NET-METERING: DEVELOPMENT OF A REGULATORY AND TECHNICAL FRAMEWORK THAT ENSURES INVESTMENT ECONOMIC VIABILITY WITHOUT ADVERSELY AFFECTING NETWORK AND MARKET OPERATORS' REVENUES

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ABSTRACT

Net-metering is a policy that encourages the installation of Distributed Generation (DG) adjacent to one user's premises, so that DG production is used to offset part or even whole of the customer's energy consumption during a defined time period. It is basically an accounting method that can be implemented on a billing-period or annual basis.

In this paper, the development of a net-metering regulatory framework is explored, that ensures the economic viability of the investment and protects both non-participating consumers from increased energy costs as well as interested stakeholders from possible loss of revenues. An array of issues relevant to Network and Market Operators' loss of revenues, optimal PV system sizing, billing policy, metering infrastructure and connection scheme is addressed.

INTRODUCTION

Net-metering is a billing policy where renewable energy is used to offset one's energy consumption during a defined time period, thus to reduce his electricity bills [1]. Successful implementation is directly connected with strategic policy planning, i.e. proper calculation of the electricity charges, definition of the time interval under which energy clearing is conducted and installation of the appropriate metering infrastructure to monitor the essential energy amounts [2,3].

Electricity charges are divided into three categories, namely competitive charges, regulated charges and taxes. Expectedly, investment economic viability is maximized when all electricity charges are calculated on the basis of the net energy, however their proper regulation is deemed crucial for the avoidance of Electricity Market distortions. In particular, regulated charges consist of two components, i.e. an energy component (€/kWh) referring to the amount of energy consumed at site, which is the dominant one in most countries, and a power component (€/kVA) regarding the maximum supply power. Calculation of the regulated charges upon net energy consumption, leads to reduced revenues for the Network and Market Operators, hindering their cost recovery.

This work considers the adoption of a net-metering scheme, taking into account load demand profiles of potentially interested investors and applicable electricity charges. A total installed PV capacity, allocated to the prospective consumer types is assumed.

INPUT DATA AND PARAMETERS

The installation of a photovoltaic (PV) system to serve the needs of a residential, commercial or industrial consumer is taken as a base scenario. Input data comprise annual energy consumption and PV production hourly time-series, capital expenditure and interconnection costs, as well as retail electricity price and its anticipated growth rate.

In the context of a net-metering scheme, electricity charges are calculated as follows:

- Competitive charges are calculated upon the net energy which is defined as the difference between energy produced and consumed at site during the contractual time-interval (billing period, year, etc). If energy production exceeds energy consumption during the clearing period, the resulting amount of energy may be remunerated e.g. at retail or wholesale electricity price or at a defined feed-in-tariff, or can be transferred as an energy credit to the next clearing period. However, these policies regarding excess energy incentivize system oversizing and lead to additional overloading of network components (lines, transformers), thus are not considered in the paper. Excess energy is simply disregarded.
- Regulated charges comprise Network Operators' and Market Operators' charges. The first component accounts for the recovery of the Network Operators' capital expenditure and maintenance costs. The second one incorporates charges which compensate for the feed-in-tariff mechanism, generally used for the remuneration of renewable energy, as well as the support mechanism for vulnerable groups of consumers.

Unlike competitive charges, which are definitely calculated upon net energy, regulated charges can be calculated on the basis of the net, the absorbed or the total consumed energy. Whereas net energy is an accounting value, absorbed energy from the Network can be recorded by a bidirectional meter installed at the connection point when the total consumed energy exceeds concurrent PV energy production. Consumed energy represents the User's total energy needs, regardless of the supplier (PV system, utility).

- Taxes are estimated according to the relevant legal provisions.

The time-interval under which the clearing process is conducted is crucial for the calculation of the net energy, and subsequently the relevant charges, e.g. competitive charges. In this paper, 4-month or annual clearing periods are taken as reference scenarios.

Basic input data and parameters are summarized in Table 1 whereas in Figure 1 average electricity charges per consumer type are presented along with their distribution. A simulation model was developed in Matlab environment for the parametric investigation of the optimal system sizing and billing policy determination.

***Table. 1.** Input data and parameters*

Input data and parameters	Consumer Type: Residential	Consumer Type: Commercial/ Industrial
PV system		
PV installed capacity (kWp)	3-6	20 - 100
Annual PV energy yield (kWh/kWp/year)	1450	
CapEx Cost (€/kW)	1500	1000 - 1220
Interconnection Cost (€)	700	
Consumption data		
Annual energy consumption (kWh)	5000-9000	30000-170000
Agreed supply power (kVA)	8	25-135
Single-phase/Three-phase configuration	Single-phase	Three-phase
Economic data		
Average retail electricity price (€/kWh)	0.20 - 0.23	0.18 - 0.20
Annual retail electricity price increase	2%	
Inflation rate	1%	

Annual time-series of PV energy production and load consumption, based on real-time measurements of the recently installed telemetry system in Greece were used. A basic time-series analysis was conducted to depict mean daily load variation per month and per annum in Figures 2 and 3, respectively. A variety of time-series regarding commercial and industrial consumers was selected to cover a wide range of their load characteristics, such as amount of annual energy consumption, load factor, hourly variation during the day, seasonality and maximum load and supply power. For the residential consumers a single time-series was used, escalated to the desired annual consumption levels. Maximum supply power was adjusted adequately to host assumed PV capacity, which was estimated roughly according to the equation between annual consumption and production energy amounts, as explained below.

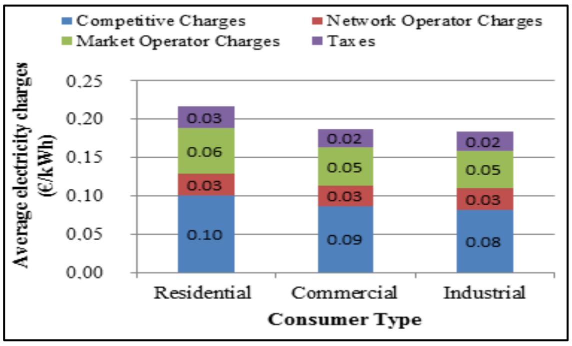


***Fig. 1.** Average electricity charges per kWh consumed*

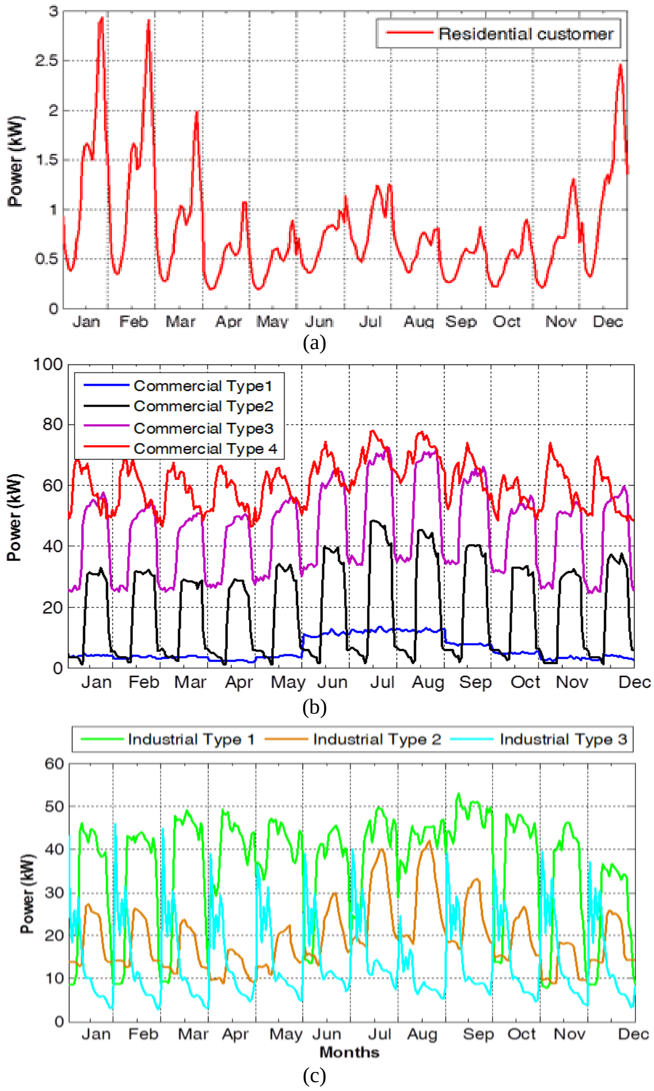


***Fig 2.** Mean daily curves of load power per month for (a) residential (b) commercial (c) industrial consumers.*

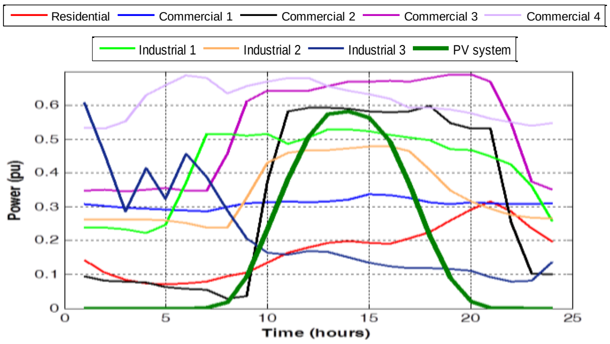


Fig 3. *Mean daily load and production curves per annum (per unit system).*

Table 2. *Basic load characteristics of the different consumer types modelled.*

Consumer Type	Supply power	Max Load Power	Annual Energy Consumption	Load Factor	PV installed capacity
	kVA	kW	kWh	%	kWp
Residential Type 1	8	3.4	5000	17.1	3
Residential Type 2	8	4.7	7000	17.1	4.5
Residential Type 3	8	6.0	9000	17.1	6
Commercial Type 1	25	11.1	30000	31.0	20
Commercial Type 2	55	19.5	55000	32.1	35
Commercial Type 3	85	25.7	120000	53.3	80
Commercial Type 4	135	31.7	170000	61.2	100
Industrial Type 1	85	27.1	100000	42.1	70
Industrial Type 2	55	18.2	55000	34.5	35
Industrial Type 3	35	20.5	40000	22.3	25

RESULTS

Optimal PV system sizing

Payback period analysis was conducted for the different consumer types to highlight optimal system sizing as well as the effect that billing policy selection has on investment viability. Competitive charges were in any case calculated upon net energy.

Figure 4 illustrates investment payback period versus PV installed capacity, considering a residential consumer of 6 MWh annual energy consumption as a base case scenario. The implementation of the regulated charges upon net, absorbed or total consumed energy (blue, red and green color lines, respectively), as well as the clearing period for the calculation of the net energy consumption are additional parameters outlined in the diagram. Investment payback period ranges between 5-18 years, showing a strong influence upon PV capacity and calculation of the regulated charges. System oversizing brings about an increased payback period putting investment viability into risk, as excess energy is injected into the Network for free. However, annual calculation of the net energy (dashed lines) can save up to 2 years compared with 4-month clearing periods (solid lines), as seasonal fluctuations of load consumption and energy production are efficiently compensated.

Expectedly, payback period is minimized when the regulated charges are implemented upon net energy, ranging around 6 years for 3-5 kWp installed capacities. Investment feasibility for around 2 kWp installed power is evident, arising from the scaling of the competitive charges, i.e. larger charges at increased consumption levels. In this way, a PV system sizing that results in the remaining, after the clearing process, energy being charged with the lowest competitive charges is viable. Calculation of the regulated charges on the basis of the absorbed energy slightly deteriorates investment profitability whereas their implementation on total consumption almost doubles payback period, compared to net energy application.

Figure 5 illustrates investment payback period as a function of annual energy consumption and installed PV capacity for a residential consumer, assuming annual clearing period. System oversizing scenarios are not considered. Optimal system sizing generally occurs near the point of annual energy equilibrium between production and consumption. Assuming annual energy clearing periods, payback period ranges between 4.5-6.5 years under circumstances of optimal system sizing when the regulated charges are calculated upon net energy, elevating at 5.5-8.5 and 9.0-10.5 years when they are calculated in terms of absorbed and consumed energy, respectively.

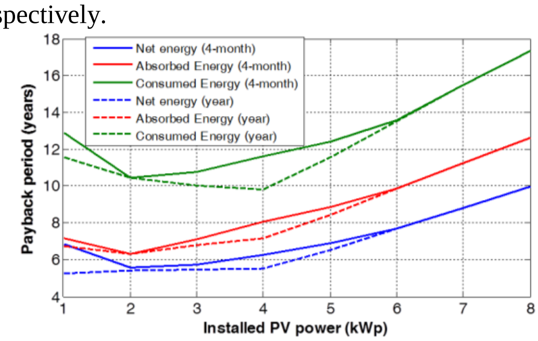


Fig. 4. *Residential Consumer. Investment payback period as a function of the PV capacity, the amount of energy upon which regulated charges are calculated and clearing period selection.*

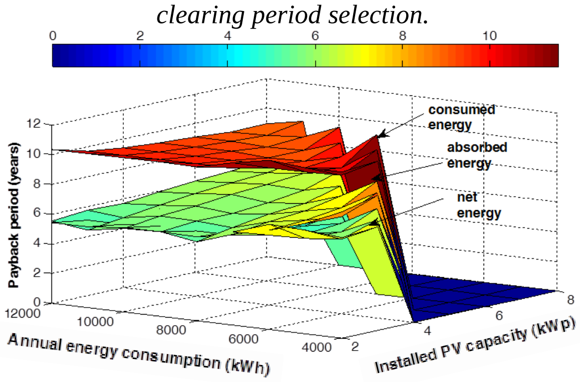
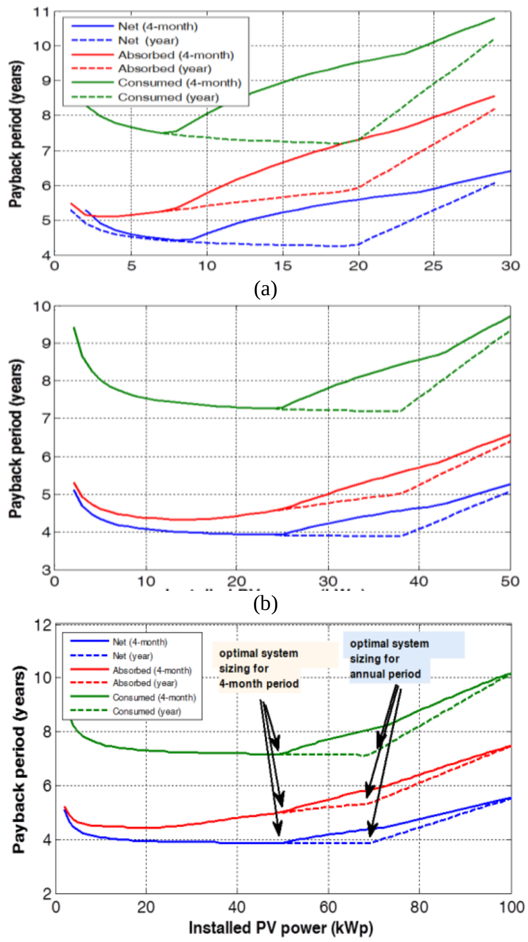


Fig. 5. *Residential Consumer - Investment payback period as a function of the PV installed capacity and the annual energy consumption.*

Investment profitability for commercial and industrial consumers is even more attractive, as daily load variation can be fairly identical to PV production variation, as presented in Fig. 3. Consequently, payback period ranges between 4-10 years for different demand profiles of commercial and industrial consumers (Fig. 6). The significance of clearing period selection in case of seasonal load profiles, e.g. Commercial Consumer Type 1, is also pointed out. Concerning industrial consumers, optimal PV sizing leads to payback periods lower than 8 years even when the regulated charges are calculated upon total consumption, as presented in Fig. 7. Under annual clearing period selection and optimal system sizing, payback period is around 4 years for commercial and industrial consumers, when the regulated charges are calculated upon net energy, elevating at 5-6 and 7 years when they are calculated in terms of absorbed and consumed energy respectively (Fig. 8).



(a) (b) (c)

Fig. 6. Investment payback period as a function of the PV capacity, the amount of energy upon which regulated charges are calculated and clearing period selection for (a) *Commercial Consumer Type 1 (b) Commercial Consumer Type 2 (c) Industrial Consumer Type 1.*

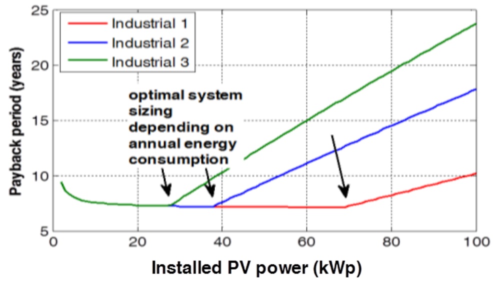


Fig. 7 *Industrial Consumers' Investment payback period as a function of the PV capacity, assuming annual clearing period and calculation of the regulated charges upon total consumption*

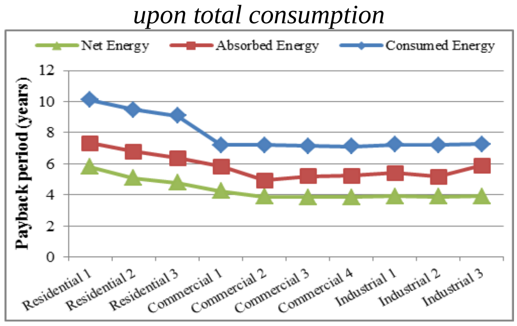


Fig. 8 *Payback period for the consumer types and PV sizing of Table 1 and for parametric implementation of the regulated charges.*

Network and Market Operators' loss of revenues

In order to assess the aggregate impact from the implementation of a net-metering scheme at national level, a cumulative installed PV power of 500 MW is assumed as reference scenario. This power is allocated to 3 main groups of consumers, i.e. residential, commercial and industrial and more specifically is equally distributed to the ten different types of consumers shown in Table 1. The power distribution and the resulting number of PV installations per category are presented in Table 3.

The annual Network Operators' loss of revenues is estimated higher than 18 M€ when network regulated charges are calculated upon net energy consumption (Fig. 9). That loss is substantially lower, around 7 M€, when the calculation regards absorbed energy and is totally reset when total consumption data are used. Similarly, annual Market Operators' loss of revenues is greater than 38 M€ and 17 M€ when the regulated charges are calculated upon net and absorbed energy, respectively. The amounts of competitive charges and regulated charges are incorporated in the taxes levying calculation, affecting state revenues as well. Loss of taxes (VAT) is substantial, estimated around 15, 11 and 8 M€ for the three scenarios considered.

Increase of the unit electricity charges as an alternative for compensating the Operators' loss of revenues must be considered with skepticism in terms of social policy since the consumers who did not afford to install a PV system in the context of the net-metering scheme are burdened with the economic benefit of those who did afford so. Another policy option is to make the power component of the regulated charges the defining factor so that net-metering impact is limited.

Table 3. *Assumed cumulative power of PV installations under the net-metering scheme at national level and its allocation to prospective consumer types.*

Total PV Installed power (MWp)	**500**		
	Ratio	**Number of PV installations**	**PV power per installation (kWp)**
Residential consumers ratio	30%		
Residential Type 1	10%	16667	3
Residential Type 2	10%	11111	4.5
Residential Type 3	10%	8333	6
Commercial consumers ratio	40%		
Commercial Type 1	10%	2500	20
Commercial Type 2	10%	1429	35
Commercial Type 3	10%	625	80
Commercial Type 4	10%	500	100
Industrial consumers ratio	30%		
Industrial Type 1	10%	714	70
Industrial Type 2	10%	1429	35
Industrial Type 3	10%	2000	25

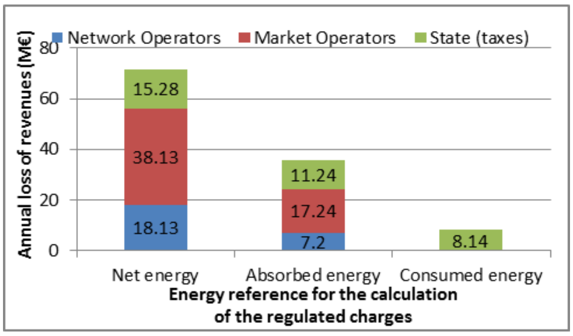


Fig. 9. *Aggregate Network, Market Operators' and State's annual loss of revenues, assuming 500 MW of installed PV capacity*

Metering infrastructure and connection

Potential metering connection schemes are presented in Fig. 10. Besides the rather popular one-meter net-metering scheme, the installation of two bidirectional meters can be selected as well. In particular, meter M1 records absorbed and injected energy data (their subtraction defines net energy) whereas meter M2 can be installed so that total consumption or PV production data are made available as well. The third scheme seems to be the most appropriate since every energy flow is recorded or can be calculated and includes a dedicated meter for the PV system which is reasonable to exist. In any case, the selection of the most suitable connection scheme depends strongly on the energy amounts that have to be measured and charged and finally on the type of net-metering policy implemented.

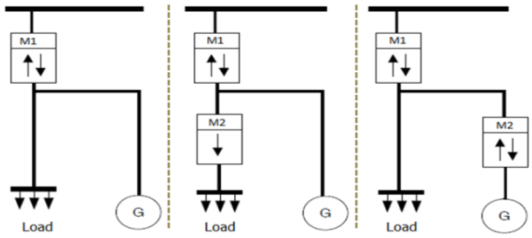


Fig. 10: *Potential metering connection schemes*

CONCLUSIONS

This work focuses on developing a net-metering regulatory framework that takes into consideration possible accruement of Electricity Market Distortions and assures investment economic viability. Annual clearing period is proposed so that seasonal fluctuations of load consumption and energy production are efficiently dealt with, whereas annual consumption is the defining parameter regarding optimal PV system sizing. Concerning billing policy selection, regulated charges can be implemented upon net, absorbed or total consumed energy. Under optimal PV system sizing and annual clearing period, investment payback period for a residential consumer ranges around 4.5-6.5, 5.5-8.5 and 9.0-10.5 years when the regulated charges are calculated in terms of net, absorbed and consumed energy respectively. The results are even more attractive for commercial and industrial consumers. The energy selection for the calculation of the regulated charges has a strong financial impact on the Network and Market Operators' revenues. The loss of revenues for both Network and Market Operators increase by more than 100% when the regulated charges are calculated upon net energy instead of absorbed, whereas impact on investment viability is mitigated. The Operators' loss of revenues is totally reset when total consumption data are used. Finally, metering infrastructure and connection scheme are dependent on the billing policy selection and energy amounts that have to be monitored.

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