NET METERING:
NEW OPPORTUNITIES FOR HOME POWER

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Introduction

In determining the economic feasibility of small-scale renewables, the two most important considerations are the capital cost and the cost of financing. For the most part, these two factors are a function of market prices, and quotes from renewable energy contractors and financial institutions will be subject to competitive pressures.

Another factor influencing the economics of these systems -- the electric utility's metering and interconnection requirements -- is decided through a political process that is largely independent of competitive pressures. In particular, the means by which the utility accounts for excess generation sold back to the utility can make a tremendous difference in the economic feasibility of small-scale renewable generation. Despite this fact, utility metering and interconnection policies with respect to small-scale, customer-owned, grid-connected renewable generators (hereinafter "small customer-generators") have received little attention.

The most likely explanation for this lack of scrutiny is that few generating technologies have proved to be economically feasible in small-scale applications. Wind energy development, for instance, has occurred mostly in multi-megawatt arrays composed of dozens of large wind turbines. This reality is in sharp contrast to the idyllic image of a lone Jacobs "wind charger" silhouetted against the sunset on a small Midwestern farm. Nevertheless, the U.S. is dotted with people who have incorporated their own means of electric generation into their grid-connected home, farm or ranch.[2] Utilities traditionally have dealt with these scattered customers on a case-by-case basis.

Recently, however, there has been a surge of interest in the use of a particular metering arrangement, called "net metering," to encourage direct customer investment in the development of renewable energy. In 1995, California enacted a law requiring utilities to provide net metering for residential PV systems.[3] Similar bills were introduced during 1996 in Hawaii and New York,[4] and at least three other states are currently contemplating the implementation of net metering.

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[2]Renewable generation is much more prevalent in grid-independent or "remote" applications. For these applications, the cost of a utility line extension is prohibitive and renewable generation is the preferred alternative. One 1989 estimate placed the number of remote photovoltaic-powered homes at 25,000. See J. Tatum, *The Home Power Movement and the Assumptions of Energy-Policy Analysis*, 17 Energy 99 (1992).

[3]California Public Utilities Code § 2827.

[4]For more information on a recent bill proposed in New York, see "Under Solar Bill, Homeowners Could Cut Electric Bills to Zero," New York Times, July 25, 1996.

The primary impetus for this resurgence of interest appears to be the improving economics of small-scale photovoltaic (PV) generation.[5] Although PV generation continues to be uneconomic for most grid-connected applications, system costs have now declined so much that "early adopters" -- individuals motivated by non-economic factors, including self-sufficiency and environmental considerations -- are considering investing in the technology. One indication of the level of interest is that Southern California Edison, one of the largest investor-owned utilities in the country, recently sought and obtained regulatory approval to begin selling grid-connected PV systems to customers in its service territory.[6]

As more customers choose to invest in small-scale renewable generation, utilities and regulators will have to consider the tradeoffs between different metering and interconnection requirements. This paper recommends that utilities consider net metering as an alternative to the traditional dual-metering approach used to interconnect other non-utility generators. If properly implemented, net metering provides a simple, low-cost, and easily-administered method for encouraging direct customer investment in renewable technology while minimizing adverse utility revenue impacts.

Metering Options for Small-Scale Renewable Generation

The two metering options available for small customer-generators are net purchase and sale, and net metering.

Option 1: Net Purchase and Sale

Net purchase and sale allows customer-generators to use their renewable generation to offset their simultaneous electricity consumption. Beyond this offset, electricity consumed is bought from the utility at the normal retail rate, and electricity generated is sold to the utility at the lower "avoided cost" rate that utilities are required to pay for power purchases under federal law.[7] Net purchase and sale requires two "ratcheted" or uni-directional meters which measure only instantaneous excess consumption or generation.
To illustrate, imagine a house with a 2-kilowatt (kW) solar PV system on the roof. Assume the system is generating electric power at its full 2-kW capacity for three consecutive hours, for a total of 6 kilowatt-hours (kWh). Further assume the retail rate is 12 cents/kWh and the avoided cost rate is 4 cents/kWh. Finally, assume the following pattern of electricity consumption:

1 During the first hour, residential power demand is also level at 2 kW. This means the PV system's output will exactly coincide with the residential demand so that neither meter is spinning.

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[5]See H. Wenger, C. Herig, R. Taylor, P. Eiffert & R. Perez, *Niche Markets for Grid-Connected Photovoltaics*, Presented at IEEE Photovoltaic Specialists Conference, Washington, D.C. (May 13-17, 1996).

[6]California Public Utilities Commission, *Southern California Edison Company's Request to Establish a Five-Year On-Grid Photovoltaic Pilot Program*, Resolution E-3438 (March 13, 1996).

[7]Under the Public Utility Regulatory Policies Act (PURPA), a utility is required to purchase electricity from "qualifying facilities" (QFs), including small power producers generating electricity using renewable resources.

2 During the second hour, power demand increases to 3 kW. At the end of the hour, 2 kWh will have been offset by the PV generation, and 1 kWh will be purchased from the utility at the retail price.

3 During the third hour, power demand decreases to 1 kW. At the end of the hour, 1 kWh will have been offset by the PV generation, and the other kWh generated by the PV systems will be sold to the utility at the lower avoided cost price.

Thus, as shown in Table 1, at the end of the three-hour period the PV system has generated the same amount of electricity as the residence consumed. However, the disparity in the timing of excess generation and consumption means that the customer-generator has purchased 1 kWh from the utility and sold 1 kWh back to the utility. The customer-generator’s total bill at the end of the three-hour period is a function of the difference between the retail price and the avoided cost price. Note that the customer could have reduced the bill to zero by shifting 1 kWh of her consumption from the second to the third hour.

TABLE 1. NET PURCHASE AND SALE

	Hour 1	**Hour 2**	**Hour 3**	**Total**
Gross Generation (kWh)	2	2	2	6
Gross Consumption (kWh)	2	3	1	6
Net Generation Meter (kWh)	--	--	+1	+1
Net Consumption Meter (kWh)	--	+1	--	+1
Effect on Electricity Bill	**0 cents**	**12 cents**	**-4 cents**	**8 cents**

Option 2: Net Metering

Net metering allows customers to offset their electricity consumption with small-scale renewable generation over an entire billing period (or in some instances over an entire year) without considering when the power is consumed or generated. Net metering uses a single bi-directional meter that registers the flow of electricity in both directions.[8] With net metering, either the customer pays for the net electricity consumed over the billing period at the retail rate, or the utility purchases the net electricity generated over the billing period at the lower avoided cost rate.

Applying the above illustration to net metering leads to a different result. As shown in Table 2, during the first hour, the single meter spins neither forward nor backward. During the second hour, the meter spins forward, registering the consumption of 1 kWh. During the third hour, however, the same meter spins backward, effectively "netting out" the 1 kWh consumed.

TABLE 2. NET METERING

	Hour 1	Hour 2	Hour 3	Total
Gross Generation (kWh)	2	2	2	6
Gross Consumption (kWh)	2	3	1	6
Net Consumption Meter (kWh)	0	+1	-1	0
Effect on Electricity Bill	**0 cents**	**12 cents**	**-12 cents**	**0 cents**

Net metering allows customer-generators to offset a higher proportion of their retail electricity consumption with their own electricity generation. Customer-generators effectively earn a higher rate of return -- the retail price rather than the avoided cost price -- on a higher percentage of the electricity they produce.

The Economics of Dual Metering vs. Net Metering

If utilities priced their retail power at marginal cost (comparable to avoided cost), then each metering option described above would yield similar results, and customers and utilities alike would be indifferent to the choice of metering options. But utilities price their retail power based on average costs, which currently are well above marginal costs. In California, for example, retail rates average about 12 cents/kWh, while non-time differentiated avoided cost rates average about 4 cents/kWh. The divergence between retail and avoided cost rates is what makes the choice of metering options so important to determining the economics of small-scale renewable generation by customer-generators.

The following examples will demonstrate the difference between the metering options described above. Assume that Sally Solar installs a 2-kW PV system on the roof of her new house in the sunny southwest. The system generates about 360 kWh/month. Sally's average electricity consumption is 400 kWh/month. What is Sally’s net monthly bill under each metering option?

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[8] An alternative is to use two meters and net the electricity generated and the electricity consumed during the billing process.

Option 1: With net purchase and sale, Sally can offset some of her consumption with some of her generation, but only by consuming electricity at the same time that her PV system is generating electricity. Sally works during the day, but with clever use of timers on some of her major appliances she manages to offset 40% of her monthly demand, or 160 kWh. Sally then calculates her net bill:

Net Bill = (240 kWh x 12 cents/kWh) - (200 kWh x 4 cents/kWh) = $28.80 - $8.00 = **$20.80/month**

Option 2: With periodic net metering, Sally can use all of the output from her PV system to offset her electricity consumption (as long as total generation is below total consumption). Sally calculates then calculates her net bill:

Net Bill = (400 kWh - 360 kWh) x 12 cents/kWh = 40 kWh x 12 cents/kWh = **$4.80/month**

Another way of looking at these numbers is to think of Sally's return on investment for her PV system as being equal to the money she avoids paying to the utility each month. Without the PV system, her monthly bill would have been 400 kWh x 12 cents/kWh = $48/month (Option 0). Sally calculates the savings in her monthly bill for each option, listed in Table 3:

TABLE 3. IMPACT OF METERING OPTIONS ON MONTHLY ELECTRICITY BILLS

	Option 0	Option 1	Option 2
Original Bill	$48.00	$48.00	$48.00
Revised Bill	$40.00	$20.80	$ 4.80
Bill Savings	$ 0.00	$27.20	$43.20

These figures are merely illustrative. The actual results will depend on various factors, including retail and avoided cost rates, seasonal variations in electricity generation and consumption and, with net purchase and sale, on hourly and daily variations in the pattern of electricity use. This simplified analysis does not account for time-differentiated avoided cost rates or other pricing options, such as the use of standby charges or minimum monthly bills. It also does not account for the cost of additional metering required for net purchase and sale.

Nevertheless, there are several conclusions that emerge from this hypothetical illustration. First, the bill savings (from the customer-generator’s perspective) and revenue loss (from the utility’s perspective) reflect only a difference in the accounting treatment of the electricity generated, not in the flow of electricity itself. That is, the same amount of electricity ends up in the same place under either billing method. The difference is in how that electricity is valued.

Second, most of the bill impact is associated with the customer’s threshold decision to self-generate rather than the choice of metering options. In the hypothetical, about two-thirds of the bill impact comes from the decision to self-generate. The final one-third comes from the switch to net metering. In analyzing the economic implications of net metering, one should be sure to distinguish between these two effects. In particular, some utilities have expressed reluctance to embrace net metering because of the total revenue impacts (the difference between Options 0 and 2) rather than the incremental revenue impacts (the difference between Options 1 and 2). Considering the total revenue impact is appropriate if a customer chooses to self-generate because of the availability of net metering. The incremental revenue impact provides a more appropriate basis for analysis for a customer who chooses to self-generate regardless of the metering option.

Third, the higher the coincidence between the customer's generation and consumption patterns, the smaller the difference between the two billing options. In the extreme, if the customer-generator's baseline demand is larger than or equal to her peak generating capacity, all of the electricity generated will be absorbed in the baseline demand. In this case, the customer-generator will never produce any net electricity for the utility grid. This typically will be true, for example, with a PV system on an office building or a small wind turbine on a working ranch. Thus, net metering is best used in a residential setting, where demand may fluctuate significantly relevant to the amount of generating capacity.

Net Metering in Practice

Many states already have net metering in place for at least some small customer-generators. The following fourteen states offer net metering on a statewide basis: California, Connecticut, Iowa, Maine, Massachusetts, Minnesota, New Hampshire, North Dakota, Oklahoma, Pennsylvania, Rhode Island, Texas, Vermont, and Wisconsin. Table 4 describes the terms and conditions of the net energy metering programs in these states. In addition to these statewide programs, individual utilities in many other states offer net metering on a case-by-case basis.

Given the prevalence of net metering programs, surprisingly little information has been published regarding the number of customer-generators participating in net metering programs or the resources being used to power the generating facilities subject to net metering. Anecdotal information obtained while developing the information in Table 4 suggests that participation in most states is very limited. For example, Public Service of New Hampshire estimated in 1994 that it had 16 customers with 158 kW that qualified for net metering.[9] The technologies most often used for net metering appear to be wind energy and small-scale hydropower, although there is very little information available on this point.

Policy Implications of Net Metering

As long as market penetration of small customer-generators remains small, utilities are likely to face few direct costs from allowing net energy metering. When the system's peak output is less than or comparable to peak building demand, no modifications to the local feeder or distribution facilities are likely to be needed. Interconnection with the utility will be conditioned on meeting reasonable safety and power quality requirements, but these costs are the obligation of the customer-generator.

However, if market penetration of solar electric buildings becomes substantial, utilities are likely to be concerned about the revenue losses associated with increased self-generation or bypass by their customers. When customers install energy-generating or conserving equipment on their premises, the utility loses revenue needed to cover the fixed costs of its investment in capital expenditures on plant and equipment, called its "ratebase." The utility, in turn, is compelled to seek higher rates from its remaining customers to recover the fixed costs. This creates an undesirable spiral as higher rates encourage additional self-generation and bypass, leading once again to higher rates for remaining customers.

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[9] New Hampshire Public Utilities Commission, *Approving Net Energy Billing for Residential Renewable Energy Projects Under 25 Kilowatts*, Order DR 93-276 (1994).

Many utilities first encountered this phenomenon during the 1980s, when large industrial customers found it less expensive to cogenerate at least some of their own power rather than purchase it from the local utility. The utilities' ultimate fear is that this spiral will continue until they can no longer cover the cost of plant and equipment in the ratebase. Utilities and regulators have been sufficiently concerned about utility bypass to offer reduced "anti-bypass" rates to large-volume customers who pose a credible bypass threat.[10]

Utilities are concerned about the adverse rate impacts of utility bypass by large numbers of small customers, while customer-generators are interested in maximizing their return from investing in renewable energy equipment. One solution that addresses the concerns of both parties is to allow net metering but limit its availability to a fixed amount of generating capacity. Imposing a cap on net metering can minimize potential adverse rate impacts while providing the incentive necessary to encourage additional investment in renewable energy technology. The capacity limit can be defined as a specific amount of capacity, or a percentage of each utility's total capacity. A relatively simple model can be used to determine the amount of net metering at which rate impacts become significant. The capacity limit can be set well below this amount and still provide adequate growth potential for private investment in renewable technology. This is so because even a small capacity limit represents a large potential increase in the market for renewables.

The new California net metering law, for example, establishes a cap on the availability of net metering equal to 0.1% of each utility's peak demand. The cap was initially suggested by proponents of the new law as a means to address utility concerns about the potential adverse revenue impacts of net metering. The cap was set low enough that the utilities could not effectively argue that there would be measurable adverse rate impacts. The cap was high enough, however, to allow for a dramatic expansion of the market for small-scale renewables.

Another advantage to the imposition of a cap is its flexibility. As market penetration by net metering customer-generators approaches the capacity limit, policymakers can regularly reassess whether additional net metering for customer-generators is in the best interests of the utilities and their customers. This periodic reappraisal will provide the impetus for policymakers to evaluate the status of small-scale renewable technologies, including the competitiveness of markets for the technologies and the ability of net metering programs to contribute to developing these markets.

An analysis of the California program's potential effect on Pacific Gas & Electric Company illustrates the consequences of the cap. For PG&E, the 0.1% cap means that it must provide net metering on a first-come, first-served basis until it has signed agreements for 17 megawatts (MW) of customer-owned, grid-connected PV generating capacity. Because PG&E probably has no more than 100 kW of customer-owned PV capacity currently on its grid, the cap provides plenty of room for growth of the PV market. At the same time, even assuming the 17-MW cap was reached in the first year (a highly unlikely worst case scenario for the utility), the incremental revenue loss from net metering would be approximately $1 million per year, or 0.02% of the utility's $5 billion annual revenues. A much more likely (though still optimistic) scenario would involve the installation of 1,000 additional 2-kW PV systems over the next five years (for a total of 2 MW).

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[10] See M. Nagelhout, *Antibypass Discounts: Load Preservation Without Discrimination*, Public Utilities Fortnightly, February 1, 1991, at 45.

These systems would lead to an incremental revenue loss of approximately $140,000 per year, or 0.0028% of PG&E's annual revenues.[11]

These figures assume that net metering provides no economic benefits to the utility that offset the revenue losses. In fact, utilities and regulators need to consider the revenue losses associated with net metering in the context of potential direct and indirect cost savings to the utilities.

Foremost among the direct benefits of net metering is eliminating the need to account separately for electricity produced by customer-generators. This accounting includes reading the second meter, calculating the payment due, and processing and mailing the payment to customer-generators. Under most circumstances, net metering customers will not produce any excess generation over the billing period. Therefore, no payment from the utility to the customer will be necessary; the customer simply receives and pays a bill for a reduced amount. A 1995 economic analysis of the California net metering law concluded that a utility's cost savings from avoided meter reading and billing costs will be comparable to the revenue losses associated with net metering.[12]

Among the indirect benefits of net metering is the value of eliminating the customer-generators' incentive to instantaneously consume all the electricity being generated. As discussed earlier, the customer-generator is allowed to use renewable generation to offset simultaneous electricity consumption.[13] In the absence of net metering, the rational customer-generator will try to maximize simultaneous use of her own generation. If the power is being generated during a period of peak demand for the utility (as is often the case with PV systems), this incentive can lead to a perverse result: the customer-generator, who might otherwise prefer to consume power during an off-peak period, may feel compelled to turn on major electricity-consuming appliances during the peak period in order to capture the higher value associated with offsetting retail purchases. This is unfortunate, as both the utility and the customer are likely to prefer having the customer-generator feeding the excess power to the grid during the peak period and deferring the additional demand until an off-peak period.

In addition, many studies (including several sponsored by utilities) have concluded that there are direct, measurable economic benefits to the utility of having generation located close to the end user.[14] These studies have concluded that under some circumstances (usually where the utility's

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[11] To put these numbers in context, PG&E in 1993 had 140 cogenerators in its service territory with a generating capacity of over 2,800 MW. Assuming these plants were operating at a capacity factor of 50% and would otherwise have been purchasing their power from the utility at 9 cents/kWh, PG&E lost over $1.1 billion in revenues from these customers. See Pacific Gas & Electric Company, *Cogeneration and Small Power Production Quarterly Report* (3rd Quarter 1993).

[12] H. Wenger, *California Net Metering Program Impact: Net Present Value Economic Analysis*, (unpublished paper) (January 8, 1995). Copy available from the Renewable Energy Policy Project.

[13] See the earlier description of net purchase and sale (Option 1).

[14] See D. Shugar, *Photovoltaics in the Utility Distribution System: The Evaluation of System and Distributed Benefits*, Pacific Gas & Electric Company, Research & Development Report (July 1991); R. Lambeth & T. Lepley, *Distributed Photovoltaic Evaluation by Arizona Public Service Company*, 23rd IEEE PV Specialists Conference, Louisville, KY (May 1993). Copies available from the Renewable Energy Policy Project.

distribution system is operating near capacity) distributed benefits are comparable in scale to traditional energy and capacity benefits.[15] Net metering allows utilities to capture these distributed benefits by encouraging generation among end-use customers.

Legal Issues Arising From Net Metering

Since PURPA was enacted in 1978, private power producers have been assured of the right to sell power to their local utility at avoided cost. Because PURPA does not explicitly address net metering, a number of utilities and utility regulators have adopted net metering programs on their own initiative. Although the legality of net metering under PURPA has never been challenged, some analysts have suggested that net metering violates recent interpretations of PURPA which prohibit states from requiring utilities to pay above 'avoided cost' for power purchases. Under this theory, net metering may be considered a payment above avoided cost because power produced by the customer-generator is used to offset retail power purchased from the utility.

In the preamble to the PURPA regulations promulgated in 1980, the Federal Energy Regulatory Commission (FERC) expressly allowed state regulators to impose rates exceeding avoided cost. The preamble declares that "the States are free, under their own authority, to enact laws or regulations providing for rates which would result in even greater encouragement of these technologies."[16] However, in *Orange & Rockland* (1988)[17] and again in *Connecticut Light & Power* (1995),[18] FERC rejected its earlier interpretation, holding that PURPA prohibits states from requiring utilities to purchase power at rates exceeding avoided cost. Both decisions triggered a storm of controversy and resulted in a number of appeals, some of which have not been resolved. Thus, the FERC's new interpretation is probably binding on the states.

On the other hand, FERC's new interpretation regarding PURPA rates exceeding avoided costs may not affect net metering, for two reasons. First, net metering may be enacted by the states under their own authority, independent of PURPA. Recent decisions from FERC suggest that

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[15] See E. Prabhu, *Finding High Value for Grid-Connected PV: Southern California Edison's Innovative Solar Neighborhood Program*, presented at the American Solar Energy Society Annual Conference (1995); J. Oppenheim, *PV Value Analysis: Progress Report on PV-COMPACT Coordinating Council's Consensus Research Agenda*, presented at the American Solar Energy Society Annual Conference (1995); H. Wenger, T. Hoff & B. Farmer, *Measuring the Value of Distributed Photovoltaic Generation: Final Results of the Kerman Grid-Support Project*, First World Conference on Photovoltaic Energy Conversion (1994). Copies available from the Renewable Energy Policy Project.

[16] F.E.R.C. Stats. & Regs. ¶ 30,128, at 30,875 (1980).

[17] *Orange & Rockland,* 43 F.E.R.C. ¶ 61,067 (1988).

[18] *Connecticut Light & Power Company*, 70 F.E.R.C. ¶ 61,012 (1995), reconsideration denied, 71 F.E.R.C. ¶ 61,012.

states may have the authority to establish their own incentives for specific technologies.[19] States that are considering establishing net metering programs should emphasize that the programs are being developed under state law, rather than under PURPA. The California net metering law, for example, makes no reference to PURPA and independently establishes customer-generators as a new class of customers for whom net metering will be available, regardless of PURPA requirements.

Second, even where states enacted net metering under PURPA, net metering may not be deemed payment above avoided cost; under most net metering programs customer-generators are allowed only to offset their own electricity consumption during the billing period. Any excess generation is purchased by the utility not at retail, but at the lower avoided cost rate. In effect, the customer-generator is merely trading electricity purchased from the utility at one time for electricity generated at another. Utilities often trade electricity during different periods without characterizing the transactions as purchases or sales. Instead, they refer to these transactions as "nonmonetary exchanges" of electricity.[20] Although these nonmonetary exchanges usually occur between utilities, there are no apparent legal obstacles to exchanges between utilities and customer-generators. The characterization of net metering as a "nonmonetary exchange" merits further exploration, particularly in light of the continuing uncertainty of PURPA.

Conclusion

Net metering programs represent a simple, low-cost, and easily-administered method for encouraging direct customer investment in small-scale renewables. Utilities, regulators, and renewable energy advocates should cons/ider broader implementation of net metering as a mechanism for promoting the commercialization of clean, renewable and sustainable energy technologies.

[19] In *Southern California Edison Company/San Diego Gas & Electric Company*, 70 F.E.R.C. ¶ 61,125 (1995), FERC said that "our order in no way affects the authority of states to adopt and implement power supply policies outside of PURPA. Our order today construes only the requirements of PURPA, and does not (indeed, could not) purport to limit the authority of states beyond the context of PURPA." (Concurring opinion of Commissioner Massey.)

[20] The Ohio Public Utilities Code, for instance, specifically excludes nonmonetary exchanges of electric power from the definition of purchased power. See ORC Ann. § 4909.159.