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Consumer Benefits of Clean Energy: Policy Brief

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

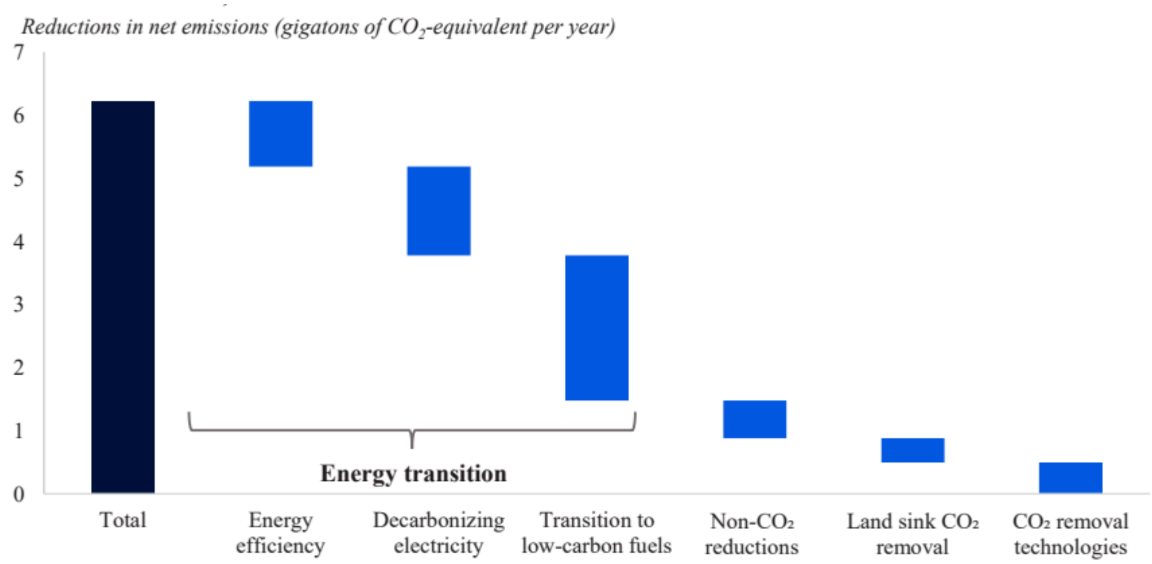
Clean energy offers many benefits to consumers, including reducing consumers' electricity bills, lowering total electricity system costs, and providing health and resilience benefits. States can accelerate consumers' access to these benefits with policies that support energy efficiency, demand flexibility,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

Clean energy offers many benefits to consumers, including reducing consumers' electricity bills, lowering total electricity system costs, and providing health and resilience benefits. Recent research by the [International Energy Agency]() identified four pillars for action to create a credible pathway that limits global temperature rise to 1.5 degrees Celsius, including decarbonizing the electricity system. The [Economic Report of the President]() identified similar actions toward meeting the Biden Administration's goal to achieve a carbon-pollution free power sector by 2035 and a net-zero emissions economy by 2050 (White House 2021) (Figure 1).



Source: U.S. Long-Term Climate Strategy.
Note: CO_2 = carbon dioxide.

Figure 1. Representative Pathway to Meet Zero Net Emissions in the US, 2005-2050. Source[: White House 2021.]()

About half of the U.S. states plus the District of Columbia and Puerto Rico have also established clean energy goals (Figure 2).

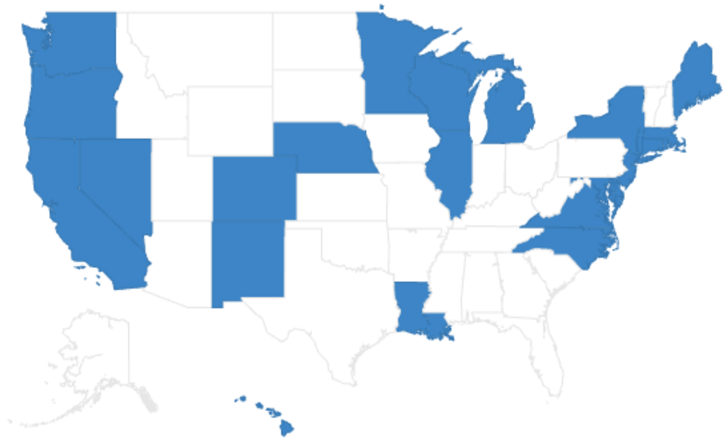


Figure 2. Jurisdictions with Clean Energy Goals. Source [Clean Energy States Alliance.]()

Deployment of clean electricity resources to meet these goals can provide many consumer benefits including reducing consumers' electricity bills and providing health, reliability and resilience benefits. Distributed energy resources (DERs) such as energy efficiency, demand flexibility, renewable energy, and energy storage technologies can reduce total electricity system costs for *all* consumers by reducing energy needs and peak demand on the grid, lowering overall emissions, and shifting consumption to align with low-cost variable renewable energy generation (Langevin et al. 2023; Bolinger et al. 2023; Frick et al. 2021). In addition, customers *hosting* DERs benefit from enhanced reliability and resilience (Akhil et al. 2015, Balducci et al. 2018) and direct bill savings.

New utility-scale renewable energy resources can generate electricity at lower cost than operating an existing combined-cycle natural gas unit (Bolinger et al 2023). That can reduce utilities' revenue requirements and lower wholesale electricity market supply costs, potentially reducing *all* customers' electricity rates and bills.

Consumer benefits are amplified with the federal incentives available for clean energy technologies in the Bipartisan Infrastructure Law (BIL) and the Inflation Reduction Act (IRA). BIL and IRA incentives reduce the cost to consumers of energy efficiency measures, building and transportation electrification, and renewable energy generation. For example, IRA provides incentives for energy-efficient home appliances, heat pumps and water heaters. Incentives also assist consumers with whole-home efficiency measures and upgrading panel service to meet vehicle charging and other electrification needs.

In addition to considering overall consumer benefits, decisionmakers consider affordability and equitable *distribution* of benefits and costs of the clean energy. As of 2020, more than a quarter of Americans were energy insecure and received either a disconnection notice, paid energy bills in lieu of other important expenses, sacrificed thermal comfort and safety by keeping homes at high or low temperatures, or lacked funds to repair or replace space conditioning equipment (2020 Residential Energy Consumption Survey).

Energy efficiency and other distributed energy resources in disadvantaged communities and energy-burdened households can reduce electricity bills and increase comfort. The U.S. Department of Energy (DOE) estimates that, compared to a future without BIL and IRA, these federal policies can save customers $27-$38 billon on electricity bills between 2022 and 2030 and reduce U.S. greenhouse gas emissions 35-41 percent below 2005 levels in 2030. Similarly, the Energy Information Administration (EIA) projects electricity prices in 2030 will be nearly 10 percent lower than they would have been without IRA, in part due to tax credits that incentivize solar and wind over natural gas generation.

To further explore the consumer benefits of a clean energy, Berkeley Lab developed a series of briefs:

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.
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Energy efficiency remains a low cost resource that contributes to a least-cost electricity system.

In many states, utilities conduct bulk power system planning to identify an optimal portfolio of resources to meet future electricity needs and policy and regulatory requirements. Best practices consider cost, risk, and uncertainty and include both supply- and demand-side resources—energy efficiency, demand response, distributed generation and storage, microgrids and managed electric vehicle charging (Biewald et al. forthcoming). Energy efficiency, from traditional measures to more time- and location-sensitive approaches, provides important grid benefits for bulk power and distribution systems.

The cost of saving electricity is the cost of acquiring electricity savings that accrue over the economic lifetime of the actions taken — at a program, sector or portfolio level — discounted back to the year that costs are paid and actions are taken.

Berkeley Lab analyses show that the cost of energy efficiency is competitive with, or less expensive than, fossil-fuel electricity generation. For example, valuation of the cost of saving electricity found that energy efficiency remains a low-cost energy and capacity resource, compared to electricity generation (Frick et al. 2024). Based on analyzing data from energy efficiency programs operated in 2021 by 64 investor-owned utilities and other program administrators in 21 states, Berkeley Lab found that more than 60 percent of the 2021 annual savings cost less than the lowest levelized cost for electricity generation ($24/MWh utility scale solar photovoltaics and onshore wind) (see Figure 3 and Figure 4). When compared to electricity generation, these energy efficiency programs stand out as a least-cost resource. About 80% of 2021 annual energy efficiency savings in our dataset (Figure 3) cost less than the lowest levelized generation costs reported by Lazard ($27/MWh utility onshore wind, Figure 4).

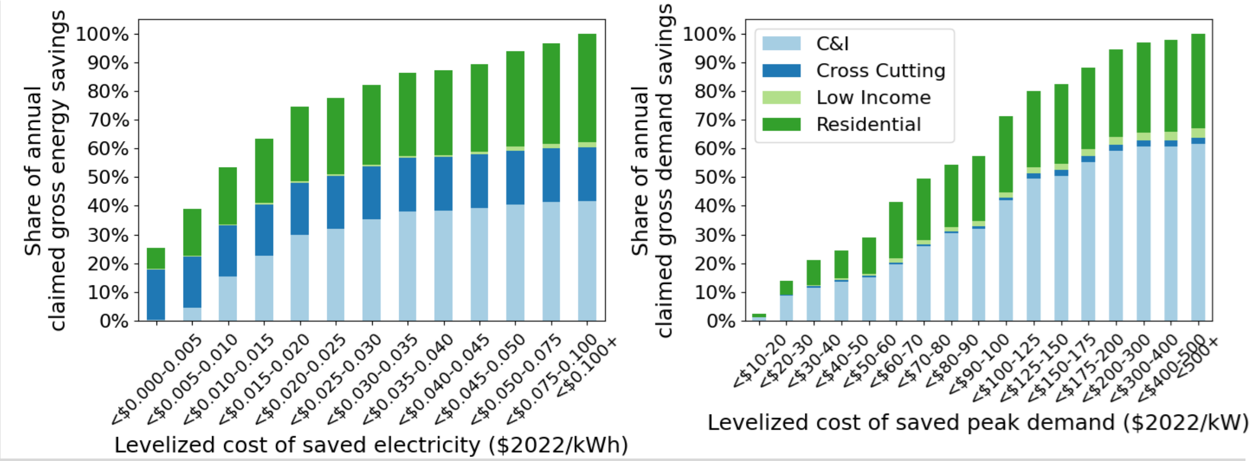


Figure 3. Levelized Cost of Saved Electricity and Peak Demand. Source: Frick et al. 2024.

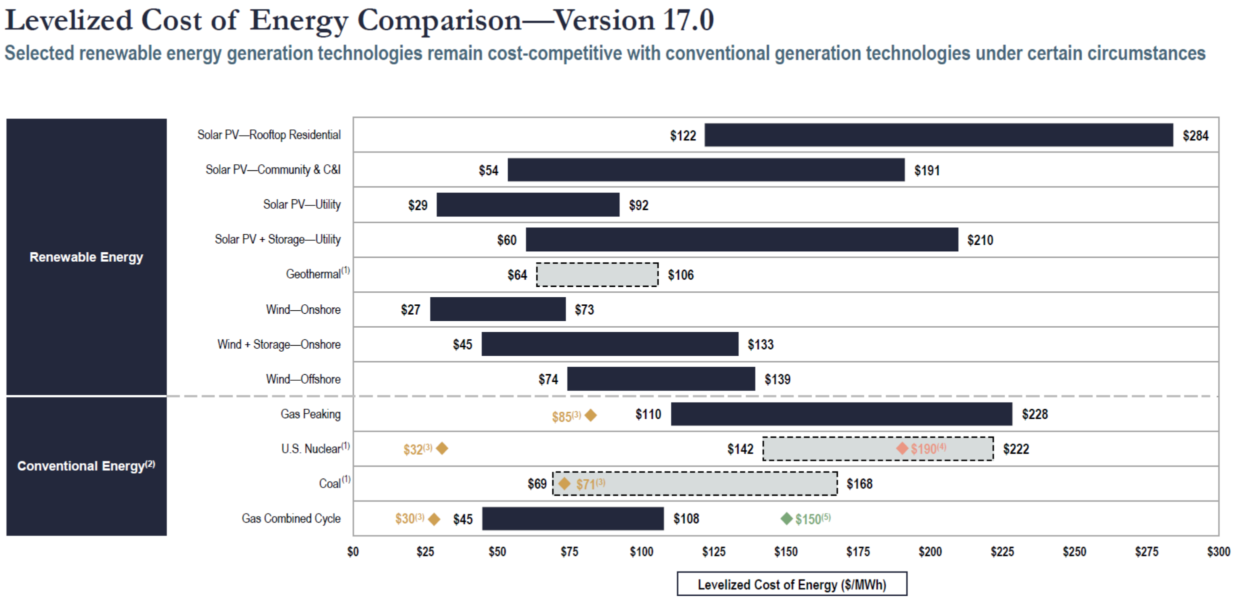
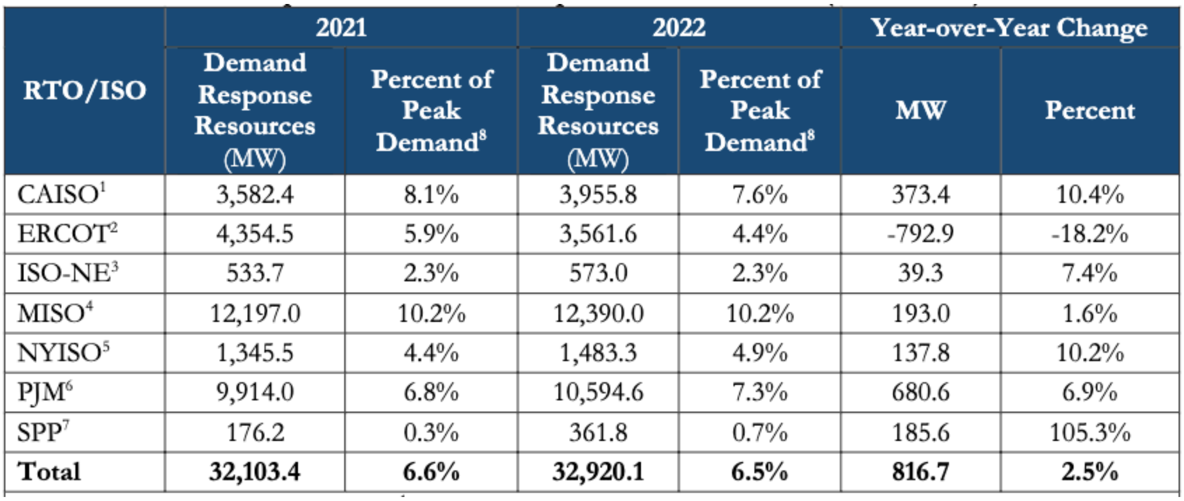


Figure 4. Levelized Cost of Energy. Source: Lazard 2024

Utilities and regional transmission operators/independent system operators (RTOs/ISOs) are beginning to use more demand response to shed peak load when electricity is the most expensive to produce, or shift load to times when variable renewable energy generation is highest (Figure 5). Utilities include demand response or demand flexibility in their long-term electricity resource portfolios because it is a least-cost resource, and many are exploring how to maximize its value to consumers through aggregation and automation (e.g., virtual power plant) (Carvallo and Schwartz 2023, Brehm and Tobin, 2024).



RTO/ISO	2021		2022		Year-over-Year Change	
	Demand Response Resources (MW)	Percent of Peak Demand[8]	Demand Response Resources (MW)	Percent of Peak Demand[8]	MW	Percent
CAISO[1]	3,582.4	8.1%	3,955.8	7.6%	373.4	10.4%
ERCOT[2]	4,354.5	5.9%	3,561.6	4.4%	-792.9	-18.2%
ISO-NE[3]	533.7	2.3%	573.0	2.3%	39.3	7.4%
MISO[4]	12,197.0	10.2%	12,390.0	10.2%	193.0	1.6%
NYISO[5]	1,345.5	4.4%	1,483.3	4.9%	137.8	10.2%
PJM[6]	9,914.0	6.8%	10,594.6	7.3%	680.6	6.9%
SPP[7]	176.2	0.3%	361.8	0.7%	185.6	105.3%
Total	**32,103.4**	**6.6%**	**32,920.1**	**6.5%**	**816.7**	**2.5%**

Figure 5. Demand Response Resource Participation in RTOs/ISOs, 2021-2022. Source: FERC 2023.

Utility-scale and behind-the-meter renewable energy are low-cost resources.

Similarly, 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 often times competitive in wholesale power markets, meaning savings for purchasers and potentially enabling consumer electricity bill reductions (Wiser et al. 2024).

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 4, 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 4) and wind ($45-$133/MWh, per Figure 4) "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 4).

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. 2023). However, costs have steeply declined over a longer historical period and learning curve theory[1] 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,[2] 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).

Modeling studies of the 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 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.

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

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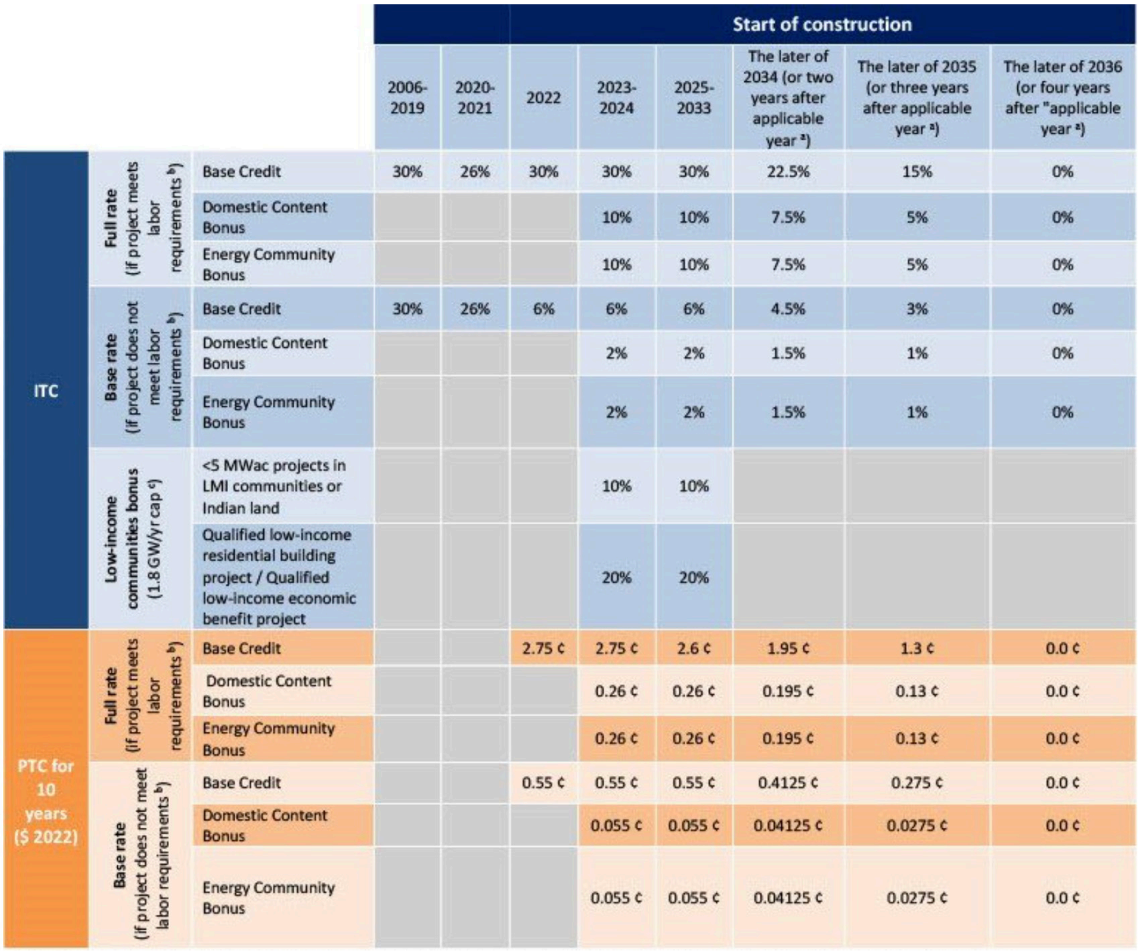
[1] Learning curve theory is the concept that as output doubles the average cost per unit drops by a fixed percentage. Harvard Business Review, 1974.

[2] 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.

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.

Residential heat pumps can reduce air pollutants.

The third brief in the series examines the health benefits of electrifying residential space and water heating by eliminating air pollutants from onsite combustion and decreasing air emissions from generation required to electrifying these end uses. Seven percent of U.S. greenhouse gas emissions are from combustion of fuel in residential buildings (EPA 2024). Electrification of space and water heating is commonly seen as the most viable pathway to decarbonization of this sector (Pigman et al. 2024). For example, the IRA provides several types of residential electrification incentives, including up to $8,000 for a heat pump and $1,750 for a heat pump water heater for low-to moderate income households (Figure 6).

Analysis by Berkeley Lab found that displacing one percent of fossil-fueled residential water and space heating in the contiguous U.S. with heat pumps can generate lifetime air quality and climate benefits of $4.6–$8.5 billion (Figure 7). Health impacts account for approximately 20 percent of these benefits. While electrification impacts varied widely by region, heat pump water heaters and very high efficiency air-source heat pumps for heating created positive (or neutral) benefits in every region of the country from health impacts alone.

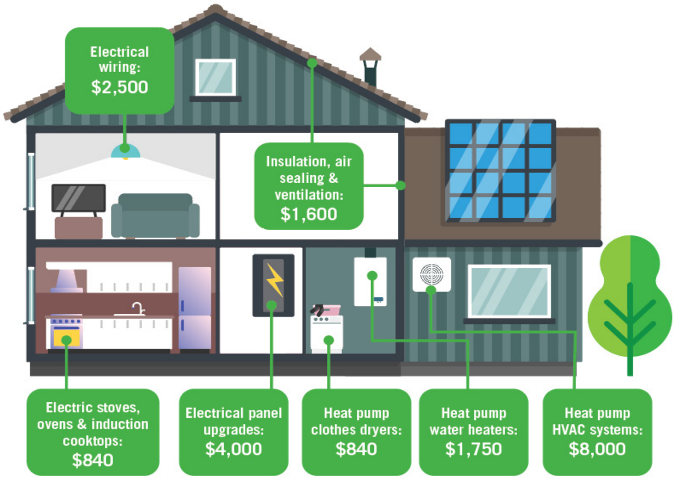


Figure 6. Home Electrification and Appliance Rebate Tax Credit. Source: [Energy Smart Colorado.](#)

Minimum efficiency air-source heat pumps created positive health impacts in nine out of fourteen regions. For example, each household that electrifies space heating with a minimum efficiency air-source heat pump in New England increases public health benefits by $3,100 but decreases these benefits by $1,700 in the Midwest, where the electricity resource mix produces higher emissions. When carbon reductions are factored in, even minimum efficiency heat pumps resulted in financial benefits for every region. U.S. policymakers can facilitate installation of heat pump water heaters and very efficient air-source heat pumps to achieve regional air quality improvements and climate goals.

Building electrification can help states meet their clean energy goals, but may also cause load growth. Berkeley Lab's analysis found that even when considering the air pollutant impacts of additional electricity generation to meet load growth from building electrification, people are exposed to fewer emissions and positive public health impacts overall.

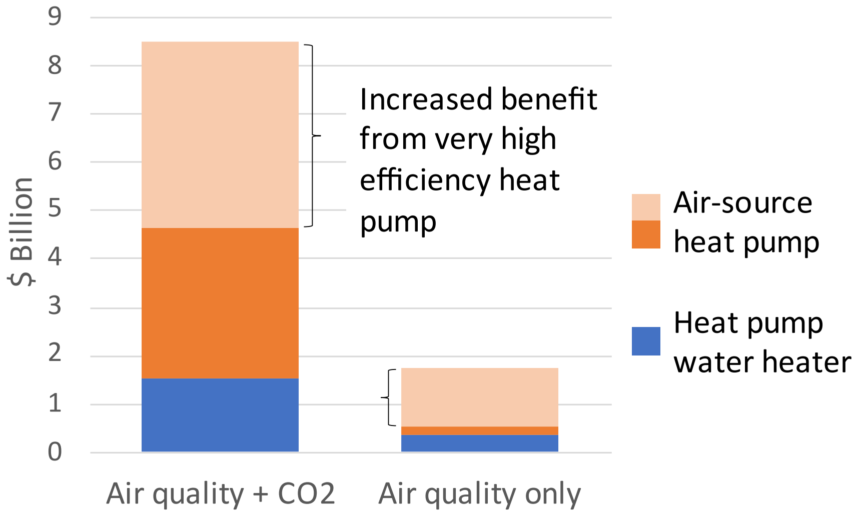


Figure 7. Lifetime Air Quality and Climate Benefits from Heat Pumps. Source: [Pigman et al. 2024.](#)

Residential solar + storage improves resilience.

The fourth brief examines the capability of residential solar plus energy storage systems (PVESS) to mitigate long duration interruptions (those lasting longer than one day) and the resilience value of these systems for residential customers—with and without the federal renewable energy investment tax credit and IRA incentives.

***Resilience* is "the ability to prepare for and adapt to changing conditions and withstand and recover rapidly from disruptions. Resilience includes the ability to withstand and recover from deliberate attacks, accidents, or naturally occurring threats or incidents" (Presidential Policy Directive 21).**

PVESS are clean energy resources that supply backup power without using fossil fuels or increasing emissions. Installations of solar plus storage systems are on the rise, with consumers identifying access to backup power as a significant reason (Figure 7).

Berkeley Lab researchers first analyzed the capability of PVESS to mitigate long duration interruptions and found that PVESS can reduce approximately 96 percent of demand losses during simulated resilience events. The analysis indicated that very small amounts of load shedding may be required during long duration events, on average 0.7 kWh per household per year (about four percent of household demand) across all counties.

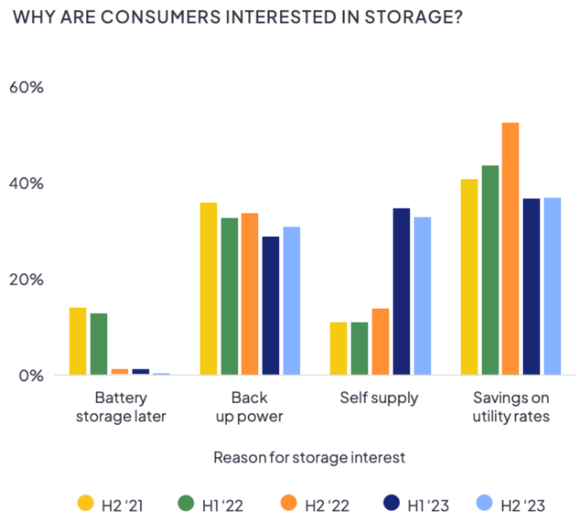


Figure 8. Reasons Consumers Are Interested in Solar + Storage. Source: Energy Sage. H1: First Half of Year; H2: Second Half of Year

Next, Berkeley Lab quantified the resilience benefits of PVESS. The value of standalone solar energy systems for self-consumption, bill savings, reduced demand charges and backup power has been studied extensively. But there is limited information on the resilience and reliability value provided by backup power applications of storage (Gorman et al. 2023, Balducci et al. 2021). Berkeley Lab calculated the benefit-cost ratio of the resilience value of PVESS for deployment of storage for typical homes in each county of the continental United States.

The results demonstrate that, in most counties, resilience benefits alone are insufficient to justify the economic addition of storage to existing solar systems (Figure 8).[3] However, PVESS have many benefit streams in addition to resilience, including bill reductions, renewable energy and carbon reduction credits, and reliability benefits from mitigating short-duration interruptions. When accounting for these benefits, storage investment costs can have a positive net benefit for participating

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[3] A benefit-cost ratio above one indicates that expected annual benefits surpass the annualized cost of storage. A benefit-cost ratio lower than one indicates that benefits do not exceed the cost.

customers. In areas that experience a high number of resilience events with longer durations, adding storage to solar systems can be justified solely on the resilience benefits.

Understanding the total value of PVESS, including resilience, allows for design of effective incentives for achieving multiple energy goals, including decarbonization, at lower costs.

Benefit-cost ratios in the resilience study vary widely. Regions with fewer outages have minimal resilience benefits, while regions with frequent and long duration resilience events accrue substantial resilience benefits. Such analysis can help target policies and programs to high-outage areas.

Berkeley Lab's analysis also assessed the impact of federal tax incentives on PVESS economics. The 30 percent investment tax credit for residential clean energy technologies improved benefit-cost ratios by an average of six percent. The combined impact from the investment tax credit and bonus tax credits, results in the average benefit-cost ratio increasing about nine percent — enough in some regions to justify battery investments solely on resilience benefits.

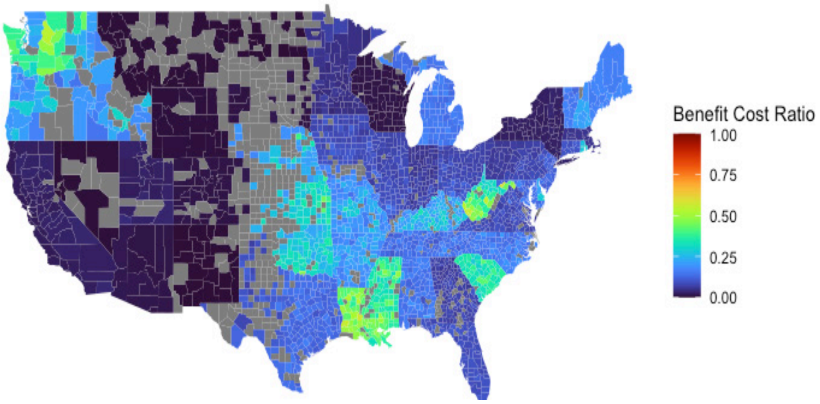

Figure 8. Resilience benefit-cost ratios for PVESS in the baseline scenario.

State decisionmakers can consider policy, regulatory, and program options to accelerate and amplify consumer benefits.

States can pursue a variety of actions, summarized below, to help take advantage of the consumer benefits of clean energy. The briefs discuss these options in greater depth.

Energy efficiency, demand flexibility and renewable energy

The IRA and BIL provide historic levels of federal funding to states to accelerate the deployment of clean energy technologies. States can **use federal funding from BIL and IRA to support adoption of efficient electrification equipment, solar plus storage and other BTM resources to advance their energy and equity goals,** among others.[4] The Grid Resilience State and Tribal Formula Grants, authorized through the BIL, can support equitable resilience solutions, such as targeting PVESS in areas with more frequent and longer duration power interruptions. The State Energy Program formula funding can be used to develop and implement resilience plans, accelerate deployment of energy efficient technologies through financing measures such as loan programs and reduce peak demand

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[4] IRA and BIL can promote many other state goals such as economic development and air pollutant reductions. Here we focus on policies to advance the consumer benefits discussed in the report series.

through programs that modify patterns of energy consumption among other activities.

States can **establish or improve grid planning processes** and identify objectives and goals to guide them. For example, utilities can file objectives-based distribution system plans that meet multiple state objectives.[5] States can provide guidance to utilities for considering DERs such as energy efficiency, demand flexibility, solar PV and storage in grid planning to support development of a least-cost portfolio. For example, guidance on grid planning might include:

- **Modeling DERs, including energy efficiency and demand response on par with other resources,** allowing for consideration of the interaction between DERs, and between DERs and other resources, to identify a least cost, reliable electricity portfolio. This includes considering all DER benefits and costs in planning analyses.
- **Considering the time and locational value of DERs** as non-wires alternatives for load relief, voltage support and reducing outages.

Procurements, pricing and programs are three options for acquiring energy efficiency, demand flexibility and renewable energy resources. States can encourage or require that utilities **competitively procure energy resources** including utility-scale renewable energy and distributed energy storage, and **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. States and utilities can **offer programs to accelerate the adoption** of clean energy technologies, leveraging federal funding if available. States and utilities can first test rates and program designs through pilot projects and use the information gathered to develop full-scale programs.

States can adopt policies to **accelerate and remove barriers to interconnecting renewable energy and storage resources** to the electricity grid. DOE's Transmission Interconnection Roadmap highlights many actions that states and others can take to more efficiently and fairly interconnect clean energy resources on the bulk transmission system. States also can address challenges on the distribution system, including adopting model interconnection procedures and interconnection policies. DOE's Interconnection Innovation E-Xchange (i2x) offers additional resources for states.

Health

States can use efficient electrification as a tool to meet **air quality** requirements or **decarbonization goals**. For example, switching fossil-fueled space and water heating in homes to highly efficient heat pumps and heat pump water heaters produces air quality benefits despite the increase in electricity generation. While minimum efficiency heat pumps produce carbon dioxide emissions reductions benefits in all regions, more efficient heat pumps are necessary to achieve all air quality benefits (such as avoiding the emissions of ammonia, nitrogen oxides, particulate matter, and sulfur dioxide).

One tool states can use to increase the efficiency of appliances such as heat pumps, and promote

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[5] See Berkeley Lab's compilation of state distribution planning requirements, as well as training materials and publications on the Integrated Distribution System Planning website.

demand flexibility and solar for buildings are **codes and standards**. Among the opportunities for advancing consumer benefits through building energy codes and appliance standards are to:

- Value energy efficiency measures for code compliance based on time-sensitive savings
- Allow demand flexibility to earn credit towards code compliance
- Require grid-connected and demand-flexible technologies
- Incorporate solar or electric vehicle technology or readiness.

Resilience

States can take action to improve resilience data**,** assess resilience metrics, and develop maps and tools to improve stakeholder and community understanding of resilience benefits. Requiring utilities to **make resilience data publicly available**, report power interruption data at a granular time and geographic scale and the impact of outages on customers, and develop standardized metrics for resilience events are all useful actions to promote data transparency.

Requiring or encouraging utilities to measure the value of lost load[6] at the customer (or highly disaggregated) level enables utilities to make informed and effective resilience investment decisions based on the specific vulnerabilities of their system and assist developers in designing value-added products for utility customers.

States also can ask utilities to **develop resilience value maps and online assessment tools**. For example, publicly available maps with spatially granular outage information would allow PVESS project developers to target specific areas of the distribution system where resilience benefits are greatest.

For additional information about these options, see the *Consumer Impacts of Clean Energy* series:

- Energy Efficiency
- Renewable Energy
- Climate and Health Benefits of Electrifying Residential Space and Water Heating
- The Resilience Value of Residential Solar + Storage Systems in the Continental U.S.

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[6] A monetary metric that can be used to measure the reliability impact on customers is the value of lost load (VOLL). The VOLL is traditionally measured through customer interruption cost (CIC) surveys that treat residential, commercial, and industrial customers separately. CIC surveys, by themselves, are considered inadequate to measure the economic impacts of long-duration interruptions or resilience events due to the customer's inability to quantify the cost of an interruption at a scale they have not experienced before (Baik et al. 2021).

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