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King Abdullah Petroleum Studies and Research Center

Commentary

Demystifying Policy Support Mechanisms for Distributed Solar Photovoltaic Systems

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Context

Solar photovoltaic (PV) distributed generation (DG) systems are installed for residential, commercial, and industrial use. PV DG systems in the residential sector typically have capacities below 20 kilowatts (kW). However, commercial and industrial PV DG systems can have capacities of several hundred kW. While most PV DG systems are deployed on rooftops, they can also be ground-mounted if there is enough space to do so.

One of the strongest motivations for households to install PV DG systems is to reduce their monthly electricity bills. When a system is installed on a rooftop, for example, it will generate electricity at a near-zero operational cost. Hence, the household reduces its reliance on the grid because it consumes the electricity generated by its system. The higher the electricity tariff paid to the utility, the more attractive PV DG installation becomes. The financial viability of a PV DG system is further enhanced if the capital cost of installing it is low.

Throughout any given year, there will likely be several occasions when the electricity generated by PV DG systems would be higher than the electricity demanded of them. For example, there would be no need to turn on air conditioners during cooler days, which would significantly reduce a household's electricity demand. Households may also travel during part of the year, again significantly reducing their electricity demand. As a result, the surplus electricity generated from PV DG systems can either be discarded (i.e., dumped), stored (which requires a battery), or exported to the grid. The assumption that distributed generation end-users can export electricity to the grid is based on the regulator allowing it. Clearly, the financial attractiveness of PV DG increases if the end-user gets credited for electricity exported to the grid. The financial viability of the system is enhanced as the credit received by the end-user increases.

Given the reductions in the costs of solar energy production globally, PV DG is considered economic in a number of countries. There are still many jurisdictions where PV DG is not deemed financially viable or attractive. However, governments can provide subsidies to make them more attractive. The reasons behind supporting PV DG deployment include, for example, deferring capital generation investment, reducing energy transmission losses, reducing carbon emissions, and/or boosting the renewable energy industry and the associated employment this produces.

Many types of financial support exist for PV DG, including investment credits, feed-in tariffs (FITs), and net energy metering (or net metering [NM]). The investment credit mechanism is the easiest to conceptualize and implement. In essence, the government provides a direct one-time payment to households and shares the burden of the capital costs associated with PV DG installation with them. However, it is unclear how and to what extent average households benefit from FITs and NM. This commentary explains qualitatively how the FIT and NM mechanisms function for households and provides numerical examples for further illustration. This commentary is timely, as Saudi Arabia's electricity regulator has only recently approved the regulations governing DG deployment within the Kingdom.

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Feed-in tariff (FIT)

The FIT is the monetary value that households receive for every unit of energy (kilowatthour [kWh]) that they export to the grid. This requires households to install smart meters to measure how much electricity they export to the grid. The PV system first meets the household's load. Then, any excess electricity it generates is exported to the grid. It is therefore possible for the PV system to simultaneously meet the household's demand and export electricity to the grid. Households could exploit the FIT by oversizing the PV system to maximize the electricity they export (as long as the compensation they receive is more than the additional capital required for a larger PV system). The regulator can set a system-size cap to mitigate against any profiteering.

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The FIT is sometimes referred to as net billing. The literature generally uses the term net billing if the utility compensates the household at what is known as the 'avoided cost,' or the avoided fuel consumption cost. This refers to the fuel cost the utility avoids when households generate their own electricity and export it to the grid. The FIT and net billing mechanisms are conceptually identical; they only differ in their monetary compensation rate. Saudi Arabia has recently adopted a net billing mechanism for its DG deployment.

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Net metering (NM)

Net metering is a form of support where the utility buys back any exported electricity at the same price it is sold for. Similar to FITs, net metering allows households to consume the electricity generated by their PV systems and export any excess electricity (i.e., when the load is below the quantity of electricity supplied by the PV system) to the grid at the utility's tariff. If a household bought 1,000 kWh from the utility but exported 1,000 kWh to the grid, then its bill is zero. If a household buys 1,000 kWh from the utility but exports more than this to the grid, the utility would pay the household the value of the net surplus. However, it is unlikely that a household would become a net exporter of electricity, as it would continue to rely on the grid during nighttime and on rainy or cloudy days. With NM, as with FITs, the household may oversize its installed PV capacity to maximize exported electricity, so a cap is advisable.

Numerical example

It is useful to illustrate the qualitative description above with a numerical example. We begin with a FIT, or net billing, scenario. Table 1, below, provides a hypothetical consumption pattern for a household with a solar PV DG system installed. It is also assumed that the household travels during July and August, and that its electricity demand during these months is low. Column A represents the total electricity consumed by the household. If no PV system were installed, and assuming the household buys electricity for 0.10 dollars per kWh ($/kWh), then it would be easy to calculate the electricity bill (column F).

However, when a solar PV DG system is installed, the household's benefits are twofold: (1) it buys less electricity from the utility since the PV DG system satisfies part of its load (columns B and C); (2) it is compensated by the utility for exporting electricity to the grid (columns D and H). Recall that the PV DG system satisfies the household's load first, and then exports excess generation (if any) to the grid. In this example, the household is compensated $0.05 for every kWh it exports to the grid. Table 1 shows the difference between the household's bill without a PV DG system (column F) and the bill with a PV DG system installed (column I). As can be seen in column J, the more energy generated and/or exported by the PV DG system, the more savings the household realizes.

During July and August, the demand from the household for electricity is low. During this time, the household is a net exporter because most of the energy generated by the PV DG system is exported to the grid, and the utility would have been paying the household (or carrying over its positive balance for use against its subsequent electricity bills). The total electricity bill for the household during this year, assuming a FIT mechanism is in place, would be $808, compared with $1,010 without PV DG installed.

Table 1. Potential monthly savings for a household with a PV DG system and a FIT mechanism in place.

	A	B	C = A – B	D	E = B – D	F = A x electricity price	G = B x electricity price	H = D x feed-in tariff	I = G – H	J = (F – I)/F
Month	Energy demand (kWh)	Energy met (purchased) from the utility (kWh)	Energy met by PV DG (kWh)	Energy from DG PV exported to the grid (kWh)	Net energy purchased from the utility (kWh)	Monthly energy bill if all energy is met by the grid and no PV DG is installed ($)	Cost of energy purchased from the grid when PV DG is installed ($)	Money paid to the household for exporting energy to the grid ($)	Household's net energy bill with PV DG installed ($)	Household's savings when PV is installed compared with no PV DG installed
Jan.	900	720	180	120	600	90	72	6	66	27%
Feb.	800	650	150	140	510	80	65	7	58	28%
Mar.	1,000	880	120	120	760	100	88	6	82	18%
Apr.	1,000	870	130	80	790	100	87	4	83	17%
May.	1,000	800	200	100	700	100	80	5	75	25%
Jun.	1,200	980	220	0	980	120	98	0	98	18%
Jul.	50	40	10	180	(140)	5	4	9	(5)	-
Aug.	50	30	20	200	(170)	5	3	10	(7)	-
Sep.	1,200	1,050	150	0	1,050	120	105	0	105	13%
Oct.	1,000	900	100	0	900	100	90	0	90	10%
Nov.	1,000	880	120	0	880	100	88	0	88	12%
Dec.	900	800	100	100	700	90	80	5	75	17%

Note: Electricity price= $0.10/kWh; FIT= $0.05/kWh.

The German FIT, initiated in 2000, compensated consumers by about 0.50 euros (€) for every kWh they exported to the grid, whereas the electricity tariff was much lower, at around €0.10/kWh. This disproportionately high FIT was the main driver behind the rapid uptake of residential PV DG in Germany.

The net metering mechanism can be implemented with either monthly or annual settlements. In the FIT scenario, the electricity exported to the grid would be compensated at a specific rate, which could be higher or lower than the retail electricity tariff. However, in net metering, electricity is always exported at the retail rate. Table 2 shows the electricity consumption and billing of the hypothetical household seen in Table 1 when using a monthly net metering mechanism.

Columns A-F of Table 2 are identical to those of Table 1. However, the electricity cost that the household pays when using a monthly net metering mechanism differs from when it uses a FIT mechanism. The electricity bill to be paid by the household in the monthly net metering scenario must be less than in the FIT scenario because the household is being compensated $0.10/kWh for each kWh exported to the grid, as opposed to $0.05/kWh in the FIT scenario (Table 2, column G).

July and August are the exceptions to this rule. Recall that during these two months, the household's demand is low and it is a net exporter of electricity. As such, the household will be compensated according to the net excess energy export price, which is assumed to be $0.04/kWh. This analysis uses this figure to calculate the bills for July and August (column G). The total annual electricity bill for the monthly net metering scenario is now reduced further to $776.

The final scenario considered in this analysis is annual net metering, in which the household is charged annually for its net use of electricity. If a household were to be a net importer by the end of the annual billing cycle, it would pay for its consumption at the prevailing retail rate. However, if the household were to be a net exporter, then the utility would remunerate it via the net excess energy export price.

Table 3 shows the household's annual electricity bill if annual net energy metering was implemented. To help calculate the annual settlement, it has an additional row at the bottom to show the sum of the respective columns. Monthly billing is inapplicable in this scenario. The sum of column B shows the total electricity the household purchases from the utility during the year, while column D shows the total electricity exported to the grid during the year. As can be seen from the bottom row, by the end of the year, the household was a net electricity importer (column E). As a result, it would pay almost $760 (column G).

As expected, the annual electricity bill in this scenario is even lower than in the monthly net metering scenario. This is because the household was compensated for its net exported electricity during July and August using the prevailing retail electricity price, which was higher than the net excess energy export price.

Based on tables 1-3, the most beneficial mechanism for the household would be the annual net metering mechanism, with the FIT mechanism being the least beneficial. The annual electricity bill with no PV DG installed would have been $1,010, compared with $808, $776, and $760 for the FIT, monthly net metering, and annual net metering scenarios, respectively. The annual net metering produces the most savings because the household acquires the maximum benefit by carrying over the credit (based on the retail rate) for any monthly net-exported electricity to subsequent months. These figures for the respective annual electricity bills, according to the different scenarios in this analysis, assume that the FIT is lower than the retail electricity price. If the FIT were higher than the retail electricity price, it would clearly be the most attractive option for the household.

Table 2. Potential monthly savings for a household with a PV DG system and a monthly net metering mechanism in place.

	A	B	C = A – B	D	E = B – D	F = A x electricity price	G = E x electricity price	H = (F – G)/F
Month	Energy demand (kWh)	Energy met (purchased) from the utility (kWh)	Energy met by PV DG (kWh)	Energy from PV DG exported to the grid (kWh)	Net energy purchased from the utility (kWh)	Energy bill if all energy is met by the grid and no PV DG is installed ($)	Household's energy bill when PV DG is installed ($)	Household's savings when PV is installed compared with no PV DG installed
Jan.	900	720	180	120	600	90	60	33%
Feb.	800	650	150	140	510	80	51	36%
Mar.	1,000	880	120	120	760	100	76	24%
Apr.	1,000	870	130	80	790	100	79	21%
May.	1,000	800	200	100	700	100	70	30%
Jun.	1,200	980	220	0	980	120	98	18%
Jul.	50	40	10	190	(150)	5	(6)*	-
Aug.	50	30	20	155	(125)	5	(5)*	-
Sep.	1,200	1,050	150	0	1,050	120	105	13%
Oct.	1,000	900	100	0	900	100	90	10%
Nov.	1,000	880	120	0	880	100	88	12%
Dec.	900	800	100	100	700	90	70	22%

Note: Electricity price= $0.10/kWh; net excess energy export price= $0.04/kWh.

* This was calculated as the product of the net energy imported from the grid (column E) and the net excess energy export price ($0.04/kWh).

Apart from the electricity price and the FIT, other factors that affect the financial viability (or payback period) of PV DG systems include, among others, the capital cost of the PV DG system, the local solar conditions, and the household's load profile. All of these factors would need to be taken into account simultaneously, using a mathematical model, to assess the economics of PV DG deployment for a given household. For simplicity and brevity, the focus of the numerical examples provided above was restricted to the electricity price and FIT rate. It is worth noting that the cost of solar modules has fallen sharply in the past decade. In 2010, PV DG cost around $2 per watt. It is now less than $0.30 per watt.

Table 3. The potential monthly savings for a household with a PV DG system and an annual net metering mechanism in place.

	A	B	C = A – B	D	E = B – D	G = Sum of column 'E' x electricity price
Month	Energy demand (kWh)	Energy met (purchased) from the utility (kWh)	Energy met by DG PV (kWh)	Energy from DG PV exported to the grid (kWh)	Net energy purchased from the utility (kWh)	Cost of energy purchased from the utility when DG PV is installed ($)
Jan.	900	720	180	120	600	-
Feb.	800	650	150	140	510	-
Mar.	1,000	880	120	120	760	-
Apr.	1,000	870	130	80	790	-
May.	1,000	800	200	100	700	-
Jun.	1,200	980	220	0	980	-
Jul.	50	40	10	190	(150)	-
Aug.	50	30	20	155	(125)	-
Sep.	1,200	1,050	150	0	1,050	-
Oct.	1,000	900	100	0	900	-
Nov.	1,000	880	120	0	880	-
Dec.	900	800	100	100	700	-
Total	10,100	8,600	1,500	1,005	7,595	759.5

Note: Electricity price= $0.10/kWh; net excess energy export price= $0.04/kWh.

The net excess energy export price is irrelevant for this scenario, as it was a net importer by the end of the billing cycle.

As a final note, it is worth reminding the reader that while the most beneficial policy mechanism for the consumer is annual net metering, this is the most costly policy mechanism for the government. Hence, when devising policies that support PV DG, the economic costs of doing so should be weighed against the benefits that PV DG would provide. In doing so, policymakers can maximize the gains of PV DG from an economy-wide perspective.

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