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Consumer Benefits of Clean Energy: Renewable Energy

Mark Bolinger and Natalie Mims Frick
Edited by Ryan Wiser

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This paper is an overview of a series reports on **Consumer Benefits of Clean Energy.**

Clean energy offers many benefits to consumers, including reducing consumers' electricity bills, lowering total electricity system costs, and providing health and resilience benefits. States can accelerate consumers' access to these benefits with policies that support energy efficiency, demand flexibility, renewable energy and storage. Berkeley Lab developed a series of briefs that explore these consumer benefits of clean energy, and identify actions states can take to promote them.

1. ***Contribute to a least-cost electricity system*** by using low-cost resources such as end-use efficiency, demand flexibility, behind-the-meter solar PV and storage, and utility-scale renewable energy.
2. ***Greenhouse gas emissions reductions and improved outdoor air quality*** from consumers shifting their home energy consumption from direct combustion of natural gas to efficient electric appliances, taking into account increased electricity generation due to demand growth.
3. ***Improved resilience*** of homes to grid outages due to installation of BTM solar PV coupled with storage.

Together, these briefs highlight how investments in clean energy technologies can provide benefits to all electricity system customers – not just those who invest in these technologies for their homes. The series also outlines options that state policymakers can pursue to facilitate the beneficial outcomes discussed.

Download the reports here.

This brief discusses examples of consumer benefits of utility-scale and behind the meter renewable energy, with a focus on how these resources can contribute to a low-cost electricity system. It begins with a literature review of modeled impacts, primarily considering consumer benefits, of the Inflation Reduction Act and Bipartisan Infrastructure Law. Next, it discusses how utility-scale renewable energy can contribute to a low-cost electricity system (e.g., in some cases, low resource costs relative to other alternatives). It concludes with a discussion of behind-the-meter renewable energy consumer benefits (e.g., reduced host electricity bill, increased property value, resilience).

Consumer benefits from the Inflation Reduction Act

Modeling studies of the Inflation Reduction Act (IRA) highlight many of the possible consumer benefits of renewable energy. For example, the DOE (2023) projects that American families will save $27 billion-$38 billion on their electricity bills through 2030, as a result of the IRA (in conjunction with the Bipartisan Infrastructure Law (BIL)). These bill savings stem from an estimated 8-9% reduction in electricity rates (attributed in part to the IRA's extension and enhancement of renewable energy tax credits) as well as energy efficiency improvements and distributed generation investments enabled by the IRA and BIL, which together reduce demand for electricity from the grid.[1] The share of electricity generated from renewables and other low-CO_2 emitting generation like nuclear and fossil with carbon capture and storage is projected to grow from 42% in 2022 to 72%-81% in 2030.

Similarly, the EIA (2023) projects electricity prices in 2030 to be nearly 10% lower than they would otherwise be without IRA, due to a combination of IRA's tax credits and a reduction in natural gas prices. By 2050, solar and wind generation are projected to provide 56% of total electricity generation under the IRA, compared to 39% without it (both up significantly from just 15% in 2022).

Looking at just the electricity sector, Steinberg et al. (2023) project a possible near-doubling in the market share of "clean electricity" under IRA, from 41% in 2022 to 81% in 2030. This near doubling is accompanied by a 9% reduction in bulk power system costs (which equates to $4.3/MWh of savings), as the capital and operating expenditures associated with the significant buildout of renewable generation are more than offset by the resulting fuel savings and tax credits.

Not surprisingly, all of these modeling studies also project a significant reduction in CO_2 emissions, which are summarized in a recent EPA meta-analysis of the prospects for electricity sector and economy-wide CO_2 emissions reductions under IRA (EPA 2023). Looking across results from a range of studies using ten different multi-sector energy system models and four different electricity sector models, the EPA finds that the IRA could reduce electricity sector emissions by 49-83% (relative to 2005 levels) in 2030. Broader economy-wide CO_2 emissions are expected to be 35%-43% below 2005 levels by 2030, versus a 26%-33% reduction without the IRA.

It is not just government analysts and modelers who have been discussing the benefits of IRA—utilities have also been vocal about the consumer savings that will result from the IRA and the energy transition more broadly. The American Clean Power Association (2023) recently compiled numerous public statements from utilities to this effect, including the following:

- "We understand our customers need some relief, and this [solar's newfound ability to elect the PTC instead of the ITC under the IRA] is an opportunity for Duke Energy to pass tax savings to our customers," said Duke Energy Florida State President Melissa Seixas.
- WEC Energy Group is projecting long-term customer savings of nearly $2 billion from planned investments in roughly 1,900 MW of solar, 720 MW of storage, and 670 MW of wind over the next five years.
- "The IRA just makes the plan [DTE Energy's 20-year integrated resource plan] so much more affordable for our customers," said DTE Energy President and COO Trevor Lauer. "If you take the 20-year plan with the renewables, the IRA lowers the cost of the plan by about $500 million."
- As part of its Upper Midwest Energy Plan, Xcel Energy plans to leverage extended and enhanced tax credits and grant programs under the IRA to pass savings on to its Minnesota customers. Specifically, Xcel estimates "$490 million in incremental savings for existing projects through 2027 and an estimated $1 billion in additional savings for new projects through 2034."

Utility-scale renewable energy

Utility-scale renewable energy resources – systems that are greater than 5 megawatts (MW) – can sometimes generate electricity at lower costs than operating an existing combined-cycle natural gas unit (Bolinger et al 2023b; Wiser et al. 2023). Related, recent research has shown that solar and wind are oftentimes competitive in wholesale power markets, meaning savings for purchasers and potentially enabling consumer electricity bill reductions (Wiser et al. 2024).

The levelized cost of energy of utility-scale wind and solar has decreased historically

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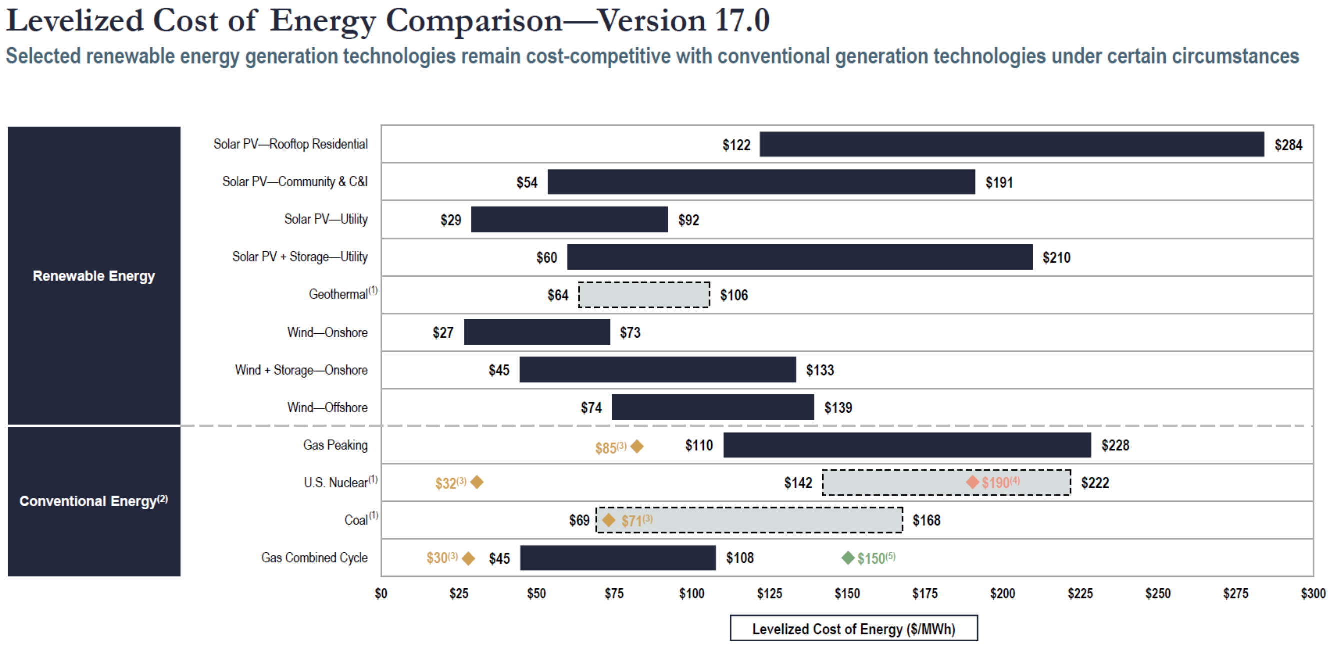
[1] Without the IRA and BIL, electricity prices are projected to fall by about half as much (~4%) over this same period, due to the ongoing energy transition proceeding at a slower pace.

Renewable forms of generation like utility-scale solar photovoltaics (PV) and onshore wind are already among the lowest-cost resources on the grid on a levelized basis—even before factoring in incentives (Figure 1, Lazard 2024). Adding 4-hour batteries to these resources to firm up their weather-dependent output adds costs, but still leaves the resulting solar ($60-$210/MWh, per Figure 1) and wind ($45-$133/MWh, per Figure 1) "hybrid" plants with a levelized cost of energy (LCOE) that is comparable to that of a new dispatchable combined-cycle gas-fired plants ($45-$108/MWh, per Figure 1).



Source: Lazard 2024

Figure 1. Lazard's Unsubsidized LCOE Analysis

Power purchase prices for wind and solar have increased in recent years, a consequence of supply chain limitations, inflationary pressures, higher interest rates, and other factors (Wiser et al. 2023; Bolinger et al. 2023b). However, costs have steeply declined over a longer historical period and learning curve theory[2] suggests that the LCOE of wind, solar, and batteries will continue to decline in the future as a result of capturing efficiencies and cost reductions through ongoing experience with manufacturing and deploying these technologies. For example, based on empirical long-term learning rates of 15% for wind and 24% for solar,[3] coupled with deployment projections that pre-date the IRA, Berkeley Lab projected that by 2035, wind and solar's LCOE could decline by 23% and 47%, respectively, from 2020 levels (Bolinger et al. 2022).

Wind and solar power purchase agreement prices are even lower than their levelized cost of energy

In the United States, power purchase agreement prices for wind and solar are lower that the underlying LCOE due to federal tax incentives. Consumer prices reflect the passthrough of tax credits and other subsidies that are not typically included in LCOE calculations (and that are excluded from Figure 1 above). More specifically, because of the environmental and societal benefits that they convey, renewable forms of generation like wind and solar enjoy significant policy support, most recently codified in the IRA via various tax credits and other incentives (see Table 1, below). When offering to sell their electricity through

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[2] Learning curve theory is the concept that as output doubles the average cost per unit drops by a fixed percentage. Harvard Business Review, 1974.

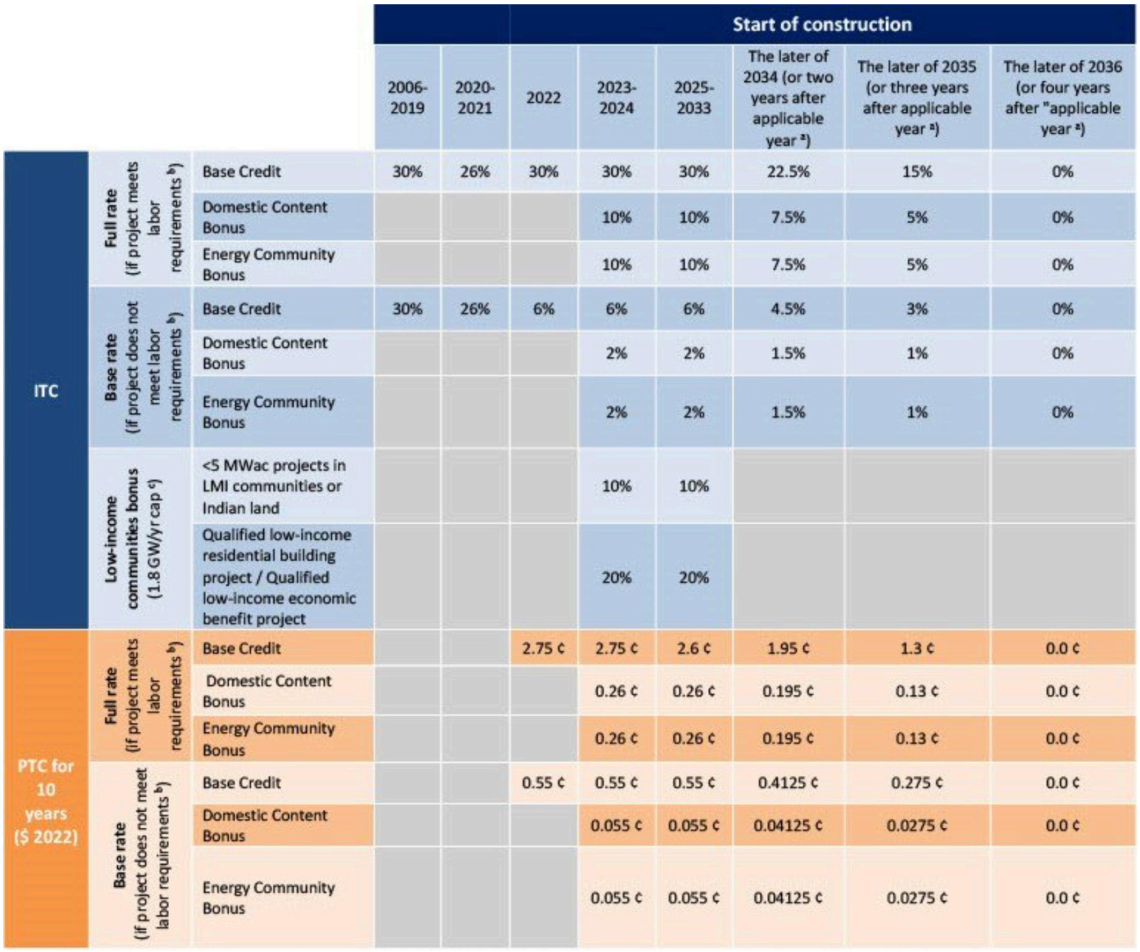
[3] The learning rate measures how much costs have fallen (and/or are projected to fall) with each doubling in cumulative output. For example, utility-scale solar's historical LCOE learning rate of 24% indicates that with each doubling of cumulative capacity deployment, LCOE has fallen by 24%. Barring a strong acceleration or deceleration of the learning rate, one might expect this relationship between deployment and cost to hold in the future as well.

long-term power purchase agreements (PPAs), wind and solar generators will typically pass through to consumers the value of these tax credits or other incentives that they have received by offering a lower price than they otherwise would have been able to (Bolinger et al. 2023b). In this way, electricity ratepayers can benefit directly from the IRA's incentives for clean power generation.

IRA renewable energy incentives significantly reduce the cost of clean electricity

Most important among the IRA's numerous provisions in support of renewable energy are the extension and enhancement of the three flagship federal tax credits for renewable generation: the §25D residential investment tax credit (ITC), the §48 commercial ITC, and the §45 production tax credit (PTC). These three credits had been in the midst of a multi-year phasedown (§48 ITC) or phaseout (§25D ITC and §45 PTC), but the IRA restored them to their full value, extended them (or their successors—i.e., the technology neutral clean electricity tax credits, §45Y and §48E) for at least 10 years, and—for the commercial §48 ITC (and §48E) and §45 PTC (and §45Y)—enhanced their potential value by layering on the possibility of various bonus credits or "adders" if certain conditions are met, such as using equipment that meets domestic content thresholds, siting the project in certain priority areas, and/or structuring the project to benefit low-income ratepayers (see Table 1).

Table 1. Summary of Investment Tax Credit and Production Tax Credit Values over Time



			Start of construction							
			2006-2019	2020-2021	2022	2023-2024	2025-2033	The later of 2034 (or two years after applicable year [a])	The later of 2035 (or three years after applicable year [a])	The later of 2036 (or four years after "applicable year [a])
ITC	Full rate (if project meets labor requirements [b])	Base Credit	30%	26%	30%	30%	30%	22.5%	15%	0%
		Domestic Content Bonus				10%	10%	7.5%	5%	0%
		Energy Community Bonus				10%	10%	7.5%	5%	0%
	Base rate (if project does not meet labor requirements [b])	Base Credit	30%	26%	6%	6%	6%	4.5%	3%	0%
		Domestic Content Bonus				2%	2%	1.5%	1%	0%
		Energy Community Bonus				2%	2%	1.5%	1%	0%
	Low-income communities bonus (1.8 GW/yr cap [c])	<5 MWac projects in LMI communities or Indian land				10%	10%			
		Qualified low-income residential building project / Qualified low-income economic benefit project				20%	20%			
PTC for 10 years ($ 2022)	Full rate (if project meets labor requirements [b])	Base Credit			2.75 ¢	2.75 ¢	2.6 ¢	1.95 ¢	1.3 ¢	0.0 ¢
		Domestic Content Bonus				0.26 ¢	0.26 ¢	0.195 ¢	0.13 ¢	0.0 ¢
		Energy Community Bonus				0.26 ¢	0.26 ¢	0.195 ¢	0.13 ¢	0.0 ¢
	Base rate (if project does not meet labor requirements [b])	Base Credit			0.55 ¢	0.55 ¢	0.55 ¢	0.4125 ¢	0.275 ¢	0.0 ¢
		Domestic Content Bonus				0.055 ¢	0.055 ¢	0.04125 ¢	0.0275 ¢	0.0 ¢
		Energy Community Bonus				0.055 ¢	0.055 ¢	0.04125 ¢	0.0275 ¢	0.0 ¢

Source: U.S. Department of Energy. Notes: (a) Applicable year is defined as the later of (i) 2032 or (ii) the year the Treasury Secretary determines there has been a 75% or more reduction in annual greenhouse gas emissions from the production of electricity in the US as compared to the calendar year 2022. (b) Labor requirements entail certain prevailing wage and apprenticeship conditions being met. (c) Low-income communities bonus is an awarded credit; the years reflect when the awards are scheduled to occur. Awarded projects have four years to be placed in service.

These adders are "stackable," meaning that qualifying projects can potentially access multiple adders, resulting in a maximum possible commercial ITC of 70% or a maximum possible PTC of 120% of the base PTC credit value (the "low-income" adders are only available to projects <5 MW that elect the commercial §48 ITC; these two adders must also be applied for and then awarded by the U.S. Treasury). Moreover, this stacking addresses only the tax credit incentives and other federal and state grants can be stacked in addition to the tax credits.

To illustrate the importance of the IRA's tax credit provisions, Figure 2 uses financial pro forma modeling to estimate the impact of these credits and adders on the levelized PPA price (i.e., similar to LCOE with tax credit passthrough) of solar across the residential, community-scale, and utility-scale sectors.[4] If not for the IRA, the §25D ITC would no longer exist, the §48 ITC would have reverted to 10%, and solar would not have access to the PTC, resulting in the sectoral LCOEs shown in the first "column" (labeled "Pre-IRA") of Figure 2. The IRA restored these credits to their full values and also gave commercial solar access to the PTC, resulting in the reduced LCOEs shown in the second "column" of Figure 2. Even in this base-case post-IRA scenario of 30% ITC and 100% PTC, which assumes no bonus credits or adders, the consumer cost of solar is 17% to 25% lower (depending on the sector) due to the IRA. The next four "post-IRA" columns successively layer on the adders described in Table 1 as applicable, resulting in even further reductions in levelized PPA prices, particularly for third-party-owned residential PV and community solar, which are potentially able to qualify for the low-income bonus credits by virtue of being under 5 MW. Also worth noting is that the ability of commercial solar to access the PTC could result in lower prices than would have been possible with the §48 ITC, particularly for projects that are highly productive (i.e., that have a high capacity factor) and/or that have low up-front capital costs.[5]

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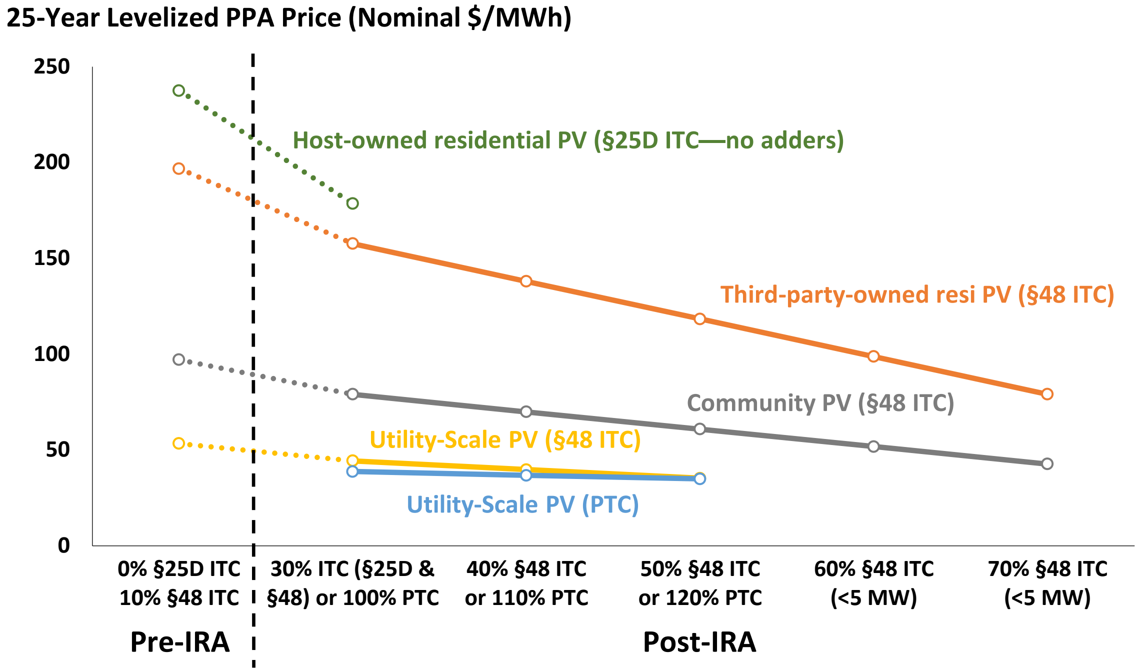
[4] Modeling assumptions include CapEx estimates of \$1.25/W_{AC} for utility-scale, \$2/W_{AC} for community, and \$3.25/W_{AC} for residential solar. Capacity factor assumptions are 25%, 20%, and 15%, respectively. Other assumptions held common across all sectors include OpEx of \$20/kW_{AC}-year, a 10% after-tax equity internal rate of return (IRR), a 25-year life and debt term with a 1.3 debt service coverage ratio (DSCR) and a 6% interest rate, a 21% federal tax rate, a 5% state tax rate, and a system performance degradation rate of 0.5%/year.

[5] The distinction between the §48 ITC and the §45 PTC for utility-scale projects in Figure 2 is not particularly pronounced, given our modeling assumptions about capital costs (\$1.25/W_{AC}) and capacity factor (25%). But for many utility-scale PV plants across the U.S.—i.e., those with a lower capital cost and/or higher capacity factor—the PTC is likely to provide more value than the ITC, particularly if there are no adders. Once multiple adders are considered, however, the balance could shift back to the ITC, given that a 10 percentage point ITC adder is worth more than a 10% PTC adder (one can see this effect in Figure 2, as the gap between the ITC and PTC narrows and ultimately disappears as the two adders are layered on). Moreover, the PTC cannot access the two "low-income" adders—these are only available to projects <5 MW that elect the §48 ITC (and these low-income adders must be applied for, and then allocated by the U.S. Treasury—they are not "guaranteed" like the base credits and other adders).



Source: Berkeley Lab. Note: §48 refers to §48 and §48E.

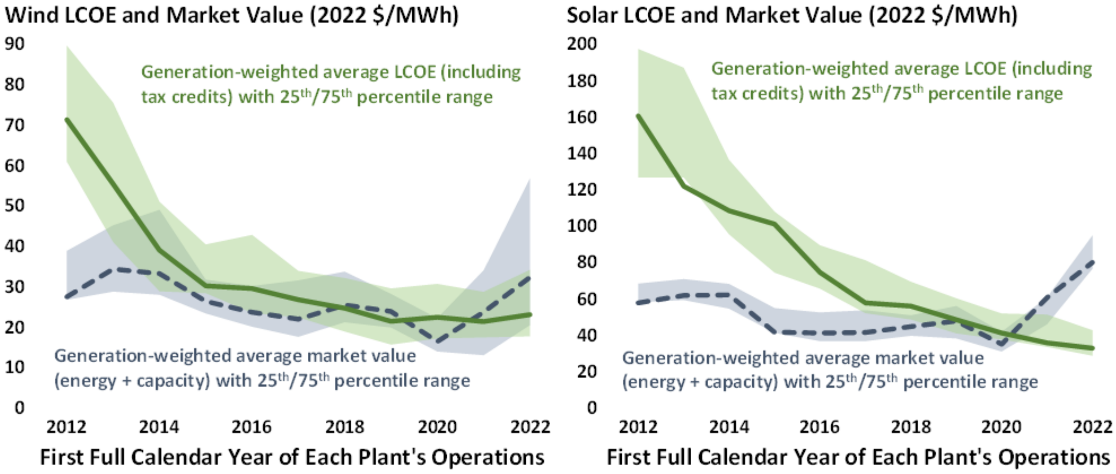
Figure 2. Levelized PPA Prices of Residential, Community, and Utility-Scale Solar Under Different Tax Credit Scenarios

To understand the cost-competitiveness of wind and solar, LCOE and PPA prices are not enough—you also need to understand what costs wind and solar help offset

This paper has discussed how wind and solar are among the lowest-cost generating resources (as measured by LCOE), and that they are able to sell their output at even lower prices (as measured by PPA prices) due to the receipt of Federal tax incentives that were extended and enhanced by the IRA. But the story does not end here. Whether wind and solar can reduce consumer electricity bills will also depend on what costs wind and solar offset, when purchased, recognizing that wind and solar are not perfect substitutes for dispatchable power plants that can respond to fluctuating consumer demand.

A recent paper by Berkeley analyzes historical post-tax-credit LCOE for wind and solar and contrasts those costs with the cost of replacement resources in wholesale power markets (Wiser et al. 2024). More specifically, the study quantifies the "net market value" of wind and solar over time. Net market value (net value, for short) is defined as the difference between the cost of replacing solar and wind generation by purchasing electricity in wholesale power markets and the post-tax-credit LCOE of solar and wind. A positive value means possible power-sector cost savings, a negative value the opposite.

The study finds that wind and solar economics have improved over time. On average, wind and solar costs (after federal tax credits) have been roughly in-line with market replacement costs (or equivalently 'market value') since 2018 or 2019. Figure 3 shows the national average post-tax-credit LCOE (green) and market value (blue) of wind (left) and solar (right), by plant vintage. (Market value is the energy value from hourly marginal electricity prices, plus the capacity value based on capacity credit rules and prices.) Improvement in the "net value" among more recent plant vintages is primarily due to declines in the levelized cost of wind and solar, coupled with an uptick in replacement costs in 2021 and especially 2022. In 2021 and 2022, on a national basis, new power purchasers typically paid less for wind or solar than it was worth in wholesale markets—a positive net value, meaning savings for purchasers and potentially enabling consumer electricity bill reductions. Before 2018, on the other hand, net value was generally negative, as most projects required supplemental support from state policies given higher LCOEs.



Source: Wiser et al. 2024

Figure 3. Comparing the cost and value of utility-scale wind (left) and solar (right)

Given those findings, the study concludes that consumer electric bill savings are possible—but not assured, as considerable regional diversity exists. Considering all solar and wind plants within the study sample (those built from 2011 through 2021), net value was found to have generally increased over time. In 2022, solar generated $2.1 billion in net value nationwide, while wind generated $100 million. Net costs in previous years were primarily due to the dominance of higher-cost early wind and solar projects, many of which were also supported through state-level policies intended, in part, to motivate cost reductions. The study also presents numerous case studies of state renewables portfolio standards, utility procurement plans, and voluntary green power purchasers – illustrating a range of impacts on consumer costs.

It will be important to track net value into the future. Wholesale power prices are decidedly lower now than in 2022 and solar and wind are beginning to saturate some markets. Yet the cost of wind and solar can be expected to decline as supply chain pressures ease, the new tax credit provisions in the Inflation Reduction Act take full effect, and technology continues to advance. Regardless, it is clear that wind and solar can offer a hedge against the uncertain cost of other generation sources.

Understanding Negative Wholesale Power Prices

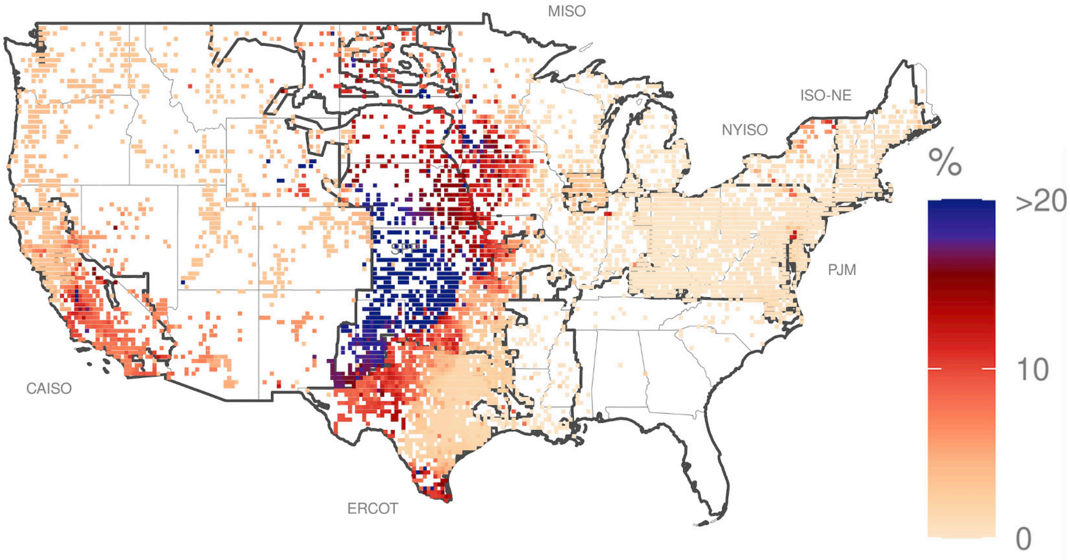
In organized wholesale electricity markets, generators compete with each other largely based on their *marginal operating costs*—i.e., fuel plus variable operation and maintenance (O&M) costs—rather than their LCOEs or PPA prices. Generators offer to sell power at their marginal operating costs, and the system operator accepts as many offers as needed—starting with the lowest-priced offers before moving to higher-priced offers—in order to satisfy demand. All successful offerors are then paid the same market clearing price—i.e., the marginal cost of the marginal generator in the supply stack.

Utility-scale wind and solar have no fuel costs and low variable O&M costs, which means that their marginal operating costs are negligible. This, in turn, enables wind and solar to offer their power into competitive wholesale power markets at prices close to $0/MWh (or even at negative prices when considering the cost of foregone production tax credits and other incentives

The willingness of wind and solar plants to continue to generate electricity at $0/MWh or even negative wholesale electricity prices has, when combined with the inflexibility of other generation sources, led to an increasing prevalence of negative pricing in wholesale markets.

Negative wholesale electricity prices—which require a generator to pay, rather than be paid, to deliver its output to the market—can result from several situations. Transmission congestion can prevent supply from reaching its intended load, leading to local oversupply conditions. In some markets with high wind or solar market share, broader system-wide oversupply is also a possibility during times of light load and high wind and/or solar generation. As noted above, given their low marginal operating costs, wind and solar generators are willing to offer their generation into wholesale power markets at very low or even negative prices in order to ensure that they will be dispatched, and thereby earn production tax credits (PTCs) and renewable energy credits (RECs). These credits only accrue if the plant is generating, and their value presumably exceeds the loss from the negative price payment (i.e., the wind or solar generator will presumably never offer a negative price whose absolute value exceeds the value of the credits). Other types of inflexible generators—e.g., nuclear plants—might also offer below-marginal-cost or even negative prices into the market if, for example, it would be more costly for them to ramp down, or even shut down and re-start later, than it would be to operate at a loss in the interim (Seel et al. 2021).

The map below (Figure 4) shows the frequency of hourly wholesale electricity prices in the real-time market that were negative in 2023 across tens of thousands of individual locational marginal pricing (LMP) nodes in the seven major independent system operators (ISOs) and associated energy imbalance markets in the United States (Millstein et al. 2024a). The average frequency of negative prices across all nodes in 2023 was 5.6%, but this average masks significant variation by region. For example, in much of the wind-rich Southwest Power Pool (SPP)—e.g., see the Texas and Oklahoma panhandles—the frequency of negative prices in 2023 was closer to 20% of all hours, presumably driven by an oversupply of wind generation during light load hours.



Source: Millstein et al. 2024a

Figure 4. Negative Pricing Frequency, 2023.

The merit order effect drives wholesale market clearing prices lower—at least temporarily

As increasing amounts of low-marginal-cost wind and solar generation enter the market—e.g., in part as a result of the incentives provided by IRA—the market clearing price that is paid to all successful offerors in wholesale power markets tend to drop as higher-marginal-cost generators are displaced from the supply stack. This can lead to a reduction in wholesale power prices that directly benefits consumers. This phenomenon is known as "the merit order effect"—i.e., generators are dispatched based on the merit of their offers, with low-marginal-cost renewable generators suppressing wholesale power prices by displacing higher-cost generators from the mix. It occurs during hours of significant wind and solar supply and is at least partially offset by increases in wholesale power prices during periods of low wind and solar supply. The effect is also anticipated to be temporary as prices readjust over time. Regardless, Wiser et al. (2017) summarize the literature on the merit order effect and its estimated impact on wholesale prices in various regions of the United States. This literature, at that time, suggested that wind and solar deployment had reduced average wholesale prices by a range of $1/MWh to $9/MWh, depending on the time period and region examined.

The reduction in power sector demand for natural gas can drive gas prices lower economy-wide

The merit order effect can have a related effect that benefits consumers across many other sectors of the economy as well. Specifically, if the higher-cost generators that wind and solar displace from the supply stack via the merit order effect are gas-fired generators—which is often the case today—then the displacement of those gas-fired generators from the supply stack means that less natural gas is burned. All else equal, as demand for natural gas among gas-fired generators drops, natural gas prices will also drop, benefiting gas consumers in all sectors of the economy. Though dated, Wiser et al. (2005) reviewed both empirical estimates of, and how various energy models incorporate, this demand-reduction-induced price effect (DRIPE) and found that, in general, a 1% reduction in demand for natural gas nationwide is expected to cause a corresponding natural gas price reduction of 0.8% to 2% over the long-term. Though updated assessments would be required to reflect current market conditions, this possible natural gas price reduction could, in turn, contribute to lower electricity prices (as gas-fired generators will pay less for their fuel) as well as consumer savings in many other sectors of the economy that use large amounts of natural gas (e.g., heating, cooking, industrial processes, chemicals, etc.).

Wind and solar's weather-dependent output, coupled with their tolerance for low wholesale power prices, takes a toll on their wholesale market value—but batteries can help

Of course, wind and solar's willingness to generate at even low or negative prices naturally means that a significant amount of wind and solar generation flows onto the grid at times of low or negative prices. When the wind is blowing strongest or the sun is shining brightest within a region, all of the wind and solar plants within that region can generate at or close to full capacity, thereby increasing supply and—assuming no corresponding increase in demand—driving down prices. Conversely, when the wind is becalmed and it is cloudy, more-expensive generators (e.g., gas-fired generators) will be dispatched to supply a greater portion of demand, leading to higher prices. This negative covariance between renewable output and price means that the generation-weighted average price that a wind or solar plant earns over the course of a year will be skewed towards lower-priced periods.

This skewness, in turn, has negative implications for the market value of these resources. Particularly in regions where wind and solar account for a significant share of the market and can therefore more-readily affect prices, their wholesale market value is often relatively low, and tends to erode even further as market share increases (Bolinger et al. 2023b, Wiser et al. 2023).

Energy storage systems, like batteries, can help stem the decline in wind's and solar's market value by storing wind and solar electricity that is generated at times of low (or negative) prices and then discharging it once prices are higher. From the perspective of the generator and the market, this time-shifting energy price arbitrage helps by boosting value (and revenue in the case of a merchant generator) and dampening price volatility. Depending on the cost of storage, it is also helpful from a consumer perspective: while storage will moderate low- or negative-prices (thereby seemingly hurting consumers), it will dampen high prices by an even greater magnitude, due to the shape of the supply curve (i.e., flatter at lower prices and steeper at higher prices) and the asymmetric price risk that shape imposes (i.e., price risk is heavily skewed to the upside).

Energy storage deployment has grown rapidly over the last few years (Bolinger et al. 2023a), driven in large part by the ability to apply the ITC to the battery if it is paired with, and charged primarily from, a solar installation. Storage should continue to grow even more rapidly in future years, now that the IRA has removed this coupling requirement: starting in 2023, even standalone storage qualifies for the ITC.

Renewable energy produces health benefits for consumers

Beyond possible consumer bill savings, clean electricity also provides societal benefits—partly in the form of reduced health and climate damages. These benefits stem, in part, from avoiding air emissions of carbon dioxide (CO_2), nitrogen oxides (NO_x), and sulfur dioxide (SO_2).

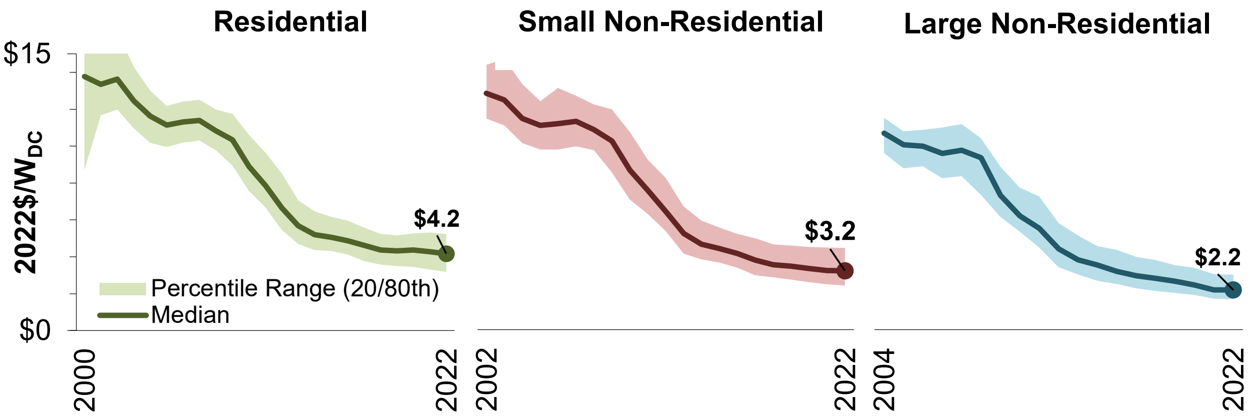
Recent research by Millstein et al. (2024b) assesses these emission reductions, focusing on CO2, SO2, and NOx, and incorporate recent estimates of global warming costs and pollution health costs to estimate the dollar value of the associated climate and air quality benefits. From 2019 through 2022, wind and solar generation in the United States is estimated to have provided $249 billion of climate and air quality benefits based on central estimates. In 2022, the normalized benefits were $143/MWh and $100/MWh for wind and solar, respectively, or $36/MWh and $17/MWh when only including air quality benefits. Combined, wind and solar generation led to 1,200 to 1,600 fewer premature mortalities in 2022 (based on a 5th–95th percentile range).

Though not tied to or reflected on electricity bills, these health and climate benefits nevertheless benefit consumers by mitigating the health risks, property damage, and social upheaval caused by pollution and climate change.

Behind-the-meter renewable energy

Installing behind the meter (BTM) PV can provide numerous consumer benefits to customer hosts. First, BTM PV typically enables system owners or hosts to reduce their own electricity bills, by self-supplying a portion of their own electricity needs. Second, studies have shown that host-owned BTM PV can increase the value of a property (Hoen et al. 2017, 2015, 2013), and that homeowners can often recoup some of the up-front installed cost of the BTM PV system when selling their home. Third, if PV is paired with storage, the customer gains potential resilience benefits during wider power-system outages.

Currently, BTM PV is more affordable than ever. Costs have declined significantly since the early 2000s, but more slowly since 2013 (Figure 3). From 2019-2022, the median installed cost of residential and small non-residential PV systems has fallen by $0.2/W_{DC}$, while large non-residential systems have fallen by $0.5/W_{DC}$ (Barbose et al. 2023).



Source: Barbose et al. 2023

Figure 3. Historical Installed Cost of Residential and Non-Residential Distributed PV through 2022

As states move away from net metering as a means of compensating BTM PV systems, BTM batteries are becoming more common as a way to manage and optimize consumer savings under the new rate structures. Barbose et al. (2023) report that 10% of all new residential and 7% of all non-residential BTM PV systems installed in 2022 are paired with batteries. Those states with the highest distributed PV market shares tended to have the highest battery attachment rates—e.g., in 2022, Hawaii at 96% and California at 11%—with most other states between 5% and 10%. California's more recent change in BTM solar compensation has led to a further dramatic increase in storage attachment rates, to around 60% (Barbose 2024). In addition to maximizing compensation under successor rate structures to net metering, BTM batteries can also provide critical backup power during power outages, providing some resilience value to consumers.

Deployment of BTM PV and batteries is expected to continue and accelerate under the IRA, in light of its restoration and extension of the ITC and infusion of funding for other important programs (e.g., see the text box on the USDA's Rural Energy for America Program). In addition, as discussed earlier (in both Table 1 and Figure 2), the IRA provides a number of "bonus credits" or "adders" that are available to third-party-owned BTM PV systems via the §48 ITC. These "stackable" adders, which could potentially enable an ITC as high as 70% ITC in some cases, are not available to host-owned residential systems claiming the §25D ITC. Given the significant impact that these adders could have on BTM PV's LCOE (see Figure 2, earlier), policymakers in states that allow third-party-owned residential solar may see a surge in third-party-ownership (relative to host ownership) under the IRA—and should consider whether to reduce any state or local BTM PV incentive programs accordingly, in order to conserve local incentive dollars and avoid over-stimulating the market. On the other hand, O'Shaughnessy (2023) finds that state and local BTM PV cash incentives can still play an important role in driving adoption among lower-income households, which suggests that a re-orientation of incentives in favor of lower-income households may make more sense than an across-the-board reduction.

The USDA's REAP Program Receives a Funding Boost from the IRA

Much of the focus on the IRA with respect to distributed energy resources centers on the extended and enhanced tax credits, including the new bonus credits described earlier. While these tax credits provide important consumer benefits, the IRA also contains many additional provisions that support distributed renewable generation.

Among these is greatly increased funding for the USDA's Rural Energy for America Program (REAP). This program, which provides grants and guaranteed loans to agricultural producers and rural small businesses to finance renewable energy systems and energy efficiency improvements, has been around for many years, but has been perennially underfunded. With a significant injection of new funding from the IRA, grants up to the lesser of 50% of project costs or $1 million are now available (doubling the pre-IRA limits), as are guarantees on loans up to 75% of project costs. Grants and loan guarantees can be combined as well. Importantly, the grant is additive to the ITC, which means that a qualifying project could conceivably combine a 50% REAP grant with a 30%-50% ITC, thereby requiring little or no remaining capital expenditure.
The USDA REAP directly benefits program participants via capital improvements and lower energy bills. But there is also potentially a significant indirect benefit to consumers more broadly, given that REAP participants—agricultural producers and rural small businesses—grow much of the food and manufacture many of the products that the rest of America consumes. By helping to defray energy costs, REAP lowers participants' overall cost of doing business, which in turn helps to combat inflation in checkout lines across America.

More information on the REAP program is available at https://www.rd.usda.gov/programs-services/energy-programs/rural-energy-america-program-renewable-energy-systems-energy-efficiency-improvement-guaranteed-loans

State actions to promote renewable energy

Renewable energy contributes to a low-cost electricity system, as compared to a system without it, and provides health benefits for consumers. BTM solar PV and storage increase property value and provides electricity bill savings for host customers. Examples of actions that states can take to promote renewable energy are listed below.[6]

Policy

- Establish clear renewable energy and transmission permitting and siting requirements (Enterline and Valalinis 2024, NCSL 2023)
- Create or improve renewable portfolio or clean energy standards (Barbose 2023, NCSL 2021)

Planning

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[6] This is not a comprehensive list of actions states can take to promote renewable energy. For more information, see the U.S. Environmental Protection Agency's State Policies to Support Renewable Energy and the U.S. Department of Energy's Office of State and Community Energy Programs' Utility-Scale Renewable Energy and Distributed Generation Policies and Programs.

- Establish or improve grid planning processes, such as distribution system planning and integrated resource planning, using:
    - Improved DER forecasting and analysis (Schwartz et al. forthcoming)
    - Current cost forecasts that consider the impact of IRA and other market forces pushing renewable energy prices down (Biewald et al. forthcoming, Bolinger et al. 2022)
    - Robust resource adequacy assessments for renewable energy and thermal resources, considering Effective Load Carrying Capacity[7] for both (Biewald et al. forthcoming)
- Consider all benefits and costs associated with renewable energy resources, including:
    - Health benefits from emission reductions associated with renewable energy generation, focusing on CO2, SO2, and NOx (Millstein et al. 2024b)
    - Integration costs calculated for each specific resource portfolio and scenario (Biewald et al. forthcoming)
- Provide guidance to utilities about modeling transmission in grid planning to support development of a least-cost portfolio (Biewald et al. forthcoming)
    - Model incremental transmission alternatives tied to resource selections and regional transmission expansion as resource options
    - Evaluate programs and technologies that can be used to avoid or defer a transmission system investment (e.g., non-transmission alternatives)
- Provide guidance to utilities about modeling and analyzing DERs (e.g., solar PV and storage) in grid planning to support development of a least-cost portfolio (Biewald et al. forthcoming)
    - Consider all DER benefits and costs in planning analyses, including the time and locational value of DERs as non-wires alternatives for load relief, voltage support and reducing outages (Frick et al. 2021)
    - Model aggregated DERs or virtual power plants to evaluate the capability of the resources to meet grid needs (Downing et al. 2023)

Procurements, pricing and programs

- Encourage or require utilities to competitively procure energy resources, including utility-scale renewable energy (Kahrl and Schwartz 2021)
- Implement rate structures for utility customers that promote consuming electricity when energy prices are low and shedding or shifting consumption when energy prices are high (Olsen et al. 2023)
- Encourage utilities to offer green tariffs for their customers (NREL 2024)
- Offer programs to accelerate adoption of clean energy technologies, including community solar programs, leveraging federal funding from IIJA and IRA (EPA 2024)

Interconnection

- Participate in regional and federal forums to remove barriers to interconnecting renewable energy resources to the bulk power system (U.S. DOE 2024, Gorman et al. 2024)

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[7] The effective load-carrying capability of a resource or portfolio of resources represents the amount of dependable capacity the resource(s) can provide.

- Address interconnection challenges on the distribution system, including adopting model interconnection policies, procedures and technical standards (IREC 2023)

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