Article 5: Grid Integration and Policy

A full accounting for any solar power project must consider not only the panel and the balance of the system at the project level (discussed in Article 3), but also the project's impact on the grid. Article 5 focuses on solar power's intermittency and only partial predictability, which are creating problems for grid management that threaten to restrict future growth of solar power. Article 5 also discusses the variety of technological and policy responses that the intermittency problem is eliciting, including the promotion of natural gas and electricity storage, the enhancement of electricity transmission in order to access a diversity of sources, and the preferential use of electricity at times of the day when electricity is available in excess.

A second focus of Article 5 is the policies that have enabled the rapid growth of solar energy, with a focus on the U.S. and, within the U.S., the State of New Jersey. New Jersey, relative to many other states, has been particularly determined to create incentives for solar power projects that provide electricity directly to users, not only to the grid. Worldwide, incentives are diminishing, and a major open question is the extent to which the growth of solar power capacity will be adversely affected. A question within that question concerns the reduced incentives specifically for small-scale and dispersed electricity production.

Article 5 concludes with a discussion of "grid parity," an awkward metric widely used by the solar industry to measure its progress against conventional energy sources. The problem with "grid parity" is that it ignores the costs of grid integration.

A. Grid Integration and Supply Variability

Electricity supply is managed today in large systems, called grids. The largest grids coordinate the provision of power to millions of customers. Grid operators working at a central location inform the operators of various power plants that output from their plant will be required, with various notice periods from less than a second to days. In this way, the grid's variable demand is accommodated. Demand variability arises from predictable behaviors (for instance, most people sleep at night, or electricity consumption rises as viewers separate themselves from their televisions at half-time during the Super Bowl) and unpredictable ones (a large motor in a factory shuts down). Variability and unpredictability are no strangers to the grid.

With solar power's arrival, however, an electric grid now needs to respond not only to predictable and unpredictable demand but also to predictable and unpredictable supply – with minimal help (at least today) from electricity storage. Solar power's intermittency over days and seasons is largely predictable. However, solar power can be unpredictably intermittent on the scale of minutes (as clouds block the Sun) and days (from bad weather). Balancing supply and demand in the presence of unpredictable intermittency is a challenge to grid management that grows in importance as solar power gains market share.

The general challenge here is "dispatchability." A dispatchable source of electricity provides power when power is required. Solar power on its own is not dispatchable. To be embedded in a dispatchable system, it must be augmented by some combination of other power sources, electricity storage, and demand management.

The Duck Curve

Figure 5.1 illustrates these issues. It shows a recently popularized curve, the Duck Curve, which highlights the complications for grid management that accompany a rising fraction of solar power on contemporary grids. The curve was developed by the California Independent System Operator (CAISO), the organization responsible for the performance of the electricity grid that provides electricity to nearly the entire state of California. Figure 5.1 shows two curves of real data: actual hourly "net load" for Saturday, March 31, 2012 (light blue) and Sunday, March 31, 2013 (dark blue). "Net load" is CAISO's total production of electricity minus its production of electricity from solar and wind energy at "utility facilities" that directly supply its grid.

A comparison of the two blue curves shows that the net load during the day shrank between 2012 and 2013. This is because the combined solar and wind contribution to total supply grew faster than the total load. As a result, there was less production of electricity during the day, in aggregate, from all of the other in-state sources (fossil fuels, nuclear power, hydropower, bioenergy, and geothermal energy) and the out-of-state plants whose electricity CAISO imported. In the evening, when the solar load was absent, the net load was substantially larger in 2013 than in 2012.

The 2012 and 2013 curves look nothing like a duck. But Figure 5.1 also shows modeled data for the same March day for several future years (at the time of the preparation of the figure). As was the case between 2012 and 2013, the production of solar and wind energy during the day increases year after year and results in an ever smaller mid day net load. Also, the future net load in the evening increases. By 2020, the net-load curve outlines the underside of a duck – with a belly that is closest to the ground not long after noon, a long neck stretching upward in the evening hours, and even a tail during the first hours after midnight.

This visual metaphor, it seems, has injected exactly the amount of levity to enable candid discussion of the challenges that are beginning to arise as intermittent resources achieve deeper penetration on the grid. There are two separate concerns in the figure, the first at midday and the second in the evening. At midday, the combined output of solar and wind energy could drive down the need for other power sources to such an extent that there is no longer any need for some current sources that would normally run continuously (baseload power plants). Reducing the power output of a baseload plant and then raising it again, if it can be done at all, is likely to degrade the plant's long-term performance. The grid operator wishing to sustain constant output from the baseload plants has an alternative, which is to require the grid's solar and wind facilities to "curtail," or "spill" some of the power they produce at midday. These renewable power sources will then sell less electricity to the grid and lose revenue. Either way, at some high level of penetration of intermittent renewable energy, system costs become formidable.

The second challenge occurs in the early evening and may become even more daunting and costly. From 4

The Duck Curve for California:
Electricity use on March 31st of various years

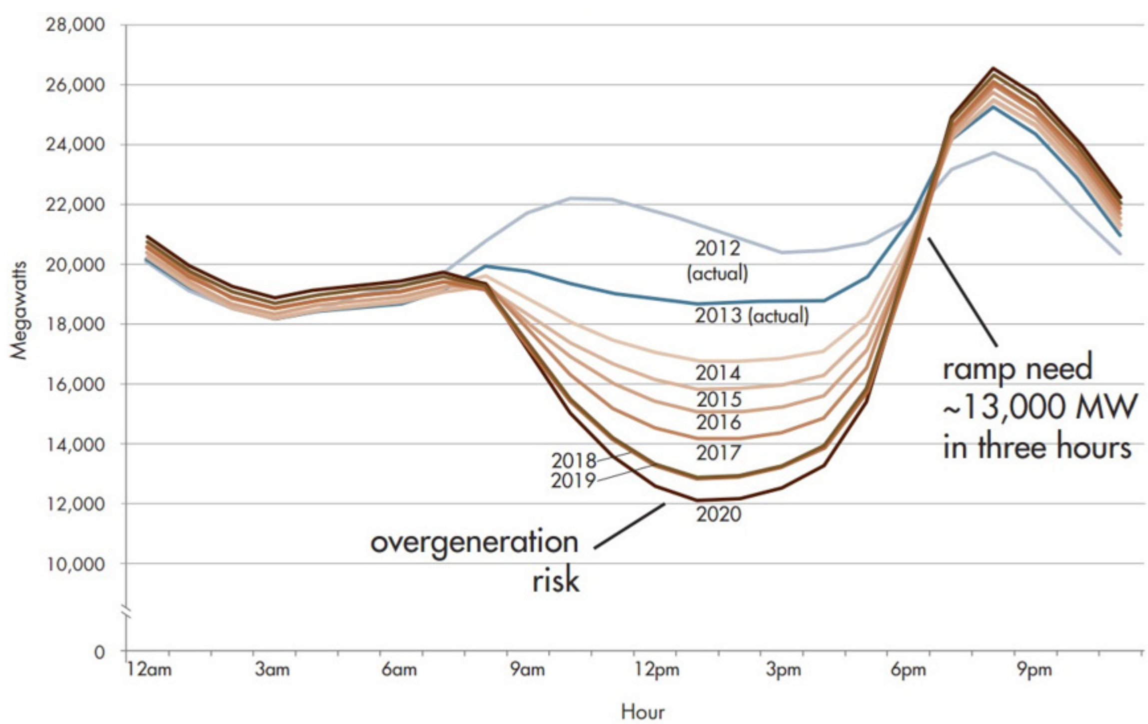

Figure 5.1: The original Duck Curve. The hourly net load (total electricity consumption minus electricity produced from utility wind and solar sources) on the CAISO grid for March 31 of successive years. Actual data for 2012 and 2013, modeled data for later years. Source: CAISO, the California Independent System Operator: https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf

p.m. to 7 p.m., as the Sun descends, solar power's contribution to the grid falls, while the demand for electricity rises (people are returning home and running appliances while stores remain open). The extra demand for power at 7 p.m. relative to 4 p.m. (most of the length of the duck's neck), as noted in Figure 5.1, is projected to reach 13,000 megawatts in 2020, as total net power approximately doubles. In the CAISO system, gas turbines have been playing the primary role, ramping up their power as needed; in the CAISO models this role continues to dominate through 2020.[18]

Figure 5.1 accounts only for solar projects where all of the solar electricity is sold directly to utilities. It does not include solar power from customer-owned projects (also called "behind-the-meter" projects and "non-utility" projects) where some of the solar electricity is not sold directly to the utilities, a category that includes solar electricity produced on residential and commercial rooftops. Figure 5.2 is an instructive augmentation of the CAISO Duck Curve that repairs this omission by including an estimate of "non-utility" solar electricity. The data shown are for August 7, 2016, when at midday about 500,000 distributed solar energy sources in California were contributing an estimated 4,000 megawatts of non-utility solar power – at the same time as utility solar projects were contributing about 8,000 megawatts.

The gray region of Figure 5.2 represents electricity provided to customers in California from all sources except wind and solar sources. The production shown comes from fossil energy sources (natural gas and coal) as well as from nuclear fuels and several renewable energy sources other than wind and solar energy ("small" hydropower, geothermal power, and electricity from biomass). Figure 5.2 also shows, as three separate regions, three other contributions to California's electricity production that day: electricity from utility wind turbines (blue), utility solar facilities (orange), and non-utility solar facilities (yellow). Note that wind power was strongest at night and weakest in

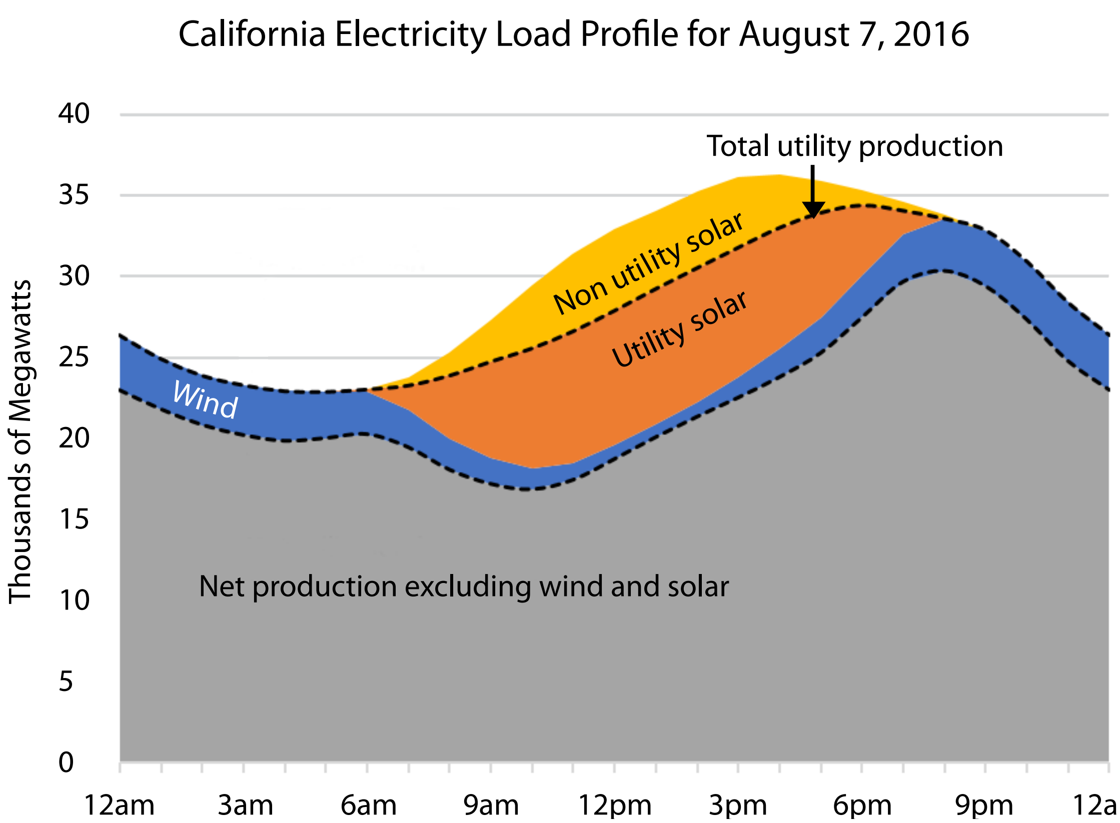

Figure 5.2: A Duck Curve for the same CAISO grid as Figure 5.1, but for August 7, 2016, and with the addition of solar electricity production from distributed sources. From bottom to top, the lowest (gray) region represents production from all utility sources aside from wind and solar. The next (blue) region is wind generation, and the region above it (orange) is utility solar generation. The top-most (yellow) region is an estimate for customer-owned ("non-utility") solar power that is produced "behind the meter." Unlike Figure 5.1, the vertical scale is a continuous linear scale from zero, without a gap. Adapted from: Paulos, Bentham, 2016 "California has more solar power than you think – a lot more." Greentech Media, http://www.greentechmedia.com/articles/read/ california-has-more-solar-than-you-think.

[18]For a sketch of a duck superimposed on the data, see http://insideenergy.org/2016/10/25/learning-how-to-adapt-to-more-renewables-as-duck-curve-deepens/. For an updated discussion from CAISO, November 3, 2016, see https://www.greentechmedia.com/articles/read/the-california-duck-curve-is-real-and-bigger-than-expected.

the middle of the day, when the Sun was strongest; this beneficial anti-correlation is observed in many locales at many times, but of course not everywhere nor all the time. As for "utility solar" power, about one tenth of the electricity in this category was electricity from solar thermal power plants rather than solar photovoltaic power plants. "Non-utility solar" can only be estimated roughly, because much of this production is used at the site of the producer without ever being sent to the grid. During that particular day, distributed solar electricity production (yellow region) was about half as large as centralized solar electricity production (orange region). Wind electricity was roughly half as large as centralized plus distributed solar electricity.

Many states have a renewable electricity target that is a percent of total electricity. Various choices for this fraction can be formulated. The data behind Figure 5.2 reveal that between them, wind and utility electricity accounted for 20 percent of the day's electricity load recorded by utilities; including non-utility solar, total electricity production from solar of both categories and wind accounted for 25 percent of total electricity production from all sources. Including, as well, the other electricity production that day that in California counts as "renewable" (from small hydropower, geothermal, and biomass sources), utility production of renewable energy from all sources was 27 percent of total utility production, and total renewable energy production including distributed solar electricity was 31 percent of total electricity production from utility and non-utility sources. Other renewables percentages could take into account renewable energy embedded in imported electricity.

The lower black dashed line in Figure 5.2 corresponds to the Duck Curve lines in Figure 5.1. Looking ahead, California can expect growth in both utility and non-utility solar power. Both will affect the grid in the same way, further suppressing daytime net load and further steepening the evening ramp. It is clear from Figure 5.2 (whose vertical scale, unlike Figure 5.1, has no "suppressed zero") that another doubling of solar capacity, keeping the total load fixed, would cut deeply into the gray baseload region, significantly increasing solar power's disruption of the grid as a whole.

Fattening and Flattening the Duck

A recent report from the U.S. National Renewable Energy Laboratory distinguishes two approaches: reduce the cost of a fat duck, and flatten the duck so that it is less fat.[19] The cost is reduced if the grid can be made more flexible, notably, by reducing the importance of sources of electricity that are hard to scale back; "must-dispatch" nuclear power plants and coal power plants are relatively inflexible, while hydropower and gas-turbine power are relatively flexible.

The duck can be flattened both by eliminating some of the sources of peak load and by shifting the load away from the peak. Some portion of peak load can be eliminated in buildings. One way is to improve the efficiencies of the electric appliances that contribute significantly to electricity demand (air conditioners, refrigerators, water heaters, lights, and electronic equipment). Another way is to build buildings with better insulated roof, walls, windows, and with façades that allow sunlight to enter the interior in winter but not in summer.

As for shifting the load, there are many alternatives that involve energy storage. Power can be used at midday to pump water uphill from a lower to a higher reservoir, and the flow can be reversed in the evening, retrieving nearly as much power as was used earlier – this strategy is called "pumped storage hydroelectric," or either "pumped hydro" or "pumped storage," for short. Storage in buildings can be in heated water, thermally charged at mid-day and discharged several hours later. Air conditioners, water heaters, and refrigerators can be made to run mostly at hours of peak electricity supply, and the batteries in electric vehicles can be charged preferentially then too. Distributed electricity storage (batteries in homes and larger buildings) and smart communication can help too.

Still another strategy is to orient solar panels southwest instead of south. This shifts the peak output of solar panels from noon to the afternoon, toward the peak in demand. There is currently a subsidy in California for new solar homes that have their panels on a roof oriented within 11 degrees of due west.

Load shifting can be incentivized by pricing. A common price incentive is the "time-of-use" rate, where electricity is valued at a higher price when demand is highest, such as on a summer afternoon. California is already offering time-of-use rates for customers installing distributed solar power, and the time-of-use rate will be the default rate for all customers in 2019.

A further strategy to reduce the stress on the grid from solar power is to extend the grid geographically to integrate loads and supplies that have complementary time profiles. For example, planning for greater integration of power sources in the western U.S. is underway, driven in this case especially by the desire

[19]Denholm, Paul, Matthew O'Connell, Gregory Brinkman, and Jennie Jorgenson, 2015. "Overgeneration from Solar Energy in California: A Field Guide to the Duck Chart," National Renewable Energy Laboratory Technical Report, NREL/TP-6A20-65023, November 2015.

to allow greater access to windpower produced beyond CAISO's territory.

A duck curve emerged from CAISO data in Figure 5.1 only because of several choices. First, on the vertical axis, the value "10,000 megawatts" was located close to the horizontal axis, truncating the vertical space; otherwise, the duck would not stand on the ground. Second, a March weekend date was chosen, when total demand is particularly low (there is minimal heating and cooling). In summer, demand is much higher. Third, in California, windpower has a smooth profile (Figure 5.2); in Texas and the Mid-West today, wind variability looks entirely different. Nonetheless the Duck Curve quickly became iconic. Alluding to the curve is a convenient shortcut for identifying the challenges of integrating intermittent renewable energy into a grid – and the solutions.

B. Enabling Policy

Government incentives have allowed solar electricity to grow rapidly, and costs to fall. A generic justification for incentives to new industries is that they accelerate the arrival of a desirable commercial product, especially when the alternative of raising the taxes on its competitors is politically infeasible. Solar power's desirability arises from its much lower emissions of traditional air pollutants and greenhouse gases, relative to fossil-fuel power sources. Traditional fossil-fuel-derived air pollutants (including soot, sulfur and nitrogen oxides, and mercury) adversely affect public health and agriculture. Greenhouse gases cause climate change. Pollution-control investments at fossil fuel power plants are gradually lowering these emissions, but usually not to the levels that solar power achieves, even when the full life cycle is taken into account.

It is useful to distinguish two kinds of solar incentives. One class of incentives lowers the cost of a solar project, independent of how large it is; in the U.S. these are largely incentives provided by the federal government through tax deductions. The other class specifically encourages distributed generation of solar power, and in the U.S. these are largely state-level policies.

We discuss two examples of the first and two examples of the second. The federal incentives are the Investment Tax Credit and accelerated depreciation. The state incentives are established through the Renewable Portfolio Standard (and the solar carve-out from that standard) and "net metering." We also mention the feed-in tariff, a stimulant of distributed generation widely used in Europe.

These five policies are not the only significant ways by which governments foster solar energy. Others include the funding of research and development and targeted aid to manufacturing companies. A carbon tax or a cap-and-trade regime for carbon dioxide emissions also improves the competitiveness of solar power, relative to many alternative sources.

Investment Tax Credit

The principal subsidy from the federal government that affects the cost of a U.S. solar project is the Investment Tax Credit. It applies to solar power projects at all scales. The recipient of an Investment Tax Credit may subtract the value of the credit from the tax that he or she (or it, in the case of a corporation) owes. Currently, the Investment Tax Credit equals 30 percent of the capital cost of a solar power project. In effect, the Investment Tax Credit allows the government to share in the cost of construction.

The size of an investment tax credit does not depend on how much power the system owner produces, only on the amount spent to bring the unit online. As a result, this kind of credit rewards investment-intensive projects. In the case of solar power, a residential project is usually more investment-intensive than a mid-scale and utility project, measured in dollars invested per kilowatt of capacity. As a result, the Investment Tax Credit may treat residential projects preferentially.[20]

In December 2015, the U.S. government renewed the Investment Tax Credit with a schedule of stepwise reductions. Projects where construction begins on or before 2019 are eligible for a 30 percent credit, those beginning in 2020 are eligible for a 26 percent credit, and those beginning in 2021 through 2023 are eligible for a 22 percent credit. After 2023, the tax credit is permanently zero for residential projects and 10 percent for mid-scale and utility projects.

Accelerated Depreciation

A fixed asset like a solar panel loses value over time, mostly due to wear and tear. The tax code in the U.S. allows businesses to recover this depreciation in the value of a fixed asset as a tax deduction spread over a specific number of years. An individual is not allowed to take the depreciation deduction for items of personal use, but a company that leases an individual's roof and puts a solar collector there can claim the deduction. According to the tax code, the solar panel is considered a "five-year asset" subject to "accelerated depreciation," and the initial cost basis for depreciation deductions is 85 percent of the original cost. The "five-year" classification is supportive of solar power. If the useful life of a solar panel for depreciation purposes were more reflective of its expected useful life – 20 to 30 years – the recovery of its initial cost basis would occur much more slowly. Also, the specific rules for accelerated depreciation allow more than half of the total depreciation to be deductible in the first and second year. The depreciation deduction is typically

[20]The Future of Solar Energy: An Interdisciplinary MIT Study, http://energy.mit.edu/research/future-solar-energy.

roughly as large as the Investment Tax Credit, where it can be claimed.[21]

The Renewable Portfolio Standard

Twenty-nine states have adopted a Renewable Portfolio Standard (RPS), which typically requires each of the state's retail suppliers of electricity either 1) to produce some minimum fraction of its electricity from prescribed renewable energy sources, or 2) to buy from others what it cannot produce itself, or 3) to pay an Alternative Compliance Payment. The list of allowed renewable sources varies from state to state but typically includes solar power, wind power, landfill gas, and small hydropower facilities.

The minimum-fraction requirement creates a market where, either under bilateral agreements or at an auction, each retail supplier meets a portion of its requirement by buying renewable electricity from other market participants, including (via brokers and aggregators) producers of distributed solar electricity. The currency in the RPS market is the Renewable Energy Certificate (REC), which is nominally equivalent to the environmental attributes of one megawatt-hour of renewable electricity. The Alternative Compliance Payment puts a cap on the REC price, because, when the supply of RECs is small relative to the required purchases, the retail electricity supplier will pay the Alternative Compliance Payment rather than pay for RECs at a higher price.

The Solar Carve-Out

Six U.S. states and the District of Columbia go beyond the RPS to incentivize solar power more directly. They have created a solar "carve-out," which requires each retail provider in the state to produce a minimum fraction of its total electricity from solar power sources. A separate market for solar power emerges, whose currency is the Solar Renewable Energy Certificate (SREC), equivalent to one megawatt-hour of solar electricity, and whose market price cap is the Solar Alternative Compliance Payment. In New Jersey (one of the six states) the authorized producers of SRECs must be connected to the distribution system serving New Jersey, whereas the authorized producers of RECs face weaker restrictions: they are required only to be connected to the much larger north-east U.S. grid ("PJM"), of which New Jersey is a part. The SREC market, therefore, directly stimulates New Jersey's in-state solar electricity production.[22]

In states with a solar carve-out, the markets for RECs and SRECs are distinct. In New Jersey, for example, the SREC market has been dwarfing the REC market, measured by the value of the certificates bought by the retail producers to meet their requirements. In 2016 the total value of the SREC market in New Jersey was 460 million dollars, and the total value of the REC market (excluding the SREC market) was 120 million dollars. The SREC price (preliminary data)[23] was 15 times higher than the REC price ($225 versus $15 per megawatt-hour).[24]

Future RECs and SREC prices are unpredictable, even when required percentages and compliance payments are announced far in advance.[25] From the perspective of a potential investor in a distributed solar energy project, the future SRECs price is one of the major uncertainties, alongside other uncertainties such as future project costs and government incentives.

[21]The initial cost basis that can be depreciated is the full value of the project, minus half of the Investment Tax Credit, thus 85 percent of the original cost. For a business with an assumed 35 percent marginal tax rate, therefore, the value of the deduction is 29.75 percent (35 percent of 85 percent) of the project value, almost exactly the same as the deduction for the Investment Tax Credit, 30 percent of the project value. As a result of the two deductions, about 60 percent of the cost of the system is recoverable through tax benefits. Governed by the Modified Accelerated Cost Recovery System (MACRS), the five-year assumed useful life leads to a six-year schedule of deductions; as percentages of the initial cost basis, they are 20, 32, 19.2, 11.52, 11.52, and 5.76, for years one through six (adding up to 100 percent of the cost basis).

[22]New Jersey's SREC market, which became operational in 2004, has had a complex interaction with its in-state solar industry. In 2010, New Jersey stimulated its in-state solar electricity industry by establishing a high value for the Solar Alternative Compliance Payment (above $600 per megawatt-hour) when the SREC supply was small, resulting in a spot-market price for SRECs at roughly the price of the compliance payment. The very high SREC price generated an abundance of new solar power projects and a plummeting SREC price. To prop up the price, in 2012 New Jersey more than doubled the effective percentage targets, starting in 2014, to above two percent, and the market stabilized.

[23]http://www.njcleanenergy.com/files/file/rps/EY%202015%20RPS%20Summary%20Result%20Tables%20Final%20082416.pdf

[24]In 2016, for New Jersey's RECs and SRECs markets, respectively, the required percentages of total electricity production for each retail supplier were 14.9 percent and 2.75 percent, and the compliance payments were $50 and $323 per megawatt-hour.

[25]New Jersey has announced a schedule for the solar carve-out and the Solar Alternative Compliance Payment through 2028. The solar carve-out in 2028 is set at 4.1 percent and the Solar Alternative Compliance Payment at $239 per megawatt-hour. See https://www.pjm-eis.com/program-information/new-jersey.aspx.

A Numerical Example: Subsidies Shorten the Payback Time

A homeowner who is eligible for the federal Investment Tax Credit and the Solar Renewable Energy Certificate finds a solar project on her roof to be much more attractive financially than a homeowner who can access neither of these incentives. In Article 2 we worked out the payback period (the number of years required for a homeowner to recoup an initial investment through a stream of savings) for a solar panel that costs $1,200 and produces 500 kilowatt-hours of electricity per year, with no incentives. We assumed the homeowner would otherwise have purchased that electricity at 15 cents per kilowatt-hour (a representative cost for retail electricity), so that she saved $75 per year. The payback period is then 16 years.

But if the homeowner actually pays only 70 percent of the cost, or $840, thanks to the Investment Tax Credit, the payback period drops to 11 years. And if the homeowner, because she lives in New Jersey, also receives Solar Renewable Energy Certificates for the 500 kilowatt-hours her solar collector produces each year, and the going rate for these certificates is (conservatively) also 15 cents per kilowatt-hour, so she receives a payment of $75 per year, as well. Each year she saves $75 by not buying 500 kilowatt-hours of electricity, and she earns a second $75 for producing that electricity with solar energy, so each year she saves $150. The new payback for the panel, with both incentives in place, is 5.6 years ($840 of one-time capital outlay, divided by $150 per year of benefit). The payback in this example is now three times shorter.

Similar calculations apply to mid-scale projects, like Princeton University's. In New Jersey, early in the SREC program, projects were eligible for SRECs only if their capacity did not exceed two megawatts. Then the cap was eliminated, and the Princeton University 5.4 megawatt project became more attractive financially. As seen in Figure 3.10, many qualifying projects larger than two megawatts have now been built in New Jersey.

Net Metering

"Net metering" is another important policy that many states have implemented to encourage residential and mid-scale solar projects, much as Solar Renewable Energy Certificates do. Net metering, in its simplest form, requires an electric utility to accept all of the electricity sent to the grid by every customer who is an approved owner of solar power systems and to value that electricity at the retail price for electricity. When the utility buys power from other sources, it pays a lower, wholesale price. Because net metering policy assigns the same price to the electricity transmitted from the customer to the electric utility and from the utility to the customer, the customer's bill can be determined by a single meter that runs forwards and backwards – hence the word, "net."

Forty-three states, Washington, D.C. and four U.S. territories have adopted some form of net metering policy.[26] However, currently, electric distribution companies in several U.S. states are seeking revisions to regulations so that the solar power delivered to them from decentralized sources costs them less. They argue that paying retail prices for this power creates uncompensated costs. Yes, for some peak hours in the summer the customer's solar power may be worth more to the utility than its retail price. But for most of the hours the power a distributed solar generator sells to the utility is less valuable than the other forms of power that the utility introduces onto the grid, because the solar power is intermittent and unpredictable. All of the arguments for and against distributed generation of electricity, discussed in the previous section, come into play.

A Side Rule Prevents the Customer from being a Net Exporter

Some states with net metering have a side rule that treats the solar electricity that a customer sells to a utility differently, once its amount exceeds the customer's own electricity purchases from the utility (typically averaged over a year). If a homeowner produces less power over a year than she consumes, all of the power her panels produce is valued at the price of retail power. But if she produces more than she consumes, the extra power is valued at the price of wholesale power. Thereby, the net-metering incentive is capped. The larger the customer's demand, the larger the available subsidy. In effect, this side rule allocates the pool of net-metering subsidies in a way that favors the large consumer.

Let's continue our numerical example. Suppose that our homeowner uses 6,000 kilowatt-hours of electricity over a year and that she confronts a retail price of 15 cents per kilowatt-hour; without any solar panels, therefore, her electricity would cost her $900 per year. Now suppose she installs an eight-panel collector on her roof. As above, each panel produces 500 kilowatt-hours each year, so her panels eight produce 4,000 kilowatt-hours of electricity and save her $600 each year. She buys the remaining 2,000 kilowatt-hours from the utility each year, at a cost of $300.

Now suppose that she decides to double her project and install another eight panels, for a total of 16, thereby producing 8,000 kilowatt-hours each year from her panels. She now is producing 2,000 kilowatt-hours *more* than she is using, and she has become a net seller to the utility rather than a net buyer. Here's where the wholesale versus retail reimbursement rule applies. In states with this restricted form of net metering, the utility pays the householder not the retail price, but the much lower wholesale price – say, 5 cents per kilowatt-hour. So the first four of her new panels earns her $300 per year (because she saves that amount by not buying retail power from the utility), but the second four of her

[26] http://www.seia.org/policy/distributed-solar/net-metering

new panels earns her only $100 per year in actual reimbursement from the utility. The final four of the 16 panels may not be worth their investment, since the power they produce is worth three times less. The homeowner may settle for 12 panels, or (if she is allowed) she may opt for the full 16 panels, if the cost of these extra panels is small enough.

This asymmetry in the treatment of a net seller and a net buyer is designed to discourage distributed solar producers from becoming solar power exporters – for example, to prohibit a farmer with limited need for electricity from installing panels on several parcels of land and connecting the panels to the grid. However, what often happens with such mid-scale projects is that a third party who already buys a large amount of electricity from the grid rents the land from the farmer, buys the panels, and offsets its own purchases from the utility with the power it is credited with producing on the farmer's land.

The Feed-in Tariff

The feed-in tariff has been the backbone of the expansion of Europe's residential solar power, led by Germany. The tariff is a constant price per unit of solar electricity that a government guarantees a homeowner for a specific number of years for all of the solar electricity that the homeowner produces. The feed-in tariff provides greater certainty about the price that will be paid for a project's future electricity, relative to the Solar Renewable Energy Certificate, because that price is determined by the government in advance, not by the market of the day.

Government reimbursement per kilowatt-hour of solar production was generally much higher when feed-in tariff programs were launched than later. In the United Kingdom, for example, the feed-in tariff was first available in March 2010, and for the first two years the very high price of 43.3 pence (about 70 U.S. cents at the time) per kilowatt-hour was guaranteed for 25 years. Prices for installations authorized in the fourth quarter of 2016 are much lower. The nominal price is about 10 times less (4.18 pence, or about six U.S. cents, per kilowatt) for small projects (those with capacities below 10 kilowatts); even after adjusting the nominal price upward to take into account a modest credit for unmeasured but assumed "exports" to the grid, the effective tariff is still dramatically lower than it first was.

Third-Party Ownership

The deployment of distributed solar energy has been accelerated by the wide use of third parties, who are able to access financial incentives that are unavailable to the host individual or host institution. The general mechanism is the "power purchase agreement," a financial arrangement where a company owns solar panels located on a property that it does not own. In one version, simplified here, a specialized company, in effect, rents the roof of a home for a fixed number of years. It installs solar panels on the roof and agrees to maintain them. The company receives three subsidies: the Investment Tax Credit, a portion of the depreciation allowance, and the RECs or SRECs. The homeowner pays no money up-front. She pays the company for the electricity produced by her panels, but the company charges her a rate that is less than the rate that she had been paying to the electricity utility, so she saves money. The company makes money too, if its project cost (panels, installation, and maintenance), reduced by the Investment Tax Credit and the depreciation allowance, is less than its revenue from the homeowner and the project's SRECs. The company may lease thousands of roofs, lowering its per-household costs by streamlining the permitting and using its labor force efficiently.[27]

At the mid-scale, the institution that hosts the project may not pay federal taxes – the project may be at a municipal government facility or a school, for example. In these cases, a third party that does pay taxes and thus can benefit from the tax credit often owns the project. The third party leases the facility to the host institution and claims the tax credit. This is the legal arrangement in place for Princeton University's field, where the third party is a financial services company.

Pressures to Reduce Incentives

The societal impact of policy incentives for solar power was modest when there were only a few beneficiaries – the early adopters. But as solar power increases its share of electricity production, some utilities are pushing back, arguing for reductions in these incentives (which they call "subsidies"). These utilities emphasize the consequences for the non-adopters, in their twin roles as taxpayers and ratepayers: subsidies that reduce the taxes of the early adopters shift the cost of paying for government services onto other taxpayers, and subsidies that reduce the electric bills of the early adopters shift utility system costs onto the rest of the utility's customers (ratepayers), whose electric bills increase.

The utility system costs most cited include the costs of maintaining reliable infrastructure, assuring back-up, incorporating new grid-related technology as it becomes available, and providing universal access. Utilities maintain that these costs account for much of the difference between the retail and the wholesale price, and therefore that sellers of distributed solar electricity to the grid must be required to accept less than the retail price. Toward that end, regulators in some U.S. states are considering a "connect charge" that every residential and mid-scale solar power producer would pay for the option of selling any of its electricity to a utility.

[27]In New Jersey 84 percent of recorded residential projects involve "third-party ownership."

Advocates for smaller incentives have become a strong political force in several European countries. Often, they align with advocates for fairness in the distribution of government benefits across income levels, who observe that current programs mostly benefit wealthy people, because they reward those who are more willing to take risks, who have stronger credit ratings, and for whom a tax deduction is worth more.

On the other side of this argument, pressing for a continuation of the incentives for distributed solar power throughout the world, are the manufacturers, distributors, and installers of distributed solar power. They emphasize that quite soon distributed electricity storage may be twinned with distributed solar power, at which point distributed energy will be able to relieve bottlenecks and provide resilience. They note that every national energy system is replete with incentives of many kinds, and thus the incentives for solar power primarily offset the incentives given to its competitors. They have allies among those who give priority to environmental objectives and maintain that solar incentives are a proven mechanism for achieving cleaner air and less rapid climate change.

Utility Ownership of Distributed Generation versus Ownership by Others

Two alternative ownership patterns for distributed energy are in contention: ownership by utilities and ownership by others. Advocates for ownership exclusively by utilities point to the efficiencies achievable when a single owner optimizes the entire system. North Carolina is one state that opted for utility ownership of distributed energy production, for example. Advocates for diverse ownership emphasize that the system encourages competition and can be expected to lead to lower costs and greater innovation.

In most states, utilities have not made a priority of owning decentralized electricity. Instead, they have urged regulators, legislators, and the public to pay attention to the risk of financial collapse of the grid, unless subsidies for dispersed ownership are reduced. They point to a “death spiral”: demand for utility power falls, the costs of maintaining the grid remain constant, prices rise for the remaining participants, and demand falls further. Demand falls as some customers leave the grid-connected system entirely and others produce substantial amounts of power on their own while remaining on the grid. Prices rise as the grid covers its total costs from the sale of fewer units of electricity. Eventually, the grid crumbles. Some argue that the death spiral is already underway.

Intrinsic Value in Distributed and Centralized Generation

An argument about intrinsic value runs beneath the surface of policy debates about distributed versus centralized energy. Proponents of distributed energy affirm that it enhances the positive values of self-reliance and self-sufficiency, whether at the level of individual households or small communities. Proponents of centralized generation see a well-maintained grid as a social structure that enhances the positive value of broad-based mutual dependency. They also see virtue in the specialization that enables the few with special skills to free the many to pay attention to other things. Arguments for and against centralization are far from unique to solar power. They appear in similar form in debates over the structures of grids for food, water, wastes, and the communication of information.

Grid Parity

There is much talk today of a “breakeven price” or “grid parity” for solar power, where a kilowatt-hour of solar power costs no more than a kilowatt-hour of power from, say, natural gas or coal. What is usually being compared is the “levelized cost of electricity,” which is the total cost for building and operating a power-generating facility, divided by the amount of electricity the facility produces over its operating life. Comparing the levelized costs for a solar power plant and a fossil fuel power plant, therefore, requires assumptions not only about the two capital costs (where the dramatic cost reductions for solar power enter the comparison), but also about the price of fuel, the number of years that the plants operate, and – crucially – the capacity factors of the two plants (where the limited availability of the solar plant enters the comparison).

This definition of “parity” is inadequate, because the levelized cost ignores the grid as a whole. Levelized costs take into account the number of hours that a power plant operates over a year, but not the characteristics of those hours. A more compelling comparison would account for the costs associated with grid integration, which will generally be larger for solar power than for fossil fuel power, given solar power’s intermittency and unpredictability. Adding complication, grid integration costs can be fully evaluated only when the complementary providers of power to the grid are also specified.

The levelized cost also ignores costs associated with today’s electricity generation that are not fully priced (the system’s “externalities”), such as damage to public health and the environment. Solar power generally reduces these costs substantially. A fascinating question is whether solar power will dominate the world’s electric power system by mid-century. That will depend on whether the positive environmental benefits of solar power can more than offset the costs of compensating for its variability.