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Rooftop Revolution

Changing Everything with Cost-Effective Local Solar

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Executive Summary

Today solar energy provides less than 1% of our nation's electricity. Yet already over 300,000 homes boast a solar array. With the cost of solar power plunging and retail electric prices rising, in the next ten years 100 million Americans may be able to "go solar" for a lower price than grid electricity. We need to plan for this transition now, eliminating barriers to the rapid growth of solar energy and changing the inflexible and inefficient tax subsidy for solar into a more flexible, transitional feed-in tariff. We need to stop investing in centralized power and long distance high voltage transmission lines and instead invest in new electricity infrastructure more compatible with decentralized power.

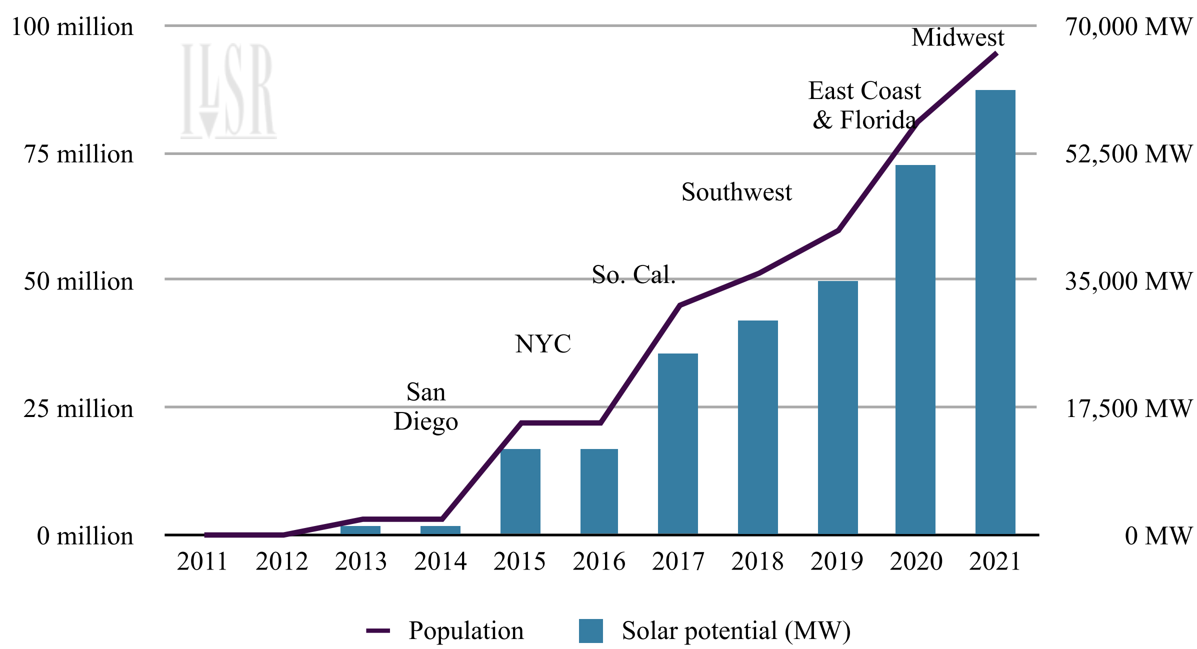
One Third of Americans Could Reach Solar Grid Parity by 2021

SOLAR GRID PARITY
(our definition)

When the cost of solar electricity – without subsidies – is equal to or lower than the residential retail electricity rate.

- The installed cost of solar has fallen 10% per year since 2006 and grid electricity prices have averaged a 2% annual increase in the last decade.
- Nearly 100 million Americans could install over 60,000 megawatts of solar at less than grid prices – without subsidies – by 2021.
- Expanding the analysis to the entire country, and to non-residential rooftops, could increase the solar potential by nearly 10 times and drive down costs.

Population at Grid Parity and Residential Rooftop Solar Potential (MW)



Millions of New Power Plant Owners Will Create a Powerful Constituency for Policy Changes

- Rooftop solar transforms Americans from energy consumers into producers.
- Each house with a solar rooftop has (on average) two voters who will strongly support smart solar policies.
- When half of Americans can install solar for less than the cost of grid electricity (in 12 years), it makes a political majority that favors local ownership of localized energy production long before solar power becomes a significant portion of total electric generation.

New Policy Must Eliminate Technical and Regulatory Barriers to Solar Energy

- Outdated rules limiting solar to 15% of the distribution grid can be revised without threat to grid safety, allowing distributed solar to supply 25% or more of the power to the local electricity grid.
- Local permitting fees – currently accounting for as much as 20% of the cost of solar installations – can be reduced fivefold with simple process improvements including checklists and electronic submissions.
- Net metering may pose barriers to the rooftop revolution unless states can lift aggregate limits (capping distributed solar at 5% or less of grid capacity) and when sufficient solar on the grid can actually affect retail electricity rates.

Solar Subsidies Should Be Redesigned to Phase Out as Solar Matures.

- Solar subsidies should not be eliminated, because it would tilt the playing field toward fossil fuel energy generation.
- The looming expiration of the federal 30% tax credit (in 2016) poses two problems: how to avoid windfall profits in regions where solar is already competitive without subsidies and how to continue expanding access to solar in areas where it is not.
- The best transition policy may be a feed-in tariff, as is used in solar-leading countries like Germany. It can adjust to local solar resources and allow schools, cities, and other non-taxable entities an equal chance to join the rooftop revolution.
- At a minimum, solar subsidies could be transformed into cash-based production payments, solving potential problems with net metering as well as the use of tax-code based incentives.

Acknowledgments

Thanks to David Morris for his patience as this project developed, to John Bailey for his always-insightful comments, and to James Farrell for reading almost every report I've ever written. All shortcomings, of course, are the responsibility of the author.

Recent Energy Publications

CLEAN v SRECs: Finding the More Cost-Effective Solar Policy
By John Farrell, October 2011

Pricing CLEAN Contracts for Solar PV in the U.S.
By John Farrell, August 2011

Democratizing the Electricity System - A Vision for the 21st Century Grid
By John Farrell, June 2011

Maximizing Jobs From Clean Energy: Ontario's 'Buy Local' Policy
By John Farrell, January 2011

Community Solar Power: Obstacles and Opportunities
By John Farrell, September 2010

Municipal Energy Financing: Lessons Learned
By John Farrell, May 2010

Electric Vehicle Policy for the Midwest – A Scoping Document
By John Bailey and David Morris, December 2009

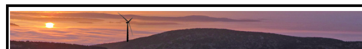
Energy Self-Reliant States: Second and Expanded Edition
By John Farrell and David Morris, October 2009

Community Choice Aggregation: An Update
By John Farrell, June 2009

Feed-in Tariffs in America: Driving the Economy with Renewable Energy Policy that Works
By John Farrell, April 2009

Meeting Minnesota's Renewable Energy Standard Using the Existing Transmission System
By John Bailey, George Crocker (NAWO), John Farrell, Michael Michaud (Matrix Energy Solution), David Morris, November 2008

Energy Self-Reliant States: Homegrown Renewable Power
By John Farrell and David Morris, November 2008



Energy Self-Reliant States: an ongoing web resource
http://energyselfreliantstates.org

Since 1974, the Institute for Local Self-Reliance (ILSR) has worked with citizen groups, governments and private businesses to extract the maximum value from local resources.

A program of ILSR, the New Rules Project helps policy makers to design rules as if community matters.

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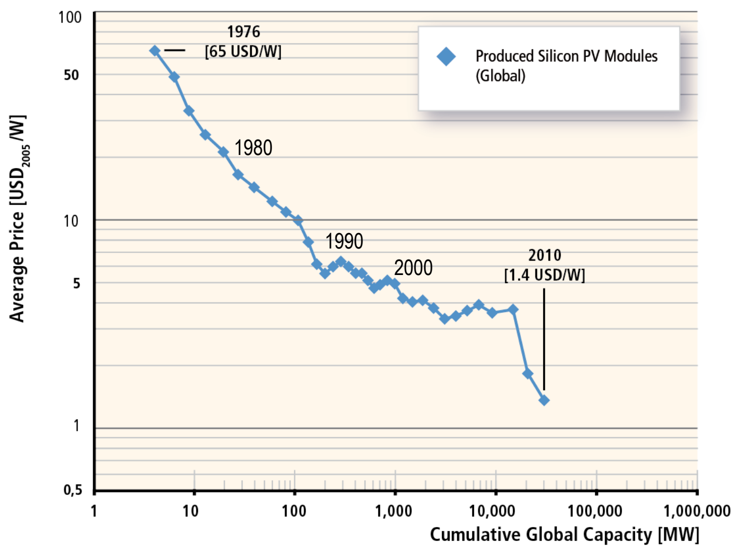
The Coming Solar Electricity Transformation

Solar cells are unusual in that they were cost-competitive from the get-go. From the Apollo space program to highway signs to lighting for buoys, solar could replace highly expensive power from batteries or other sources and eliminate the need for the construction of electric distribution lines.

When the Institute for Local Self-Reliance was founded in 1974, the first factory producing solar cells for terrestrial applications had just opened in Gaithersburg, Maryland. The cost of solar power was over $3.00 per kilowatt-hour (kWh), compared to $0.03 per kWh for grid electricity. The output from that factory the first year was sufficient to power only a few dozen homes.

By the late 1980s, the price of solar was low enough that solar cells were finding their way to second homes and remote cabins off the grid. In 1990, the total installed capacity of solar was 200 megawatts (worldwide, with about 25% in the U.S.), sufficient to power 4,000 homes.[1] During the ensuing decade, federal and later state incentives for solar ushered in the era of grid-connected solar. By 1999, grid connected solar projects exceeded non-grid applications.

Global Installed Solar Capacity



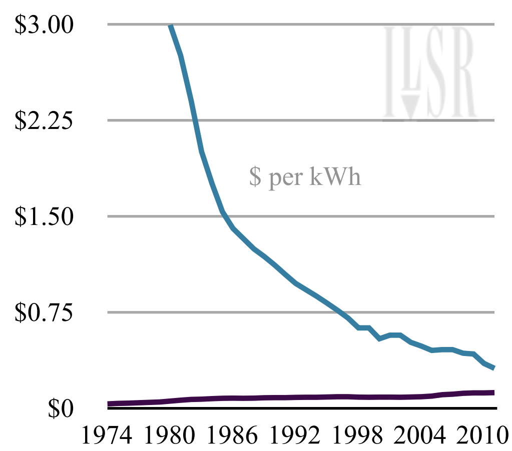
Renewable Energy Sources and Climate Change Mitigation. (Special Report of the IPCC, 2012). Accessed 12/20/11 at http://tinyurl.com/6bh5cv8.

By 2000, sufficient solar cells were installed to power 135,000 homes (with just over 20% in the U.S).[2] The cost of solar was $0.50 per kWh, equivalent to an installed cost of approximately $10 per Watt. Since 2000, solar electricity production has grown exponentially. The annual installed solar capacity first exceeded 1 gigawatt (GW = 1,000 MW) in 2002 (globally).

By the end of 2010, installed solar capacity in the U.S. alone exceeded 2.5 GW (sufficient to power 400,000 homes) and global capacity was over 40 GW, sufficient to power 8 million homes. Annual solar module production exceeded 30 GW worldwide.[3]

As production has increased the cost of solar has fallen. Since 2006, the cost of solar has dropped by 58% – 10% per year.[4] Grid connected solar is on the verge of becoming competitive – without incentives – with conventional electricity.

Cost of Residential Solar v. U.S. Residential Retail Electricity Price (Nominal)



In 1974, solar electricity cost more than 100 times the residential retail electricity rate, today the differential is 2 times or less in many communities.

A Grid with Solar Parity

The policy and on-the-ground implications of "solar grid parity" are enormous. Even though solar still generates less than one-tenth of 1 percent of the nation's electricity, public officials, towns and businesses and households will soon have a newly cost-competitive and widespread energy source to develop their own power supply. Locally produced electricity will offer an unprecedented opportunity to connect electricity production with local jobs and economic development.

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When the cost of solar electricity – without subsidies – is equal to or lower than the residential retail electricity rate.

The opportunity of solar grid parity will also threaten the fundamental nature of a 20th century electricity system. Utilities will have to rethink their role in the electricity network when electricity can be generated by anyone and owned by anyone. No longer will the paradigm of centralized power generation, ownership and distribution make sense when electricity can be economically produced at or near most homes and businesses. Even the concept of backing up solar power is poised to change, as electric vehicles have begun to enter garages and driveways and parking lots, adding a potentially vast number of tiny backup plants and storage systems that will have to be integrated into the grid system.

The nearness of solar grid parity brings urgency to the discussion of electricity policy, from incentives to grid design. Well before any new fossil fuel power plants have passed their infancy, electricity from solar will be cheaper. It means that policies that continue to subsidize a centralized grid and its attendant infrastructure may cost ratepayers for decades. It means that citizens and their elected leaders will have to carefully consider the policies that guide investment in the electricity system.

This report discusses a nation on the verge of widespread expansion of decentralized electricity generation and on the cusp of a new electricity system that enables more of us to produce the electricity that we consume. We identify the first American cities where solar will be competitive without incentives and estimate the amount of competitive solar that can be generated over the next decade. We discuss the implications of this massive introduction of solar and the urgency of crafting public policy that will support the transition to solar power while maintaining a balanced and reliable grid. We examine the opportunity of redirecting solar incentives – like the 30% tax credit – toward new methods of accelerating solar development that can continue to drive down the cost of solar electricity in ways that can fundamentally change our electricity system for the better.

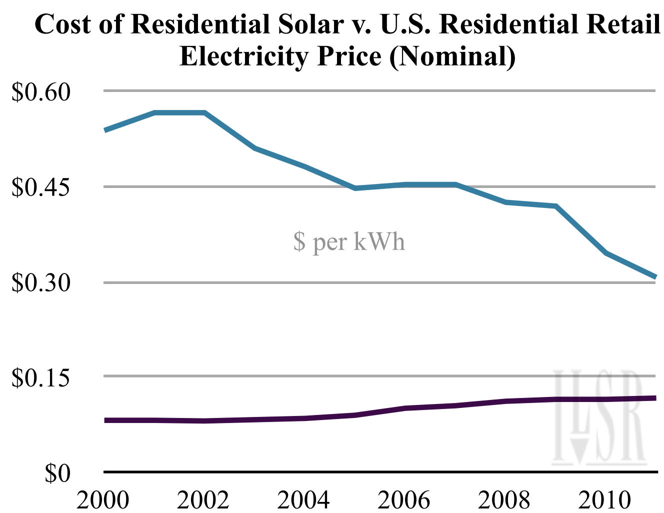
We believe that in the next 3 to 5 years you'll be able to get power cheaper from the roof of your house than from the grid. Solar is going to go from this thing that right now is like .1 percent of the market to 20 to 30 percent of the overall electricity mix.

NRG CEO David Crane in 2011
http://tinyurl.com/cyehdhm

Solar Costs and Grid Prices On a Collision Course

With the cost of solar continuing to fall rapidly (50% in the past five years) and electricity prices rising steadily, if slowly, the approach of solar grid parity is near. The following chart illustrates the trajectory of solar cost and electricity price, hinting at the coming intersection.[5] The chart compares the cost of a residential solar installation to the cost of electricity for a residential property. The numbers are national averages, and do not reflect the wide variation in the cost of electricity (from $0.067 per kWh in Seattle to over $0.170 per kWh in New York City, for example).

In particular, the two lines have been converging rapidly since 2007. The key moment for solar is the cross-over, when electricity from solar – without subsidies – costs less than grid electricity. The following analysis identifies this moment of "solar grid parity" for the top 40 metropolitan areas in the United States (representing just over half of the national population). For the list of the metro areas, see the Appendix (although Hawaii is already at solar grid parity, we did not include the Honolulu metro area as it ranks #53 in population).



In our analysis, we focus exclusively on residential solar grid parity, rather than commercial solar (and commercial electricity prices) or utility-scale solar with electricity sold on the wholesale market.

Why Focus on Residential Solar?

The focus on residential solar instead of commercial or utility-scale solar is a conscious choice. While larger-scale solar is cheaper (by 10-25%) because of economies of scale and will likely represent a significant source of new solar installations, there are a few drawbacks to using it for a grid parity analysis.

For commercial-scale on-site solar, the problem is that electricity pricing is much more complex for commercial businesses than for residences. Electricity bills are divided into an energy charge (per kWh consumed) and a demand charge (based on the peak energy capacity needed during a given time period). It's therefore much more difficult to determine when commercial solar has reached grid parity.

Utility-scale solar suffers from a similar constraint, where availability of wholesale electricity prices by region is a challenging exercise.

More importantly, residential solar is more likely to have significant political implications, shifting individuals from electricity consumers to producers and giving them a stake in electricity production and energy policy. Therefore, residential grid parity appears more crucial for democratizing the electricity system. See the Appendix for more discussion on the residential focus.

Solar Grid Parity Analysis

To determine the year of grid parity for major cities, we compare the cost of solar power installed on a residential property averaged over an expected project lifetime – the "levelized cost" – with the expected change in the average residential retail electricity rate.

Assumptions for Solar Grid Parity Analysis
- Residential solar
- Installed cost of $4.00 per Watt
- 5% cost of capital, 80% financed
- 5% discount rate
- 3% inflation
- 25-year project life
- Operations cost of 1% of the installed cost, per year
- Output based on the local solar insolation data from the National Renewable Energy Laboratory's PVWatts calculator
- Solar output degradation of 0.5% per year

The First Half of Grid Parity: The Cost of Solar

The levelized cost of solar is calculated with the following assumptions. First, we use an installed cost for residential solar power of $4.00 per Watt. This number may seem low, as the average cost of residential solar installations in mid-2011 was $6.40.[6] But at the same time, residential solar installations completed under a group purchase have received significantly lower prices. In Los Angeles, for example, the Open Neighborhoods group purchase achieved an installed cost of $4.40 per Watt.[7] Some solar industry experts and observers have suggested costs are even lower. Furthermore, installed costs for small-scale solar in Germany average $3.40 per Watt or less, suggesting that there are near-term opportunities for lower cost solar in the U.S.[8]

The cost of capital for residential solar installations is calculated at 5% based on the historically low interest rates that persisted in 2011. We also assume that homeowners will finance 80% of the cost of the installation. To account for the changing value of money over time, we use a 5% discount rate (equal to the cost of capital) and a 3% inflation rate (the historical U.S. average) to account for the smaller cost of payments made on debt in later years.

The project life of solar was estimated at 25 years, based on the the longevity of early installations and the quality of current solar panels. Operations and maintenance costs were estimated to be 1% of the initial installed cost, a slightly higher assumption than that used in many other studies. The output of the solar array is based on the local solar insolation data from the National Renewable Energy Laboratory's PVWatts calculator. Panel output was forecast to degrade by 0.5% per year.

We used the same installed cost for solar nationwide, ignoring variations that currently exist in the solar market. We assume that as the national market for solar grows, regional variation in prices will become insignificant.

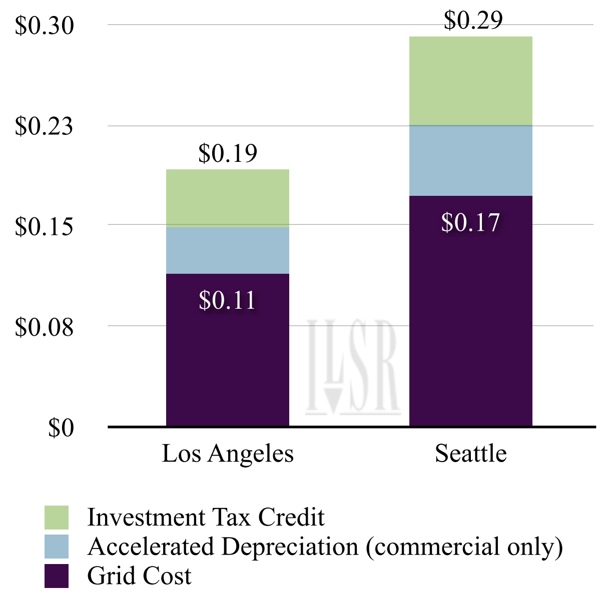
Based on these assumptions, the levelized cost of solar today – without any incentives – varies from around $0.19 per kilowatt-hour (kWh) in Los Angeles to $0.29 per kWh in Seattle. For more discussion on the cost of solar, see the Appendix or for some context, see the Sensitivity Analysis.

Solar Incentives and the Cost of Solar

Currently, there are a variety of incentives that reduce the cost of solar electricity. At the federal level, a 30% investment tax credit and accelerated depreciation (worth an additional 20% discount) significantly reduce the levelized cost of solar. In many states and utility service areas, rebates and other incentives are added to the federal incentives.

With incentives, commercial- and utility-scale solar is already competing with new fossil fuel power plants. California utilities have 4.5 gigawatts of signed contracts for solar below the cost of a new natural gas combined-cycle power plant (the "market price referant").[9] San Antonio's public utility, CPS Energy, asked for bids for 50 MW of solar and was so pleased with the prices that they increased their order to 400 MW.[10]

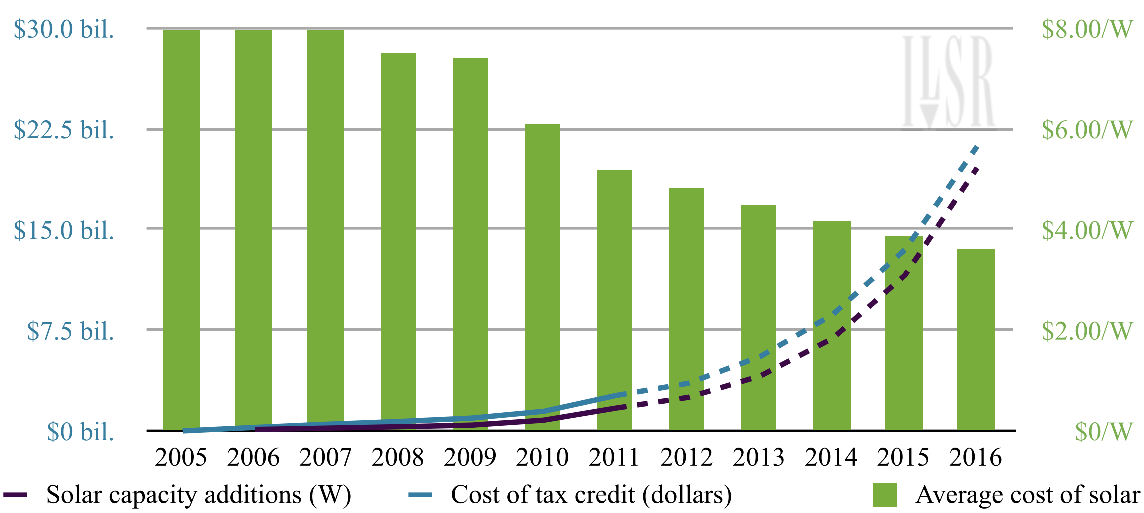
Solar Power Cost Before and After Federal Incentives



Even residential solar can be competitive with grid prices, especially with the rising popularity of third-party ownership models. Solar leasing allows residential property owners to have solar installed with no or low upfront cost, and typically means they will see an immediate reduction in their electricity bill, even when factoring in the lease payments to the third party. The third party is able to capture the federal tax incentives (including depreciation, otherwise not available to residential users) and therefore can compete favorably with those making cash purchases of solar power for their homes.

The cost of these incentives is not insignificant. For example, the federal tax credit allows solar projects to get back 30% of the installed cost. Claimed by nearly all solar projects, in 2010 the tax credit amounted to nearly $1.6 billion (for 878 megawatts of solar at an average price of $6.20 per Watt).[11] The following chart illustrates how the exponential growth of solar means an exponential growth in the cost of the tax credit, despite significant forecast price decreases. Values after 2011 are forecast, with a best fit line estimated for solar capacity additions, and a 7% annual decline assumed for the installed cost of solar.

Cost of Federal Solar Tax Credit



The cost of the tax credit will reach $22 billion a year by 2016 and the tax credit isn't the only subsidy. The federal government estimates that accelerated depreciation for solar and geothermal projects costs about $300 million per year, forecast to rise to $7 billion by 2016.[12] With solar capacity growing rapidly and costs coming down, the following analysis suggests that it may be time to re-evaluate incentives for solar power. For more on this issue, see Planning for Phasing Out Incentives.

To avoid complication in the analysis all solar costs in this report, with the exception of the preceding section, reflect the unsubsidized cost of solar power.

The Second Half of Grid Parity: The Cost of Grid Electricity

Using the unsubsidized cost of solar reported earlier for each metropolitan area, we contrast it with each city's average residential retail electricity price, as reported by the PVWatts calculator (and derived from the Energy Information Administration). Once again, there is wide variation. Prices varied from $0.067 per kWh in Seattle to $0.175 in New York City.

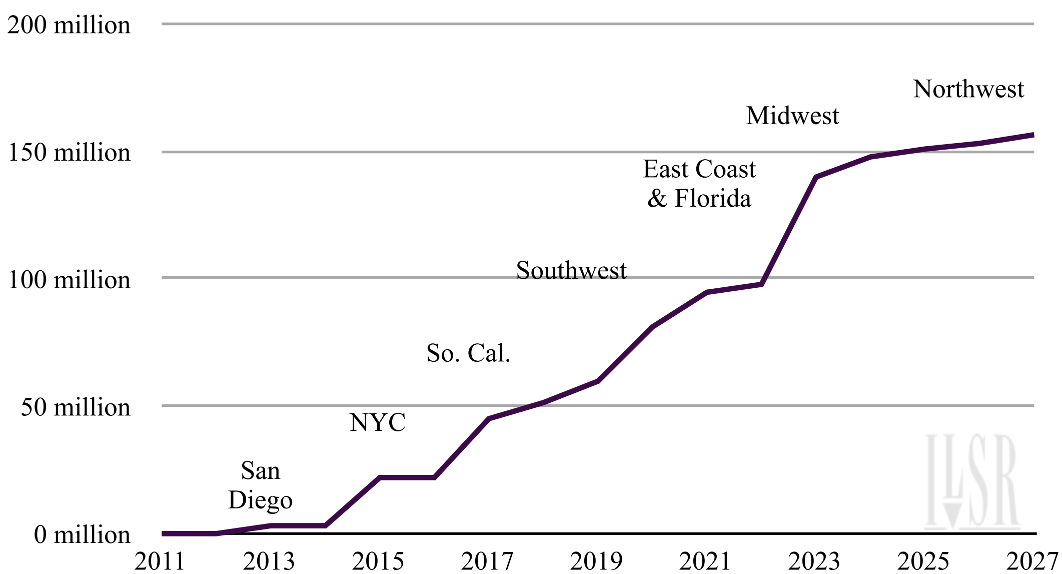
Assumptions for a Grid Parity Forecast

- Annual decrease in solar prices: 7%
- Annual increase in retail electricity prices: 2%

To determine when cities reach residential solar grid parity, we assumed that electricity prices would continue to rise at 2% per year (the historical average[13]) and that the cost of solar would decline at 7% per year (less than the 5-year average of 10%). It is possible that the cost of solar will plateau, or that electricity prices will rise much more slowly, and we have conducted a sensitivity analysis to examine some of those contingencies.

The following chart illustrates the number of Americans in the top 40 metropolitan areas who could go solar for less than the retail grid electricity price by year, from 2011 to 2027. San Diego is the first city at grid parity, in 2013. Seattle is the last, in 2027. Geographic regions are listed on the chart when cities in those regions reach grid parity. For a table showing the chart data through 2021, see the Appendix.

U.S. Population Reaching Solar Grid Parity (at Average Local Grid Prices)



In the short-term, Southern California reaches grid parity with moderately high electricity prices and excellent sunshine, with New York coming soon after due to particularly high grid prices. By the end of the decade, 1 in 4 Americans in the largest metropolitan areas could go solar at better than grid prices.

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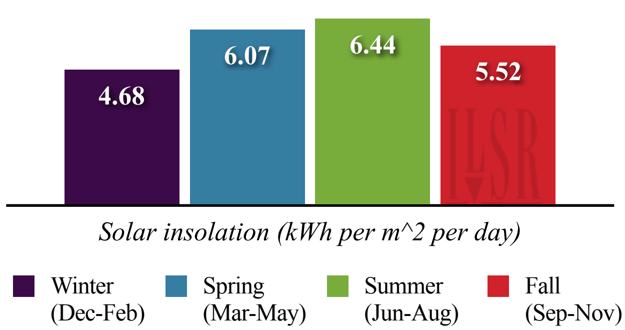
Time-of-Use Pricing

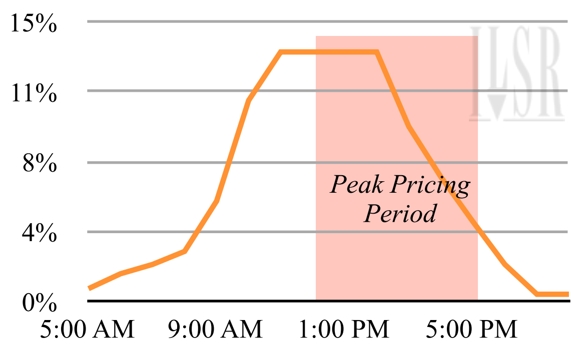
Although the comparison above between solar and average retail electricity prices is accurate, it misses an important element of grid electricity pricing and the value of solar power. In some areas of the country, utilities have begun to offer "time-of-use" pricing that varies the rates for electricity during times of the day (and seasons) to reflect the higher costs for generating power during times when demand is particularly high. In general, these high demand (e.g. high cost) times are on hot, sunny afternoons when air conditioning loads are highest. Of course, these hot, sunny and high demand days (and high grid prices under time-of-use pricing) tend to coincide with high levels of potential solar power production. This means that solar can provide a lot more economic value to the utility by reducing demand and providing extra generation at a time when it's most needed.

The following two graphics illustrate how solar PV systems produce more electricity during the times of day and year when electricity demand is high. For example, a solar panel in Los Angeles will deliver a disproportionate 28% of its annual electricity during summer months (June through August) and also deliver 43% of its daily electricity output during peak pricing hours.

Average Solar Insolation by Season (Los Angeles)

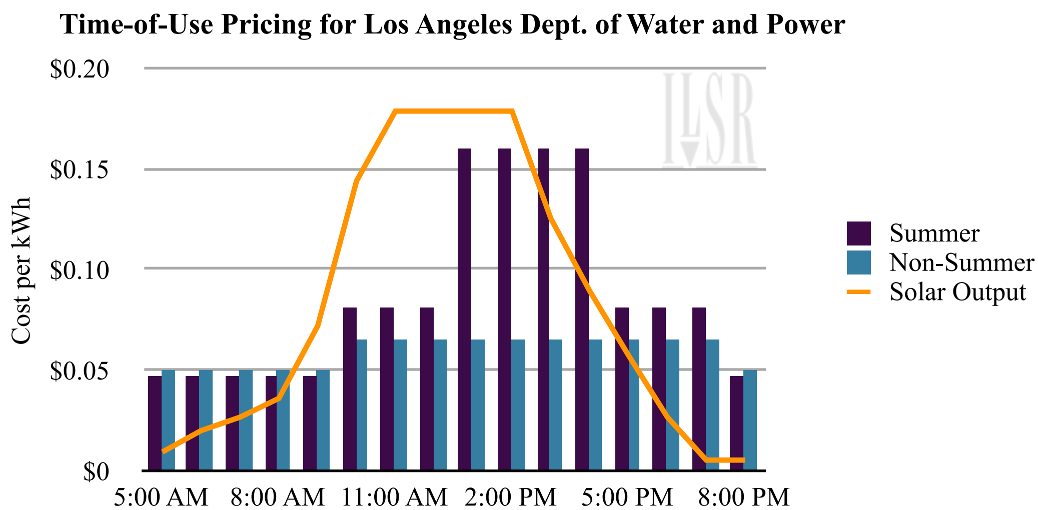


Percent of Daily Solar Electricity Output by Hour

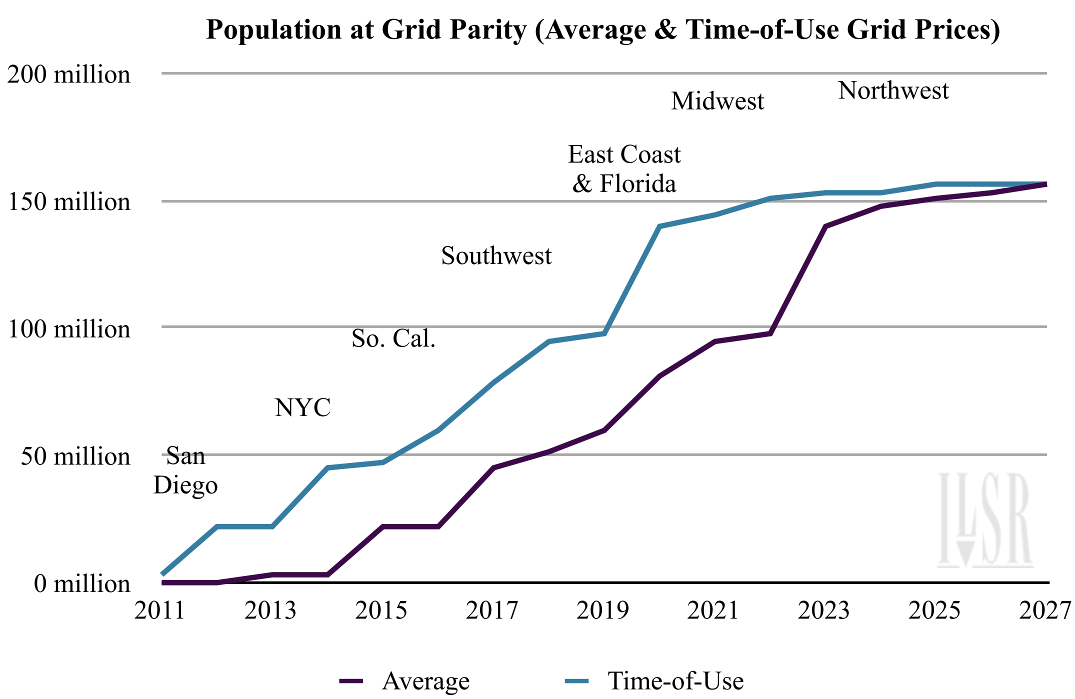


The overlap of solar panel output with high electricity prices means that in Los Angeles and other communities, the utility's time-of-use pricing plan makes solar power pay back faster, because the customer is offsetting more expensive electricity than average with their solar array. And if set up properly, any net excess generation flowing back to the utility grid should be compensated at peak power prices.

The following chart illustrates the time-of-use pricing plan for the city of Los Angeles municipal utility that charges higher prices during certain daytime hours during the summer months of June, July and August.



The availability of time-of-use pricing means that comparing solar to the average grid electricity price underestimates its value to a residential customer. A solar panel will reduce a homeowner's consumption from the grid during the most expensive time periods. Therefore, we ran the solar grid parity analysis a second time, increasing the retail electricity price by 30% (to reflect the time-of-use value of solar).[14] In this scenario, solar grid parity advances by two to three years for most cities, as shown in the chart below. For a more detailed table, see the Appendix.



> *Fifty percent more people achieve grid parity by 2021 – nearly half of all Americans – with a time-of-use pricing plan compared to data using average retail electricity prices.*

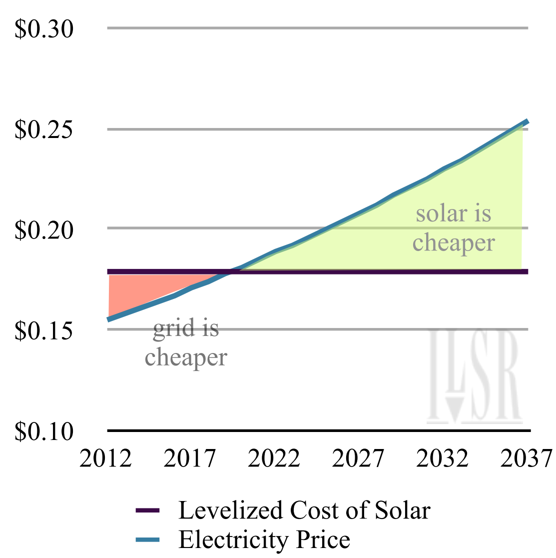
Fifty percent more people achieve grid parity by 2021 – nearly half of all Americans – with a time-of-use pricing plan compared to data using average retail electricity prices. One could conclude that implementing time of use pricing should be a cornerstone for any policy advocates seeking to make solar competitive sooner. As distributed solar generation expands significantly, the financial advantage of peak pricing may fade, but in the near term it's a pricing mechanism that can make solar more affordable.

Economic Grid Parity

Most people think of grid parity in simple terms: "is the cost of solar electricity lower than grid electricity right now?" But with electricity prices rising 2% per year over the last decade, installing solar immediately could save money in the long run even if the current cost of solar electricity is higher than grid prices. Thus, we modeled a third pricing scenario, called "economic grid parity," and the concept can accelerate the year of grid parity.

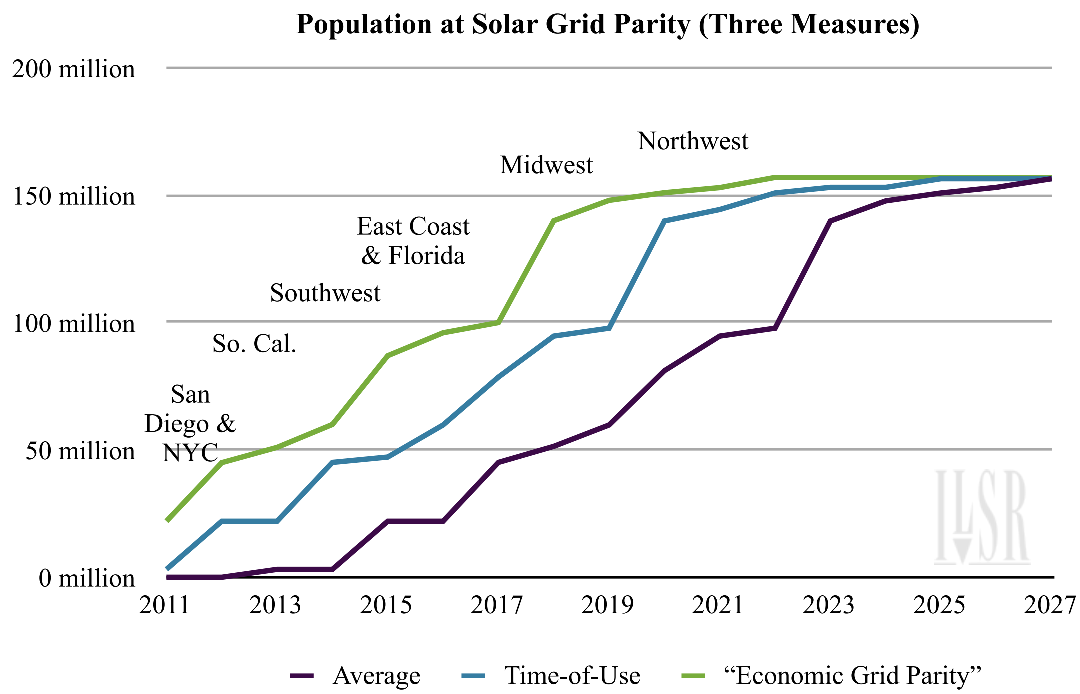
Economic grid parity happens because rising electricity prices make solar installed today increasingly worthwhile over time. The cost of solar electricity is fixed, based on the cost to install the array. It will continue to provide electricity with no fuel cost and with minimal maintenance for 25 years or more. Grid prices typically increase, however, making the value of solar greater over time. The adjacent chart illustrates the concept for Los Angeles. Grid electricity is cheaper than rooftop solar for the next few years, but then the two flip. Over 25 years, the savings from solar grow significantly.

Lifetime Savings from Solar Power (Los Angeles)



To calculate the year of economic grid parity for each city, we simply matched up the lifetime cost of solar (the levelized cost over 25 years) to the expected cost of grid power in the year it was installed. Each year, the grid price rises by an expected 2%, while the cost of solar stays the same. We use the net present value[15] of the costs and savings to determine the economic grid parity year.

In general, using this method accelerates solar grid parity by an average of two years for most major metropolitan areas, as shown in the following chart. A detailed table is in the Appendix.

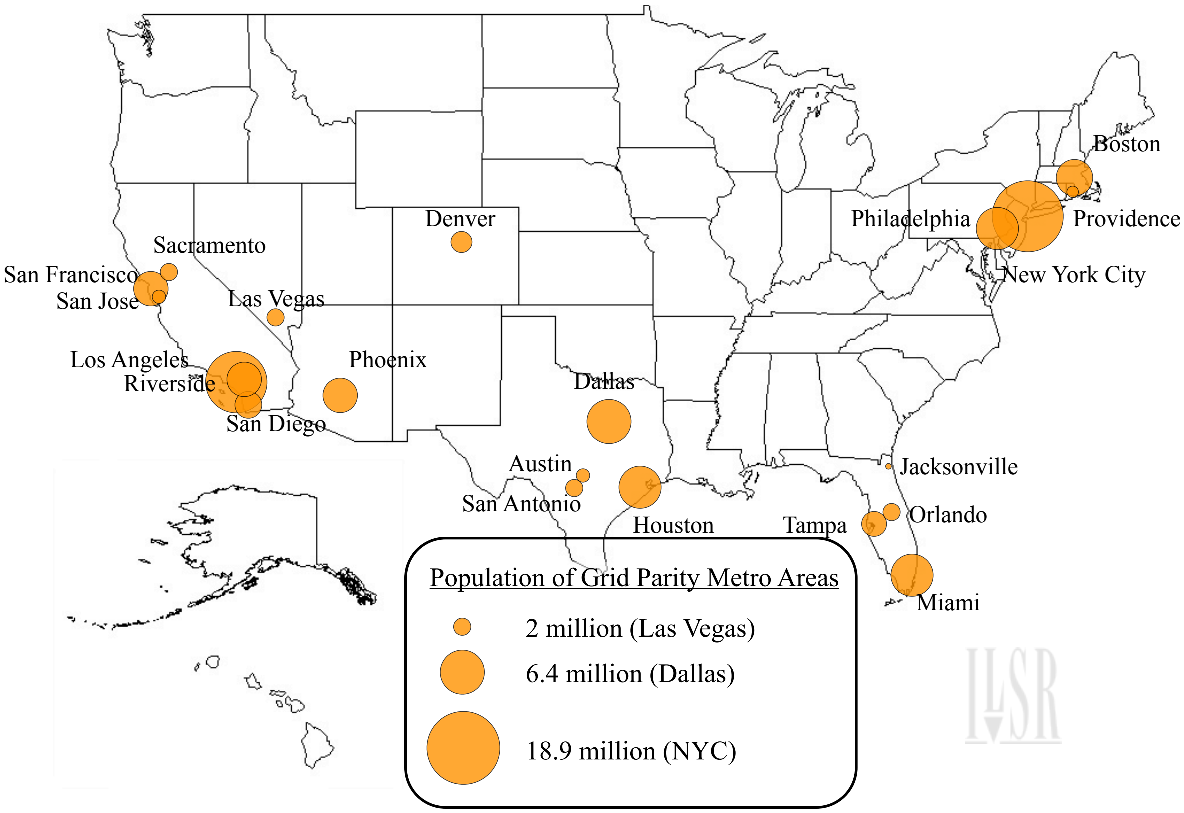


The choice of measuring stick matters a great deal for solar grid parity. With time-of-use prices implemented and a careful look at the lifetime value of solar power production, the next five years could bring one-third of the U.S. population to solar grid parity.

The following map shows the metropolitan areas that could reach grid parity by 2016 with time-of-use pricing and using "economic grid parity," representing a total population of 96 million.

> *With time-of-use prices implemented and a careful look at the lifetime value of solar power production,* ***the next five years could bring one-third of the U.S. population to solar grid parity****.*

Large Cities at Solar Grid Parity by 2016 Using Economic Grid Parity with Time-of-Use Pricing



Sensitivity Analysis

Although we're confident in our various solar grid parity analysis assumptions, conditions may change in unexpected ways. This section examines the impact of variations in the assumptions used for the solar grid parity analysis, including the inflation in grid electricity prices, the cost of solar, a potential plateau in the cost of solar, and the initial installed cost of solar power.

The default assumptions are:

- Electricity inflation of 2% per year
- Solar cost decrease of 7% per year
- Solar cost decreases steadily through 2027
- Initial solar cost of $4.00 per Watt

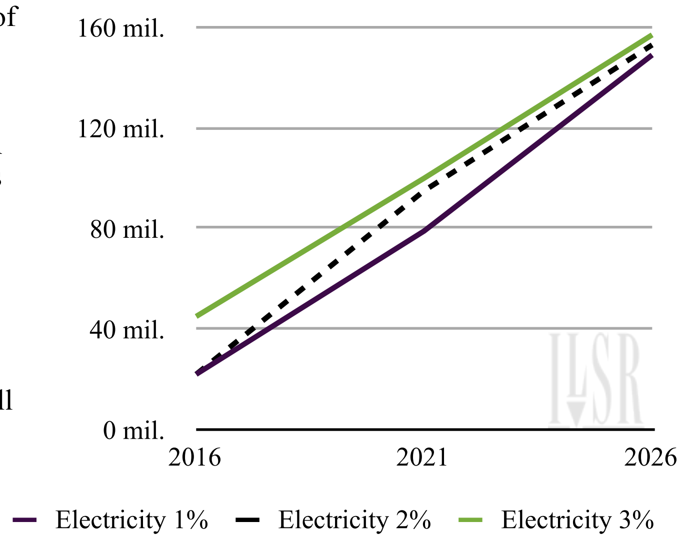
Sensitivity Analysis for Solar Grid Parity at Average Grid Prices

	Population at Solar Grid Parity (millions)			
Factor	**2016**	**2021**	**2023**	**2026**
Electricity inflation 1%	22	79	98	149
Electricity inflation 3%	45	100	148	157
Solar cost decrease 5%	22	60	87	119
Solar cost decrease 6%	22	79	98	148
Original	*22*	*95*	*140*	*153*
Solar cost decrease 8%	45	111	149	157
Solar cost decrease 9%	47	140	153	157
Solar cost plateau 2020	22	87	95	98
Initial cost of $5.00/W	3*	60	95	140

**In this scenario, the grid parity population is 22 million in 2017, so the change isn't as dramatic as the data cell suggests.*

Electricity prices are relatively stable, so the small range tested in the sensitivity analysis also has a relatively small impact on the eventual coming of grid parity (see adjacent chart).

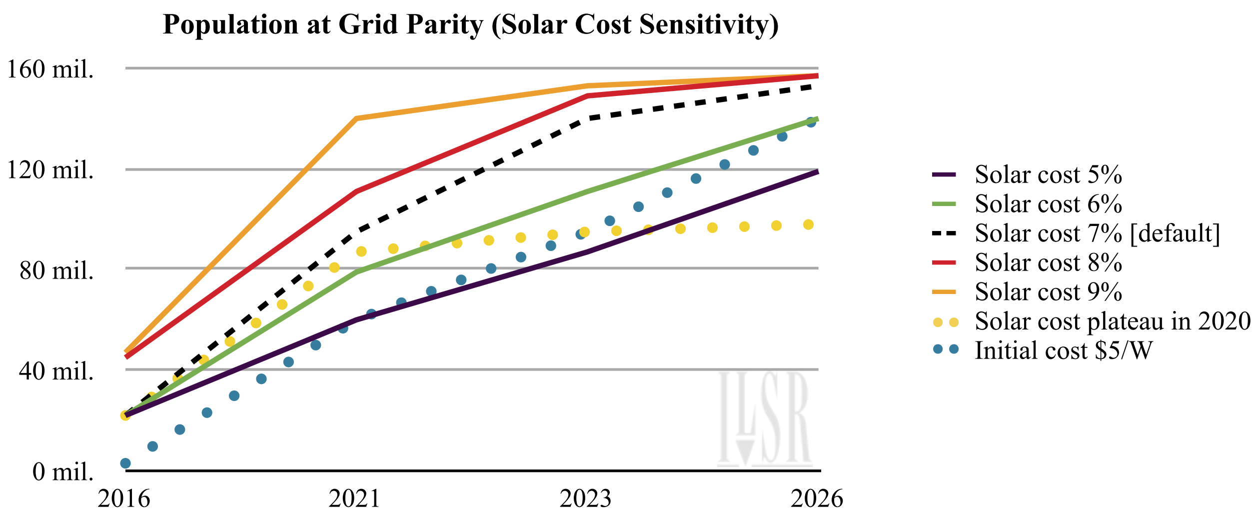
Population at Grid Parity (Electricity Sensitivity)



Since the role of solar costs plays a disproportionate role and is less predictable than electricity prices, our sensitivity analysis reveals how changes in the solar cost assumption could have a significant impact on the overall results.

A ±2 percentage point change in the annual cost trajectory of solar could change the number of Americans at grid parity by 30 million in either direction by 2026 (the chart doesn't show the full impact because our universe is artificially constrained to the top 40 metro areas).

A plateauing of solar costs after 2020 could severely limit the expansion of grid parity thereafter, but interestingly a starting cost $1.00 per Watt higher is no worse (in the long run) than a 1 percentage point slower decrease in solar costs.



Some might argue that even the sensitivity analysis underestimates is too bullish on solar costs, but the world market suggests otherwise. At the end of 2011, while the average installed cost of U.S. solar lingered at $5.20 per Watt, Germans installed solar at an average cost of $2.80 per Watt.[16] The enormous difference suggests plenty of room for downward cost movement.

The Solar Opportunity

The coming of solar grid parity offers an opportunity for millions of Americans to go solar affordably. But it also means a potential transformation, a democratization of an electricity system long dominated by centrally-controlled utilities and centralized ownership and production of electricity. When solar can undercut grid electricity prices, it may also undercut this 20th century system of centralized ownership, bringing economic sunshine and self-reliance to communities along with solar electricity.

Millions of People, Thousand of Megawatts

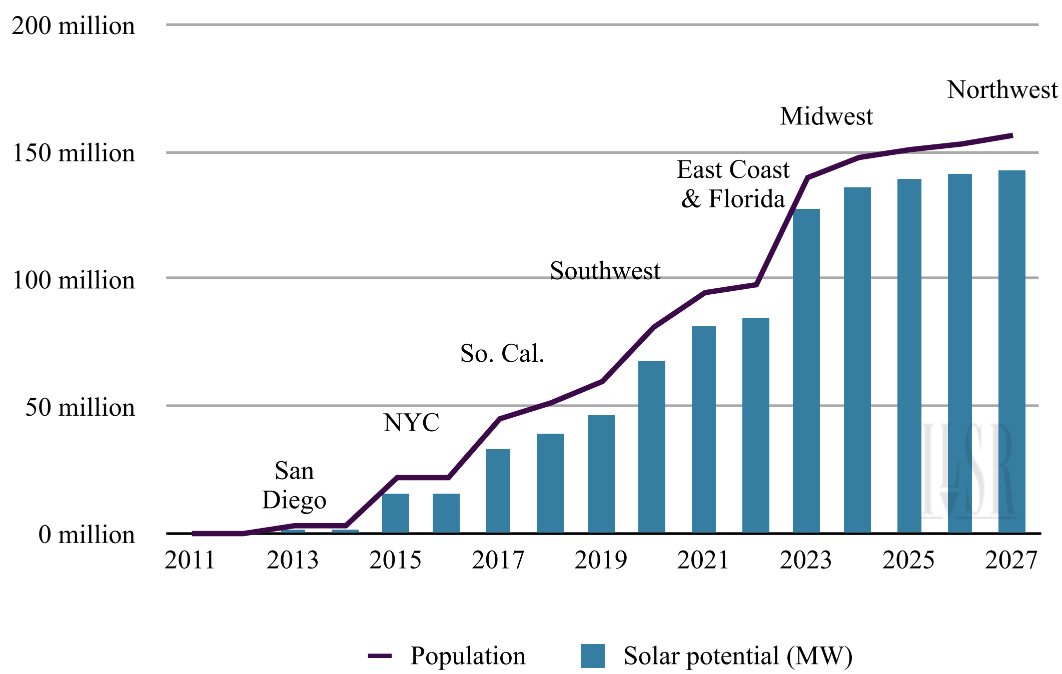
When solar grid parity arrives, it won't mean that everyone can go solar. The most likely participants in the residential sector will be folks who own their own home. Even then, there will be some homes whose roof is unsuitable for solar power for one reason or another (e.g. shading). The following analysis takes the year of solar grid parity for the nation's largest cities and translates it into megawatts of solar power potential.

We used the following assumptions to calculate the residential solar rooftop potential for each metropolitan area:

- Only non-vacant, owner-occupied properties were considered. Nationally, about two-thirds of homes are owner-occupied and not vacant, with major metropolitan areas varying from 50 to 70%.[17]
- We estimated approximately 1,000 square feet of total roof space per home.
- We assumed that only 27% of this space (in the aggregate) would be suitable for solar, based on national studies of rooftop solar potential.[18]
- We assumed that 1 kW of solar could be installed for every 100 s.f. of suitable roof space.

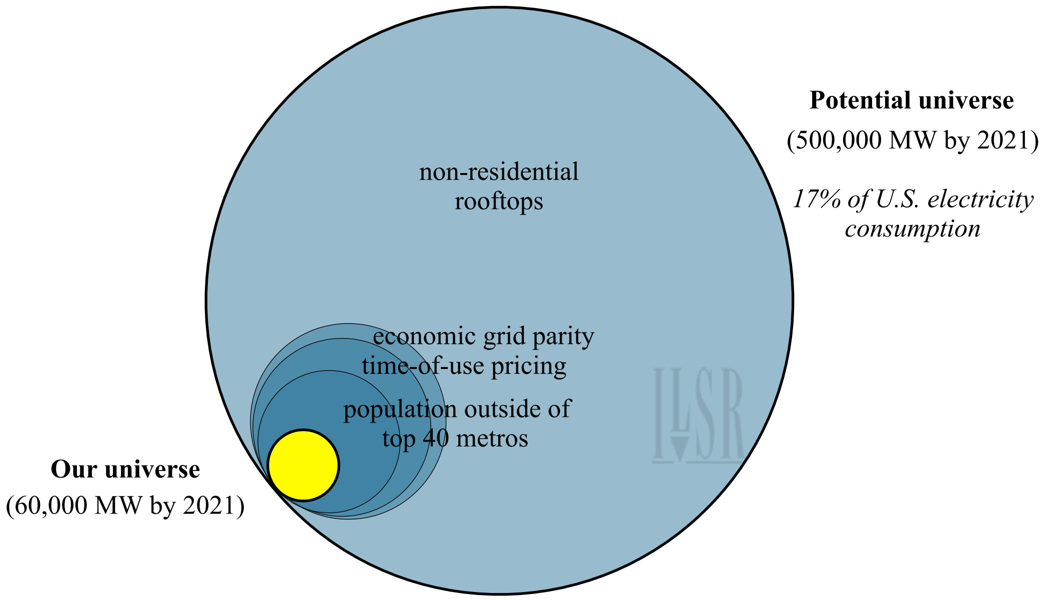
With these assumptions, we can use our previous analysis of the year of solar grid parity (based on the average residential retail electricity rate) to estimate the potential capacity of solar power that could be installed on home rooftops at grid-beating prices each year until 2027.

Population at Grid Parity and Residential Rooftop Solar Potential (MW)

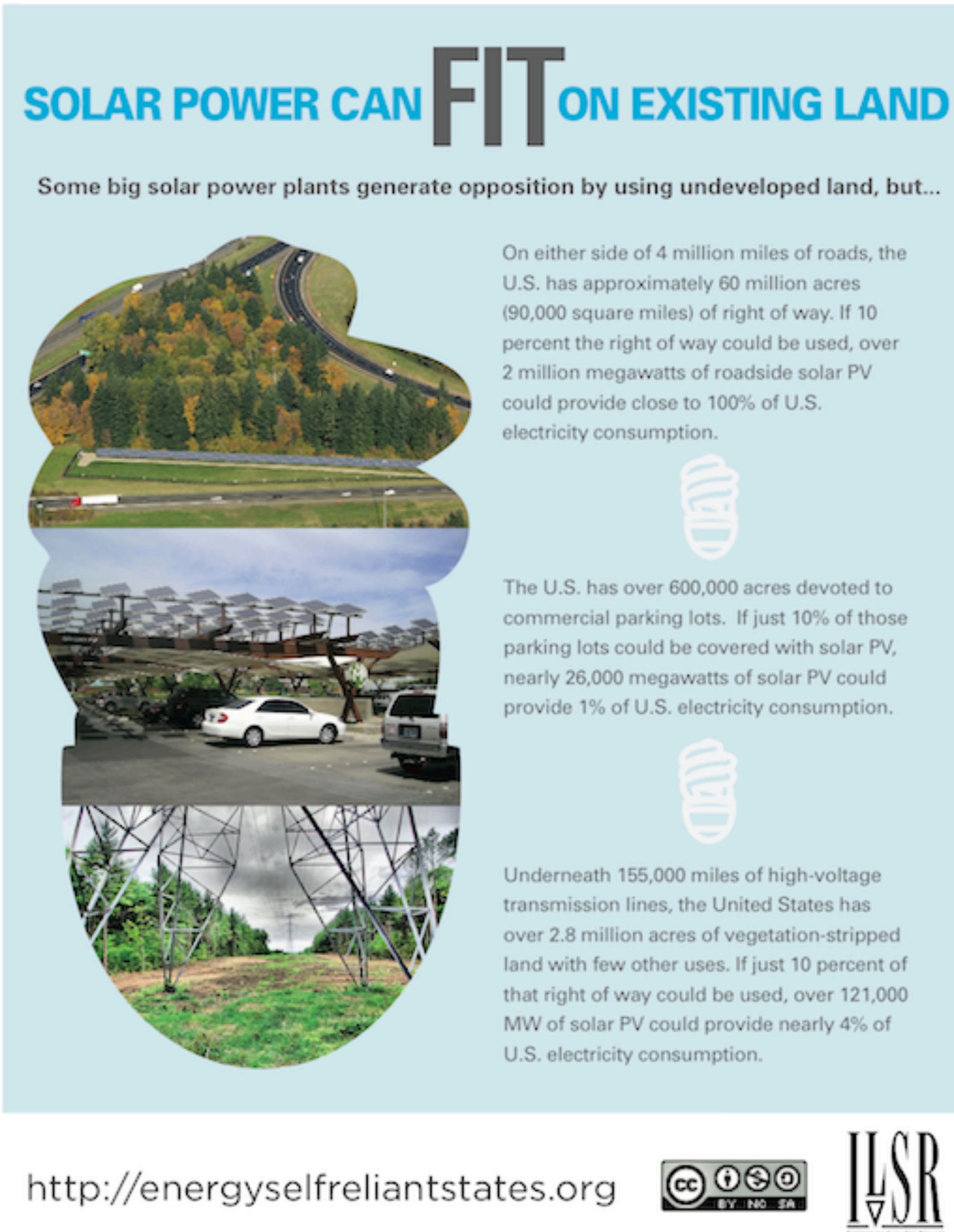


The above chart is quite conservative. For one, the data only reflect the 50% of Americans that live in the largest 40 metropolitan areas. Additionally, we used average grid prices and did not factor in time-of-use pricing or "economic grid parity." Finally, residential solar is only a fraction of the total solar market. In California, the largest U.S. solar market, residential solar represents approximately 30% of the installed capacity in the California Solar Initiative program.[19] Thus, the grid parity potential numbers above are a fraction of the actual solar potential when considering commercial and public sector property, as well as communities smaller than the 40 largest cities.

A Very Conservative Solar Megawatt Grid Parity Estimate



Additionally, rooftops aren't the only place for solar, and the availability of other locations could further expand the grid parity opportunity. The following infographic illustrates the opportunity for solar over parking lots, near highways, and underneath existing transmission lines. It still doesn't factor in solar placed on the ground near existing buildings.

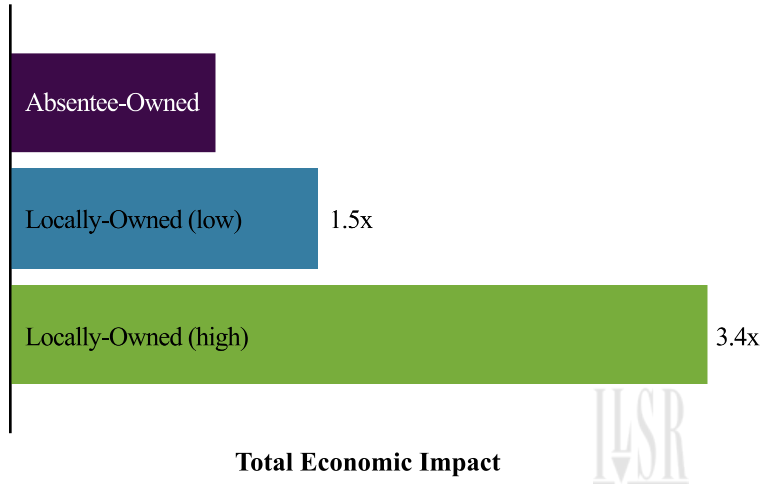


Jobs and Economic Development

Solar provides an unparalleled economic opportunity for local power generation and local economic benefits. Each megawatt of solar power generates as many as eight jobs and $240,000 in economic activity, and most solar power projects can be built right next to or on top of the building that will use the electricity.

Previous studies by the National Renewable Energy Laboratory indicate that locally owned renewable energy projects multiply the job and economic benefits of renewable energy projects.

Local Ownership Boosts Economic Benefit of Renewables



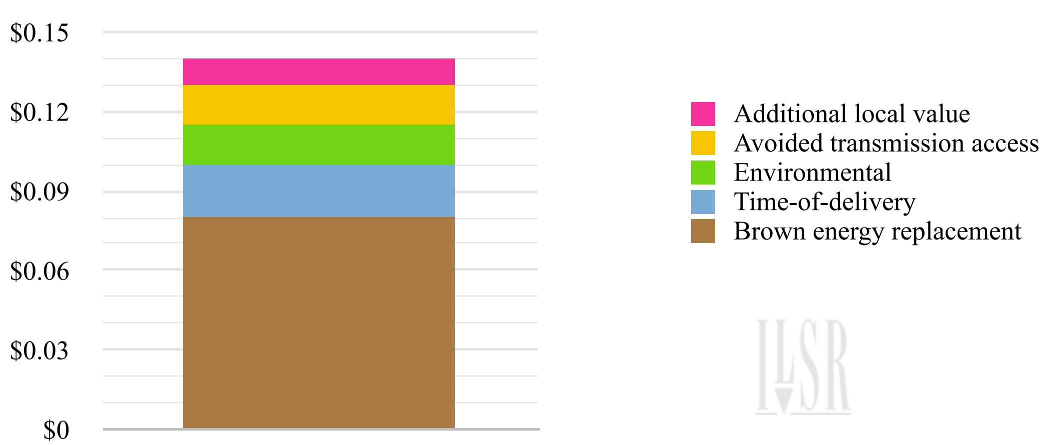
With a potential for 30,000 megawatts of residential solar in the next 6 years, communities across the country could gain over a quarter million jobs and create over $18 billion in economic activity.

Value to the Electricity System

There's also ample evidence that distributed solar power has much greater value to the grid than simply electricity output. The delivery of power during peak periods (covered by time-of-use pricing) is just one element. The ability of solar to avoid transmission access charges, supplant long-distance power sources, reduce stress on the distribution system during peak power events and hedge against fossil fuel price fluctuations can vary from $0.03 to $0.14 per kWh. Solar also has environmental benefits (relative to existing power production) that provide additional value.[20]

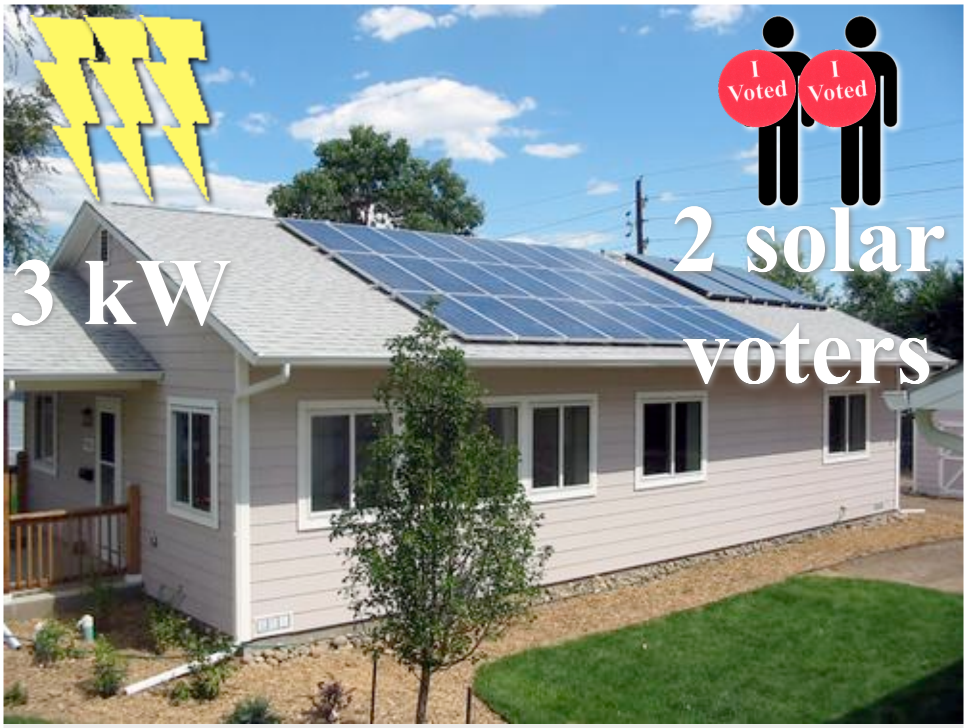
The following chart illustrates how utilities are recognizing the value of solar power, illustrating the willingness of a municipal utility to pay more for local solar power because of its various grid and local economic benefits.

Value of Local Solar Power to Palo Alto Municipal Utility



Democratizing the Electricity System

Perhaps the greatest benefit of the solar grid parity opportunity will be its political impact. As millions of Americans become self-reliant energy producers, it will create an enormous constituency for continued support of distributed renewable energy development and distributed solar in particular. As an illustration, the following residential rooftop solar installation might have the capacity to produce 3 kW of electricity, but the two adults likely to live in the residence represent two solar voters.



Which matters more? 3 kilowatts or 2 solar voters?

Photo credit: Pete Beverly (NREL PIX)

Positive Policy Changes

From outdated technical rules to local permitting to incentive policies, there are opportunities to increase the potential for local solar.

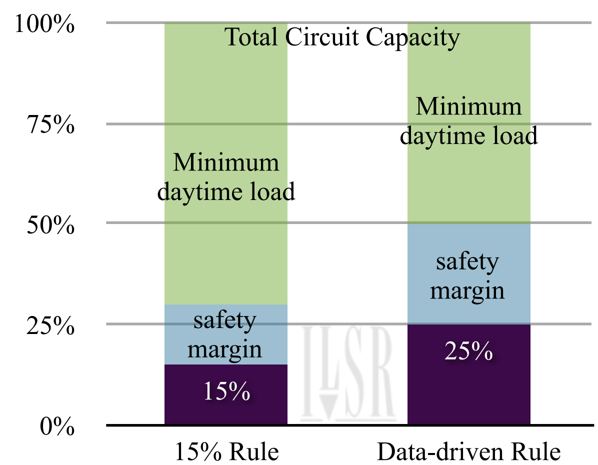
Technical Barriers

A prominent "technical" barrier is the so-called "15% rule." It's a rule adopted in many states that says that distributed renewable energy systems can only make up 15% of the peak energy demand on the portion of the electricity system that serves residential areas (called the distribution system). To go beyond the 15% limit, proposed solar power projects would have to complete complex and costly engineering reviews to connect to the grid, making more solar cost-prohibitive.[21]

The 15% rule was first adopted in California's "Rule 21" for interconnecting distributed generation in the year 2000. The 15% rule comes from an assumption and a simple calculation. It's assumed that the daytime minimum load on a distribution circuit (one strand of the local electric grid) is approximately 30% of the peak demand. This 30% represents the most solar capacity that could be installed on a distribution circuit without potentially producing more than the circuit's load. The 30% was divided in half as a safety margin, making the threshold 15% of peak load.

The 15% rule now governs most state distributed generation policies (and is part of FERC's Small Generator Interconnection Procedures) and has started to create problems in states with the most local solar power development, including Hawaii and California.

More Room for Solar on the Distribution System



However, the 15% rule may be too conservative. Research from the federal Department of Energy suggests that daytime minimum loads are likely closer to 50% of peak load, rather than 30%. This means that a more appropriate (and still very conservative) threshold for unintentional islanding is closer to 25% of peak load, rather than 15%.

Raising the threshold seems reasonable because potential impacts of high distributed generation penetration (such as maintaining a constant voltage on the grid) have not proven out.[22] In particular, there are several illustrations of the ability of the distribution grid to handle very high portions of solar PV generation, much more than the 15% rule:[23]

- *Kona, HI, has a 700 kW solar array that is 35% of the capacity of its distribution circuit, with no reported issues.*
- *Las Vegas, NV, has over 10,000 kW of commercial solar PV on a distribution circuit (50% of capacity, 100% during low load) with no reported issues.*
- *Atlantic City, NJ, has 1,900 kW of commercial solar PV on a distribution circuit (24% of capacity, 63% during low load) with no reported issues.*

Las Vegas, NV, has over 10,000 kW of commercial solar PV on a distribution circuit (50% of capacity, 100% during low load) with no reported issues

Energy storage is among other potential technical solutions to the 15% (or 25%) rule. Electric vehicle batteries or other storage connected to the distribution system could absorb some portion of solar electricity at periods of high production and low demand, and push the power back into the grid when it's needed. Research at the Department of Energy and many private companies continues to search for ways to maximize the penetration of distributed solar power with storage and electric vehicles.

Modernizing Policy Expands Distributed Solar Potential

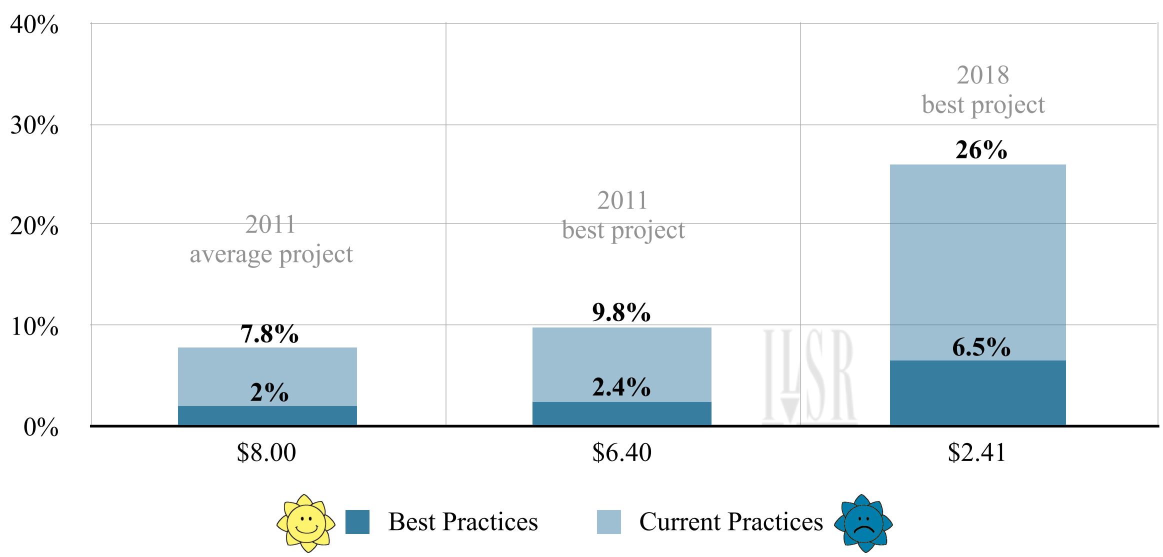
Local Permitting

Local permitting rules significantly increase the cost of installing solar projects, especially on residential property. In a study released in early 2011 by solar installer SunRun, permitting costs represented 8-10% of the total project cost ($6.40 per Watt) of typical residential solar projects (3-4 kW). At $4.00 per Watt (our estimate for the best possible residential solar installed cost today), these permit costs would be 16% of project costs for a 4 kW array. If nothing changes by 2018, when solar installed costs could fall to $2.41 per Watt, unchanged permitting policies would represent 26% of the price of a 4 kW solar array.[24]

> *Solar installers [in Minnesota] estimate that dealing with different local permitting processes, as well as installation and design and maintenance rules, make up 40 percent of the cost of a solar installation.*
>
> St. Paul Pioneer Press, 12/13/11

Fortunately, the Solar America Board of Codes and Standards has already developed a set of best practices that may significantly reduce the cost of permitting for solar projects. Their exhaustive list of strategies (such as expedited review based on a checklist, email rather than in-person permit submission, etc) can reduce permitting costs by 75%, giving a very different picture.

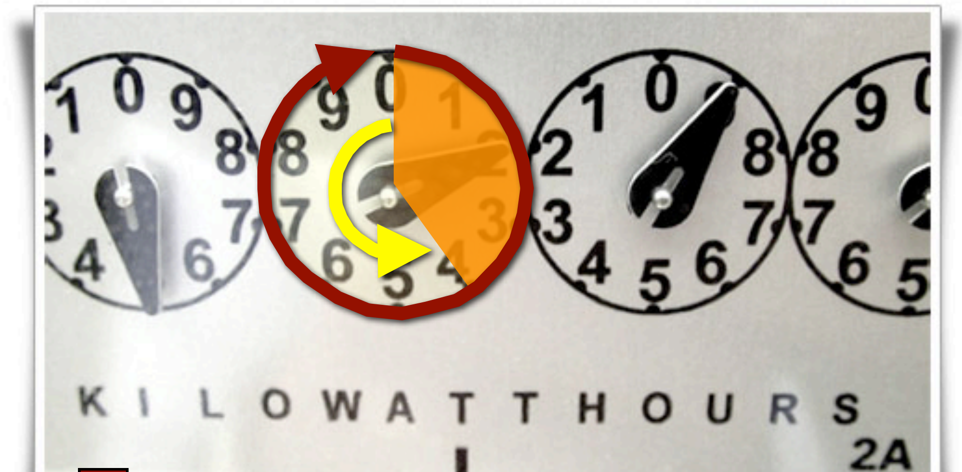
Best Practices Can Significantly Lower Solar Permitting Costs (% of Installed Cost for 4 kW)



Net Metering

Another potential barrier to fulfilling the potential of solar grid parity are limits on and limitations of net metering. Net metering laws in 43 states allow for on-site solar power producers to rollback their electricity consumption. For every kilowatt-hour (kWh) offset by on-site solar, the customer saves the retail charge for electricity, e.g. $0.10 per kWh. The following chart provides a simplified example, where the customer uses 100 kWh in a month, but because their solar array produces 60 kWh, they only pay for the "net" consumption, 40 kWh.

Net Metering Explained (on an electric meter)



Total electricity use

Solar energy production

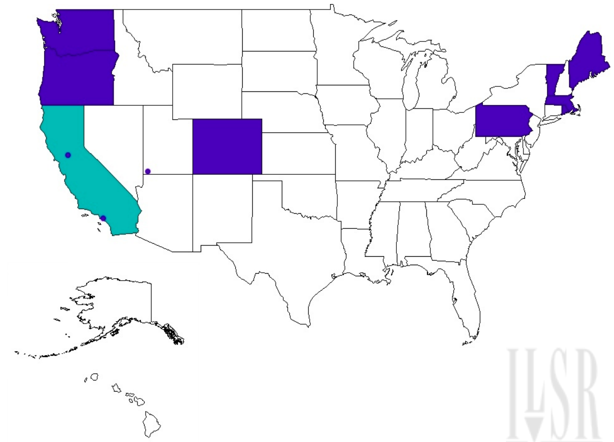
"Net" use (what customer is billed for)

In general, customers using net metering get paid the retail rate for solar electricity so long as production does not exceed on-site consumption (by very much). The advantage of net metering is that people generally find a combination of energy efficiency and solar power that minimizes their electric bill, and the accounting is all handled by the utility using a single meter.

Net metering has political advantages as well. Since it doesn't require any public money (but instead requires the utility to provide the accounting measure), it feels free.

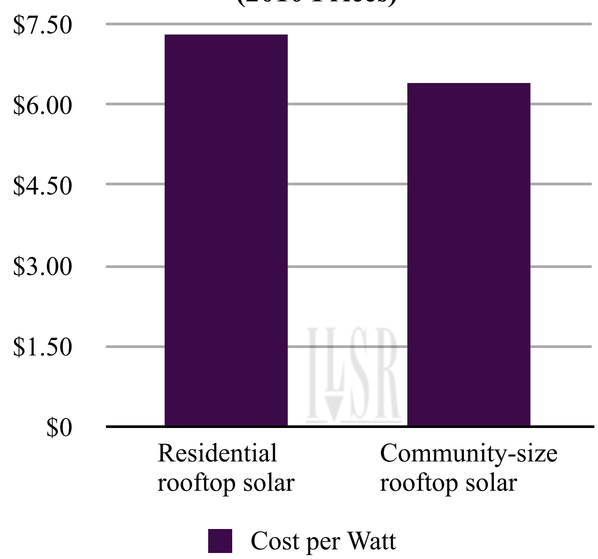
One drawback of net metering is that a person must own a suitable, sunny rooftop or open space to install solar. Since only two-thirds of residential properties are owner occupied, and scarcely 25% of residential rooftop space is suitable for solar,[25] that significantly shrinks the potential universe for solar power. Additionally, net metering can encourage sub-optimal economies of scale for distributed solar. Since people who regularly produce more solar electricity than they use on-site get paid a very low rate for that power (rather than the retail electricity rate), it discourages people from maximizing the size of their solar project. And with steep economies of scale at small project sizes, this means the social cost of solar power is higher with policies that cap project sizes (net metering) than with those that do not.

Community Net Metering Provisions (2010)



One policy solution to this net metering limitation is generically called community solar. At its simplest, community solar policy means "community net metering." This policy, adopted by seven states and a number of individual utilities as of 2010, allows customers to build a common solar panel array and share the output via net metering on their individual bill. For example, the electricity from a 30 kW solar array on a nearby church could be shared among ten local owners, each receiving a share of the electricity output in proportion to their ownership share. The accounting is identical to net metering, minus the on-site solar. Customers still cannot get credit for significantly more solar electricity than they consume, but they do not need to have a sunny rooftop.

Community Solar Captures Economies of Scale (2010 Prices)



Community net metering is simply an accounting measure, but it can provide a way for many people to share the electricity output from a single solar array in their community, and make centrally located community solar projects possible. In addition to opening the door to solar for folks without suitable rooftops, by allowing people to share larger solar arrays it can also modestly reduce the cost of going solar. The following chart illustrates the economies of scale of solar power installed in the U.S. To use the example of a church rooftop array, it's possible to see the cost savings from sharing a 30 kW array with a typical cost of $6.50 per Watt compared to 10 individual 3 kW arrays at $7.30 per Watt.[26]

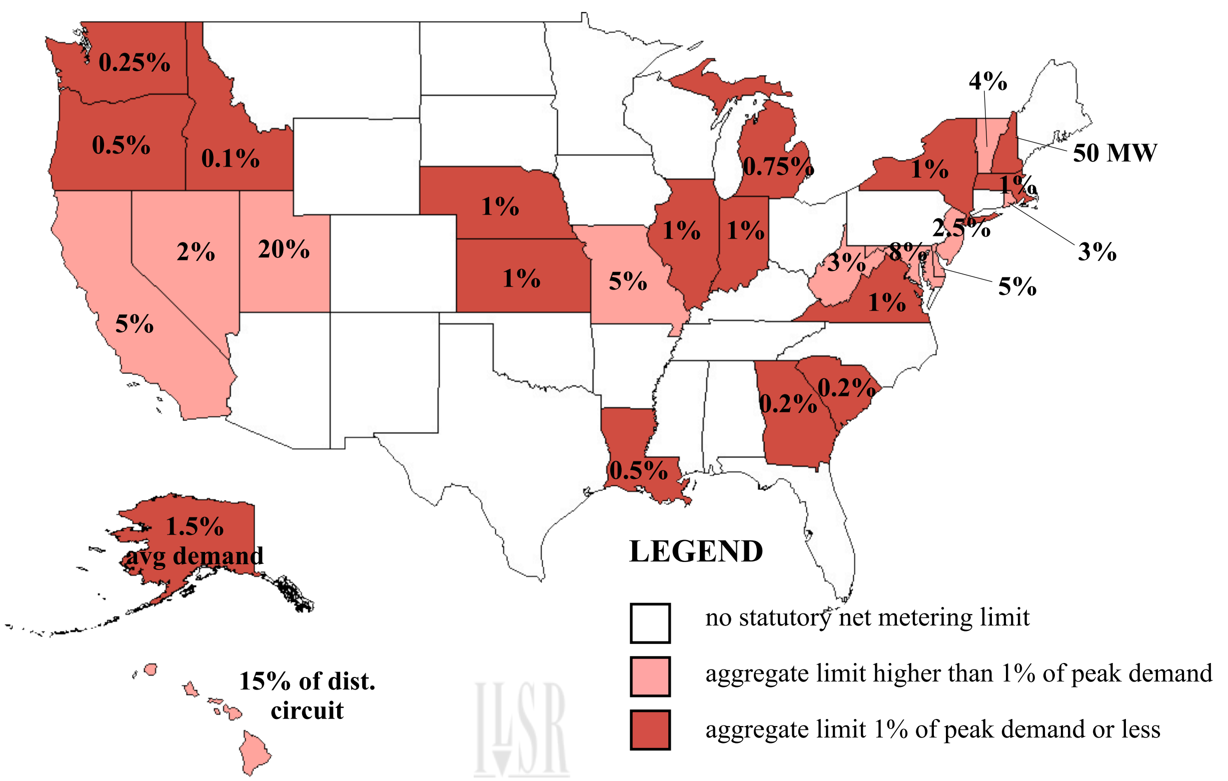
In one state, Colorado, a new state law has established a legal framework for community solar projects called community solar gardens. These gardens are solar projects 2 MW or smaller with 10 or more "subscribers" sharing the solar output. Utilities must buy the output from up to 6 MW worth of community solar projects by 2013.[27]

Community Solar Helps People Overcome Net Metering Limitations

Photo credit: http://www.flickr.com/photos/aaronknox/5006491776/sizes/z/in/photostream/ (left); Clean Energy Collective (right)

Another drawback of net metering is that it is often limited on a system-wide basis in many states, to a certain percentage of a utility's load or peak load. California, for example, requires utilities to accept up to 5% of their peak demand from net metering, but no more.[28] Most states limit net metering to 1% of a utility's peak demand or less. The following map shows states with an aggregate net metering limit.[29] States in dark red have limits 1% or less and states in light red have limits that are higher. States with no color have no statutory limit on net metered systems.

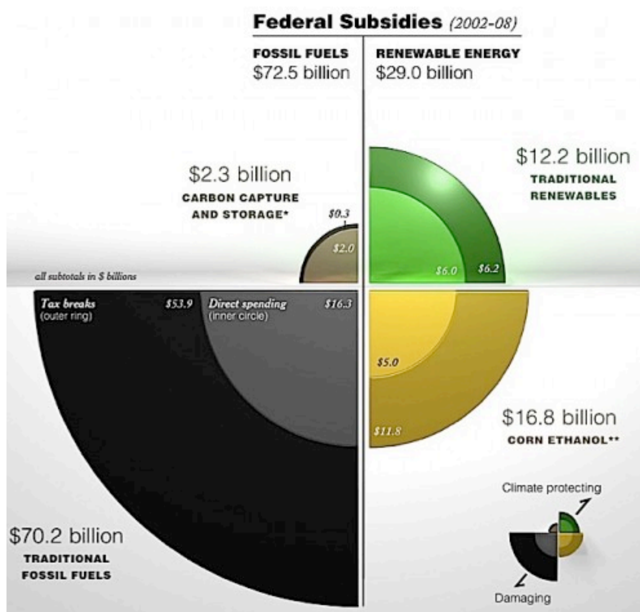
States with Aggregate Demand Limits on Net Metering



Fortunately, states can change their aggregate limits, as California did in 2006 (to 2.5%) and 2010 (to 5%).[30] However, there's no guarantee of a sufficiently favorable political environment in other states.

Planning for Phasing Out Incentives

The success of solar is remarkable, no less because the amount of federal subsidy in absolute terms has been far less for renewable energy than for fossil fuel resources (see adjacent graphic).[31] As the cost of solar drops toward – and below – grid parity, the question is how to adjust solar subsidies appropriately. Should they be eliminated immediately? Phased out? Or shifted from reducing the upfront cost to some other solar-boosting strategy?



Eliminating solar subsidies makes little sense as it could severely constrain the expansion of solar just as it becomes grid competitive. It will mean short-term grid parity for the sunniest (or most expensive electricity) regions and leave the rest of America out in the cold for many years, hardly a prescription for increasing clean energy and democratizing the electricity system. It could also severely damage the domestic solar industry with a boom and bust cycle, a poor return for one of the few growth industries in the recent economic downturn. It also makes little sense for Americans to be providing incentives for established fossil fuel industries that make billions in profits each year.

But keeping solar subsidies unchanged also seems senseless. Solar developers in sunny regions like California or high electricity price areas like New York would get out-sized returns from installing solar even as solar reached grid parity in the rest of the country. Furthermore, the tax incentive system continues to create friction by preventing cities, schools and other non-taxable entities from using federal incentives.

The guiding principle for solar subsidies should be to continue the enormous strides toward democratizing the electricity system by maintaining the growth of distributed solar while maximizing local ownership and economic benefit.

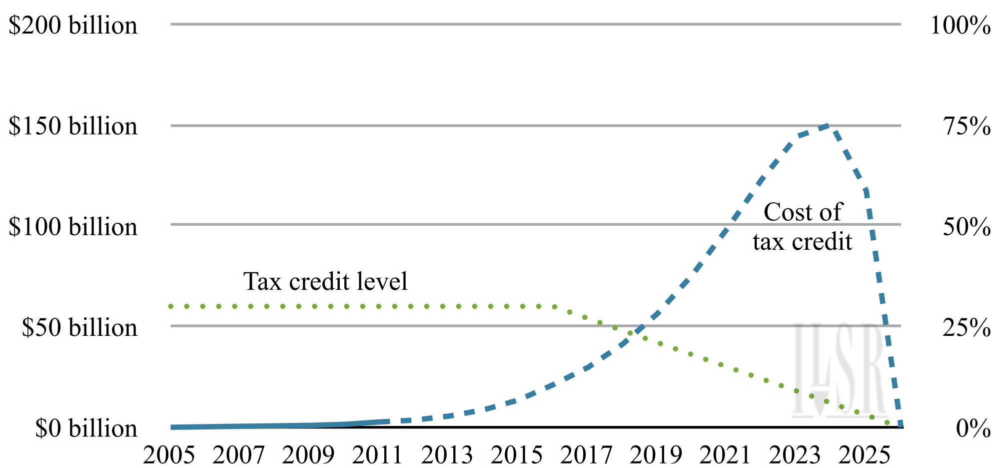
One strategy would be to shift away from the tax code. The use of the tax code for solar incentives has long discriminated against solar for schools or libraries (and other public buildings) because these entities don't pay taxes. The public-private partnerships required to make use the tax credits have inevitable transaction costs that mean public solar can never quite compete with private solar and that also water down the value of federal money for solar.[32]

One option is to shift to a refundable tax credit, allowing those who are eligible for tax credits to take the full value whether or not they have sufficient tax equity. A better step would be to shift away from tax credits entirely, using cash payments. Research has shown that federal taxpayers can get twice the solar for each dollar of solar subsidy given in cash rather than credit.[33]

Shifting from Tax-Based Incentives to Cash Means More Solar

The solar subsidy level should also be reduced (assuming costs continue to decline) when the current tax credit expires in 2016. Reducing the 30% incentive by 3 percentage points per year would allow moderately sunny areas to continue solar growth without over-rewarding the sunniest regions. The incentive would expire fully at the end of 2026 (the year before Seattle finally reaches grid parity). The following chart shows that even with exponential growth in solar installations, a phase out would cap the impact on taxpayers.

Cost of Federal Solar Subsidy with Phase Out



The phase out could be further enhanced by linking the subsidy cuts to the number of solar installations, price indices or the local solar resource. Strong market performance could reduce prices faster while slow growth could mean slower price decreases. Flat electricity prices or a plateau in solar costs could slow the phase out, while high price inflation or large decreases in the cost of installing solar could accelerate it. Sunny areas like Los Angeles could have the tax credit immediately cut to 10% in 2017, while less sunny areas like Ohio could keep the 30% credit a bit longer.

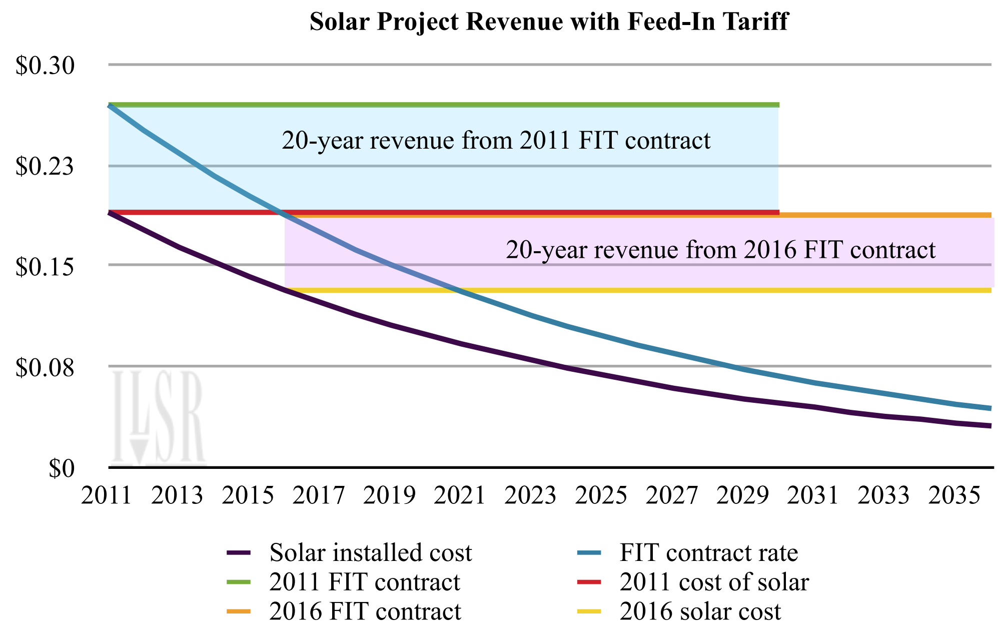
Many of these concepts are already included in one of the world's leading solar policies: a feed-in tariff.

The Feed-In Tariff

The intersection of electricity and solar prices and the need for new policy provides an opportune moment to consider changing American solar policy to match what is used in the most advanced solar economies. Three of the top four solar nations and nearly 90% of the world's solar capacity has been installed with a policy called a feed-in tariff.[34]

This solar financing tool is not a tax credit, but is a combination of a long-term contract, a guaranteed grid connection, and a contract price sufficient for a modest return on investment. The contract provides secure financing for solar projects, reducing borrowing costs and the total cost of solar electricity.

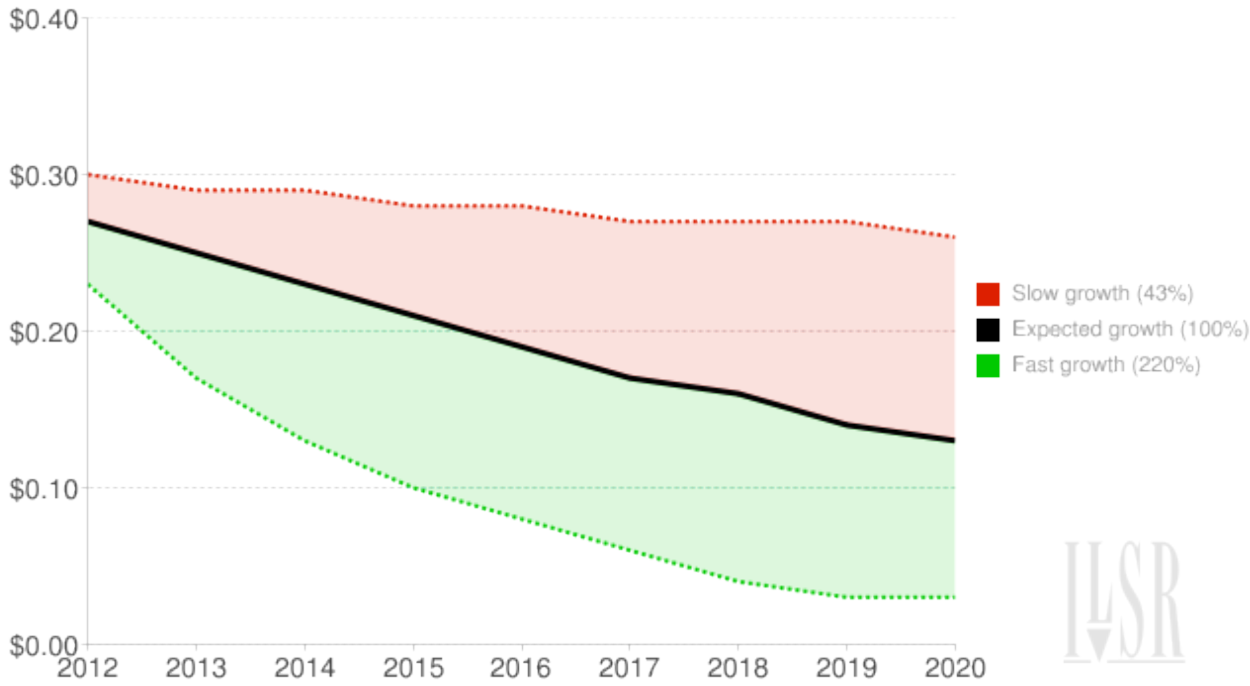
The following chart illustrates the concept. A project with a feed-in tariff (FIT) contract in 2011 gets paid a fixed rate per kWh over 20 years (the green line). The project's revenue is higher than the levelized cost of solar (red line), and the area between these lines indicate the project's return (blue shaded region). Since the feed-in tariff contract price falls each year, by 2016 an eligible solar project would get a much lower payment (orange line), commensurate with the falling cost of solar (yellow line). The project's return on investment is the area between the two (pink shaded region).



Feed-in tariffs provide several potential advantages over a tax credit.

Unlike the federal tax credit, feed-in tariff contract prices follow the falling cost of solar. Without change, the federal tax credit could offer very high margins to solar power developers in Southern California and other places where inexpensive solar competes with expensive electricity. But the contract price of the German feed-in tariff continues to fall each year, in accordance with the size of the solar market (much like California's Solar Initiative production incentive). When the market is particularly strong, the price falls faster; if the market is weak, the price declines slower, creating a "growth corridor." The following chart illustrates the concept.

"Growth Corridor" Provides Market Input to German Solar Subsidies



This may also prove useful as solar grows substantially. Right now, solar demands a price premium because it can deliver electricity when utilities need it most – on hot, sunny afternoons. But with critical mass, solar can erase utility price peaks, undercutting the time-of-day advantage. A feed-in tariff can provide price stability for solar producers.[35]

Second, the German feed-in tariff has been changed in recent years to encourage more on-site use of solar power. Individuals and businesses with on-site solar can install a separate meter to track actual on-site use of solar electricity produced from their array, and receive bonus payments if it serves a higher portion of their load. The Germans hope the policy will encourage the installation of on-site storage, because the more electricity is kept on-site, the higher the payments. In contrast, American net metering policy simply reconciles solar electricity production with grid electricity consumption, on-site use is coincidental.

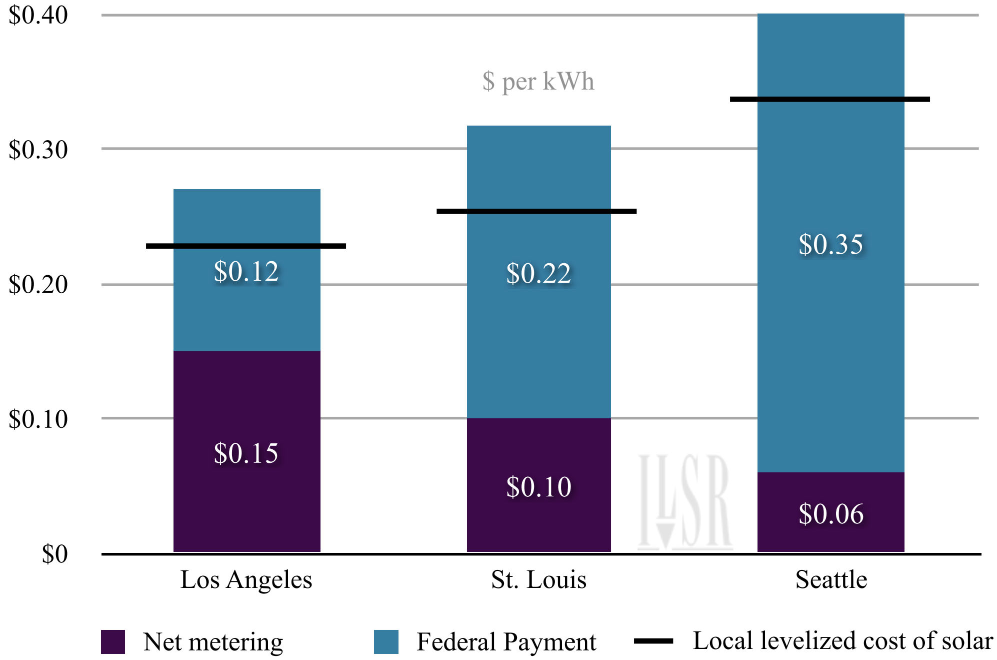
The feed-in tariff also solves the tax credit problem for the public sector, because the long-term contract is available to anyone, not just taxable entities or large corporations with tax equity. It also allows more individuals to install and finance solar without needing a solar leasing arrangement (although that remains an option). This can increase local ownership of solar, and with it, the economic value of distributed solar power for communities it serves.

Production Payments ("Feed-In Tariff Lite")

Since there are potential legal and political hurdles to implementing a full feed-in tariff program in the United States, a compromise policy might be a "Feed-In Tariff Lite." Instead of providing the full contract price, the existing federal solar subsidy could be converted to a production payment that would cover the difference between a regionally appropriate contract price for solar (sufficient for the owner to earn a modest return on investment over 20 years) and the local net metering rate.

The following chart illustrates how the payments would be relatively small in regions with ample sun and high electricity prices (and net metering rates). Payments would be larger in places like Seattle, where cheap electricity and more moderate sunshine dominate.

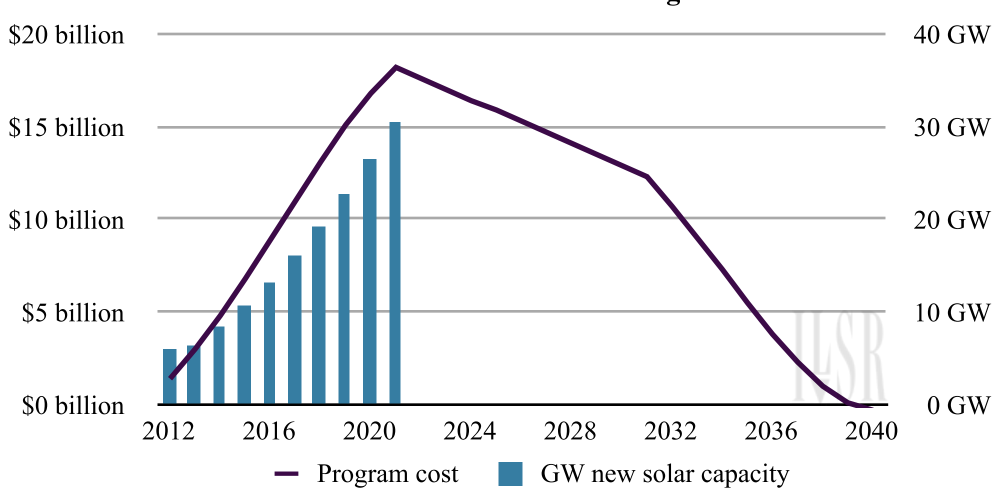
Mechanics of a Federal Production Payment or "Feed-In Tariff Lite" (20-year contract price)



Since the value of net metering tends to rise with electricity prices (2% per year in our assumptions) and the cost of solar is falling (at 7% per year), using this program won't be particularly expensive. If the federal government provided the margin for solar projects on a 20-year contract, and supported every solar project in the next 10 years based on the growth expectations we used earlier, the program's peak cost would be under $20 billion in 2021, supporting 160 gigawatts of solar. This is in comparison to the current 30% tax credit, which cost over $3 billion in 2011, in support of 1.7 gigawatts of solar.

The following chart shows the cost of the FIT Lite program over the next 30 years (projects coming online in 2021 would have contracts through 2040). We used the cost of solar and net metering rates for St. Louis as a proxy for the entire country.

Federal Cost of FIT Lite Program



Conclusion

The explosive growth of solar power has created a convergence of solar and grid electricity prices. Within the next few years, millions of Americans will have a local, cost-effective, and cleaner alternative to grid electricity.

The coming of solar grid parity opens an enormous opportunity for democratizing the electricity system via thousands of distributed solar power systems. Unlike traditional electricity generation – centrally planned and centrally owned by large, private utilities – solar on residential rooftops across the United States can open the electricity system to widespread ownership of decentralized solar energy systems. The economic benefits of the transformation would likewise be widely spread.

Technical and political barriers remain, but are surmountable.

The most serious barrier is the potentially serious disruption posed by the looming expiration of the federal 30% tax credit (in 2016). A thoughtless extension will enrich solar developers at the expense of taxpayers; an abrupt expiration will seriously affect the solar market in the many regions that have not reached solar grid parity by 2016. A hybrid policy approach is needed, whether to phase out the federal tax credit in a fashion that is geographically equitable or to shift to a feed-in tariff strategy to be more comprehensively prepared for the economic issues of grid parity.

Guidelines for limiting distributed generation on local electricity systems can be modernized, vetted by data from actual solar power plants, and the limits raised. Already, public utility commissions are considering changes to the 15% rules to allow more solar power on distribution systems, and further research may reveal even greater potential without significant upgrades to the electric distribution system.

Policies like net metering have provided a simple accounting method for financing on-site solar power and can be improved by allowing for community net metering, lifting aggregate demand caps, and providing policy alternatives like feed-in tariffs.

The coming of solar grid parity portends an enormous opportunity for citizens to become more energy self-reliant, to become power producers themselves, and to transform the grid to a decentralized and democratized electricity system.

Appendix

Top 42 Metropolitan Areas of the U.S., by Population

Although in the text we refer to the "Top 40 metropolitan areas," in this analysis we actually used the top 42, because their cumulative population is just over half the national population. The list is at Wikipedia (see endnote).[36]

Year of Grid Parity by Three Measures

The following tables provide detail for the charts showing the cumulative population at grid parity in the major metropolitan areas, by our three measures (average grid prices, time-of-use prices, and economic grid parity). Metropolitan areas are listed next to the year they reach residential solar grid parity (through 2021), along with the cumulative U.S. population that represents.

Population at Solar Grid Parity in Next 10 Years (using Average Grid Prices)

Year of Grid Parity	Metropolitan Area	Cumulative Population
2013	San Diego, CA	3.1 million
2015	New York, NY	22 million
2017	Los Angeles, CA San Francisco, CA Riverside, CA San Jose, CA	45.1 million
2018	Sacramento, CA Phoenix, AZ	51.4 million
2019	Dallas, TX Las Vegas, NV	59.8 million
2020	Philadelphia, PA Boston, MA Tampa, FL Denver, CO Orlando, FL Austin, TX Providence, RI	81.1 million
2021	Houston, TX Miami, FL San Antonio, TX	94.7 million

Population at Solar Grid Parity (Time-of-Use Grid Prices)

Year of Grid Parity	Metropolitan Area	Cumulative Population	Year of Grid Parity (Avg. grid price)
2011	San Diego, CA	3.1 million	2013
2012	New York, NY	22 million	2015
2014	Los Angeles, CA San Francisco, CA San Jose, CA Riverside, CA	45.1 million	2017
2015	Sacramento, CA	47.2 million	2018
2016	Dallas, TX Phoenix, AZ Las Vegas, NV	59.8 million	2018-19
2017	Philadelphia, PA Boston, MA Tampa, FL Orlando, FL Austin, TX Providence, RI	78.6 million	2020
2018	Houston, TX Miami, FL Denver, CO San Antonio, TX	94.7 million	2020-21
2019	Charlotte, NC Jacksonville, FL	97.8 million	2022 or later
2020	Chicago, IL Washington, DC Atlanta, GA Detroit, MI Minneapolis, MN St. Louis, MO Baltimore, MD Cleveland, OH Kansas City, MO Virginia Beach, VA Milwaukee, WI Memphis, TN	140 million	2022 or later
2021	Pittsburgh, PA Cincinnati, OH	144 million	2022 or later

Population at Solar Economic Grid Parity (Based on TOU Grid Prices)

Year of Grid Parity	Year of Grid Parity (TOU)	Metropolitan Area	Cumulative Population
now	2011-12	San Diego, CA New York, NY	22 million
2012	2014	Los Angeles, CA San Francisco, CA Riverside, CA San Jose, CA	45.1 million
2013	2015-16	Sacramento, CA Phoenix, AZ	51.4 million
2014	2016	Dallas, TX Las Vegas, NV	59.8 million
2015	2017-18	Boston, MA Providence, RI Philadelphia, PA Miami, FL Tampa, FL Denver, CO Orlando, FL Austin, TX	86.7 million
2016	2018-19	Houston, TX San Antonio, TX Jacksonville, FL	96 million
2017	2019-20	Charlotte, NC Virginia Beach, VA	99.5 million
2018	2020	Chicago, IL Washington, DC Atlanta, GA Detroit, MI Minneapolis, MN St. Louis, MO Baltimore, MD Cleveland, OH Kansas City, MO Milwaukee, WI Memphis, TN	140 million
2019	2021-22	Pittsburgh, PA Cincinnati, OH Columbus, OH Nashville, TN	148 million
2020	2022	Indianapolis, IN Louisville, KY	151 million
2021	2023	Portland, OR	153 million
2022	2025	Seattle, WA	157 million

The Cost of Solar

In general, the parameters of this grid parity analysis err on the side of conservative. For one, we largely used the average retail electricity price for comparison, despite the fact that many utilities could implement time-of-use prices that would better reflect the value of solar during period of peak electricity demand. In a few states, most prominently California, TOU pricing can increase the value of solar electricity from 5 to 200% or more.[37] Furthermore, it's possible to make a return installing solar prior to grid parity, because the lifetime savings will still exceed the cost of the system.

Secondly, the estimated lifetime of a solar array for this analysis is 25 years, despite ample evidence that solar panels can still produce over 80% of their original annual output after that time period. If calculated over 30 or more years, the cost of solar is significantly lower.

The only issue hanging over our cost estimates is the potential demand for backup or energy storage to support a significant distributed solar market. While research suggests that dispersion of solar power production over a wide geographic area can smooth output variations from weather, solar power doesn't work when the sun goes down. Until solar reaches the 15% threshold, however, few places in the electricity system will require additional backup or storage. As more renewable energy has come onto the grid in recent years, utilities have shown an interest in backing down output from coal and natural gas power plants. As the latter have additional capacity, they can be used to firm up output from many distributed solar arrays.

Other Studies of Rooftop Solar PV Potential

We aren't the first to estimate the potential for rooftop solar in major U.S. cities. To validate our estimates of residential rooftop, we found five other studies of rooftop solar potential. The results of these studies are listed below along with our estimate. Where possible, we included the figure for residential rooftops (if so, the study result is in italics). See below for more detail.

	Rooftop Solar Potential Study Results (MW)					**Our Estimate**
City	Megawatts	MW per 10,000 ppl	% of peak	GWh per year	% of sales	Megawatts
San Diego	*2,770*	9.3	110%	6,300	51%	1200
New York	5,850	7.3	50%	7,096	14%	10,500
San Francisco	378	4.7	35%	547	9%	1,700
Seattle	7,500	133	407%	7,400	79%	1,070
Austin	2,446	24	84%	3,300	28%	1,090

San Diego County

Anders, Scott, et al. Potential for Renewable Energy in the San Diego Region. (San Diego Regional Renewable Energy Group, August 2005). Accessed 12/7/11 at http://tinyurl.com/7k9qby6.

- Population of 3 million
- Residential rooftop solar potential of 2772 MW (AC), 6310 GWh per year
- Commercial rooftop solar potential of 1624 MW (AC), 3263 GWh per year
- Total: 4400 MW (>100% of peak demand) for 9,600 GWh per year (50% of energy sales)
- SDG&E peak demand in 2004 was 4,065 MW with energy sales of 19,000 GWh

New York City

Navarro, Mireya. Mapping Sun's Potential to Power New York. (New York Times, 6/16/11). Accessed 12/12/11 at http://tinyurl.com/7j2llmk.

- City population of 8 million
- Two-thirds of city rooftops could sport solar PV, generating 5850 MW. Half of peak demand, and 14% of year-round consumption.

San Francisco

Garbesi, Karina, PhD, and Emily Bartholomew. The Potential for Solar Electricity Generation in San Francisco. (Environmental Law and Justice Clinic of Golden Gate University Law School, 6/1/01). Accessed 12/12/11 at http://tinyurl.com/6svn2qs.

- Population of 805,000
- Low-end estimate of 547 GWh per year (378 MW based on PVWatts estimate of 1446 kWh per kW of DC capacity)
  - horizontal, not tilted panels
  - Rooftop space found by estimating 35% of land covered by buildings (average city-wide), a total rooftop area of 36 million sq. meters, with 5-30% availability. Low end estimate was ~15%.
- City electricity consumption of ~6000 GWh per year, peak demand estimated at 1077 MW for 2012.[38]

Seattle

Liddell, Ryan. Estimating Rooftop Solar Electricity Potential in Seattle from LiDAR Data. (Presentation to Northwest GIS Users Group, October 17 - 21, 2011). Accessed 12/12/11 at http://tinyurl.com/6uar3fl.

- 563,000 population
- 26 TWh per year potential
- Study assumes 30% of rooftop space is unusable. Change assumption to 80% unusable, and it's 7.4 TWh potential (79% of production).
- City uses 9.4 million MWh per year (city utility, EIA), peak demand of 1845 MW

Austin

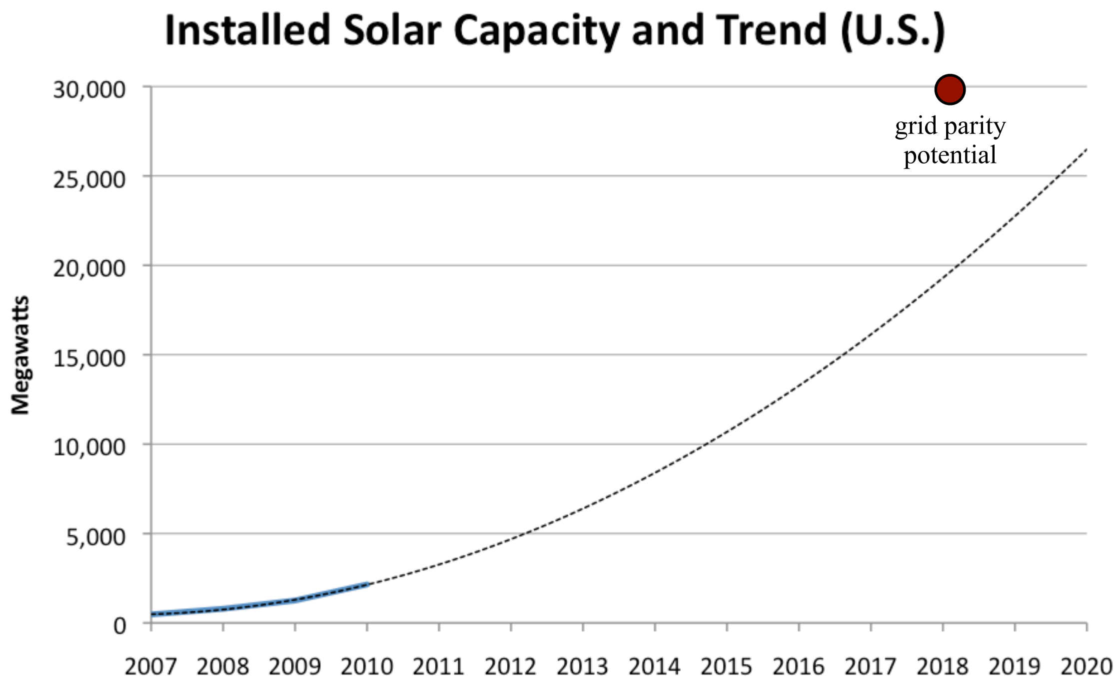
Wiese, Steve, et al. A Solar Rooftop Assessment for Austin. (American Solar Energy Society, 2010). Accessed 12/12/11 at http://tinyurl.com/6wg6tnw.

- 1 million people in service territory
- 536 million s.f. of rooftops
- 204 million s.f. suitable for PV
- 142 million s.f. estimated
- 2,446 MW (84% of existing power plant capacity) for 3.3 TWh per year (28% of existing energy use)

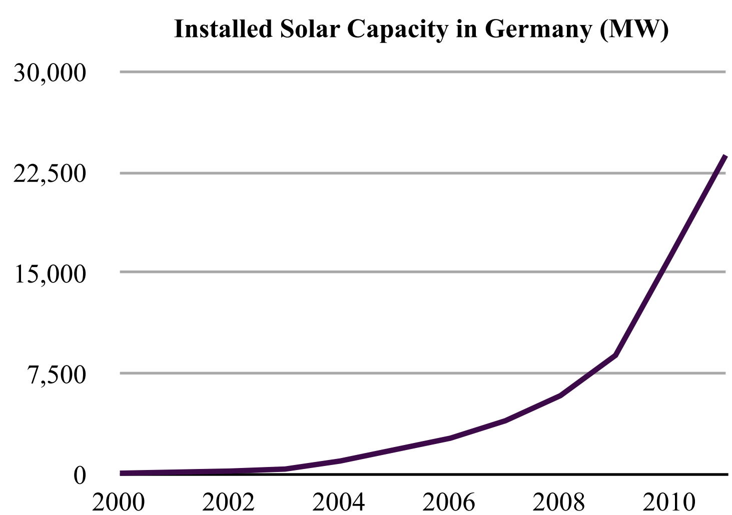
Solar Installation Capacity

While the converging cost of solar and electricity suggest a forthcoming explosion of solar power, competitive cost is just one of several hurdles that solar power must overcome. Sufficient labor and manufacturing must keep pace with exponentially increasing demand for solar power installations. The electricity system may have to adapt to overcome technical limitations. And various interest groups, including incumbent utilities, present political opposition to widespread democratization of the electricity system.

By 2018, 1 in 6 Americans will live in a major metropolitan area at solar grid parity, with a potential universe of 30,000 MW of rooftop solar on residences (sufficient capacity to supply over 2.7% of residential electricity needs).[39] The following chart shows the growth in U.S. solar capacity from 2007-10 and a best fit line through 2020. The trend line is based on the installation trend with the federal (state and local) solar subsidies in place.



Could installations in the U.S. accelerate beyond their current, torrid pace to meet this potential? Evidence from Germany suggests that they could. From 2000-2010, the German market grew enormously, from annual installations in the tens of megawatts to over 7,000 megawatts per year. On a per capita basis, Germany installs as much solar per year (35,000 MW) as the U.S. would need in total (30,000 MW) to reach its residential solar grid parity potential in 2018.



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Cover photo: http://www.flickr.com/photos/briankusler/23331054/sizes/l/in/photostream/

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Note: actual government estimates of the cost of the tax credit revealed estimates that it would cost less than $50 million per year. See: Staff of the Joint Committee on Taxation. Estimates of Federal Tax Expenditures for Fiscal Years 2010-2014. (Prepared for the House Committee on Ways and Means and the Senate Committee on Finance, 12/15/10). Accessed 1/4/12 at http://tinyurl.com/44atzuz.

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[15] *Net present value compares the "present value" of revenues and expenses over time, adjusting those figures for inflation and a discount rate. A discount rate is a method of accounting for the fact that people value a dollar given them today more than one given in a month.*

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