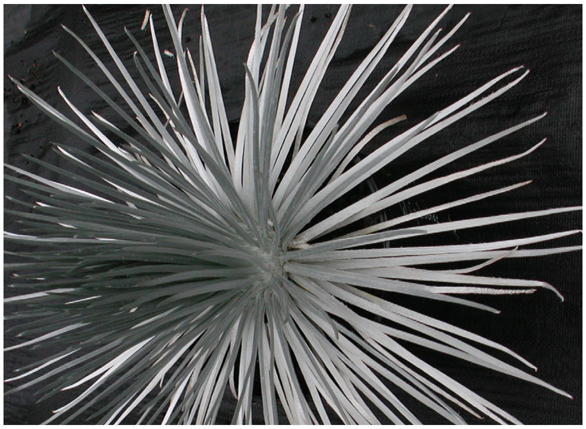

UHERO

THE ECONOMIC RESEARCH ORGANIZATION
AT THE UNIVERSITY OF HAWAIʻI

ENERGY POLICY & PLANNING GROUP

Efficient Design of Net Metering Agreements in Hawaii and Beyond

AUGUST 5, 2015

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Introduction

In Hawaii, like most U.S. states, households installing rooftop solar photovoltaic (PV) systems receive special pricing under net-metering agreements. These agreements allow households with rooftop solar to buy and sell electricity at the retail rate, effectively using the larger grid to store surplus generation from their panels during sunny times and return it when the sun isn't shining. If a household generates more electricity than it consumes over the course of a month, it obtains a credit that rolls over for use in future months. Net generation supplied to the grid in excess of that consumed over the course of a full year is forfeited to the utility. Net metering agreements often include a monthly fee to support billing, transmission and operation of the grid. On Oahu, the customer charge is $9, and additional monthly fees can bring the minimum bill up to about $17. Households who have installed enough rooftop solar such that they are "net zero" currently pay at most $200/year for grid connection and load-shifting services.

A growing concern is that the utility has many costs besides the fuel used in electricity generation, and most of these "fixed costs" are lumped in with per-kilowatt hour (kWh) charges. As a result, under current net metering agreements, when a solar customer provides their own power, they don't pay the fixed-cost component for each kWh they produce. Under a revenue-decoupling rule, those costs are shifted to households and businesses without rooftop solar. As

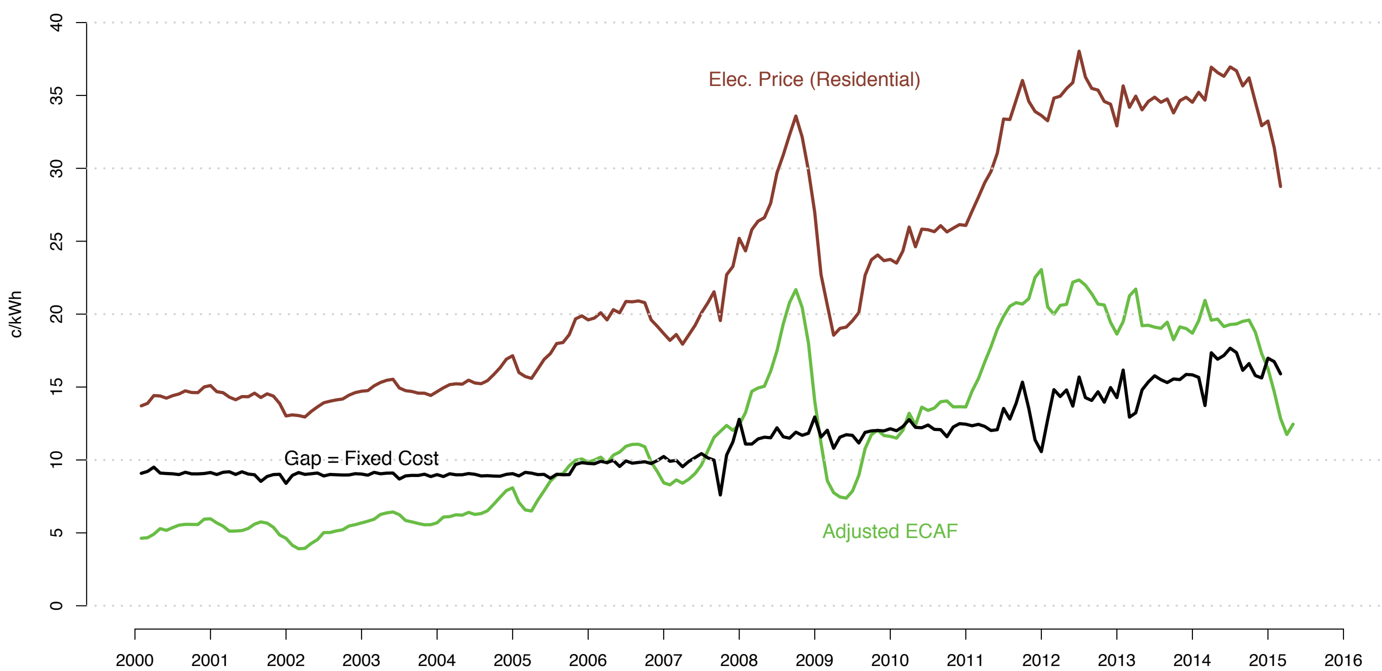


Figure 1. Oahu's Residential Electricity Prices and Growing Fixed Costs. The graph shows the average residential electricity price from 2000 to the present, and breaks out the generation component from the total (Adjusted ECAF). The difference between price and the Adjusted ECAF (Gap) accounts for all non-fuel or fixed costs.

less power is sold in Hawaii, fixed costs per kWh are rising fast (Figure 1). Most of the decrease in power sales is due to gains in efficiency, but some of it is due to installations of solar PV. Residential customers now pay roughly $0.17/kWh for fixed costs. For a household consuming 15 kWh per day—which is about average—that amounts to $76.50 per month. After the drop in oil prices earlier this year, well over half the utility's revenue from residential customers goes toward fixed costs.

A longer-term concern, particularly in Hawaii with its high electricity rates, is that an inefficient pricing system could encourage many households and businesses to install stand-alone systems, unplug from the grid, and further raise costs for everyone else.

So what would a better net metering agreement look like? There is no single answer to this question, but there are some basic economic concepts that ought to guide policy. A perfectly efficient scheme--one that minimizes waste--would set real-time per-kWh prices equal to the "marginal" generation cost, and allow anyone to buy or sell as much power as they want at this price. Marginal cost is the incremental cost of power production—the cost of generating one more kWh. This cost can vary a lot depending on total demand and the amount of renewable power, among other things, so ideal prices would vary over the course of each day, week, season and year. This variation is likely to become especially pronounced as the variable supply from renewable sources becomes more prominent. Fixed costs could be handled a few ways, but would not necessarily be included in the per-kWh price today. Implementing true marginal-cost pricing would solve problems with net metering agreements and make achieving the State's renewable energy goals much less costly overall. It would also entail a number of challenges.

Here we sketch out a set of long-term solutions based on marginal-cost pricing as the primary platform. We also offer some near-term suggestions for interim policy. But first, we briefly review some of the benefits and challenges of distributed solar, and explain why net metering agreements were originally set up as they were.

Benefits of Rooftop Solar

There are good reasons to subsidize renewable energy. Renewable energy is an accepted way to reduce emissions of greenhouse gases and other pollutants, particularly in the absence of more direct tools like a carbon tax.[1] Another argument has to do with infant industries, which sometimes merit

[1] Economists have long advocated pollution taxes. See, for example, Paul Krugman's excellent essay, "Building A Green Economy." (LINK: http://www.nytimes.com/2010/04/11/magazine/11Economy-t.html)

government support so they can achieve a scale sufficient to bring costs down to a point where the industry is viable on its own. The idea is to jump start a fledgling industry that is critical to achieving renewable energy goals. On a national and international scale, subsidy-driven growth of solar has likely facilitated economies of scale, technological change, and remarkable declines in costs. In Hawaii, residents receive a state income tax credit of up to 35 percent of solar installation costs, which supplements a 30 percent federal income tax credit. Net metering agreements implicitly provide another subsidy, by shifting fixed costs onto other customers as described above.

Another benefit from early solar installations is that they act to reduce production from the least efficient generators, particularly during hot summer months (Figure 2). The utility's power generation is now markedly lower than it was just a few years ago. While most of the decline is due to conservation and efficiency improvements, a some of it is due to distributed solar, as daytime net demand has declined much more than evening and nighttime demand (Figure 3). In summer months, solar has reduced the most expensive peaks faced by the power system. A report by GE Consulting from April 2013 estimates that increasing solar from 1.2 percent of total production on Oahu to 7.5 percent

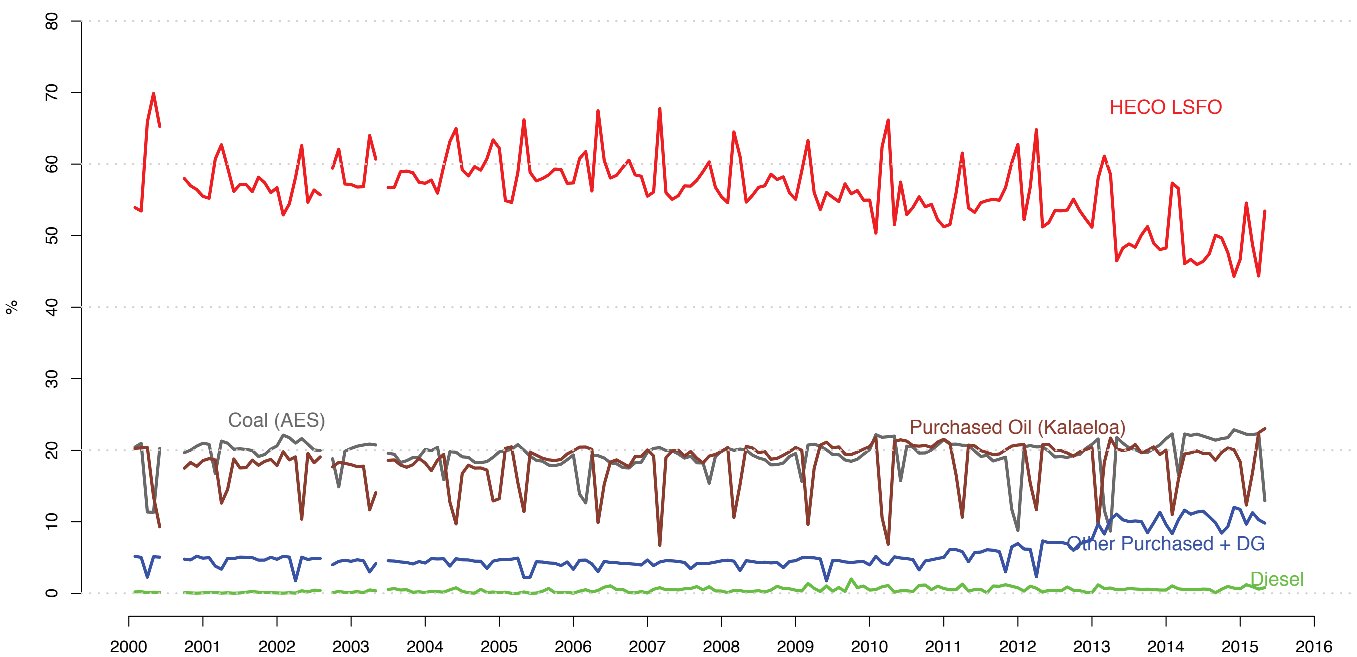
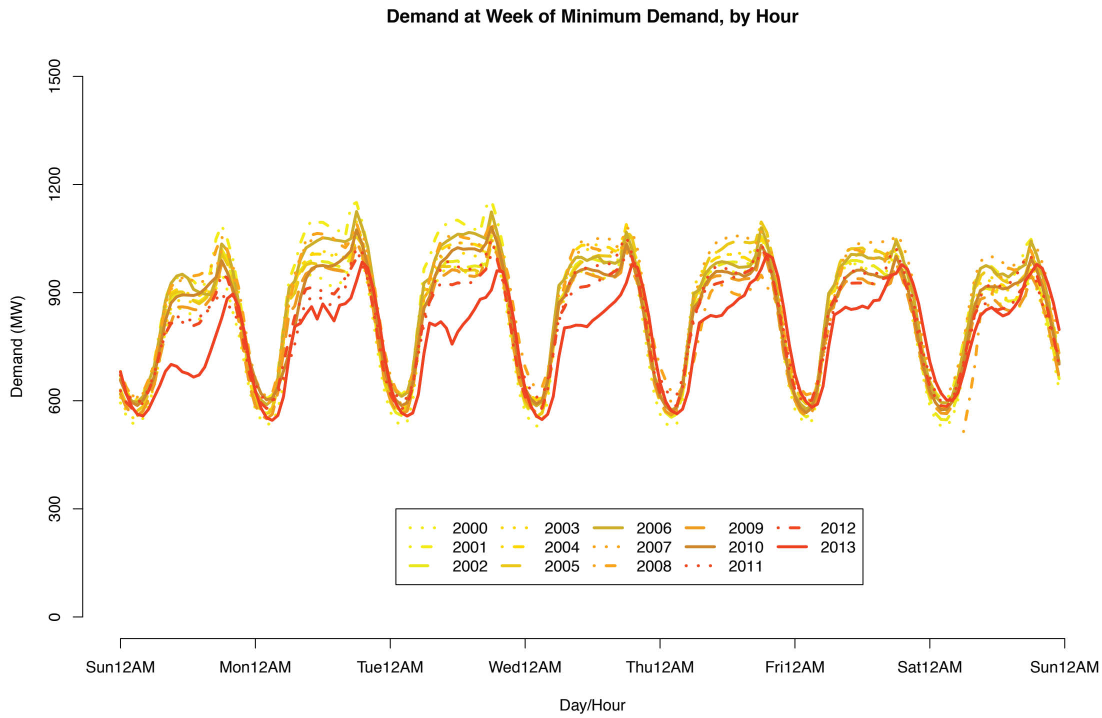


Figure 2. Shares of Net Generation from Key Sources. The graph shows the shares of net generation on Oahu from principal sources. Electricity purchased by from AES and Kalaeloa is less expensive than that from HECO's older power plants burning low sulfur fuel oil (LSFO). The recent decline in HECO's generation, coming in part from reduced demand from homes and businesses that have installed photovoltaic solar systems, should have reduced costs. Note that distributed generation in this graph (DG) only includes generation under feed-in tariff agreements.



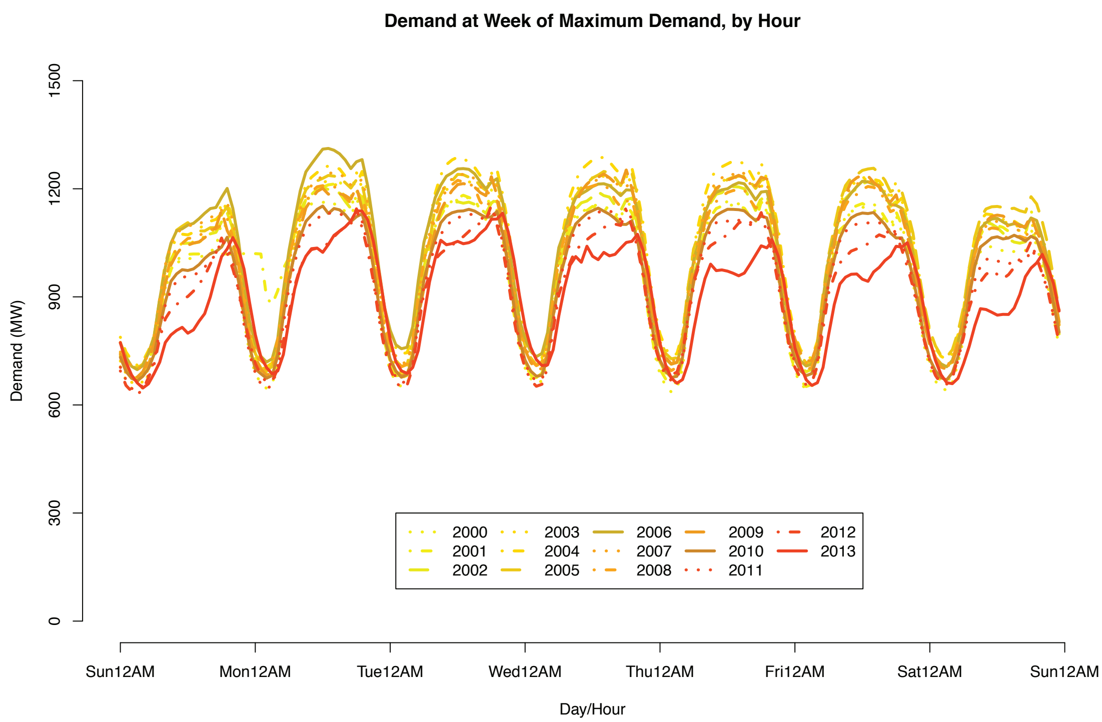


Figure 3. Oahu Electricity Demand During High and Low Demand Weeks. The top graph shows system demand during the *lowest-load* week (typically in March) in each year from 2004 to 2013, and the bottom graph shows system demand in each hour during the *highest-load* week. Over time, loads have declined, partly due to gains in efficiency and partly due to solar penetration. A few years ago, peak daytime loads occurred midday during summer weekdays, but that is no longer the case, since distributed solar has reduced net load during midday. The data are publicly available the Federal Energy Regulatory Commission (http://www.ferc.gov/docs-filing/forms/form-714/data.asp).

(nearly what it is today) reduces the utility's generation costs by 9.2%.[2] These numbers suggest that solar power has been displacing generation that costs 46% more than average.

Rooftop solar generation has two other benefits over utility-scale solar PV installations. Distributed rooftop generation does not need to be transmitted as far to homes and businesses that use it, so there is less line loss as compared to central-station generation. Also, passing clouds cause less variability in the overall system as compared to large, utility-scale installations, simply because they are geographically distributed and cloud cover doesn't change everywhere at the same moment. The tradeoff is that large-scale utility installations are usually less expensive to build, although Hawaii might be an exception. Due to land costs, regulatory costs, scale and perhaps limited competition, bids for utility-scale solar in Hawaii have been expensive, and could be higher than the cost of rooftop solar, especially once federal and state incentives are taken into account. Thus, to achieve the State's renewable energy goals in an efficient manner, Hawaii may want to make better use of existing rooftop space, something that current net metering agreements inhibit (a point we'll come back to).

[2] An executive summary of the GE Consulting report can be found here: http://www.nrel.gov/docs/fy13osti/57215.pdf

Challenges with Solar

Net-metering agreements were initially conceived as a simple way to encourage early technology adoption, and may well have been justified for all the above reasons. But as solar installations continue to increase, much of the logic supporting net metering vanishes.

One key challenge with solar PV is that its supply is variable and unpredictable. Variability isn't much of a problem when solar makes up a relatively small share of demand, as existing power plants can easily cycle generation up or down to accommodate changing supply from solar. After all, cycling is what power plants have always done, since demand itself tends to vary unpredictably. But when renewables make up an increasing share of the load, it becomes increasingly difficult to balance renewable supply by cycling traditional power plants. Today, these challenges are most acute on Maui, where supply from its plentiful wind turbines often exceeds what the system can accept, so the power must be curtailed, a euphemism for throwing away energy.

It is worth taking a moment to ponder the breathtaking waste of curtailment. While Maui residents often pay over 40 cents per kilowatt-hour for electricity—about four times the national average—electricity is simultaneously being discarded as if it were worthless. Surely some families and businesses might have found productive uses for the discarded electricity if it were being given away. And, in principle, it would be costless to let them use it.

Curtailment happens when existing power plants are cycled down to their minimum operating load, and that minimum load, plus the renewable energy, exceeds the amount demanded. Thus, renewables can be curtailed even when they comprise far less that the total energy demanded. Part of the problem is that Hawaii's power plants are old, cycle slowly, and cannot be quickly shut down and restarted. As a result, the utility keeps many power plants running simultaneously, in order to reduce stress on the plants, speed up cycling time and ensure a "spinning reserve" that can ramp up in case renewable supply falls off or demand spikes. When many power plants run, they generate a substantial amount of electricity, even when backed down to their minimum stable operating level.

Solar capacity on Oahu and the other islands is not yet at a level where curtailment (or worse) could be an issue. But given the growth of solar and the age of the infrastructure, the island could be there fairly soon. The GE Consulting solar study referenced above estimated there would be some solar curtailment when solar reached 15 percent of Oahu's total demand. A potentially critical problem is that distributed solar cannot be curtailed like the utility-scale installations considered in the study. Instead, if overproduction were to occur, the excess power would drive the system's operating frequency above the allowed range; this would be highly disruptive and could even lead to a system-wide blackout. Note, however, that the study assumed no storage, investment in new fast-cycling generators, or demand response to variable pricing—key points we will come back to.

Besides challenges with balancing overall supply and demand, the utility has long expressed concern about backfeeding of solar energy from residential circuits into the larger grid. These concerns have proved largely unfounded, in part because improved inverters greatly diminished the largest risks from backfeeding. As a result, the Public Utility Commission has pushed the utility to approve a large backlog of net metering agreements that were held up due to these concerns, and solar installations are accelerating again.

Problems with Current Net-Metering Agreements

Now that the solar market is fairly well established and costs have declined, subsidies probably don't need to be as large as they have been. In addition, since the benefits from reducing peak loads have been largely exploited, there is less justification for paying a premium price for solar power. In the current environment, we see at least three big problems with current net metering agreements:

One. The subsidy for non-generation costs to solar PV customers, implicit in net metering agreements, is unnecessary, imprecise, regressive and divisive. The subsidy is unnecessary because installing solar is economical in Hawaii even without it, because electricity prices are high, solar costs have declined, and federal and state tax credits remain substantial—though solar might be economical even without tax credits. Worse, those installing solar PV tend to live in large detached homes and have relatively high incomes, while their implicit net-metering subsidy is paid in part by relatively lower-income households who live in apartments and condominiums and cannot install solar.

Two. Net-metering agreements limit the amount of electricity that households can sell back to the grid. This actually gives rise to two separate issues. First, it can discourage homes and businesses from conserving energy or investing in energy efficiency. Second, if distributed solar turns out to be less expensive than utility-scale installations, the policy limits use of valuable rooftop space that could be used for solar power generation. We could end up paying more than necessary and obtaining less renewable power.

The first issue arises because households have a strong incentive to install solar generation capacity that exceeds the amount they consumed when paying retail prices. This follows in large part from the remarkably low cost of subsidized solar. Facing a lower cost of electricity, households may be less inclined to replace incandescent light bulbs with compact fluorescent lamps or LEDs, replace old appliances with new Energy Star units, limit use of air conditioning and so on. And to the extent that households are uncertain about future demand, it costs less to over-install solar than to pay the retail price for electricity if they don't have enough, so it's better to install too much than to install too little. Under the current net metering agreement, once a household or business installs greater capacity than they use, they effectively face a zero price for electricity up to that capacity, which further discourages conservation. This may not be a problem during the day, when solar power is abundant, but under net metering customers may also increase hard-to-serve evening loads at no cost.

We already see a hint of backsliding on energy efficiency. In Figure 3, note how nighttime loads increased markedly in 2013 relative to earlier years. That may be an indication that homes and businesses with solar PV are using more electricity.

The second issue arises if residential solar turns out to be less expensive than utility-scale solar. At present, this appears to be a real possibility in Hawaii, if not the rest of the country. Offers for utility-scale solar and wind installations, at around 15 cents per kilowatt hour, are between two and three times mainland offers with comparable subsidies. Residential solar installations appear to be much more competitive with mainland costs. Although data are not available for systematic comparisons, installed costs for residential solar in Hawaii are currently around $4 per Watt of installed capacity, which pencils out to about 16 cents per kWh at conventional interest rates (4.5-5%), while the national average is about $3.48 per Watt.[3] With federal subsidies but no state subsidies, this corresponds to a price of 12-13 cents per kWh, which is notably less than contracts offered for utility-scale solar or wind in Hawaii.[4] Add state subsidies to the mix, and the price falls as low as 7 cents per kWh.[5]

Three. In time, as both utility-scale and residential solar installations grow, midday electricity is likely to become less valuable than evening or nighttime electricity, so it makes little sense to apply the same rate for electricity sent to the grid as drawn from it.

Even today, the marginal cost—the cost of generating just a little more electricity—can vary considerably depending on total demand and the mix of generation currently being used. This variability in cost is likely to become much more extreme as renewable energy grows. When rates differ from marginal cost, perverse inefficiencies occur, like we have in Maui with curtailment. Curtailment implies zero or perhaps even negative marginal cost at a time when retail prices are among the highest in the world. If the price for electricity equaled marginal cost, homes and businesses would use more electricity or store it, and curtailment might be avoided. If prices always equal marginal cost, we achieve the economic paragon of efficiency: the amount people and businesses are willing to pay for electricity at each moment just equals its cost, and no mutually advantageous transaction is left uncompleted.

Of course, to achieve efficiency would require rates that vary, not necessarily for buying versus selling, but by the overall balance of supply and demand for electricity in each moment.

Even under the most ideal circumstances, if solar electricity must be stored or curtailed, we would expect to see a 10 to 15 cent per kWh difference in the marginal value of electricity between peak sun and early evening peak demand.[6] At best, by crediting solar PV households at the same rate regardless of

[3] See Greentechmedia for data on costs: http://www.greentechmedia.com/articles/read/solar-pv-system-prices-continue-to-fall-during-a-record-breaking-2014.

[4] Federal subsidies for utility-scale installations include the 30 percent tax credit that residential installations receive, plus an accelerated depreciation allowance that is probably worth another 10-12%.

[5] These estimates were made using the solar calculator at http://www.uhero.hawaii.edu/news/view/274 with the following assumptions: (a) a system size of 4kW that is always less than or equal to electricity use; (b) an installed cost per Watt of $3.83; (c) an interest rate of 4.8%; (d) a decay rate of 2% on panel efficiency; (e) annual maintenance costs of $100; and (f) no monthly connection fee. Under these assumptions, a price was selected that makes the internal rate of return as close to the interest rate as possible.

[6] This is the smallest price gap that can be achieved by using conventional plants or batteries to serve nighttime loads. This limit reflects optimistic near-term costs for fuel or batteries; with higher costs the gap would be wider.

when they supply energy to the grid or draw from it, the subsidy implicit in net metering agreements could grow. Worse, the agreements provide no incentive for customers (with or without solar power) to shift electricity use to times when the most solar energy is available.

Feed-in Tariffs

As an alternative to net metering, households and businesses in Hawaii can enter into a feed-in tariff agreement that grants a guaranteed sale price on solar generation for a 20-year period. There is no cap on how much solar generation can be sold and rates are set based on system size. In Hawaii, most households would likely qualify under "Tier 1" rates, applicable for systems under 20kW, which are 21.8 cents/kWh if state investment tax credits are claimed and 27.4 cents/kWh otherwise.[7] The latter rate exceeds current residential rates[8] (about 26 cents/kWh, which have fallen from an average of 37 cents in 2014) and is roughly double our estimated cost for residential solar with only federal subsidies. For homes and businesses that have enough rooftop space to install more solar energy than they can reasonably use, these rates are an attractive alternative to net metering agreements, especially now that retail rates have declined. The capacity limit for feed-in tariffs (60 megawatts on Oahu, 80 megawatts statewide) was fully subscribed a while ago, but it has taken time for installations to occur.

Feed-in tariffs solve the second problem with net metering agreements. Indeed, if these generous fixed rates do not change and net-metering agreements become much less attractive, it's possible that far more businesses and homeowners would sign onto the the feed-in tariff, if given the opportunity. At the same time, current feed-in tariff rates still embody a substantial implicit subsidy to solar PV owners, one that may be unnecessary and would be passed on to other customers. And fixed-rate tariffs do nothing to account for the eventually diminishing value of solar energy provided to the grid. Worse, these subsidies and high costs for other customers would be locked in for twenty years.

A Future Without a Grid?

Some envision a future without transmission wires or utilities, one in which everyone installs solar or other on-site renewable generation and uses either batteries or small generators for storage and backup. We have seen comparisons to mobile phones and cellular technology, which have arguably made telephone lines obsolete in some developing countries.

Such concepts may seem remote or even fanciful

[7] "Hawaiian Electric: Feed-in Tariff Program," http://www.heco.com/fit/

[8] "Hawaiian Electric: Hawaiian Electric Rates," http://www.heco.com/heco/Residential/Electric-Rates/Hawaiian-Electric-Rates

in most parts of the world, but might be conceivable in Hawaii. Depending on assumptions, the levelized cost of installed residential solar generation might be as low as 16 cents per kWh, excluding tax credits, and as low as 7 cents with tax credits. If storage could be bought for around 19 cents per kWh, then off-grid residential solar looks competitive with current rates from the utility, even with low oil prices, but still requiring current federal and state subsidies. Tesla's new battery is in this price range. It isn't hard to imagine oil prices rising again and further technological change, which could make economic grid defection a reality even without tax credits or other solar subsidies.

But would this kind of grid defection really make economic sense on a broader scale? In the current regulatory environment, grid defection would simply mean that more fixed costs would be pushed onto non-solar customers. And it would render useless the presumably valuable transmission and distribution network connecting homes to each other and to the utility.

Part of the issue is that some of the fixed costs are sunk. Sunk costs include all existing transmission wires, power plants, substations and other equipment that, for all practical purposes, cannot be salvaged for other uses. These costs are typically recovered by the electric utility via electricity rates. However, if customers are charged for these costs, it could ultimately lead to grid defection that is uneconomical from a social perspective. This problem cannot be solved through a simple restructuring of rates. To ensure efficiency, customer charges for sunk costs would need to be eliminated. Given the age of our infrastructure, most of it is probably depreciated by now anyway. To the extent that the utility ought to be compensated for sunk costs (a political allocative decision), they might also be compensated from general tax revenues instead of through electricity charges.

More difficult questions arise from new infrastructure investments. What if the utility, the State or other party installs expensive cables between the islands, and these subsequently become obsolete due to continued declines in solar and battery storage costs? It would be prudent for the State to have a clear plan for such contingencies before such large investments take place. And given the risk, it would make sense to have investors bear some of the risk of obsolescence. The degree to which investors are willing to bear that risk might shed some light on how prudent the investment may be.

Similar arguments would apply to new investments in transformers, transmission lines and generation capacity. The standard regulatory model that guarantees returns that far exceed conventional interest rates only encourages excess investment by the utility. Part of this divergence may arise because guaranteed rates of return have fallen less than market interest rates have. In this time of great uncertainty about future technological opportunities, such investments need to be made with care, and it might make sense for the utility to bear some of the risk. On the other hand, if the State is guaranteeing returns, we see no sound reason to guarantee rates above conventional Treasury bill or low-risk municipal bonds, which are around 3 percent today.

The Long-Term Solution

Here we propose three simple ideas to achieve a more efficient and equitable electricity system that is particularly relevant for systems with a lot of variable renewable supply, like rooftop solar.

I. To improve efficiency, all households and businesses should have an option to buy or sell as much electricity as they like at a price equal to the marginal cost of electricity production.

II. Fixed cost of grid construction and maintenance (power plants, transmission cables, transformers, etc.) not covered by marginal-cost rates should be spread as widely as possible in order to limit grid defection and improve fairness.

III. Subsidies for solar power, to the extent that they are necessary to achieve renewable energy goals, should be paid via more transparent mechanisms.

These simple ideas are easier to write down than to implement. In particular, marginal-cost pricing could imply prices that vary a lot from day to day and hour to hour. As a practical matter, such pricing would require smart meters that could measure electricity use on a short time step, and smart meters are costly. There would also be practical challenges surrounding basic measurement and regulation of what constitutes true marginal cost, which may include not just incremental generation costs, but adjustments for critical peaks that push the limit of what the whole system can supply. The marginal cost of electricity can even vary by location in power systems with limited transmission capacity.

Interim Solutions with Customer Choice

In our view, it would be best to offer a tariff to all customer classes with hourly prices that reflect the continuous variation in supply and demand of electricity. This balance will evolve over the coming years as renewable energy grows. Some customers will be able to reduce their bill by curbing electricity use during times of high marginal cost (high loads with low renewable power production) and increasing it during times of low marginal cost (low loads and/or high renewable power production). These customers will choose the hourly pricing tariff, and in so doing they will reduce their own costs and the system's costs.

Many kinds of electricity loads are relatively easy to shift between hours of the day. Examples include water heating, water pumping, pre-cooling of commercial buildings, and electric vehicle charging. We expect this option to be attractive to many customers. Their private gains from shifting loads toward renewable supply would then significantly improve integration of renewable energy with the existing system.

Moreover, variable pricing would open a door to innovative ideas for storing electricity or otherwise shifting loads over time. Anyone with a good idea for shifting demand toward renewable supply could profit from it, and simultaneously improve the whole electrical system. In the future, we expect demand response to changing prices to be automated by a panoply of smart machines that a growing share of customers will use, because it will be economical to do so.

We also recommend that a flat-rate tariff be offered that is based on the average marginal cost for the overall power system. Customers selecting this tariff would pay a flat price per kWh that is adjusted monthly based on the average marginal cost. This tariff offers a less volatile option for customers who fear a "bill surprise" from hourly pricing. Although the calculation would differ somewhat from current billing, we expect the total bill would not look much different from current pricing for the average customer, although there may be some adjustment between residential and larger scale customers.

It would also be possible to offer a time-of-use (TOU) tariff, with flat rates each month that differ between peak, shoulder and off-peak hours. The rates for each slot would be the average marginal cost during these periods. This tariff would provide an intermediate option for customers willing and able to shift loads, but who prefer a more predictable size and timing of rate changes.

All three tariffs are based on the system's marginal cost of power production; they do not include other costs in the per-kWh rate. Customers with solar therefore do not avoid paying any costs when they produce renewable power. It is possible that marginal-cost pricing would recover enough revenues to cover both fixed costs as well as generation costs, but this is not necessarily the case. We address the tricky question of residual fixed costs (or profits) below.

Although a flat-rate marginal-cost tariff does not provide an incentive for customers to shift use from current peak-load times to high-renewable times, it serves as an important backstop for risk-averse customers. In order to protect this option, it may be necessary to move high-solar customers off of this tariff and onto one of the time-varying tariffs once daytime marginal costs become significantly lower than nighttime marginal costs. Otherwise, by producing power at low-value times and consuming it at high-value times, solar customers would raise rates for other customers on this tariff, effectively obtaining a cross-subsidy from them.

Residual Fixed Costs or Profit

In the long run, marginal-cost pricing could generate more or less revenue than total costs. Marginal cost is typically above each hour's average generation cost, since the utility draws from a mix of low-cost and high-cost generators, and marginal cost is based on the highest-cost generator currently operating. So revenue from marginal-cost pricing will exceed fuel and other variable costs, leaving a potentially large sum to cover grid management and capital costs. It is not clear whether this extra revenue will be greater or less than fixed costs.

Given the reductions in demand that we have seen in recent years, and the further reductions in peak demand that we would expect under marginal-cost pricing, it seems likely that revenue from marginal-cost pricing will fall somewhat short of total system costs. A large component of these costs are labor and other grid management costs, which tend to increase with wages, and are likely to increase further with more complex grid management. The practice of keeping most power plants running at all times also contributes to a possible revenue shortfall, since it raises fuel costs (the large amounts of fuel needed to run plants at minimum load), while artificially reducing marginal costs. At the same time, kilowatt hours sold are declining.

The best way to deal with these residual fixed costs is not completely clear. To keep the systems as efficient as possible, residual fixed costs probably should be recovered through some combination of fixed monthly fees or general tax revenues. Options include a flat charge on every customer's bill, demand charges based on peak use from the grid, a small adder or percentage markup on per-kWh rates, or possibly a one-time Legislature-funded markdown of sunk costs. When choosing among these options or combining them, it will be necessary to find the right balance between prompting inefficient grid defection (via high base charges or demand charges) or producing unintended cross-subsidies of PV customers (by including residual costs in the kWh rate).

To the extent that fixed costs are not sunk costs, but rather fundamental to management of the grid itself—like the utility's labor force—it makes sense to pass these costs on to customers in one form or another. If these costs, unlike sunk costs, cause grid defection, then it suggests grid defection is truly economical.

If the power company continues to use older generation and transmission assets for which capital costs have already been completely recovered, marginal-cost pricing could produce surplus revenue, reducing or eliminating residual fixed costs. Although it seems unlikely, in the case that marginal-cost pricing brings excess profits to the utility, the excess profits could be taxed to supplement the State's general resources or otherwise used to offset income or excise taxes.

Demand Response: The Least Cost Option

Besides traditional cycling of power plants, there are just two ways to deal with the variability challenges of renewable energy: store it or shift it. Batteries can store energy over hours or days. Or we could build dams and reservoirs that could store energy by pumping water uphill during surplus times and later use it to make hydroelectric power. These would require huge capital outlays and have significant social and environmental implications.

Alternatively, we can try to shift demand toward the sun and wind. Shifting demand to cope with variable renewable supply is highly attractive because it doesn't require major capital outlays. It only requires rate restructuring, a restructuring that would enhance efficiency and lower costs regardless of our renewable energy goals. Those who choose to have hourly marginal-cost pricing would require smart meters, but these costs are modest and they would be targeted at those most willing to shift loads. Those on time-of-use tariffs could get by with simpler meters.

Although it remains unclear how much demand could shift in response to variable marginal cost pricing, and whether large-scale storage will ultimately be prudent, it makes sense to start by taking advantage of the most flexible, least cost option.

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