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Original Research Article

A comparative assessment of net metering and feed in tariff schemes for residential PV systems

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ABSTRACT

In this work, a comparative assessment of net metering vs. feed-in-tariff (FiT) supporting schemes for residential PV systems is carried out. A formulation for the computation of net metering supporting scheme parameters, in half hour intervals, is developed and typical household integrated with a rooftop PV system is investigated. The effect of the size of PV system with respect to the net metering supporting scheme is examined by varying the PV capacity and the effect of the electricity retail cost rate is investigated by varying the electricity retail cost rate. The comparative results indicate that net metering supporting scheme performs better than a FiT supporting scheme when the household electricity bill is taken into account. From the analysis it is clear that under certain conditions net metering supporting scheme becomes profitable.

Introduction

A feed in tariff (FiT) scheme provides a guaranteed premium price to the renewable electricity producer and put an obligation on the grid operators to purchase the generated electricity output. The price is typically guaranteed for a long period in order to encourage investment in new renewable energy sources for power generation (RES-E) plants. FiT schemes are well known for their success in deploying large amounts of wind, biomass and solar energy (both photovoltaics (PV) and concentrated solar power systems) mainly in Germany, Denmark and Spain. The biggest advantage of FiT schemes is the long-term certainty of financial support, which lowers investment risks considerably. An overview of the FiT supporting schemes available in Europe is provided in [1].

Net metering is an electricity policy which allows utility customers to offset some or all of their electricity use with self produced electricity from RES-E systems [2]. Net metering works by utilizing a meter that is able to spin and record energy flow in both directions. The meter spins forward when a customer is drawing power from the utility grid (i.e., using more energy than they are producing) and spins backward when energy is being sent back to the grid (i.e., using less energy than they are producing). Another way is when each channel is metered separately and the one is subtracted from the other. In both cases at the end of a given month, the customer is billed only for the net electricity used. Net metering works only for grid connected systems and what makes it so beneficial, besides offsetting a home's energy consumption with a RES-E system, is that excess energy sent to the utility can be sold back at retail price. If more energy is produced than consumed, depending on the legislative arrangements in place as well as the arrangements with the electric utility, producers may receive benefit for this positive balance, such as, renewable energy credits (REC), which is credited on the customer's account toward the next billing cycle. If at the end of the year a surplus remains, then the customer depending on the utility policy may (a) paid for the total REC collected at avoidance cost rate or retail cost rate, or, (b) the total REC collected can be transferred and could be used as a compensation for a possible negative balance in the following years, or, (c) the total REC collected are granted back to the utility [3]. Net metering is gaining recognition as an effective RES-E promotion incentive and it is currently used in the USA and Australia. In Europe only Denmark and Italy are using net metering [1].

Some variations of the net metering mechanism are the time of use (TOU) metering and the market rate metering. TOU net metering employs a specialized reversible smartmeter that is programmed to determine electricity usage any time during the day. TOU allows utility rates and charges to be assessed based on when the electricity was used, i.e., day or night and seasonal rates. Typically the production cost of electricity is highest during the daytime peak usage period and low during the night, when usage is low. TOU metering is a significant issue for RES-E, since, for example, solar power systems tend to produce energy during the

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daytime peak-price period, and produce little or no power during the night period, when price is low. In market rate net metering systems, the user's energy use is priced dynamically according to some function of retail electric prices. The users' meters are programmed remotely to calculate the value and are read remotely. Net metering applies such variable pricing to excess power produced by qualifying systems [4].

In this work, a comparative assessment of net metering vs. FiT supporting schemes for residential PV systems is carried out. For the analysis the IPP algorithm version 2.1 (independent power producer technology selection algorithm) software tool is employed [5]. In the case of a FiT supporting scheme, for the computation of the annual electricity unit cost as well as for the various financial indicators, in half hour intervals, the methodology presented in [6] and in [7] is used. In the case of net metering supporting scheme the formulation is developed in this work and integrated in the IPP algorithm version 2.1 [5]. A typical household integrated with a rooftop PV system is investigated. The effect of the size of PV system with respect to the net metering supporting scheme is examined by varying the PV capacity from 1 kWp up to 7 kW and the effect of the electricity retail cost rate is investigated by varying the electricity retail cost rate from 16€c/kW h up to 24€c/kW h. For the purpose of this work, in order to demonstrate the applicability of the developed net metering formulation, available data from the Cyprus electricity market is used.

In "Net metering for PV residential systems", the benefits and misconceptions of net metering scheme are discussed; similar discussion concerning FiT supporting schemes is provided in [1]. In "Mathematical formulation", the simulation methodology used for this comparative assessment as well as the mathematical formulation developed for the net metering scheme computations are presented. In "Case study", the different cases simulated are presented and the results obtained are discussed. The conclusions are summarized in "Conclusions".

Net metering for PV residential systems

There are benefits that accrue to the utility, the customer, and the community from net metering. For the utility, a well-designed net metering policy provides a simple, low cost, and easily administered way to deal with PV residential systems. Utilities obtain electricity and capacity from small, distributed PV installations. This is electricity they do not have to generate themselves or purchase on the market. For PV systems, this generation takes place every day of the year with a very high correlation with utility peak loads. Utilities call this a high load carrying capability since sunshine is relatively easy to predict. Thus, utilities obtain the benefit of additional capacity in their service territory paid for by their customers.

PV residential systems can, also, strengthen the distribution grid, especially in rural areas. This is because voltage tends to drop at the end of long distribution lines when loads are high, and if it drops below a threshold level, the breakers will trip and a temporary blackout occurs. Grid connected PV systems tied to the distribution grid strengthen voltage and improve overall service. And this grid support can defer maintenance and upgrades in the power distribution system, which is a tangible benefit to utilities. Customers benefit from net metering of PV residential systems because they obtain a long-term guarantee of low utility bills. Communities benefit from the investment in local generation. This investment not only increases local property values but increases local business opportunities as well. It is the difference between paying rent and paying a mortgage [8].

There are also some misconceptions about net metering, such as that net metering hurts the utility bottom line by reducing revenues. This argument is similar to the one against energy efficiency that customers reducing their purchases of electricity hurt utility revenues. This would be true if all households bought a PV system and put it on their roofs. However, the current PV market is increasing, therefore, any net metering policy should receive regular review to monitor progress of the technology and development of the market [9]. If PVs, and especially energy efficiency, which has a much larger potential for impacting rates than PVs, gets to the point where it actually reduces utility revenues, then rates should be restructured to guarantee that service.

Another misconception is that net metering represents a subsidy from one group of customers to another. This argument has to do with the methodology that utilities use to charge customers. The argument is that utilities charge all customers in the same class a single rate, which represents an average cost of doing business plus profit. Thus a household who uses a lot of electricity during the day when the cost of obtaining electricity is higher pays the same as the household who uses electricity at night during off-peak hours. One could argue that one type of consumer subsidizes another based on patterns of consumption, etc. Utilities and their customers have supported this averaging formula for years. For example, building a new home represents a cost for a utility because it must invest in new generating capacity in order to supply this electricity. Therefore, customers subsidize solar systems through net metering no more than they subsidize construction of new homes. Both represent expanding business opportunities, and electric utilities have figured out a way to accommodate this economic growth through existing rate structures for more than a century [10]. Still complicated issues such as capacity payment as well contribution of net metering PV systems to the power system ancillary services need to be an in depth examination.

A final misconception is that net metering represents a burden for small utilities. The opposite is actually true because large organizations are better equipped to handle more complicated arrangements. Net metering requires only a net meter, no new rates to establish and no new procedures. All that is required is that the utility adds a line in the ledger for each net metering customer to carry forward credits until the end of the year. Compare this with the alternative of FiT supporting scheme, which requires installation of another meter. Then the utility must make special trips to read this meter and readjust its accounting procedures to keep track of another meter for a single account. A survey found that the cost of reading the extra meters for residential PV systems alone outweighed the cost of net metering [4].

Mathematical formulation

In order to carry out a comparative assessment of FiT and net metering RES-E supporting schemes for all simulations, the IPP algorithm version 2.1 software tool is employed [5]. The software, allows the user to input various technical, financial and environmental parameters of a PV system, such as efficiencies, solar potential, discount rates, FiTs, etc. Then the operation of the PV system is simulated and the key financial feasibility indicators, such as internal rate of return (IRR), payback period, net present value (NPV), etc. are calculated based on the following algorithm (a) calculate solar radiation in plane of PV system, (b) calculate electrical energy delivered by PV system, (c) calculate system losses, such as, temperature effects and inverter losses, (d) calculate electrical energy delivered to the grid, (e) calculate RES-E avoidance cost, (f) calculate CO_2 emissions avoided benefit and (g) calculate financial feasibility indicators assuming that the initial investment year is year zero, the costs and credits are given in year zero terms, thus any inflation rate (or the escalation rate) is applied from year one onwards and the timing of cash flows occurs at the end of the year.

During the simulations procedure the following financial feasibility indicators are calculated: (a) electricity unit cost before tax (in €/kW h), (b) after tax cash flow (in €), (c) after tax NPV, (d) after tax IRR and (e) after tax payback period [5].

In the case of a FiT scheme, for the computation of the annual electricity unit cost as well as for the various financial indicators, in half hour intervals, the methodology used is presented in [6] and in [7]. In the case of net metering supporting scheme the following formulation is developed and integrated in the IPP algorithm version 2.1 [5].

The electricity demand of a household E, in kW h, is given by:

$$E = \sum\nolimits_{j=1}^{m}\sum\nolimits_{i=1}^{n}E_{ij} = \sum\nolimits_{j=1}^{m}\sum\nolimits_{i=1}^{n}P_{Dij}T_{ij}, \tag{1}$$

where P_D is the power demand in kWe during the specified time period T (i.e., for every 30 min period, $T = 0.5$), $j = 1,2,3,\ldots,m$, is the number of day under consideration (i.e., for 1 year, $m = 365$) and $i = 1,2,3,\ldots,n$, is the number of the daily time period (i.e., for every 30 min, $n = 48$).

The electricity generation by the PV system G, in kW h, is given by:

$$G = \sum\nolimits_{j=1}^{m}\sum\nolimits_{i=1}^{n}G_{ij} = \sum\nolimits_{j=1}^{m}\sum\nolimits_{i=1}^{n}I_{ij}P_{\mathrm{PV}}A_{\mathrm{PV}}\eta_{\mathrm{PV}}\eta_{s}, \tag{2}$$

where I is the available solar potential in kW h/m^2, P_{PV} is the installed capacity of the PV system in kWp, A_{PV} is the PV panels frame area in m^2/kWp, η_{PV} is the efficiency of the photovoltaic panels in % and η_S represents the additional losses (such as, inverter and wire losses) in %.

The net electricity based on the net metering reading N, in kW h, is simply the difference between the energy demand E, Eq. (1) and the generation by the PV system G, Eq. (2):

$$N = \sum\nolimits_{j=1}^{m}\sum\nolimits_{i=1}^{n}N_{ij} = \sum\nolimits_{j=1}^{m}\sum\nolimits_{i=1}^{n}E_{ij} - \sum\nolimits_{j=1}^{m}\sum\nolimits_{i=1}^{n}G_{ij}. \tag{3}$$

Taking into account a simple net metering scheme or more advance net metering schemes, such as, TOU or market rate net metering, the electricity demand cost C_E, in €, is given by:

$$C_E = \sum\nolimits_{j=1}^{m}\sum\nolimits_{i=1}^{n}C_{Eij} = \sum\nolimits_{j=1}^{m}\sum\nolimits_{i=1}^{n}E_{ij}Z_{Rij}, \tag{4}$$

where Z_R is the electricity retail cost rate in €/kW h. The net metering electricity cost C_{NET}, in €, is given by:

$$C_{NET} = \sum\nolimits_{j=1}^{m}\sum\nolimits_{i=1}^{n}C_{NETij} = \sum\nolimits_{j=1}^{m}\sum\nolimits_{i=1}^{n}N_{ij}Z_{Rij}. \tag{5}$$

The net savings S_{NET}, in €, is given by:

$$S_{NET} = \sum_{j=1}^{m}\sum_{i=1}^{n}S_{NETij} = \sum_{j=1}^{m}\sum_{i=1}^{n}(C_{Eij} - C_{NETij}). \tag{6}$$

The renewable energy credits REC, in kW h, for a particular month k (where $k = 1,2,3,\ldots,12$) are provided by the relation:

$$if\left\{N_k = \left[\sum\nolimits_{j=1}^{m}\sum\nolimits_{i=1}^{n}N_{ij}\right]_k < 0\right\},$$

then,

$$REC_k = \mathrm{abs}(N_k). \tag{7}$$

Finally, the benefit based on the total REC generated over a year C_{REC}, in €, is given by:

$$C_{REC} = \sum\nolimits_{k=1}^{12}REC_kZ_{Ak}, \tag{8}$$

where Z_A is the avoidance cost rate in €/kW h for a particular month k. In the case the benefit is paid for the total REC collected at retail cost rate, then Z_A can be substitute with Z_R in Eq. (8) above. Finally, if the total REC collected are granted back to the utility then $C_{REC} = 0$.

Case study

For the comparative assessment of net metering and FiT RES-E supporting schemes a typical household is examined. In order take into account and compare all available net metering REC policies the following scenarios are investigated for a household integrated with a rooftop PV system: (a) FiT supporting scheme only, (b) FiT supporting scheme and taking into account household electricity consumption (i.e., monthly electricity bill of the household), (c) Net metering supporting scheme with REC granted back to the utility, (d) Net metering supporting scheme with REC payment at avoidance cost rate and (e) Net metering supporting scheme with REC payment at retail cost rate.

Data and assumptions

The input data and assumptions used for the analysis are tabulated in Table 1. For the purpose of this comparative study we assume the installation and operation of a rooftop PV system on a typical household with an annual power demand as illustrated in Fig. 1 and of a total annual electricity demand of 10,310 kW h. The monthly power demand is presented Fig. 2 with a maximum power demand of 2.6 kW and a minimum power demand of 0.6 kW. The household is assumed to be located in an area with available annual solar potential of 1968 kW h/m^2. The available annual solar potential in 30 min intervals used during the simulations is presented in Fig. 3. A typical mono-Si solar PV module has been selected with a capacity of 185 W, efficiency 14.2% and area of 1.3 m^2.

The effect of the size of PV system with respect to the net metering supporting scheme is examined in this analysis by varying the PV capacity from 1 kWp, in steps of 1 kWp, up to 7 kWp, which is the maximum allowable installed capacity for rooftop PV systems in Cyprus. Thus for 1 kWp PV system approximately six modules are required with a total required area of approximately 7 m^2/kW and for 7 kWp PV system approximately 38 modules are required with a total required area of approximately 50 m^2/kW.

Table 1
Summary of input data and assumptions.

Parameter	Value
Technical data	
Household annual power demand	See Fig. 1 for annual 30 min distribution power demand and Fig. 2 for monthly distribution
Household annual electricity demand	10,310 kW h
Annual solar potential	1968 kW h/m^2 (see Fig. 3 for annual solar potential 30 min distribution)
PV module type	Mono-Si
PV module area	7.03 m^2/kW
PV module efficiency	14.20%
PV system losses	18.04%
PV capacity	1–7 kWp
Economic data	
PV specific capital cost	2700€/kW
PV annual operation and maintenance cost	3€/kW-month
PV system economic life	20 years
Discount rate	8.0%
Loan interest	7.8%
Annual inflation	2.3%
Annual income tax rate	10%
FiT supporting scheme	28€c/kW h
Electricity retail cost rate	16–24€c/kW h
Avoidance cost rate	10.67–16.00€c/kW h (see Fig. 4)
Environmental data	
CO_2 indicator	800 g/kW h

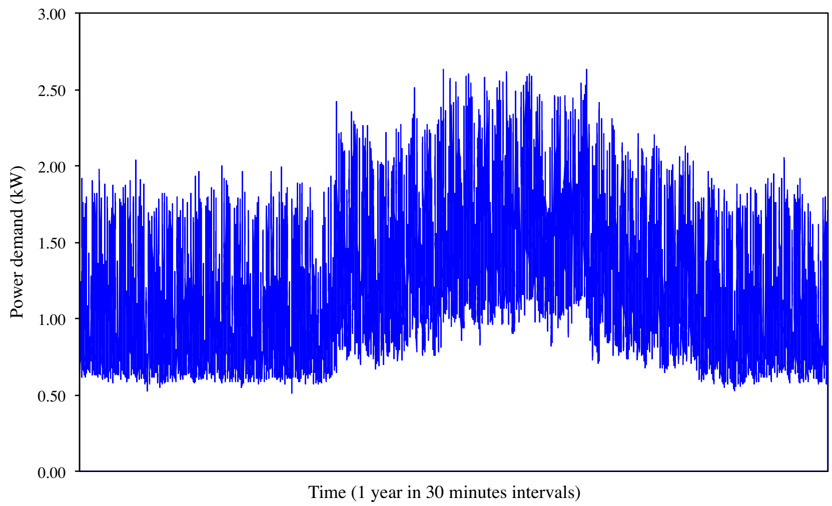

Fig. 1. Annual power demand.

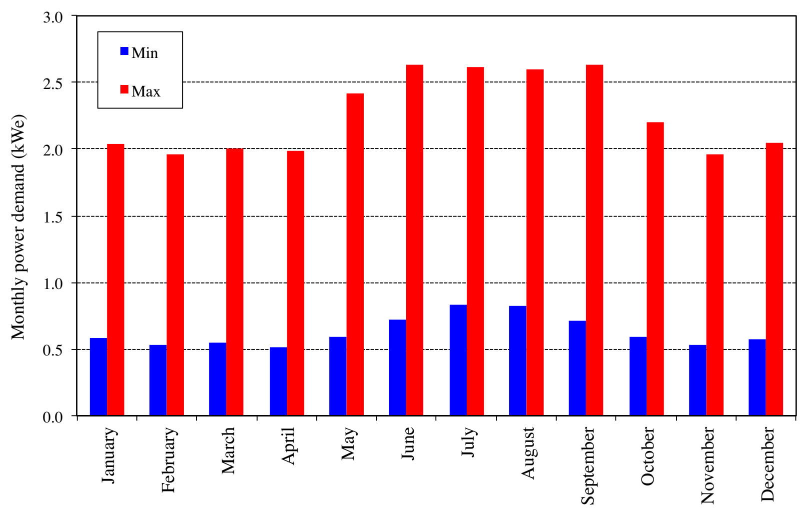

Fig. 2. Monthly power demand.

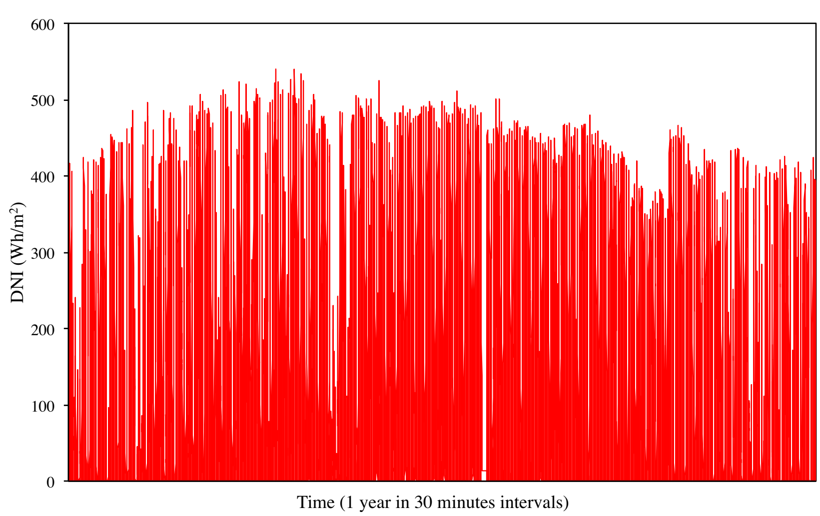

Fig. 3. Annual solar potential.

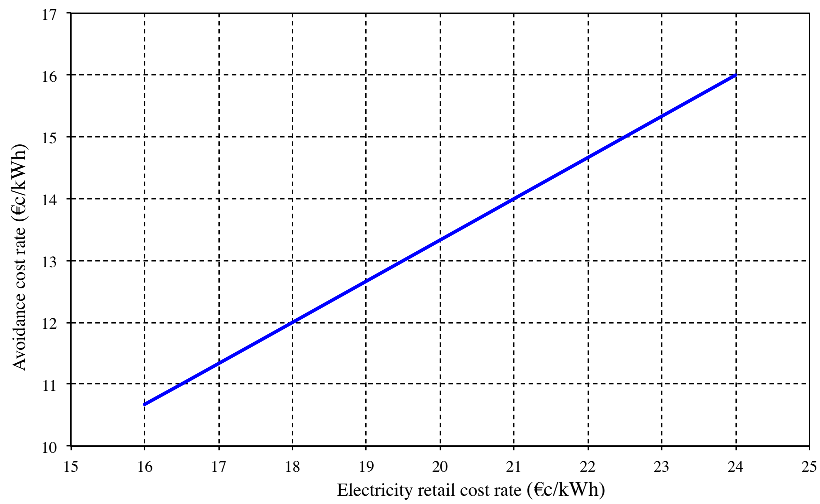

Fig. 4. Avoidance cost rate dependence on electricity cost rate.

Table 2
Simulations annual results.

Parameter	Unit	PV system capacity						
		1 kWp	2 kWp	3 kWp	4 kWp	5 kWp	6 kWp	7 kWp
Electricity demand	kW h	10,310	10,310	10,310	10,310	10,310	10,310	10,310
PV electricity generation	kW h	1611	3221	4832	6442	8053	9664	11,274
Net metering reading	kW h	8699	7088	5478	3867	2257	646	−965
RECs	–	0	0	0	0	64	361	1126
Annual CO_2 avoided emissions	t_{CO_2}	1	3	4	5	6	8	9
Annual barrels of crude oil not consumed	bbl	3	5	8	11	13	16	19

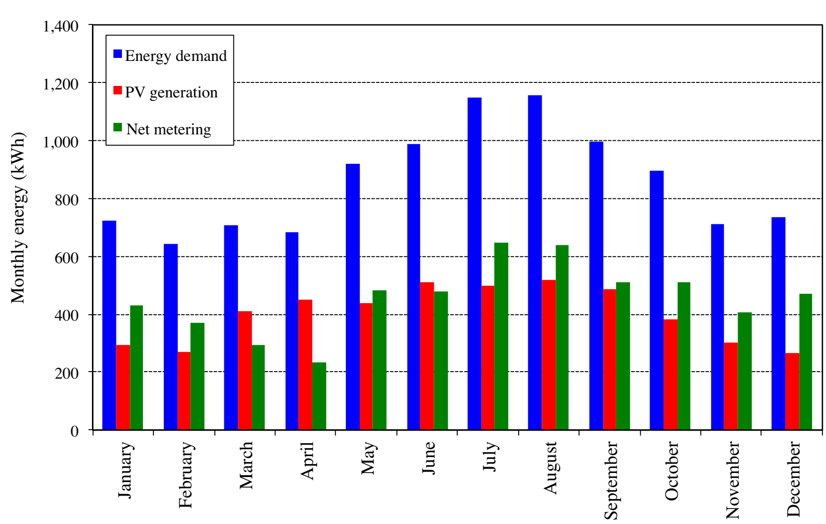

Fig. 5. Monthly energy balance in the case of 3 kWp PV installation.

For the PV system a capital expenditure of 2700€/kW is used and for the annual operation and maintenance a typical value of 3€/kW-month is assumed [6]. For all simulations, costs are updated to 2012 values. In particular, the economic life of the PV system is assumed for 20 years with a discount rate of 8%, an average annual inflation rate of 2.3% and an average loan interest of 7.1%. In order to calculate the after-tax cash flows and after-tax financial indicators a single 10% income tax rate is assumed, that remains constant throughout the PV system life and applied to net income. In the case of FiT supporting scheme a FiT of 28€c/kW h is assumed.

The effect of the electricity retail cost rate and the effect of the avoidance cost rate to the net metering supporting scheme is investigated by varying the electricity retail cost rate from 16€c/kW h, in steps of 2€c/kW h, up to 24€c/kW h. The avoidance cost rate is then changing accordingly as illustrated in Fig. 4.

To estimate the annual CO_2 avoided emissions from the operation of the PV system, a CO_2 environmental indicator of 800 g/kW h is used.

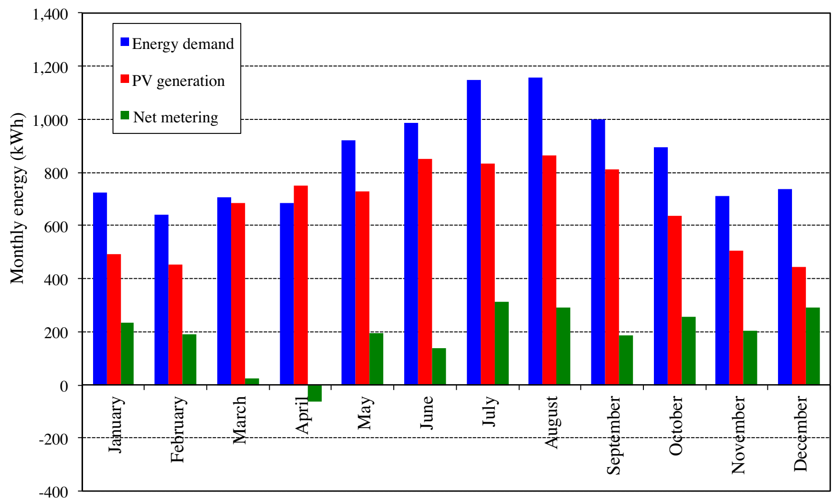

Fig. 6. Monthly energy balance in the case of 5 kWp PV installation.

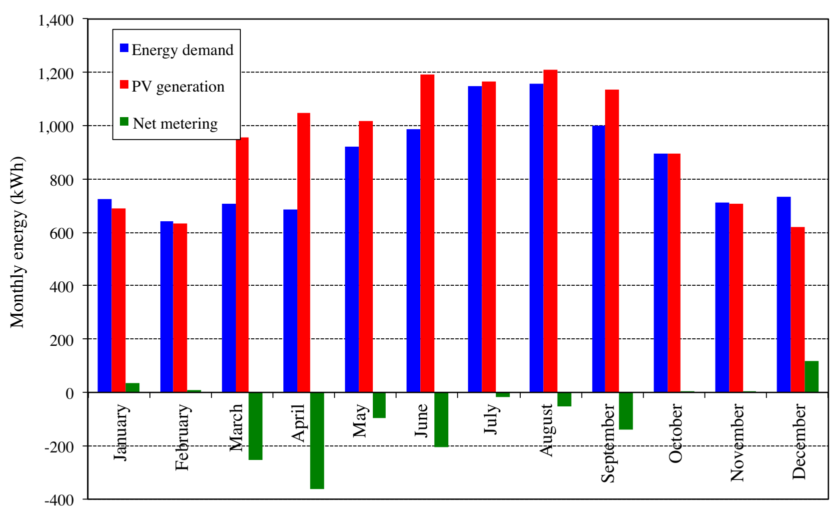

Fig. 7. Monthly energy balance in the case of 7 kWp PV installation.

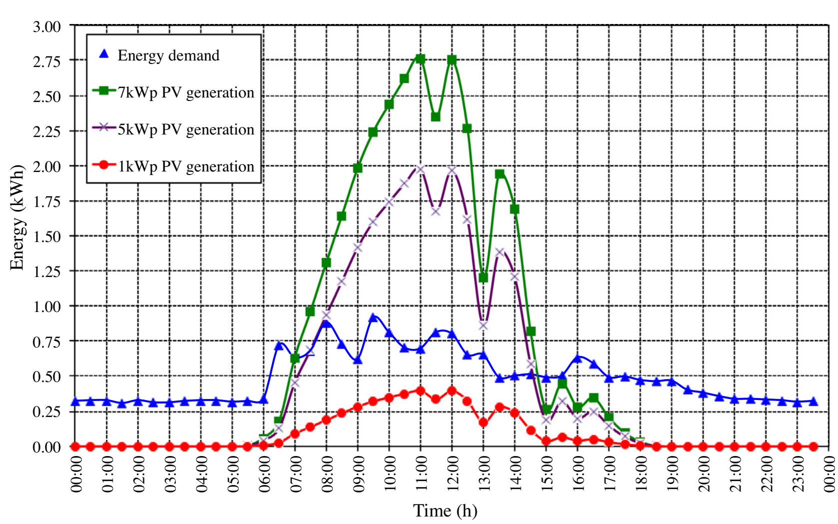

Fig. 8. Energy demand and PV generation in April.

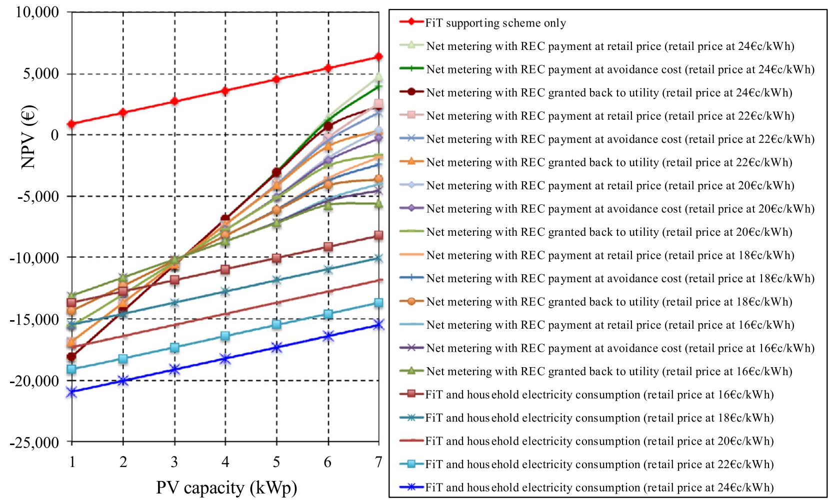

Fig. 9. After tax NPV results.

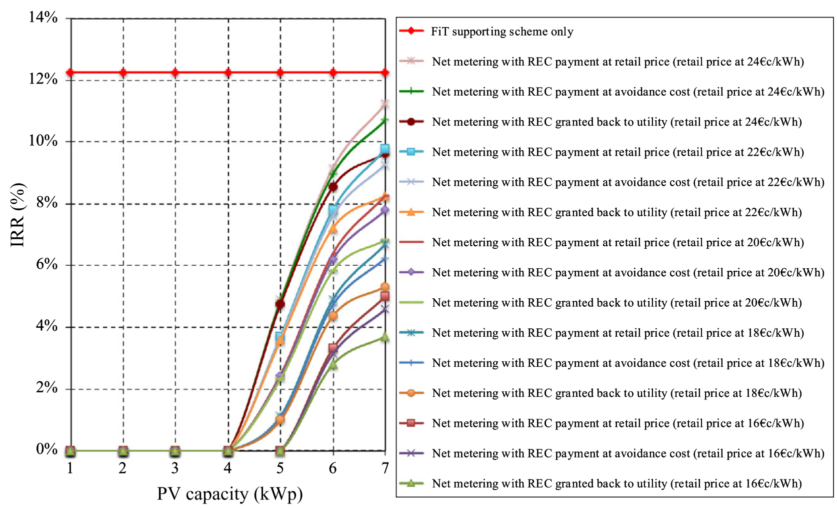

Fig. 10. After tax IRR results.

Simulations results and discussion

The results concerning the household annual electricity demand and the electricity generation from the capacity range of rooftop PV systems investigated, as well as, the results concerning net metering reading and RECs credited are tabulated in Table 2. We observe that net metering reading decreases with the increase in the PV system capacity. In the case of 7 kWp PV system the net metering reading is negative meaning that a surplus, of electricity generated from the PV system, of 965 kW h exists. However, the credited RECs are 1126 since the clearance of surplus electricity is carried out for each month. Although in the case of 5 kWp and 6 kWp PV systems there is no annual surplus of the generated electricity the credited RECs are 64 and 361, respectively.

The monthly energy balance in the case of 3 kWp, 5 kWp and 7 kWp PV system are illustrated in Figs. 5–7, respectively.

In the case of 3 kWp PV system, shown in Fig. 5, the results indicated that for all months there is no surplus of electricity generated from the PV systems. However, in the case of 5 kWp system, shown in Fig. 6 the results indicated that in April a total of 64 kW h of electricity is exported to the grid resulting to an equivalent number of RECs benefit. For a PV system of 7 kWp, shown in Fig. 7, electricity is exported to the grid for seven months resulting to a number of RECs benefit of 1126. Daily results for April concerning various PV system capacities are presented in Fig. 8. In the case of 1 kWp no electricity is exported to the grid, however, in the case of using 5 kWp or 7 kWp PV systems electricity is exported to the grid.

Referring to Table 2, the annual avoided CO_2 emissions are estimated at 1 t_{CO_2}, which corresponds to three barrels of crude oil not consumed in the case of 1 kWp PV system. In the case of 7 kWp PV system the annual avoided CO_2 emissions are 9 t_{CO_2}, which corresponds to 19 barrels of crude oil not consumed.

The comparative results concerning after tax NPV for the various scenarios examined are presented in Fig. 9. We observe that in the case of evaluating the economics of the PV system under FiT supporting scheme without taking into account the household electricity bill is profitable with an after tax NPV ranging from €909 to €6361 depending on the capacity of the installed rooftop PV system. In the case, however, of residential PV system installations except from the FiT support a utility customer is required to take into account the cost of electricity imported for satisfying the energy needs of the household as illustrated by the bottom lines of

Fig. 9. We observe that depending on the level of electricity retail cost rate and the rooftop PV system capacity negative after tax NPVs ranging from €8215 to €20955 are calculated.

In the case of net metering scenarios examined all computations provided after tax NPV results greater than the above scenario (i.e., FiT and household electricity consumption). Also, depending on the rooftop PV system capacity, the electricity retail cost rate and the REC policy examined indicated that after tax NPV becomes positive reaching a value of €4763.

The comparative results concerning after tax IRR are illustrated in Fig. 10. The results of the scenario FiT and household electricity consumption are not illustrated since IRR values calculated are below 0%. Based on this analysis, using data from the Cyprus electricity market, it is clear that net metering supporting scheme becomes profitable for values of after tax IRR above 8%. This is the case when electricity retail cost price is above 22€c/kW h.

Conclusions

In this work, a comparative assessment of net metering vs. FiT supporting schemes for residential PV systems was carried out. A formulation for the computation of net metering supporting scheme parameters, in half hour intervals, was developed and a typical household integrated with a rooftop PV system was investigated. The effect of the size of PV system with respect to the net metering supporting scheme was examined by varying the PV capacity from 1 kWp up to 7 kW and the effect of the electricity retail cost rate was investigated by varying the electricity retail cost rate from 16€c/kW h up to 24€c/kW h. The comparative results indicated that net metering supporting scheme performs better than a FiT supporting scheme when the household electricity bill is taken into account. From the analysis it is clear that under certain conditions net metering supporting scheme becomes profitable. The promotion of rooftop PV systems using a net metering supporting scheme maybe beneficial both for an energy policy point of view since a reduction in the green tax is expected as well as for the household owners due to the significant reduction in the final electricity bills.

References

[1] Poullikkas A, Kourtis G, Hadjipaschalis I. An overview of the EU member states support schemes for the promotion of renewable energy sources. Int J Energy Environ 2012;4:553–66.
[2] Darghouth NR, Barbose G, Wiser R. The impact of rate design and net metering on the bill savings from distributed PV for residential customers in California. Energy Policy 2011;39:5243–53.
[3] Parmesano H. Standby service to distributed generation projects: the wrong tool for subsidies. Electr J 2003;10:85–92.
[4] Network for New Energy Choices. (2009). Freeing the grid – best and worst practices in state net metering policies and interconnection procedures, New York: www.newenergychoices.org.
[5] Poullikkas A. A decouple optimization method for power technology selection in competitive markets. Energy Sources Part B 2009;4:199–211.
[6] Poullikkas A. Parametric cost-benefit analysis for the installation of photovoltaic parks in the island of Cyprus. Energy Policy 2009;37:3673–80.
[7] Poullikkas A, Kourtis G, Hadjipaschalis I. A hybrid model for the optimum integration of renewable technologies in power generation systems. Energy Policy 2011;39:926–35.
[8] Ferrey S. Net zero: distributed generation and FERC's midAmerican decision. Electr J 2004;10:33–42.
[9] Rokach J. Net metering needs safety net. Electr J 2011;11:106–8.
[10] Yin H, Powers N. Do state renewable portfolio standards promote in-state renewable generation? Energy Policy 2010;38:1140–9.