**Network Cost billed per year (€)**
Uni-directional metering (1M1&2M1)		***Monthly* rolling credit (3M1)**	
Billed Energy Consumption	61.12	Billed Energy Consumption	14.08
Separate metering (No-net-metering) (2M2)		***Seasonal rolling credit(3M1)***	
Billed Energy Consumption	61.12	Billed Energy Consumption	12.44
Billed Energy Production	0.7945		
***Hourly* rolling credit (3M1)**		***6 Monthly rolling credit (3M1)***	
Billed Energy Consumption	61.12	Billed Energy Consumption	0.56
***Daily* rolling credit (3M1)**		***Yearly* rolling credit (3M1)**	
Billed Energy Consumption	18.84	Billed Energy Consumption	0

Table 2: Billed yearly network costs with an energy tariff

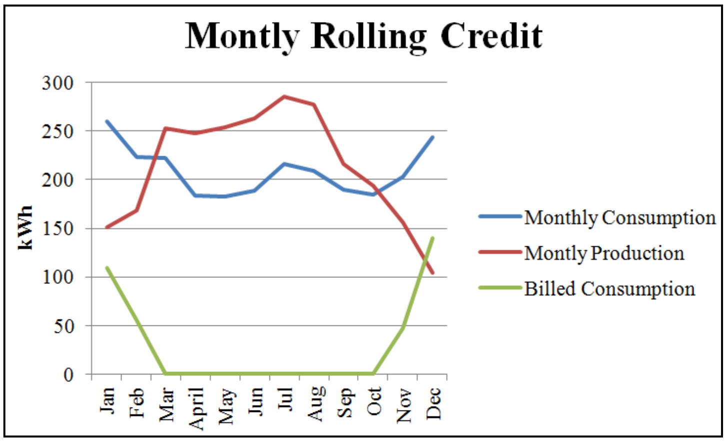
The no- net-metering option displays consumption that is fully being charged and not discounted by production. Due to the fact that self-consumption takes place, the net feed-in of electricity is lower than consumption and thus also the costs that have to be paid by the network user. The other alternatives with a rolling credit present decreased billed network costs and consequently reduced incomes for the DSO. Due to the fact that incomes decrease significantly for the DSO, regulation allows here for adjustment of energy charges per kWh. Therefore, with an energy charge, high potential for cross subsidies develops between DG owners and non-DG owners.

More visually, as seen in Graph 1, with an hourly rolling credit production and consumption levels are differently depending on the day of the year. Similarly so with a daily rolling credit, however compared to the hourly rolling credit, only a single value is accounted for consumption and production for each day at midnight.

Graph 2 shows the development of this monthly rolling credit on a yearly timespan, showing that in summer periods also billed consumption reaches zero with some days exceptions. More than the daily rolling credit, with a monthly rolling credit in the sunny periods of the year total net consumption is zero and therefore only in the months January, February, November and December customers have to pay for their network usage (see Graph 2).



Graph 1: Electricity consumption and production on 1st of January and July 1st (3M1h)



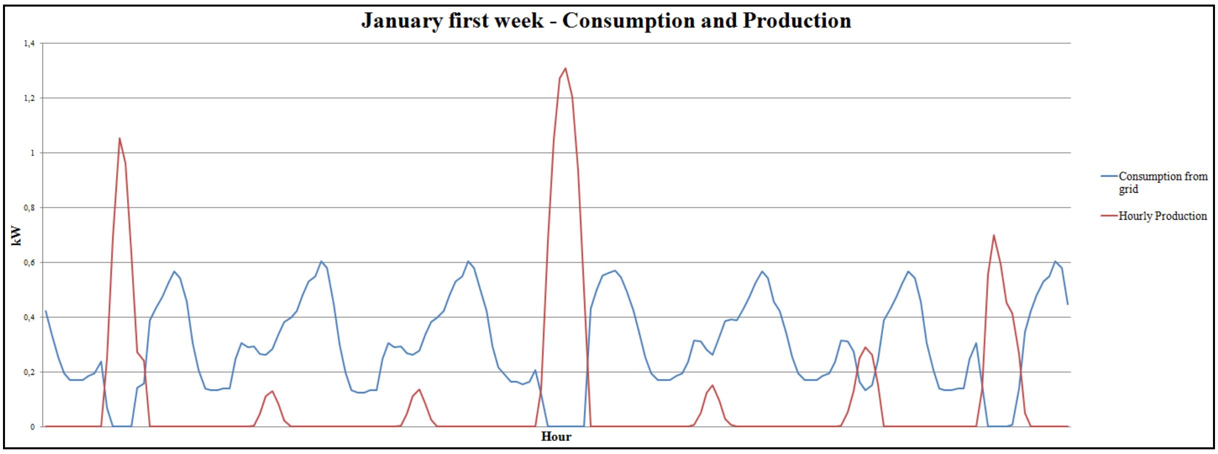
Graph 2: Monthly rolling credit for a year

3.2.2 **Capacity network tariff**

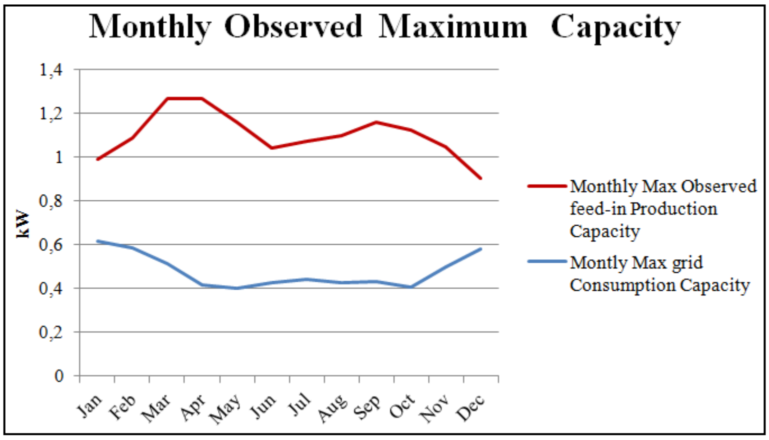
Besides the energy charge, network tariffs could be consisting of a capacity charge for consumption and/or production. This implies that network costs are billed trough a price for observed maximum consumption and/or production capacity (kW_{max}) within a certain time period. In order to take into account the grid perspective and the impact of the network user on this grid, this maximum observed capacity value should be a netted value. This signifies that for consumption this value is based on the maximum net consumption from the grid and for production this based on the value of maximum net production fed-into the grid.

As visible in graph 3, consumption capacity values are not affected by DG production due to the fact that simultaneous consumption and production do not occur at peak consumption times in Spain. Therefore, if solely a consumption capacity charge would be applied, there would be no difference if the user has a PV unit installed or not. However, difference could be observed if a storage unit would be added. The variability found between observed maximum net consumption levels range between 0.40 kW and 0.61 kW throughout the year.

However, differently, if a production capacity charge would be applied this results in different outcomes. The production feed-in depends both on solar irradiation levels and the households' self-consumption levels at that moment in that year. Therefore as visible in graph 4, lower observed feed-in capacity is found in the months December (0.91 kW) and highest in the months April (1.27 kW).



Graph 3: Capacity first week of January



Graph 4: Capacity first week of January

From the results certain conclusions can be drawn. Firstly, applying solely consumption based capacity charge would incentivize network users to decrease this maximum observed capacity with the use of local storage. However, when also a production capacity charge would be applied, this incentive would be stronger due to the fact that observed production capacity feed in is significantly higher than consumption capacity. Applying such charge could incentivize the user to install local storage and self-consumption in order to decrease its impacts on the grid, and therefore has further positive impacts on sustainability and security of supply. This could furthermore significantly decrease grid consumption and thus their observed consumption capacity.

Furthermore, applying a production and consumption observed capacity, large DG penetration levels could and local storage numerous network users decrease their observed capacity, and capacity charging is the prominent network cost driver, this does result in reduced DSO income levels. This development should therefore be taken into account ex-ante in policy if a capacity charge is the main cost driver for DSO incomes.

3.2.3 **Fixed network tariff**

Lastly, the application of a fixed network tariff is unrelated to electricity consumed, produced or the observed capacity values. Therefore, this type of tariff driver for network users does not affect cross subsidies or DSO cost recovery. However, from the regulatory perspective, this type of network charging does neither reflect any cost reflectiveness of the network users'. Even though fixed tariffs are clear, from an energy policy perspective where cost reflectiveness and sustainability objectives are of importance, fixed network tariffs are worth reconsideration.

Differently from the energy charge and capacity charge, a fixed charge does neither affect the cost recovery of the DSO, but could results in cross subsidies between network users (Castro & Dutra, 2013).

4 Conclusions

Net-metering presents an important dilemma between incentivizing distributed generation (DG) on one side and securing financial stability of the Distribution System Operator (DSO) on the other. This issue is increasingly complex due to the fact that net-metering itself can be applied differently with regard to processes of metering, accounting and billing of the network user. This paper presents a study to provide insight into these dynamics and reveals the impact of net-metering on income for arising cross subsidies between network users. For this study hourly consumption and production data of an average Spanish household were used with a Madrid based photovoltaic (PV) panel of 2 kWp capacity.

The main outcome of the study showed that the DSO income levels drastically decrease and furthermore cross subsidies arise when applying an energy network tariff (or volumetric charge) in combination with larger rolling credit time frame. Generally, the longer the chosen rolling credit, the more electricity consumption is netted by DG production in such period. Daily net-metering with an energy charge (volumetric charge) would decrease DSO income per household by 69% compared with the non-net-metering alternative and by 77% if monthly time periods would be applied. More drastically yearly based rolling credit would result in zero network incomes for the DSO. This also presents, beside DSO cost recovery issues, a large potential for the development of cross subsidies between network users if energy charges are upwards adjusted.

Differently, applying a capacity charge for production would cause the network user to pay according to its maximum observed consumption and/or production capacity. If this capacity charging is based on observed maximum capacity, instead of contracted capacity, this type of charging provides improved cost-causality and does not impact upon cross subsidies. If for a prosumer peak consumption of the household coincided with PV production, its observed capacity is reduced compared to the non DG owning household. However, in Spain this is not the case because daily peak consumption occurs at night times (22:00) when there PV electricity production is absent. Therefore, for all alternatives the observed maximum *consumption capacity* is found to be equal. However, observed maximum peak *production capacity* coincides with consumption and therefore those values are different each month. Applying such production capacity charge could incentivize local storage and self-consumption for the network user in order to decrease its costs and impact on the grid and therefore has further positive impacts on sustainability and security of supply.

Besides the energy charge and capacity charge, a fixed charge is commonly applied for network users. A fixed charge for network users does not affect costs of the DSO due to net-metering practices, however does not incentivizes efficient network use and causes cross subsidies between network users. Even though this option can be easily applied without any metering efforts, it is not an optional option from the perspective of cost causality and efficient network use.

Consequently, mainly the practice of volumetric charging combined with net-metering must be reviewed. Net-metering, which was meant to encourage DG penetration seems to lead to financial instability of the DSO and furthermore is the source for potential cross subsidies between network users.

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