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Local Self-Reliance

IS BIGGER BEST IN RENEWABLE ENERGY?

CONVENTIONAL WISDOM SUGGESTS THE BIGGEST WIND AND
SOLAR POWER PLANTS WILL BE CHEAPEST, BUT WHERE THEY
DELIVER POWER, AND WHO WILL OWN THEM, MATTERS MORE

John Farrell - September 2019 Re-release

ACKNOWLEDGEMENTS



Thanks to David Morris for his thoughtful review and to the many researchers at the National Renewable Energy Laboratory and Berkeley Labs for their excellent data on the wind and solar markets. All errors are my own. John Farrell, jfarrell@ilsr.org

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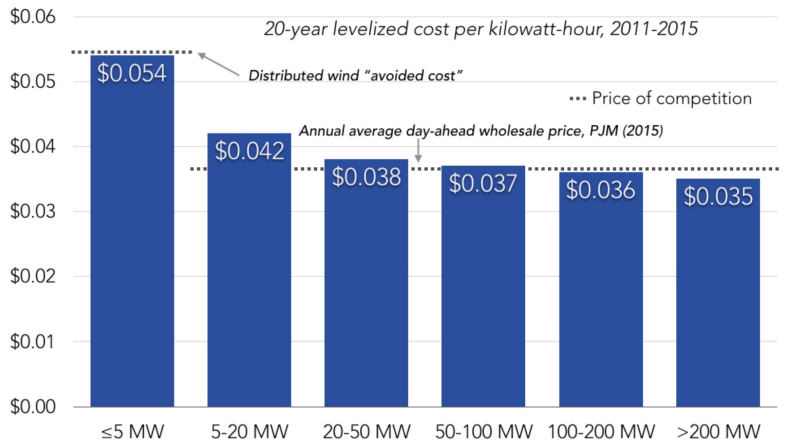


EXECUTIVE SUMMARY

Limits to Scale Economies in Wind Power

- Most of the economies of scale in producing wind electricity are from scaling up from one to two turbines to about ten turbines.
- Local delivery of distributed wind can compete with avoided costs at the distribution level just as large projects can compete at the wholesale level.

WIND PRICES V. THE MARKET

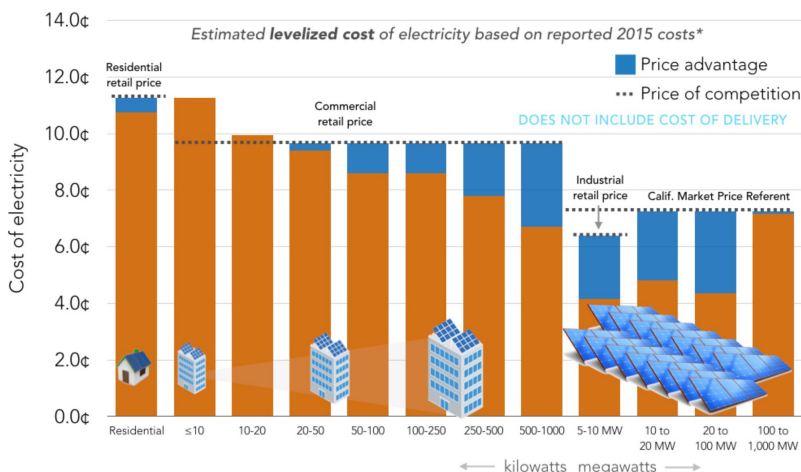


Source: Wind Technologies Market Report



Limits to Scale Economies in Solar Power

SOLAR COMPETES AT MOST SIZES



Sources: Tracking the Sun IX and Utility-Scale Solar 2015 (SunShot, Berkeley Labs); EIA (2014 data); CPUC (2011); NYMEX (2016); ILSR



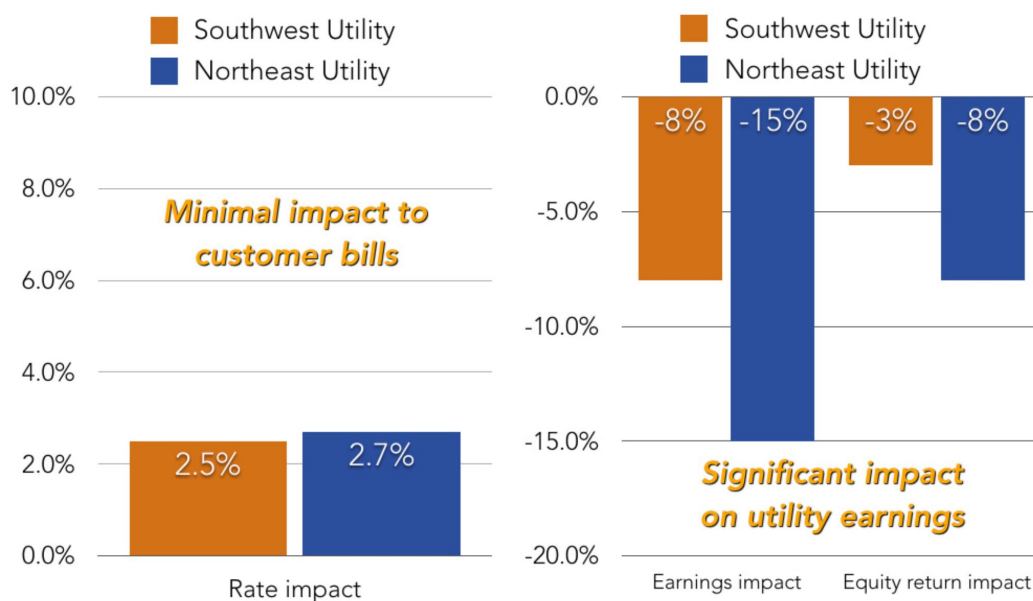
- Solar power is competitive at nearly any scale, if compared to the price of its competition (note: figures for large-scale solar do not include transmissions costs).
- Community solar projects may hit the sweet spot for competitive solar, capturing economies of scale but delivering power locally.

EXECUTIVE SUMMARY

Why Economics Isn't the Issue

- The proper size of solar is a proxy fight: distributed solar isn't at odds with utility-scale solar as much as it runs counter to the traditional utility business model.
- The question is whether our regulatory and business models can use 21st century technology to create an efficient and reliable electricity system where profits from participating are distributed according to their value to the system, rather than a legacy of monopoly control.

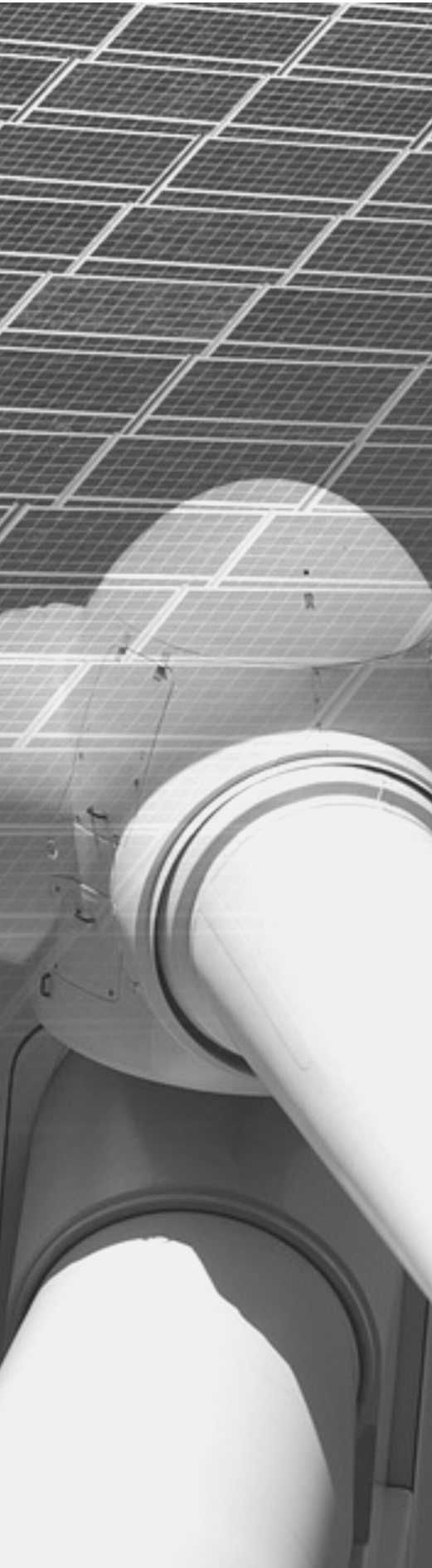
BOTTOM LINE OF 10% CUSTOMER-OWNED SOLAR



Source: *Financial Impacts of Net-Metered PV on Utilities and Ratepayers: A Scoping Study of Two Prototypical U.S. Utilities* (NREL, 2014)



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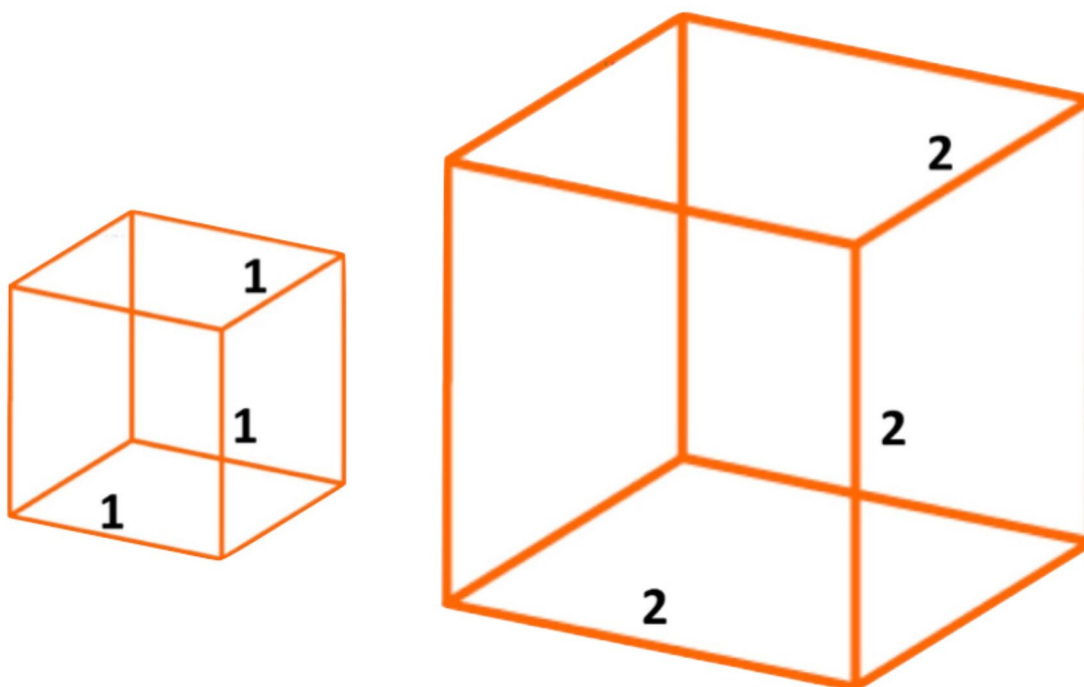
Despite an American fascination with big things, economies of scale don't dominate renewable energy.

34 **SUMMARY**

INTRODUCTION: THE SAVINGS OF SIZE?

For nearly a century, it's been considered conventional wisdom that larger-scale power generation means lower-cost electricity. This wisdom is built on two basic theories of economies of scale: volume and mass production. In electricity, only one still holds.

The economies of scale of volume stems from the simple fact that larger containers (boilers, storage bins, etc.) are more cost-effective. This simple illustration explains how materials costs don't rise as fast as the volume of a container. The box on the left has a volume of $1 \times 1 \times 1 = 1$ cubic foot. To assemble the box, you need 6 square pieces of material, each with an area of 1, for a total of 6 square feet. The box on the right has a volume of $2 \times 2 \times 2 = 8$ cubic feet. The larger box can be assembled of 6 square pieces, each with an area of $2 \times 2 = 4$ square feet, for a total of 24 square feet. We've increase the volume of our container 8-fold, with only a 4-fold increase in material costs.



Volume	1 cubic foot	8 cubic feet	<i>8 times bigger</i>
Materials required	6 sq. feet	24 sq. feet	<i>4 times more material</i>

Imagine the larger box as the bigger boiler in a coal or oil power plant. As power plants became bigger in the first half of the 20th century, they captured this economy of scale in materials.

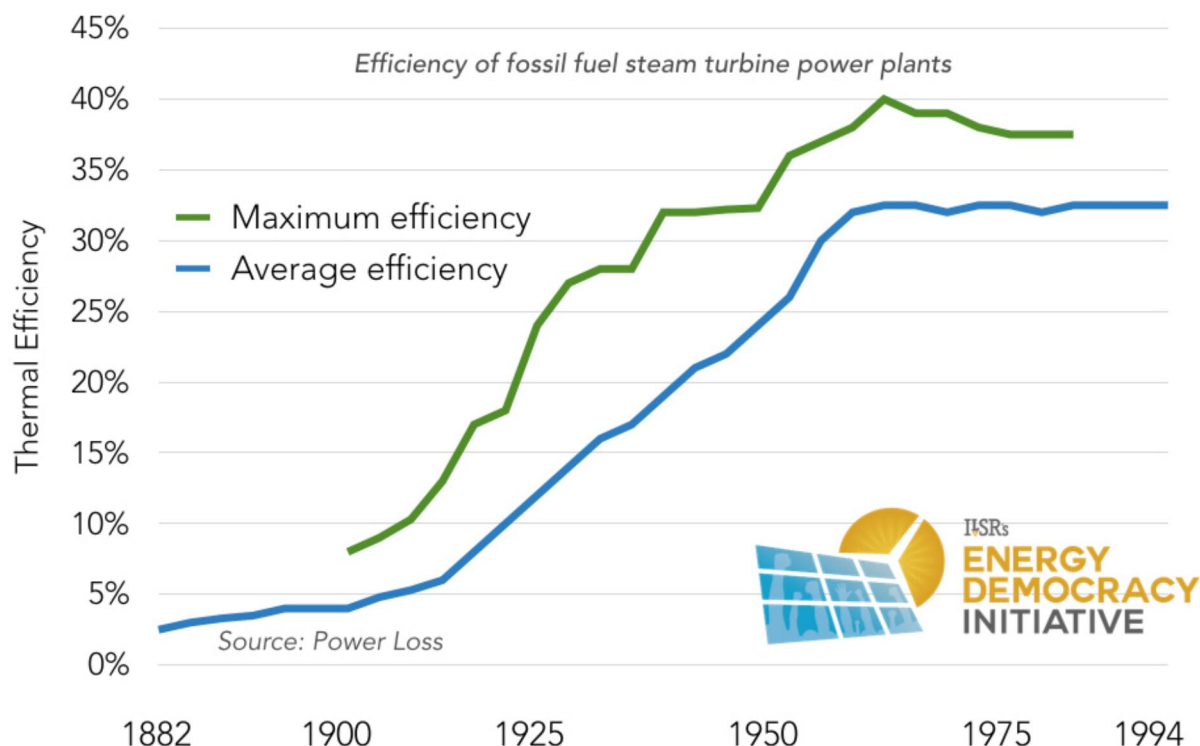
The second economies of scale theory is that the average cost of a product decreases the more you make of it. This takes into account the scale economies in material costs (in building the factories), but also the notion that some overhead costs (such as annual registration fees, insurance, etc) are fixed or grow more slowly than the total output of a business.

Both of these theories were well supported by data in the early years of electricity generation in the 1900s, with coal, oil, and then nuclear power plants producing lower cost power from larger sized plants. The advantage to size also supported the conventional wisdom of monopoly utilities. Big power plants required large amounts of capital, and capital markets offered lower interest rates to companies that did not have the risk of competition for their ever-larger power plants.

**AFTER DECADES OF SUCCESS, THE
“BIGGER-IS-BETTER” MANTRA STOPPED
GENERATING RETURNS ON INVESTMENT,
NEARLY 50 YEARS AGO.**

But after decades of success, the “bigger-is-better” mantra stopped generating returns on investment, nearly 50 years ago. In super-large fossil fuel power plants, specialized equipment required excessively high temperatures and special materials that were more expensive than the marginal gains in efficiency. This graphic, from a book called **Power Loss**, illustrates the plateauing of power plant efficiency in the mid-1960s, as challenges in operating giant power plants offset their economies of scale.

POWER PLANT EFFICIENCY PEAKED



The plateau in plant efficiency from technical challenges was accompanied by a leveling off in the cost reductions of building bigger. Bigger power plants, **evidence suggested**, incurred higher indirect costs, such as much longer construction time. In the 1970s in particular, high inflation and other factors made up as much as 60% of a power plant's cost, and made delay costly.

Despite evidence of the limits to scale economies, the conventional wisdom that bigger is better has persisted into the renewable energy industry. It's particularly ironic, since the costly ever-bigger power plants of the 1970s led Congress to pass the 1978 **Public Utility Regulatory Policies Act (PURPA)**, the federal law that opened the door to renewable energy alternatives to conventional power plants. This lesson seems lost on many observers of the renewable energy industry.

RENEWABLE ENERGY ECONOMIES OF SCALE

The assumed economies of scale of renewable energy take three forms, slightly different than those for fossil fuels:

- 1.) That larger solar or wind power plants will produce less costly power than smaller ones, given a similar level of sunshine or wind.
- 2.) That renewable electricity is best produced in areas of the highest resource quality, and then transmitted long-distance to users.
- 3.) That the road to deploying the most renewable energy the most quickly is via the largest power plants.

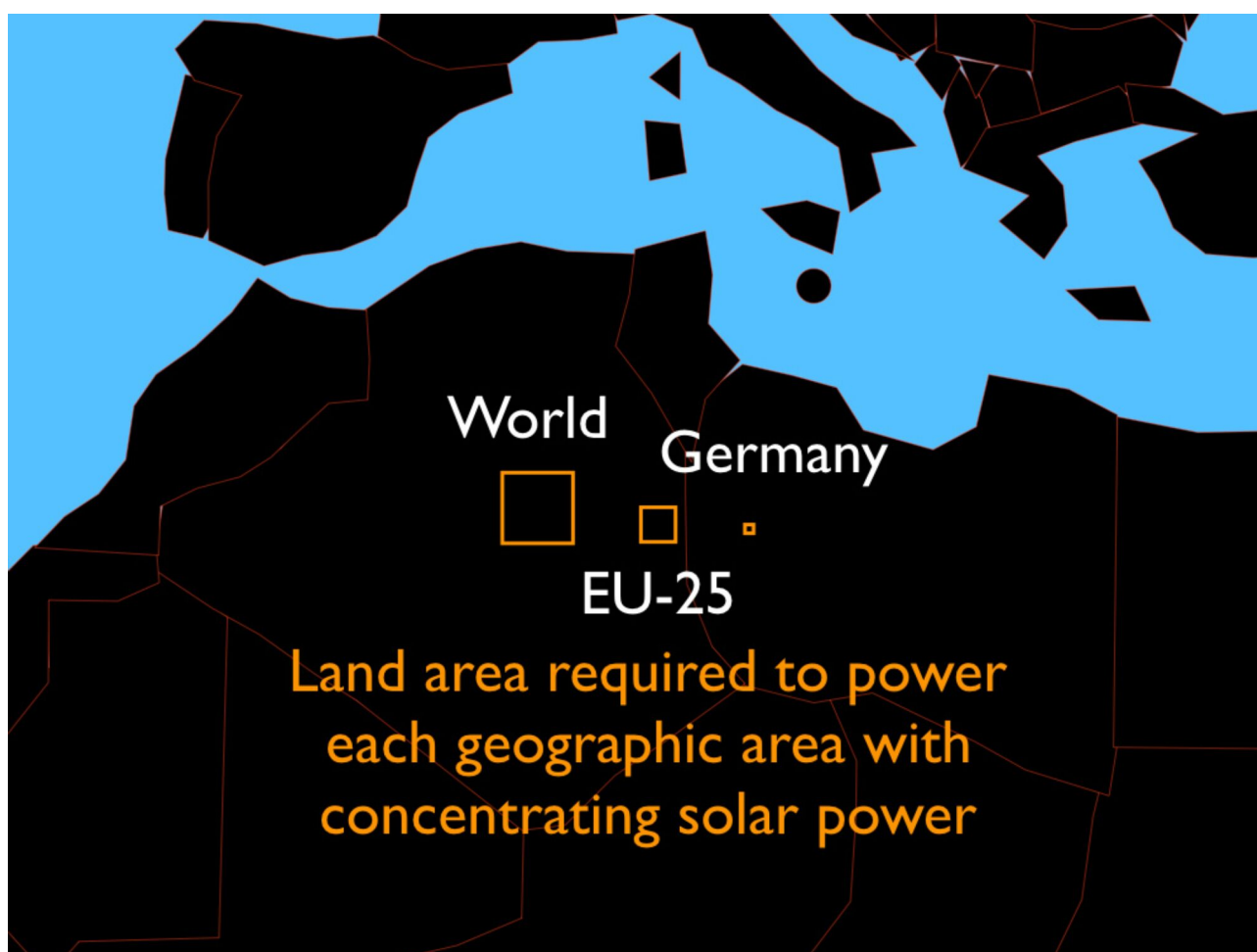
In 2008, New York Times reporter Matthew Wald hit all three of these assumptions. He suggested that the major barrier to expanding the nation's wind power was **lack of transmission capacity**. To tap the country's wind resources required building vast wind power projects in the windy Midwest and then shipping that power to population centers on the coasts, argued Wald (and others).

In the same article, Wald described "immense solar-power stations in the nation's deserts," a reference to **concentrating solar thermal power plants** that focus sunlight with hundreds of mirrors to generate heat, then steam, then electricity.



Like Wald, many observers **thought** that the quickest way to mass deployment of solar energy was building out many of these multi-hundred-megawatt facilities in the world's deserts, then shipping that electricity via new transmission lines back to population centers.

One initiative, called **Desertec**, even proposed to power all of Europe with concentrating solar thermal power plants in the North African desert. An image like the one below was circulated widely at the time, with the squares representing the areas that could be covered with reflective mirrors to generate enough electricity to power the entire world, the EU-25, or Germany.



The arguments over scale have continued. Investor-owned utility Xcel Energy released a **video** in 2015 decrying “thinking small” in favor of “large scale solar projects that deliver energy more economically.”

Similarly, a Brattle Group **study** suggested that utility-scale solar power plants were much less costly than distributed ones. These are just two shots fired in a larger battle over the size and scale of renewable energy deployment.

EVIDENCE TO THE CONTRARY

The managers of electric utilities eventually realized there were limits to scale economies of fossil fuel power plants, in part because smaller-scale cogeneration and renewable energy power plants allowed under PURPA undercut the utility's electricity costs. In renewable energy, a similar analysis is underway. The question is whether large, custom-built wind and solar projects can compete with small, mass-produced ones, when the former require access to big, expensive infrastructure that the latter do not.

LIMITS TO SCALE IN WIND

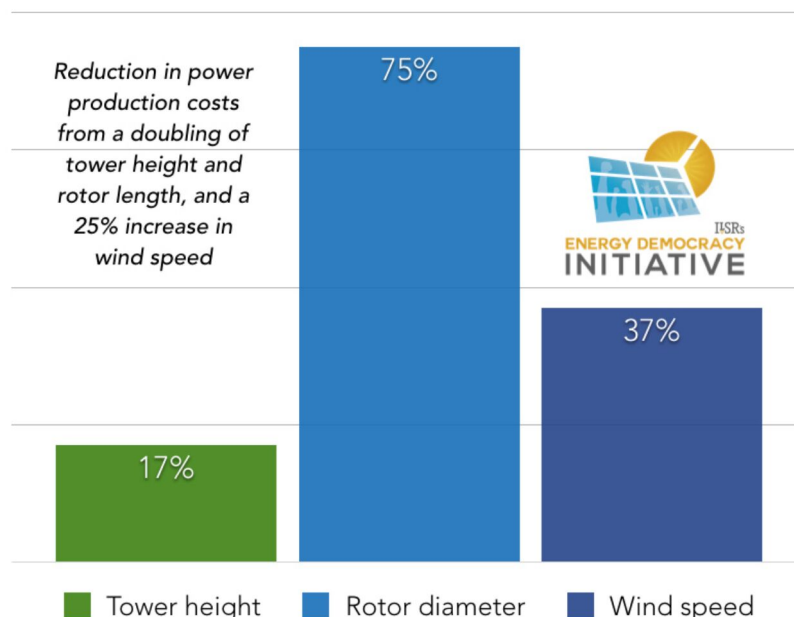
To address the economies of scale question for wind power, there are three considerations: scale economies of a single turbine, a group of turbines (called a wind farm or wind project), and whether it's better to chase the best resource or build (at smaller scale) close to demand.

On the question of the single turbine, there are several ways to get more electricity out of a single wind turbine:

- Make it taller
- Make the blades longer
- Put it in an windier place

In a [2007 report](#), ILSR detailed the significant benefits of these changes (shown in the graphic below).

SIZE MATTERS IN WIND POWER



Doubling the height of a wind turbine can reduce the cost of electricity it produces by 17 percent; doubling the size of the rotors can do even more, reducing the power cost by 75 percent.¹

Although average turbine height seems to have leveled off near 80 meters, there's little sign that the scale economies of a single turbine have reached their limits. Data from the [2015 Wind Technologies Market Report](#) shows a steady increase rotor length and rated capacity, allowing individual wind turbines to produce more electricity.

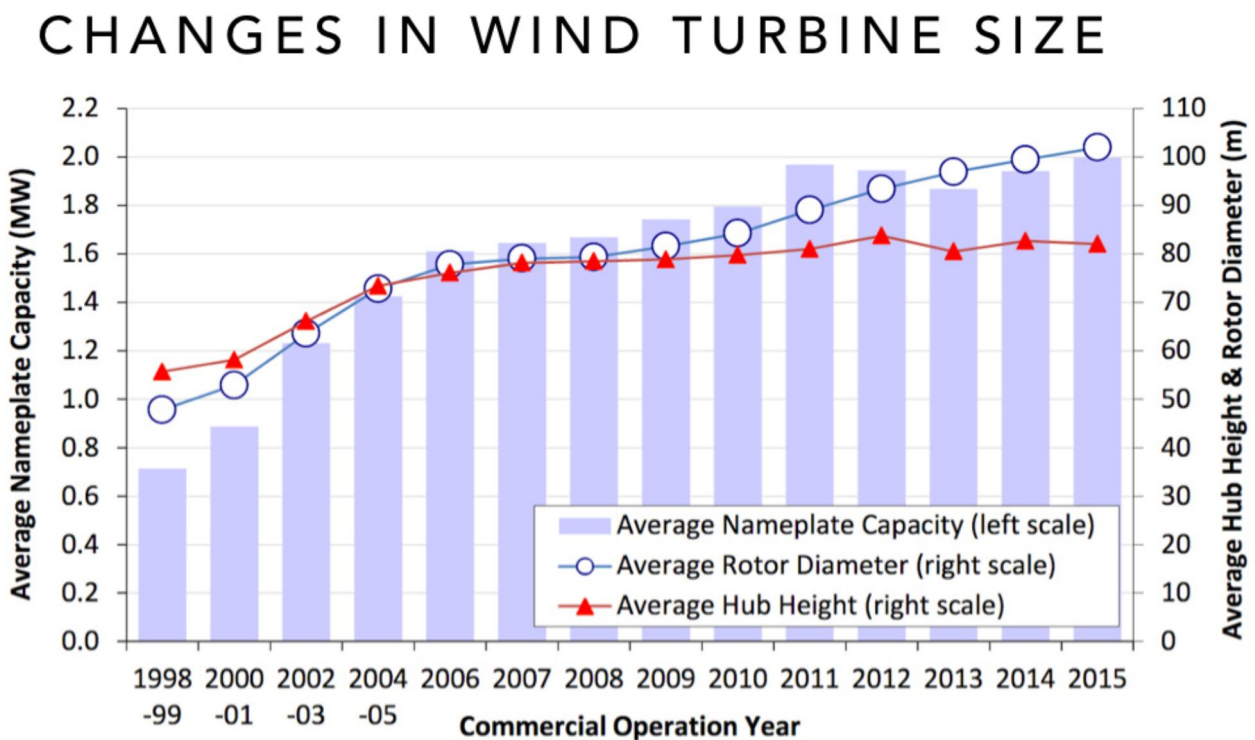


Figure 20. Average turbine nameplate capacity, rotor diameter, and hub height installed during period

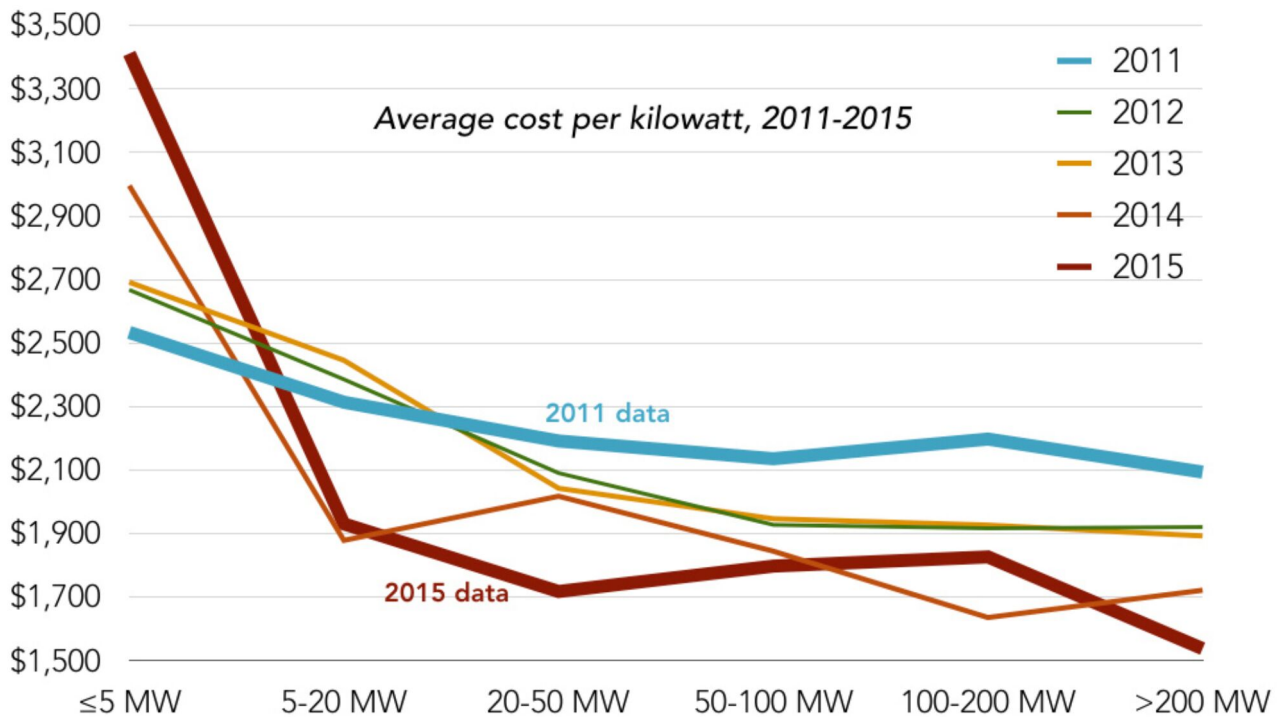
Source: 2015 Wind Technologies Market Report , Lawrence Berkeley Labs

In other words, there are clear economies of scale in the size of a single wind turbine.

Given these scale economies, the next question is whether large wind farms or smaller ones make economic sense.

The following chart shows the economies of scale data for wind farms by size. It's clear that very small projects—less than 5 megawatts—cost much more per kilowatt. The savings for size continue, but much less dramatically, for larger projects.

WIND ECONOMIES OF SCALE

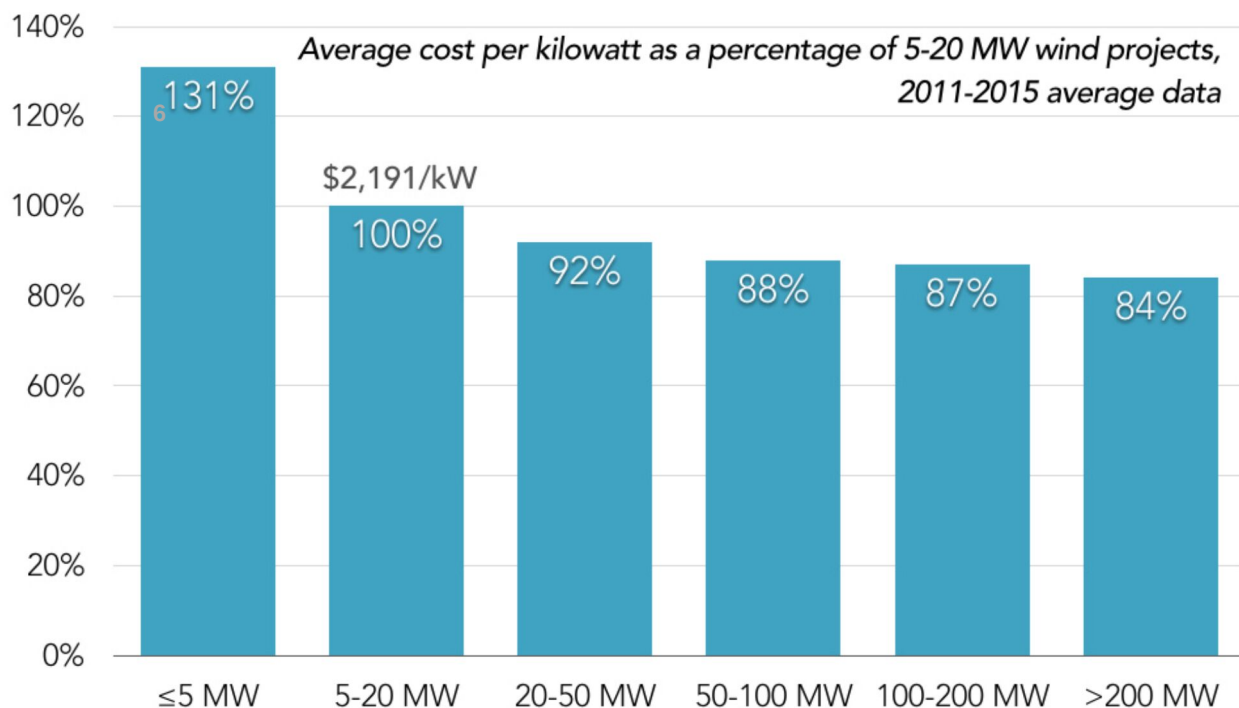


Source: Wind Technologies Market Report



The chart below combines five years of data to show the cost per kilowatt for wind farms as a percentage of projects sized 5 to 20 megawatts. The lesson: two-thirds of the size savings for wind farms is captured when a project reaches 5 to 20 megawatts. Additional savings from scaling up are more modest.

WIND ECONOMIES OF SCALE



Source: Wind Technologies Market Report



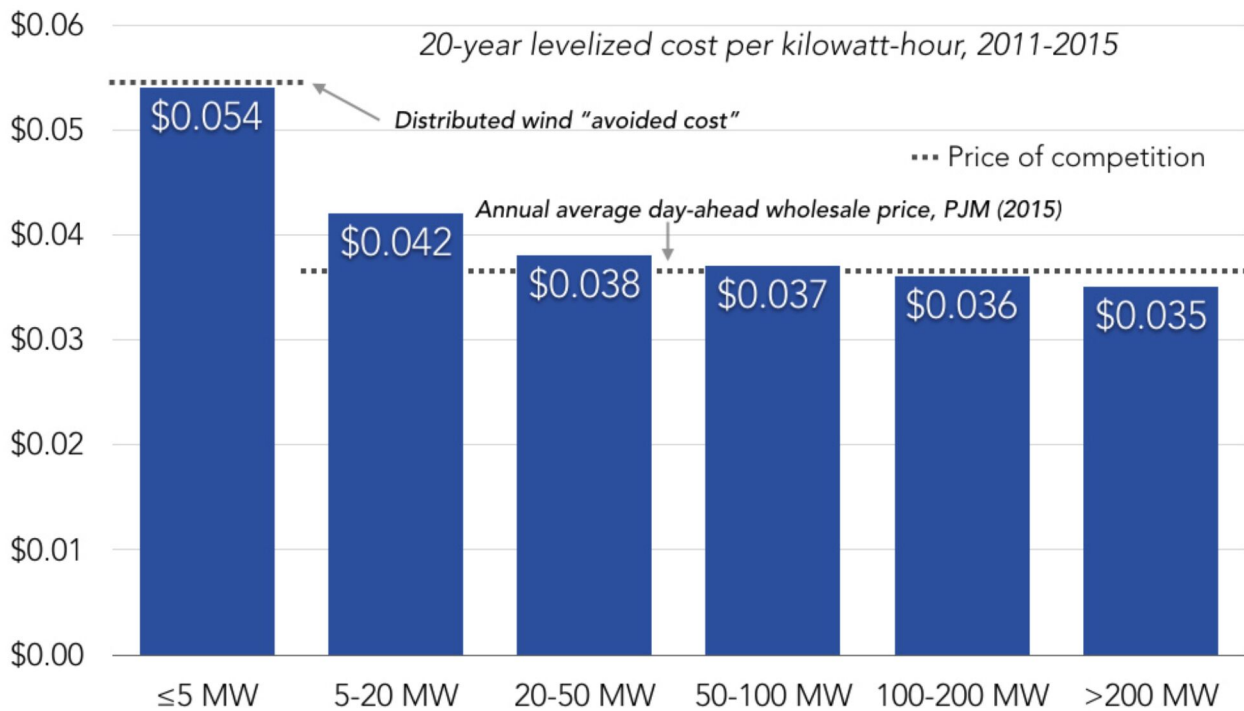
THE LESSON: TWO-THIRDS OF THE SIZE SAVINGS FOR WIND FARMS IS CAPTURED WHEN A PROJECT REACHES 5 TO 20 MEGAWATTS. ADDITIONAL SAVINGS FROM SCALING UP ARE MORE MODEST.

There are two caveats about data showing lower prices for larger projects: the price of competition and the cost of transmission.

While nearly all commercial scale wind projects sell electricity into the grid, the smallest projects may be competing against a different price than the larger ones. There's some **evidence** from community-scale developers that the fair contract price for electricity for projects under 5 megawatts that connect near utility substations (receiving the "avoided cost" utilities are required to pay under PURPA) may be much higher than grid wholesale prices because it avoids both generation and transmission costs.²

The following chart (converting the costs per kilowatt from the prior chart into a 20-year price of electricity) illustrates how this avoided cost is much higher than the **wholesale market price**, sometimes called the “day-ahead locational marginal price.” It means that even the smallest wind power projects can be cost-effective.

WIND PRICES V. THE MARKET



Source: Wind Technologies Market Report



This value advantage of small projects may be an opening for community-based wind projects that have previously been seen as uneconomical in comparison to large-scale ones. However, “community shared wind” has yet to enjoy the popularity of community shared solar, as noted in ILSR’s 2016 **report**.

Transmission costs are the second caveat to the advantages of scale. All of the costs shown in the above charts include interconnection to the electric grid, but may not include costs to upgrade the transmission system to accommodate the new capacity. Larger projects are more likely to incur these system upgrade costs, which are typically spread among all electric customers. Therefore, it's hard to disaggregate transmission costs and get an accurate picture of whether the largest wind projects are truly the most economical.



In the third economies of scale issue, of wind farm size and distance from the best wind resources, the data is also muddled. The windiest and most remote sites likely have the greatest amount of space for new wind projects, whereas projects sited close to consumers may have to be smaller. ILSR's [2007 report](#) on wind economies of scale examined this issue and concluded that the cost of transmission—about 1.8 cents per kilowatt of energy produced per 500 miles of transmission—can consume the advantage of building larger in a better wind resource. The following table provides some illustrations, with values in green showing wind speed increases that can offset transmission costs, and red values showing where the cost to transmit outweigh wind resource benefits (assuming a similarly sized wind power project).

WIND V. WIRES: RELATIVE COST OF GETTING WIND POWER FROM FAR AWAY

		Distance from electric customers (miles)			
		250	500	750	1000
Increase in wind speed	10%	108%	131%	154%	176%
	20%	93%	116%	139%	162%
	30%	78%	101%	124%	147%
	40%	64%	86%	109%	132%
	50%	49%	72%	94%	117%
	60%	34%	57%	80%	102%

Baseline cost of 3.6¢ per kilowatt-hour

- Transmission cost outweighs wind speed benefit
- Transmission lowers cost

Source: ILSR

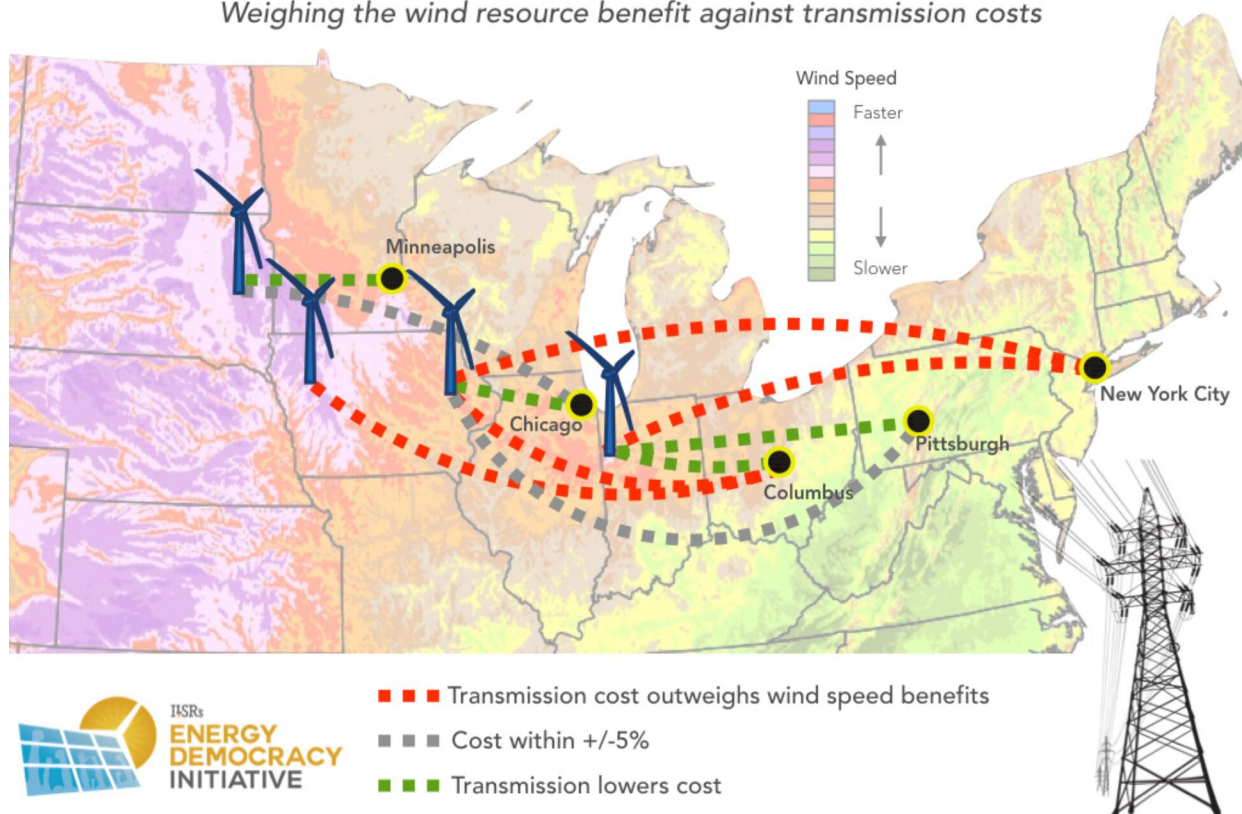


To get a sense of how these calculations play out in the real world, the following map shows that many large cities could benefit from getting electricity from wind farms within 400 miles, but that longer transmission distances cannibalize the savings of higher wind speeds. For this map, projects close to the city are assumed to be smaller (between 100 and 200 megawatts) and produce electricity that is more costly by about 3.5 percent.

MANY LARGE CITIES COULD BENEFIT FROM GETTING ELECTRICITY FROM WIND FARMS WITHIN 400 MILES, BUT LONGER TRANSMISSION DISTANCES CANNIBALIZE THE SAVINGS OF HIGHER WIND SPEEDS.

SHORT TRANSMISSION WORKS BEST

Weighing the wind resource benefit against transmission costs



The issue of transmission infrastructure is complicated by the fact that transmission planning tends to **lack transparency and access** for local communities, and a serious consideration of alternatives.

In summary, wind power economies of scale fall into three categories. Individual wind turbines have a massive scale advantage—bigger turbines are better. Wind farms have less of a scale advantage, with most savings captured with relatively small projects. Finally, the savings from building the largest wind farms may not outweigh the cost to transmit the power to cities, compared to building smaller and closer to load.

A final consideration is that big wind farms, unlike smaller ones, aren't compatible with ownership structures that deliver greater economic benefits to the local community. Since sub-5-megawatt wind projects may be able to compete at a different price point, having community ownership may prove more economically lucrative (even with a slightly higher electricity price) than purchasing power from a remote wind farm.

LIMITS TO SCALE IN SOLAR

The question of scale economies in solar has been both a technological and an economic one. As mentioned before, the contention in the late 2000s was that concentrating solar thermal power plant technology would outstrip solar photovoltaics (PV) because the latter was marginally more efficient (at the point of generation) and could incorporate energy storage.

Frequently left out of that argument were the cost and loss of energy in transmission. In 2010 comments to the California Public Utilities Commission on the now-constructed Ivanpah concentrating solar power plant (called the Genesis Solar Energy Project at the time), transmission and generation expert Bill Powers explained that the cost of electricity from Ivanpah was likely to be higher than from distributed solar PV.

“There is no justification for...using an obsolete cost assumption to eliminate large-scale distributed PV as an alternative to the Genesis Solar Energy Project...The assertion that the high distributed generation case is significantly higher cost than the reference case was incorrect in June 2009 and is definitively obsolete in June 2010.”

With energy losses varying from an average of 7 percent to a peak of 14 percent, the marginally better solar resource at its remote location was lost in transmission, especially when there was ample rooftop space to accommodate local distributed solar.

The Ivanpah plant finally came online in January 2014, supplying power at 20¢ per kilowatt-hour, although to date supplying less than two-thirds of its anticipated output. For comparison, the 20-year cost of energy from a distributed solar PV project completed in 2013 would have been 14.0¢ per kilowatt-hour with a 15 percent profit margin.²

It's also worth noting that the higher output from a concentrating solar thermal power plant is in part due to the use of natural gas to ramp up plant output in the morning. The Ivanpah facility **consumed nearly 744,000 thousand cubic feet of natural gas** in 2014, about what 8,400 Minnesota homes **use** in a year.



Another, often overlooked, issue with concentrating solar thermal is water use. As with traditional power plants, concentrating solar thermal power plants use heat to make steam, and steam to turn turbines to generate electricity. In a **2011** post, ILSR noted that concentrating solar power used nearly twice as much water as a coal-fired power plant if wet cooled, and nearly as much as a natural gas power plant even if dry cooled (see chart below). Solar PV, on the other hand, uses no water to generate electricity because sunlight is converted directly into electric current. Water use is particularly problematic because many regions with the best solar resource for concentrating solar power are the most arid.

Over time, the cost parity of solar thermal electricity and solar PV disappeared, as the following chart shows. While solar PV costs have fallen rapidly, the **cost of concentrating solar** has not followed suit.

CONCENTRATING SOLAR POWER COSTS NOT FALLING

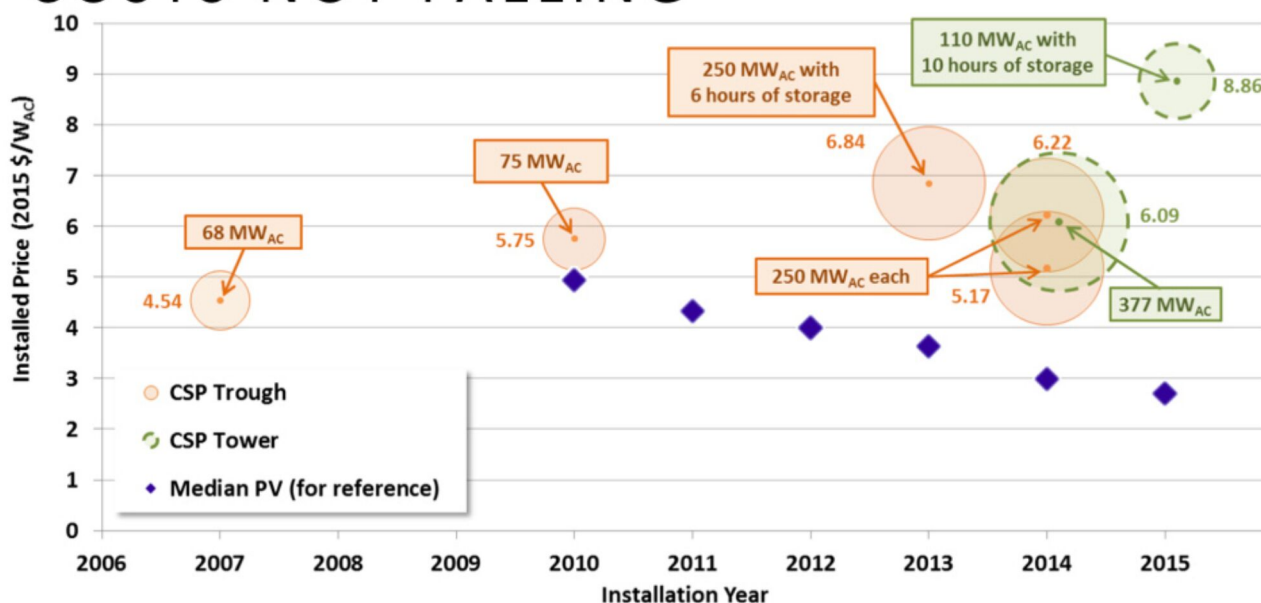
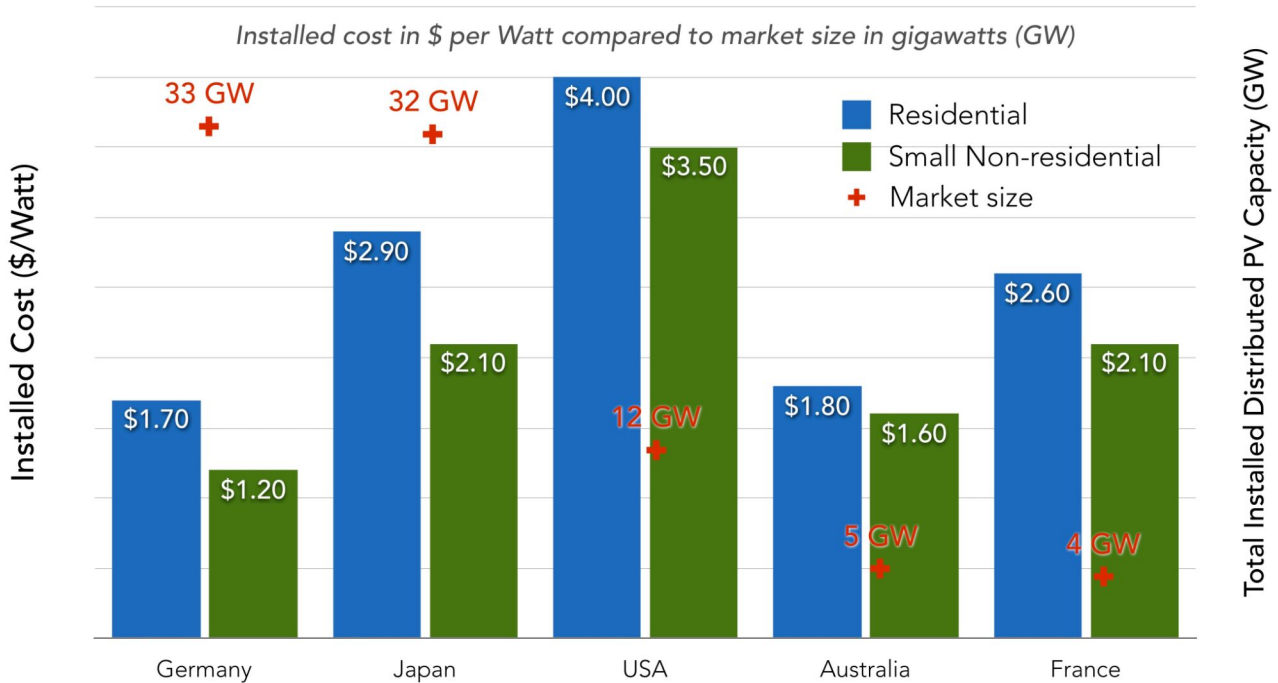


Figure 25. Installed Price of CSP Projects by Technology and Installation Year

The prospects for **continued reduction in solar PV prices** remain good, given impressively lower costs in Germany and Japan. At least half of the differences can be explained by the gap in deployment, with three times the amount of solar deployed in Germany and Japan relative to the U.S. Other **differences** include “installation labor; permitting, inspection, and interconnection; [and] customer acquisition,” according to the Rocky Mountain Institute. In other words, while the U.S. might not reach price parity with its international solar neighbors, the market development history in others nations suggests there are more distributed solar cost savings to capture.

COMPARISON OF DISTRIBUTED SOLAR INSTALLED PRICES



Source: Lawrence Berkeley National Laboratory



The availability of energy storage was (and is) another touted advantage of concentrating solar thermal, but it's unclear that it can offset significantly higher prices. Thermal storage at concentrating solar power plants is much cheaper per megawatt-hour than batteries, and plants commonly have from three to six hours of storage. But since the thermal energy has to heat water and create steam, the response time from energy storage to useful electricity is in minutes rather than seconds. Early uses of batteries, however, tend to be in providing "ancillary services," such as maintaining a consistent voltage on the grid. These services require a relatively small amount of total capacity, but require a quick response. Shifting production from day to night has not proven economical.

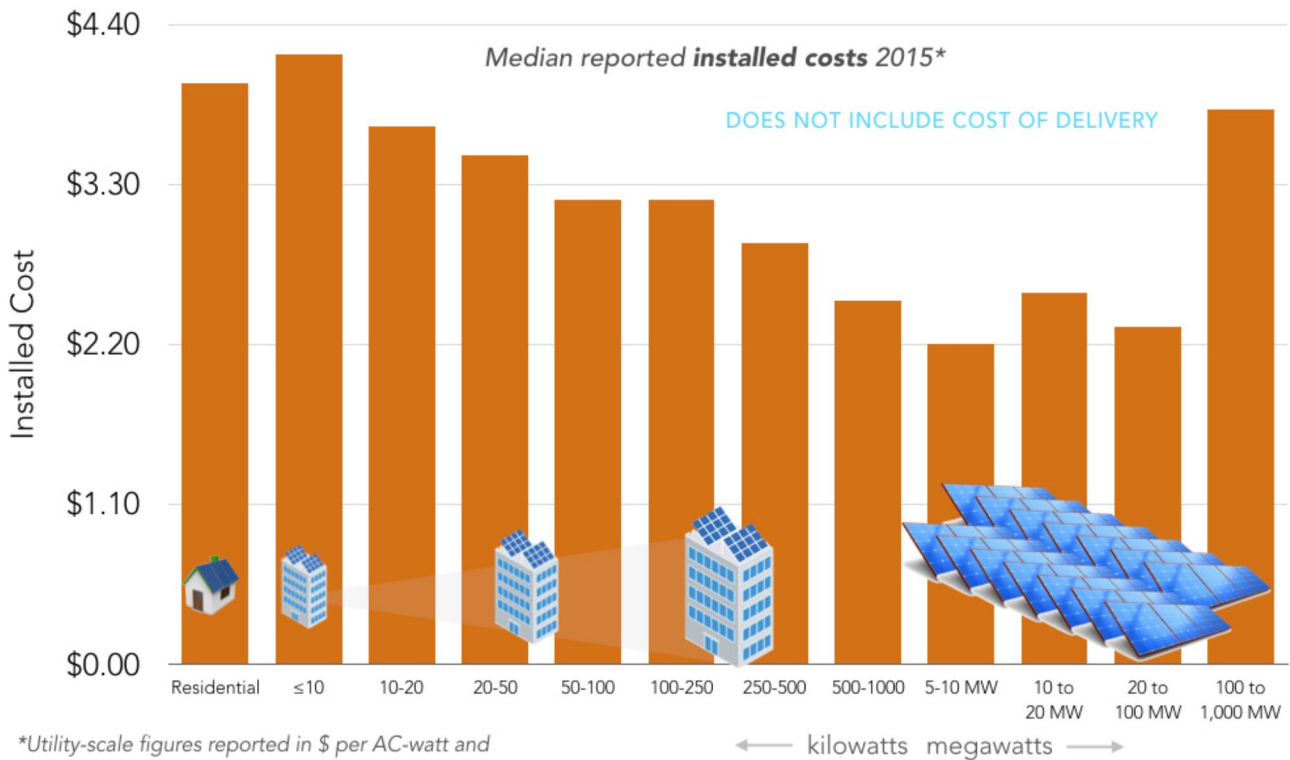
On the other hand, as the prevalence of solar PV in California is **shifting the electricity peak into the later evening** hours, thermal storage at concentrating solar plants could become more valuable. So far, however, the challenges and costs of concentrating solar thermal have spurred **a shift toward solar PV**, even for large projects, resolving the technology debate in favor of mass-produced solar PV.

The scale issue remains a fight within the technology of solar PV. As mentioned in the introduction, the Brattle Group fired the **latest salvo** in the utility-scale versus distributed solar debate. The group argues that resources should be disproportionately invested in utility-scale PV, since it can produce electricity at half the cost of distributed PV.



In a set of 2016 reports on solar, Berkeley Labs and the Department of Energy's SunShot initiative provided data on distributed and utility-scale solar costs. This chart combines the two analyses, and shows that the sweet spot for low-cost solar development—measured by the cost per kilowatt-hour of electricity generated—is in the middle, rather than at the ends of the size spectrum.

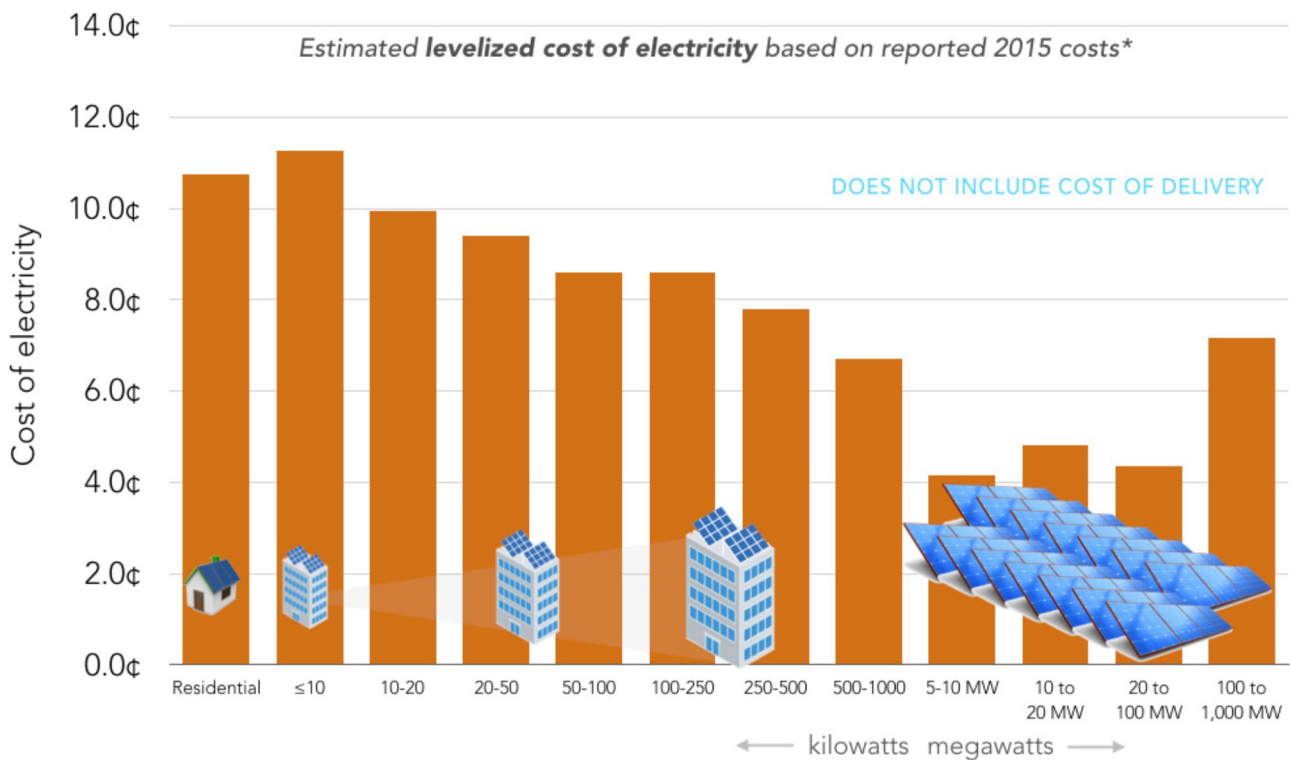
SOLAR ECONOMIES OF SCALE



In the chart of upfront costs above, the largest utility-scale projects are nearly as costly as rooftop commercial-scale solar projects.

However, utility-scale projects typically use panels that track the sun, with commensurately higher electricity output. The following chart, of the inflation-adjusted levelized cost of electricity, offers a more accurate picture. Data comes from the National Renewable Energy Laboratory's System Advisor Model to generate a real, levelized cost of electricity for a \$2.50 per Watt solar array of 6.71¢ per kilowatt-hour (including the 30 percent federal tax credit), adjusted accordingly for the other capital costs. Utility-scale projects (those 5 megawatts and above) are assumed to have tracking, with 30 percent higher output and therefore 30 percent lower levelized energy costs.

SOLAR ECONOMIES OF SCALE



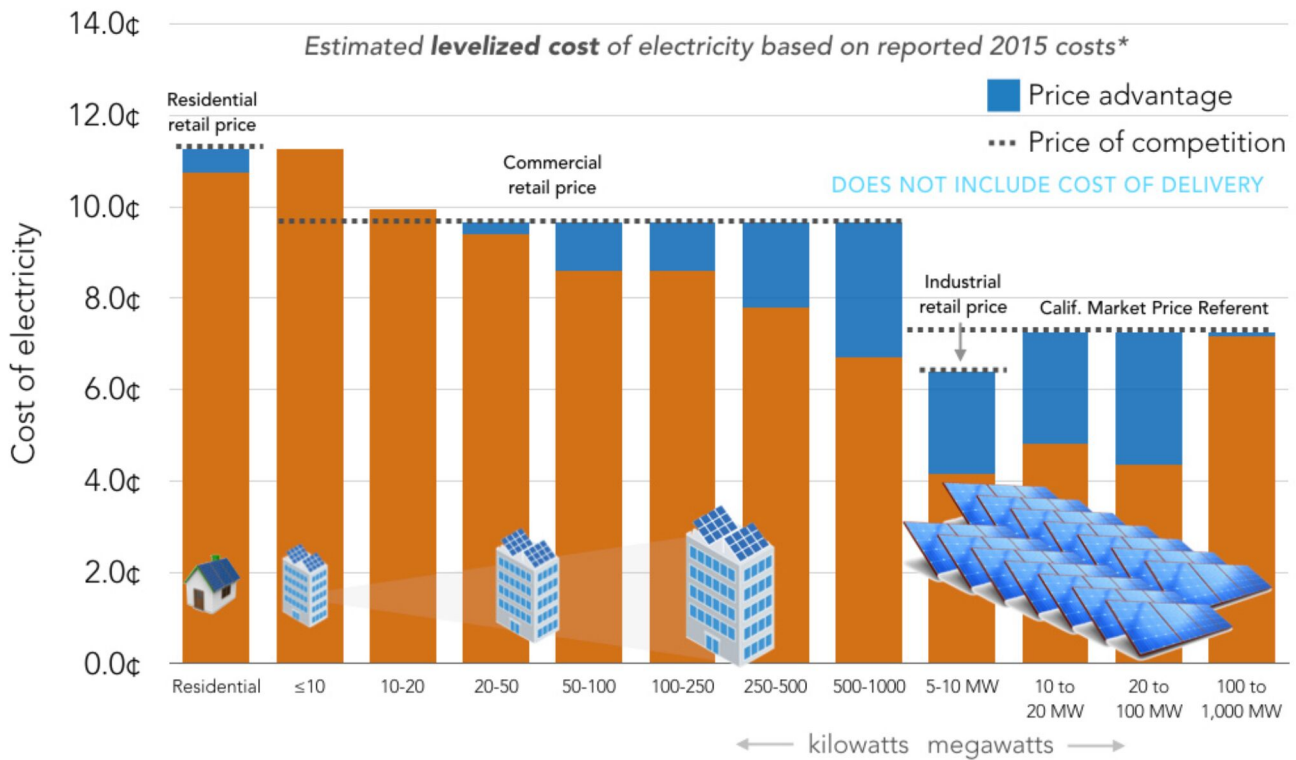
Sources: *Tracking the Sun IX and Utility-Scale Solar 2015* (SunShot, Berkeley Labs); SAM (NREL); ILSR



This chart seems to support the Brattle Group’s contention that bigger solar is better, aside from projects exceeding 100 megawatts.

But what’s still missing in this analysis is the price of competition. As noted in an ILSR analysis from 2015, utility-scale may cost less, but it’s also **worth less** to the electric grid because of its remote location. The following chart replicates the levelized cost chart, but adds in the relevant market price against which these various sources of solar compete.³

SOLAR COMPETES AT MOST SIZES



Sources: Tracking the Sun IX and Utility-Scale Solar 2015 (SunShot, Berkeley Labs); EIA (2014 data); CPUC (2011); NYMEX (2016); ILSR

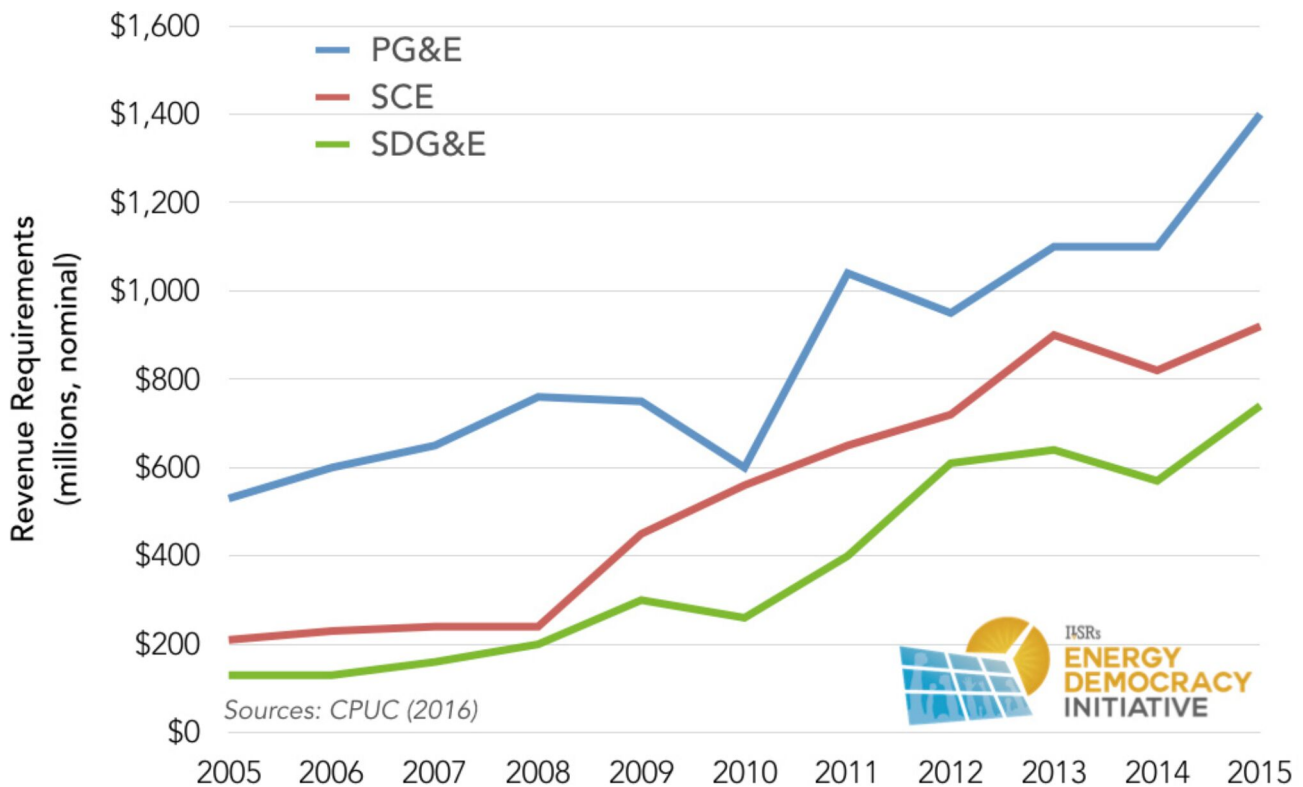


This chart shows that solar produced at small scale where energy is consumed favorably competes with the retail electricity price. The national average residential electricity price used for this chart is close to 12¢ per kilowatt-hour, but is 15¢ in California (and even higher in some states in the Northeast). Commercial scale solar also competes relatively well against average commercial retail prices of around 10¢ per kilowatt-hour. Megawatt-scale projects, connecting and competing into the wholesale market, compete against other new power generation, like natural gas, that produces electricity for 5¢ to 8¢ per kilowatt-hour.⁴ Worthy of note, the rise of community solar projects looks to hit that sweet spot of cost and benefit, with projects typically around 1000 kilowatts, providing a cost-effective way for those without a sunny rooftop (or enough capital to finance their own solar project), a way to participate.

While solar at nearly any scale is competitive, the price of solar from large scale solar projects does not include the cost of transmission for delivery, relevant for most projects over 5 megawatts.

Writ large, the cost of this transmission is rising. In California, transmission costs for the three major investor-owned utilities have been rising by nearly 10% per year.

RISING TRANSMISSION REVENUE REQUIREMENTS



In contrast, there is a lot of available capacity on the distribution grid for smaller-scale solar projects. From the same post as the chart above (emphasis mine):

A 2015 Energy Institute at Haas working paper, described [here](#), performed a detailed analysis of Pacific Gas & Electric’s distribution grid and concluded that **solar penetration equal to 100% of capacity on all circuits would require only small cost** to accommodate [less than 1/1000th of a percent of the utility’s operations and maintenance budget]

San Diego Gas & Electric (SDG&E) has estimated that **their grid can accommodate about 1,000 Megawatts of distributed generation**. That’s equal to around **20% of the utility’s peak demand**.

So big solar projects might produce somewhat cheaper electricity, but unlike your Amazon Prime membership, there’s no free delivery. And comparing utility-scale and distributed-scale solar misses an important point: they do not compete with each other on price.

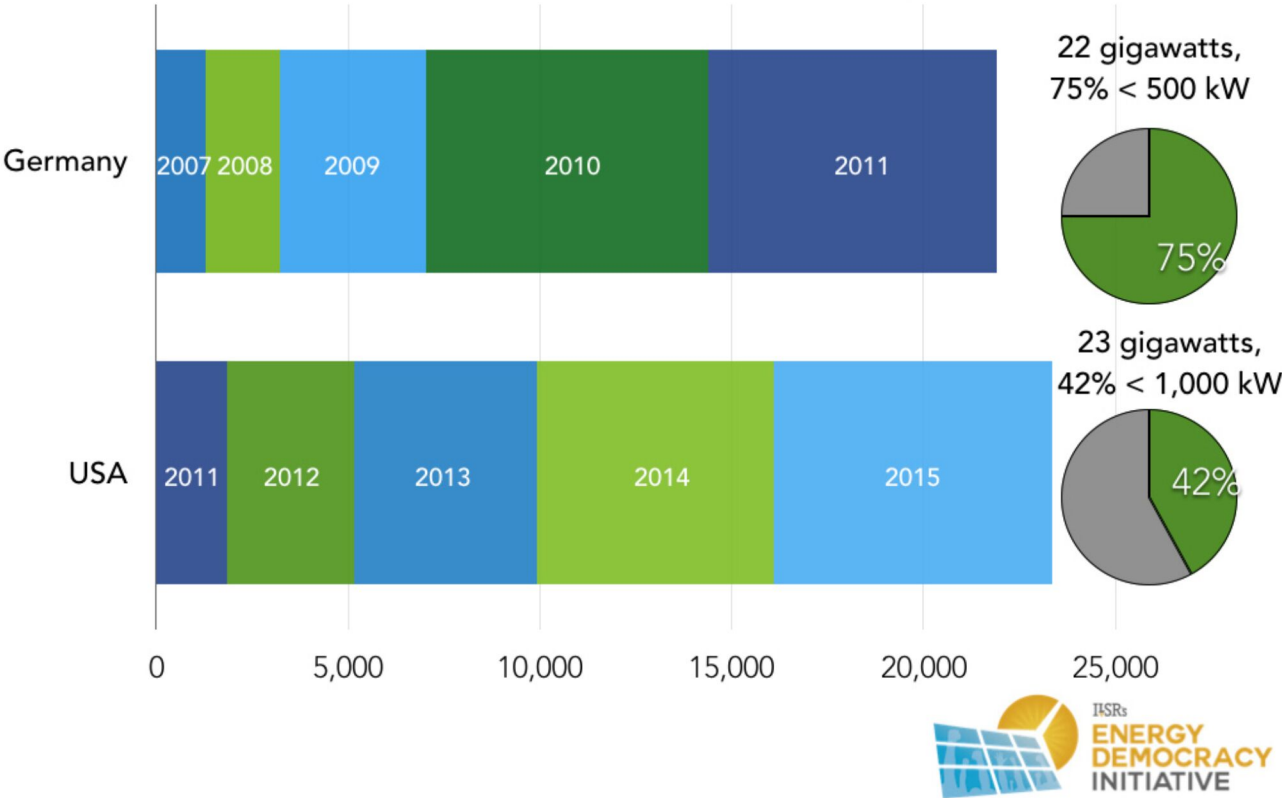
COMPARING UTILITY-SCALE AND DISTRIBUTED-SCALE SOLAR MISSES AN IMPORTANT POINT: THEY DO NOT COMPETE WITH EACH OTHER ON PRICE.

DOES BIG OR SMALL GROW FASTEST?

A final contention in the size debate is whether, driven by the urgency of climate change, it is possible to most quickly deploy wind and solar in small chunks or big ones. Two powerful anecdotes suggest that big changes in renewable energy deployment come in packages of any size.

SOLAR'S SPEEDY AT ANY SIZE

Annual installed megawatts, similar five-year period



Prior to 2007, Germany had installed about 2,900 megawatts of solar. Prior to 2011, the U.S. had installed a similar amount. Over the next five years, Germany installed 22 gigawatts of solar, 75% of projects smaller than 500 kilowatts. In a similar timeframe, 2011-2015, the United States installed over 23 gigawatts of solar capacity, with just 42% smaller than 1 megawatt. In other words, in scaling up solar, the size (of individual projects) didn't matter.

While the total capacity was similar, Germany's focus on local ownership meant that much more of the economic benefit of its new solar capacity accrued to ordinary citizens, instead of incumbent utilities.

In Denmark, electricity had long been the province of cooperatives, so when the "feed-in tariff" program offered a guaranteed grid connection and a fair price on a 20-year contract for wind power in the early 1990s, **many Danish citizens became part of wind power cooperatives**. Wind energy capacity surged from around 500 megawatts to over 3,000 megawatts, and 80% of this wind energy was owned by 150,000 Danish citizens (3% of the population). On a per-capita basis, this would be the same as adding 150,000 megawatts of wind power in the U.S. (twice the total installed capacity at the end of 2015). In the Danish example, wind power grew much faster when connected to local ownership, even though **typical projects** were just three to seven turbines, each about 500 kilowatts in size.

WHY ECONOMICS ISN'T THE ISSUE

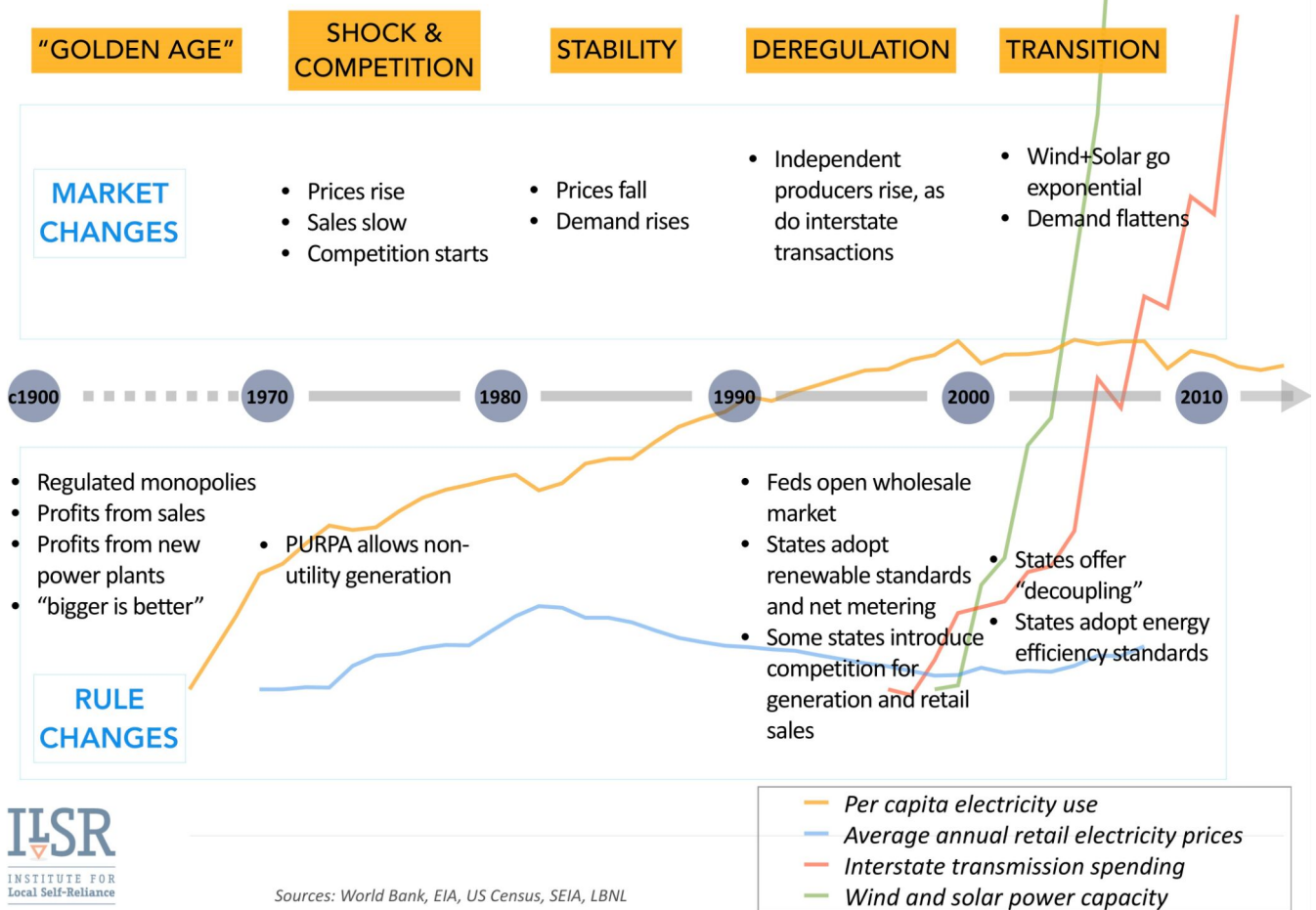
Despite an American fascination with big things, economies of scale don't dominate renewable energy. On the other hand, incumbent utility companies (and their incentive to build big things to make money) play an outsized role in the debate over the right size of wind and solar.

At stake is **\$364 billion a year in electricity sales**, which individuals and communities have an opportunity to retain rather than send to utility companies. Every megawatt of solar installed, for example, **adds \$2.5 million and 20 construction jobs** to the local economy. In its 25-year lifetime, a locally owned solar project will redirect an additional \$5.4 million of electricity spending back into local pockets, instead of to utility shareholders. The calculus for wind power is similar, with local ownership returning as much as three times more jobs and **three times greater local economic benefits** as non-local ownership.⁵

Utilities are profoundly aware of the cost shift enabled by smart technology, distributed solar, and local ownership.

For nearly 100 years, electric utilities have enjoyed protected status as regulated monopolies. While regulators have changed some elements of the market, explained in the “rule changes” section of the graphic below, most utilities still rely on increasing sales of electricity and the capital deployed for new power plants for their revenue and profits.

TIMELINE OF U.S. ELECTRIC MARKETS

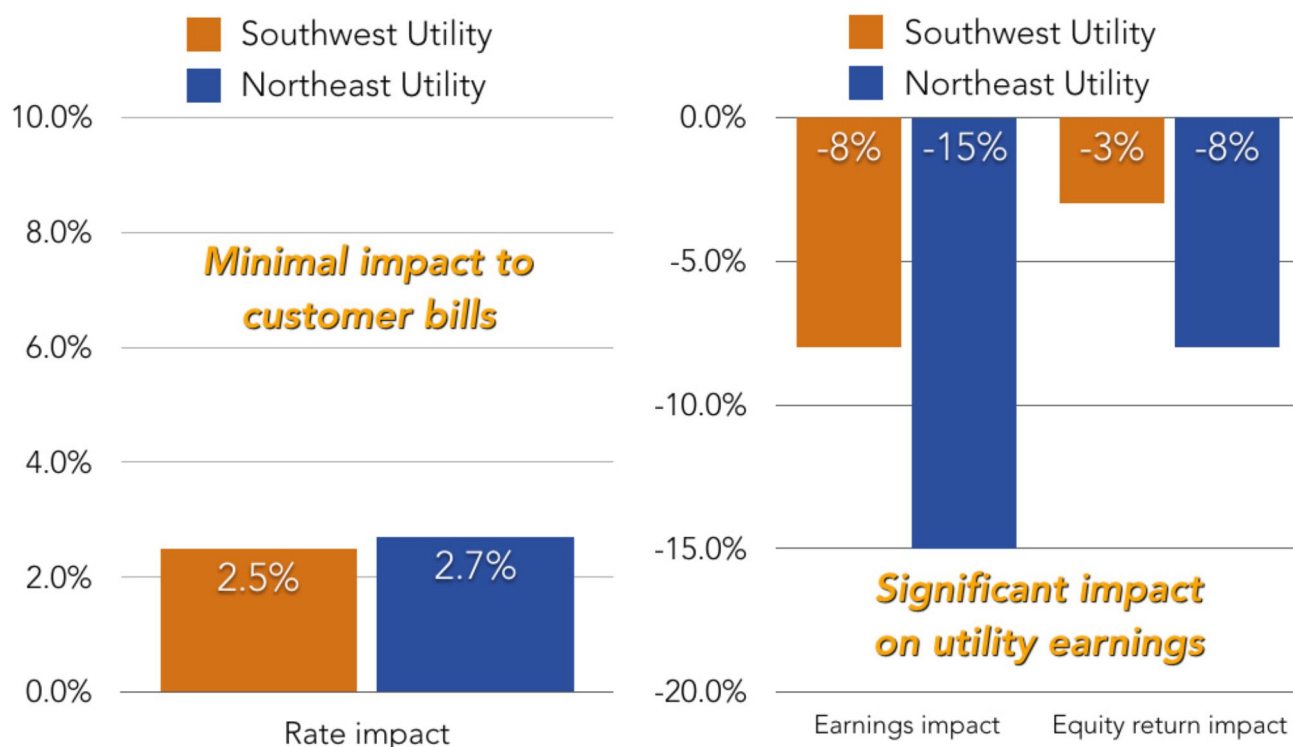


The economies of scale debate isn't so much about the cost of power (generation) as it is who retains the power (of ownership) over the electricity system. If the utility owns large-scale solar and wind projects or buys power from big ones, it will still need to deploy capital to bolster the transmission system (and earn a return on that investment). But if trends continue, and electric customers instead reduce their purchases with efficiency and by producing their own electricity (e.g. with rooftop solar), the old model falls apart.

The utility response to this trend shows they fear a potential business failure.

The Brattle Group’s 2015 study exhorting the benefits of utility-scaled solar was financed by the Edison Electric Institute, the trade organization representing investor-owned utility companies. A 2013 study from Edison noted that competition from customer-owned distributed solar was an existential threat to their business model, and a 2014 report from Berkeley Labs confirms this fear: more solar won’t be bad for customers, but it could be **really bad for utility shareholders**. The graphic below illustrates data from the Berkeley Labs report, showing the minimal impact to electricity rates if one in 10 customers had solar power, but the much bigger hit to utility shareholder profits.

BOTTOM LINE OF 10% CUSTOMER-OWNED SOLAR



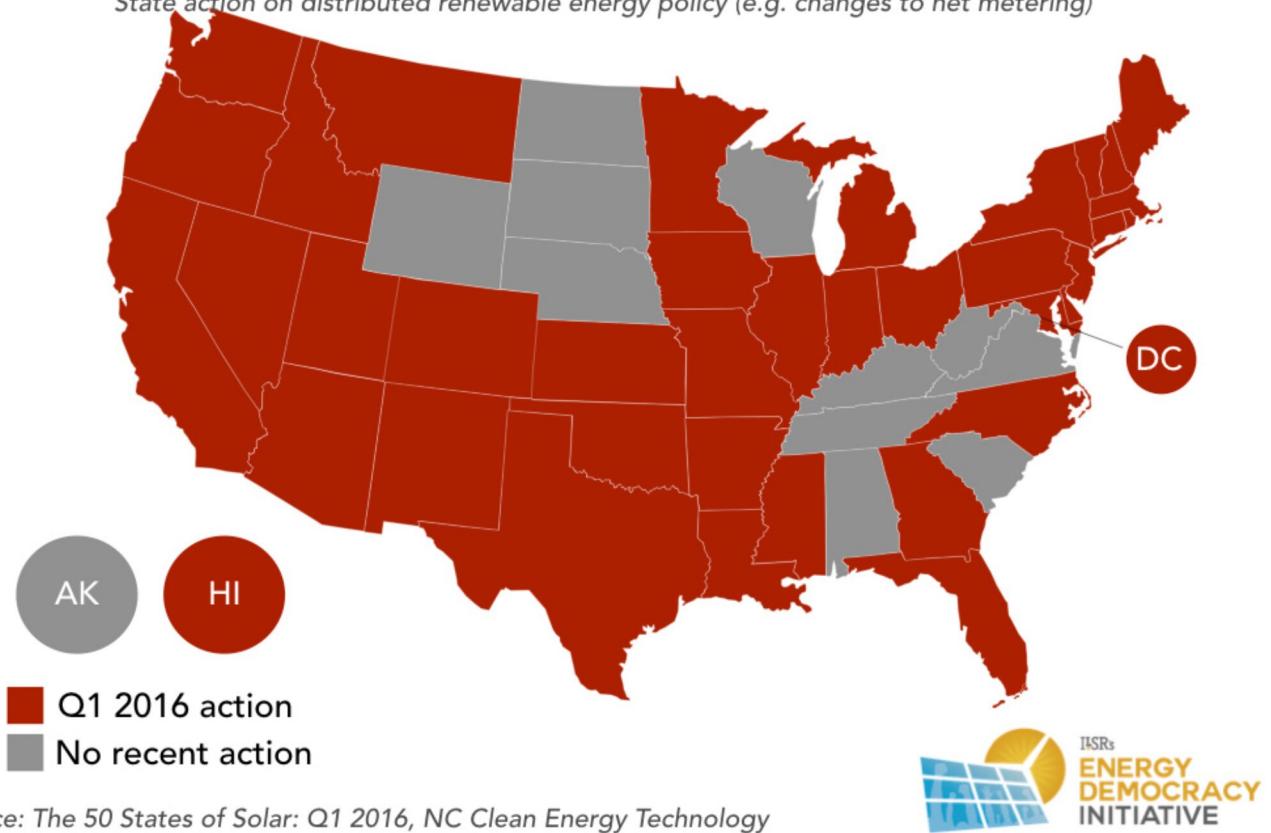
Source: Financial Impacts of Net-Metered PV on Utilities and Ratepayers: A Scoping Study of Two Prototypical U.S. Utilities (NREL, 2014)



The relative costs of distributed solar to the customer versus the shareholder help explain the political landscape for solar, where **utilities are fighting rearguard actions** against net metering and other policies that support distributed solar across the country.

DISTRIBUTED GENERATION UNDER FIRE

State action on distributed renewable energy policy (e.g. changes to net metering)



Source: *The 50 States of Solar: Q1 2016*, NC Clean Energy Technology

The poor outlook also explains why utilities are trying to change the language of renewable energy, to favor their continued control and ownership. In their Orwellian newspeak, rooftop solar becomes “private solar,” in contrast to “universal solar” that utilities will own and control.

SUMMARY

In a 100% renewable energy future, there's room for big, utility-scale wind and solar and distributed renewables, too. Understanding the relative cost of our investments matters, because resources are limited. But understanding the relative benefits (and the recipients) matters, because making the transition doesn't require us to remain married to a century-old and increasingly archaic business model.

The economic arguments between big and small can't be taken at face value, because the largest players have a vested (dare I say oversized?) interest in the outcome. Bigger wind and solar projects can generate cheaper electricity, if the power can be used right at the point of generation. But smaller renewable energy systems compete at the retail level, where their relative benefit and the costs they offset are higher.

BIGGER WIND AND SOLAR PROJECTS CAN GENERATE CHEAPER ELECTRICITY, IF THE POWER CAN BE USED RIGHT AT THE POINT OF GENERATION. BUT SMALLER RENEWABLE ENERGY SYSTEMS COMPETE AT THE RETAIL LEVEL, WHERE THEIR RELATIVE BENEFIT AND THE COSTS THEY OFFSET ARE HIGHER..

The choice between big and small is more than a spreadsheet analysis. Instead, it's an argument about whether the economic windfall of the renewable energy transition will accrue to the incumbent players, or whether tapping the wind and sun in communities across America will result in benefits everyone can share.

NOTES

- 1 The original report shared an analysis of 2007-09 wind project data showing an oddity, that larger wind farms were more costly. One potential culprit was that transmission upgrade costs were allocated to specific projects prior to 2010, when regional transmission authorities adopted cost-sharing policies to spread those costs among all customers in a region."
- 2 Projects may need to include some form of electricity generation like solar that overlaps with peak energy demand to receive this price.
- 3 Based on an installed cost of \$2.80 per Watt, the weighted average cost reported by the Solar Energy Industries Association, financed over 10 years at 10% interest and using both the 30% federal tax credit and accelerated depreciation. Modeling done with the National Renewable Energy Laboratory's SAM software.
- 4 For distributed solar, the average retail price by industry sector was taken from the [EIA's 2014 data](#) and adjusted down by 10% to account for fixed customer costs. For utility-scale solar, the price of competition was California's 2011 "[market price referent](#)," the comparable cost to generate electricity from a new natural gas power plant (with gas prices updated with data from [EIA](#) and [Henry Hub gas futures](#)).
- 5 Commercial and industrial customers do not just pay a flat amount per kilowatt-hour used, but also a demand charge based on their highest monthly consumption. The average price is used for illustration purposes.
- 6 There has been less local ownership of wind power for many reasons: 1) state net metering limits cap require the use of smaller, less productive wind turbines, 2) IRS rules have made it challenging to share ownership and still capture federal tax credits, and 3) securities law makes it hard to pool capital to create community wind projects. More on this issue is in ILSR's 2016 report [Beyond Sharing](#).