Empowering Homes and Strengthening the Grid: Analyzing the Benefits of Distributed Solar Plus Storage for North Carolina

Prepared for:

SOLAR UNITED NEIGHBORS

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Executive Summary

After three decades of relatively flat electricity demand, the United States is experiencing a significant increase in demand with the construction of data centers, new domestic manufacturing facilities, and the electrification of vehicles and technologies. Demand is expected to increase by up to 15% in some regions of the country by 2030.[1] In North Carolina, electricity demand is projected to grow by 4 GW from 2024 to 2030.[2] As a result, the state, utilities, and their electricity customers are looking for strategies to meet new demand in as little as six years. One solution is to harness residential solar plus storage systems.

Developed on behalf of Solar United Neighbors (SUN), this report seeks to answer the following policy question:

What are the benefits of distributed solar paired with battery storage for individuals and the grid in North Carolina, and what policies should Solar United Neighbors advocate for to maximize these benefits?

This report estimates the benefits of distributed rooftop solar plus storage systems in North Carolina to inform SUN's messaging to discuss the benefits of solar plus storage with diverse stakeholders, including homeowners, utilities, and lawmakers. This report also provides recommendations for SUN's lobbying efforts to encourage broader residential solar adoption and the potential of virtual power plants (VPPs) in the state.

Through a mixed-method approach of a national survey, qualitative case studies, and quantitative analysis, this report provides a holistic view of the state of distributed solar adoption in North Carolina and current barriers to higher adoption. It provides policymakers and advocates with a strategy to overcome these barriers.

FINDINGS

1. High upfront costs and lack of education on the benefits of residential solar plus storage and available financial incentives are the primary barriers to adoption.

2. Voters support policies that financially compensate residential solar owners for the economic and reliability benefits they provide to the grid.

3. Case studies emphasize the importance of state-sponsored distributed solar programs through solar carve-outs for renewable targets.

4. State and utility-level renewable energy tax credits are important in improving the affordability of residential solar, especially for enabling greater battery co-installation.

5. Factoring in the reliability benefits, solar plus storage can be cost-beneficial for North Carolinians.

Based on the findings, this report recommends the following policy strategy for SUN's future efforts in North Carolina:

RECOMMENDATIONS:

1. High upfront costs and uncertainties about the reliability and cost-saving benefits of residential solar plus storage remain key barriers. SUN should continue to educate the public on the availability of federal and utility-level tax credits and the additional benefits of a solar plus storage system.

2. North Carolina should adopt policies to encourage more battery co-installation with solar adoption to support resiliency during power outages, such as additional battery incentives.

3. North Carolina and solar companies should adopt innovative financing and ownership models to enable low-income and rental households to benefit from rooftop solar without having to commit to the high upfront cost of a permanent solar system.

4. Customers need a favorable net metering policy to recover the upfront cost of solar systems. A combination of incentives to bring down the upfront cost and generous net metering rates that reflect the true value of solar reduce the financial burdens of residential solar systems.

5. The North Carolina Utilities Commission should require consideration of VPPs and battery storage in Integrated Resource Planning.

6. To specifically encourage distributed generation, the NCUC should establish a VPP goal of 300 MW by 2030 to prioritize the integration of residential solar plus storage systems.

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I. INTRODUCTION

The United States is experiencing a period of rapidly growing electricity demand driven by data center expansion, domestic manufacturing, and the electrification of the economy, with national demand expected to increase by more than 15% by 2029.[3] In North Carolina, which has attracted companies like Toyota, Vinfast, Meta, and Apple, electricity demand is expected to increase by 4 GW from 2024 to 2030.[4] This rapid demand growth is occurring faster than new power plants can come online, with the average thermal generation plant taking four years to construct and utility-scale renewable projects around two years.[5] The dangers of a mismatch between electricity supply and demand include poor reliability, lower quality, and blackouts.[6] As a result, policymakers, the energy sector, and large energy consumers are scrambling to answer this reliability problem.

Conventional solutions to balancing the grid include restarting retired generating facilities and pausing new retirements, curbing energy usage through demand-response programs, or building new utility-scale generation, such as natural gas or renewable energy facilities. A less common solution is harnessing residential solar plus storage systems through a virtual power plant (VPP), which combines hundreds or thousands of residential solar plus storage systems into a single generating entity capable of providing the equal power of a conventional generator. The reliability challenge presents an opportunity for the residential solar plus storage industry to show its ability to meet rising demand, decarbonize the economy, and ensure a reliable grid.

I. POLICY QUESTION

Solar United Neighbors (SUN) is a national 501(c)(3) nonprofit organization representing the interests of solar owners and clean energy supporters. SUN collaborates with solar manufacturers and installers across the United States to advocate for policies to grow solar adoption. A growing discussion in the solar industry is the potential of distributed solar plus battery storage projects to lower energy costs, increase renewable energy adoption, and enable independent power generation. Distributed generation is defined as electricity generated near the point of use.[7] This analysis will interchangeably use the terms “distributed,” “rooftop,” and “residential” solar. The pairing of battery storage with a solar system allows generation to be stored for later use or sold to the grid during periods of high demand. SUN is interested in how to spur distributed solar plus storage adoption at a larger scale through the following policy question:

What are the benefits of distributed solar paired with battery storage for individuals and the grid in North Carolina, and what policies should Solar United Neighbors advocate for to maximize these benefits?

This report outlines residential solar plus storage policies to provide reliable electric service for North Carolina. This research will inform SUN’s messaging strategy to increase distributed solar plus storage adoption in North Carolina. Additionally, SUN is interested in exploring what policies or regulatory regimes would facilitate the creation of virtual power plants (VPPs). VPPs further optimize distributed solar plus storage systems by aggregating hundreds or thousands of solar systems to balance demand and supply like a traditional power plant.[8] Higher adoption of distributed resources, like solar plus storage, is required to make VPPs a reality.

Using a mixed-method approach of a national survey, qualitative case studies, and quantitative analysis, this report finds:

II. FINDINGS

1. **High upfront costs and lack of education on the benefits of residential solar plus storage and available financial incentives are the primary barriers to adoption.** A lack of education refers to consumer uncertainty about the reliability and cost-saving benefits of installing solar plus storage systems on their home, with more than one-third of voters thinking there is no impact or being unsure of the impact on reliability and their electric bill. Additionally, only one-third voters are aware of the federal tax credits available to reduce the upfront cost. The lack of education is a significant problem, as the most common barrier to installing solar is the high upfront cost.

2. **Voters support policies that financially compensate residential solar owners for the economic and reliability benefits they provide to the grid.** In a national survey of U.S. likely voters, 68% of voters support net metering policies that provide greater compensation to solar owners when they sell excess power back to the grid, and 80% support a VPP program to compensate solar plus storage owners for making their system available to the grid during high periods of demand.

3. **Case studies emphasize the importance of state-sponsored distributed solar programs through solar carve-outs for renewable targets.** While North Carolina has a Renewable Portfolio Standard of 12.5%, other states such as Arizona and Massachusetts have significantly more aggressive renewable energy goals that encourage greater solar adoption by utilities and require a certain percentage of renewable energy to come from solar or distributed resources.

4. **State and utility-level renewable energy tax credits are important in improving the affordability of residential solar, especially for enabling greater battery co-installation.** As shown in **Figure 1**, states will higher residential solar incentives are correlated with higher rates of distributed solar adoption. Arizona provides a tax credit of up to $1,000 for a solar system, and as a result, has seven times the amount of distributed solar generation per capita than North Carolina. Similarly, Massachusetts incentivizes solar plus storage adoption with a renewable energy tax credit of up to $1,000 for solar installation plus up to $500 annually for storage. Massachusetts has nearly eleven times the distributed solar generation per capita as North Carolina. One of the most generous state tax incentives is Hawaii’s $5,000 tax credit, resulting in Hawaii having more than twelve times the distributed solar generation per capita as North Carolina.

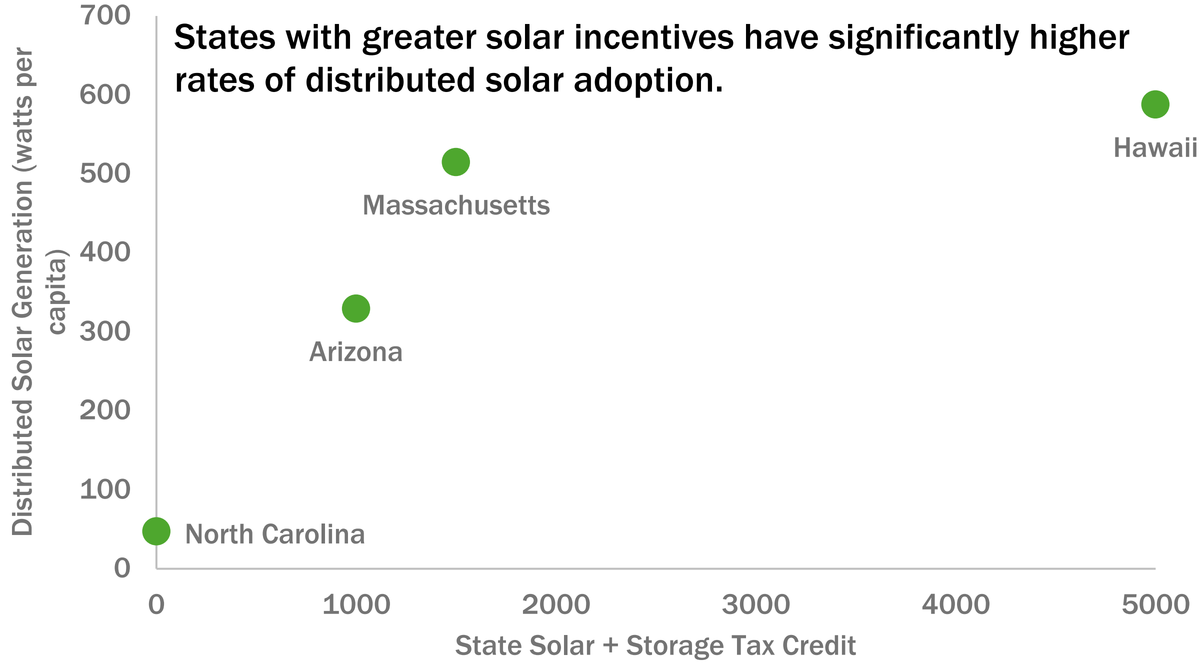


Figure 1: State tax incentives are correlated with higher rates of distributed solar generation, as seen incrementally in Arizona, Massachusetts, and Hawaii.

5. **Factoring in the reliability benefits, solar plus storage can be cost-beneficial for North Carolinians.** As experienced in Puerto Rico, a major driver for residential solar plus storage adoption is poor electric reliability and high electricity prices. This has spurred alternative sources of generation, with 84% of solar generation in Puerto Rico now coming from small-scale distributed solar. Under a Levelized Cost of Electricity (LCOE), utility-scale solar plus storage is more economical than residential solar plus storage, however, analyses fail to incorporate the ancillary reliability benefits of residential solar plus storage during extreme weather or other outage events. In North Carolina, the LCOE of $175.1/MWh for residential solar plus storage systems is minimal considering the alternative of residential customers losing an aggregated $2,120/MWh during an outage event.

Based on these findings, this report recommends the following policy strategy for SUN's future efforts in North Carolina:

III. RECOMMENDATIONS

1. The national survey finds that high upfront costs and uncertainties about the reliability and cost-saving benefits of residential solar plus storage remain key barriers. SUN should educate the public on the availability of tax credits and the additional benefits of a solar plus storage system. Many consumers are unaware of the ability of residential solar plus storage to lower their utility bills and enhance reliability. Despite the disconnect, the two most common reasons for voters to install solar are to lower their electric bill and to be insulated from extreme weather events.

2. North Carolina should adopt policies to encourage more battery co-installation with solar adoption to enable their use during power outages. While solar systems can lower customers' electricity bills on their own, energy storage is required to provide a reliability benefit. Additionally, battery storage allows for greater integration into a VPP to provide services to the central grid. However, battery storage can be cost-prohibitive for many customers, and state incentives are needed to alleviate the upfront cost barrier.

3. North Carolina and solar companies should adopt innovative financing and ownership models to enable low-income and rental households to benefit from rooftop solar without having to commit to the high upfront cost of a permanent solar system. This is another way to reduce the upfront cost while also improving equity of home solar installations.

4. Customers need a favorable net metering policy to recover the upfront cost of solar systems. A combination of incentives to bring down the upfront cost and generous net metering rates that reflect the true value of solar reduce the financial burdens of residential solar systems. Offering below retail value for residential solar disincentives sales back to the grid, as that electricity is worth more to the solar owner.

5. The North Carolina Utilities Commission should require consideration of VPPs and battery storage in Integrated Resource Planning, modeling their ability to not only reduce demand but also the additional benefits from reduced capital construction needs. During periods of peak demand, VPPs can be the lowest cost resource relative to running uneconomical peaker plants. Otherwise, the state will likely overbuild generating facilities without accounting for their capacity.

6. To specifically encourage distributed generation, the NCUC should establish a VPP goal of 300 MW by 2030 to send a clear signal to Duke Energy to prioritize integration of residential solar plus storage systems. This short-term goal will provide additional lessons for further VPP deployment.

IV. POLICY BACKGROUND

Distributed Solar is Needed to Accelerate Electric Sector Decarbonization

In 2021, North Carolina passed House Bill 951 (HB 951) which requires the state to reduce carbon emissions in the electricity sector by 70% by 2030 and to be carbon neutral by 2050.[9] The electricity sector is the second-largest contributor to the state's GHG emissions, accounting for 30% of emissions in 2020.[10] Emissions are driven by the 61% of electricity generated from fossil fuels.[11] Decarbonization of the grid will require a shift to more renewable energy sources, including utility-scale wind and solar projects.

Renewables present the opportunity for localized generation near end-users, or the use of distributed energy resources. Distributed solar can speed decarbonization by avoiding the long construction timelines, local opposition, high capital costs, and lengthy interconnection periods facing utility-scale solar projects. The median completion time for a utility-scale solar project is

25 months, compared to as little as three months for the average residential rooftop solar installation.[12]

The state's dominant utility, Duke Energy, has proposed and the North Carolina Utilities Commission (NCUC) has approved plans to build new fossil-fuel-fired generation and extended the emissions reduction timeline.[13] Due to increasing demand from electrification, manufacturing, and data centers, utilities are ramping up generation capacity over the next decade. Duke did not incorporate growth in distributed solar plus storage or the potential of VPPs in their Integrated Resource Plan (IRP), instead relying on utility-scale natural gas, solar, and wind to meet demand. Duke Energy has several VPP pilot programs, though has not scaled beyond these initial pilot programs with limited enrollment. Scaling up VPP programs is one strategy to meet the goals of HB 951 and address the simultaneous electricity demand growth.

Duke Energy has expressed an intention to include VPPs in its next IRP, and one company representative has called for an "all-of-the-above" strategy to ensure reliable electric service.[14] Identifying the benefits of distributed solar plus storage and the potential of VPPs in North Carolina can better inform future generation decisions by Duke Energy and policymakers.

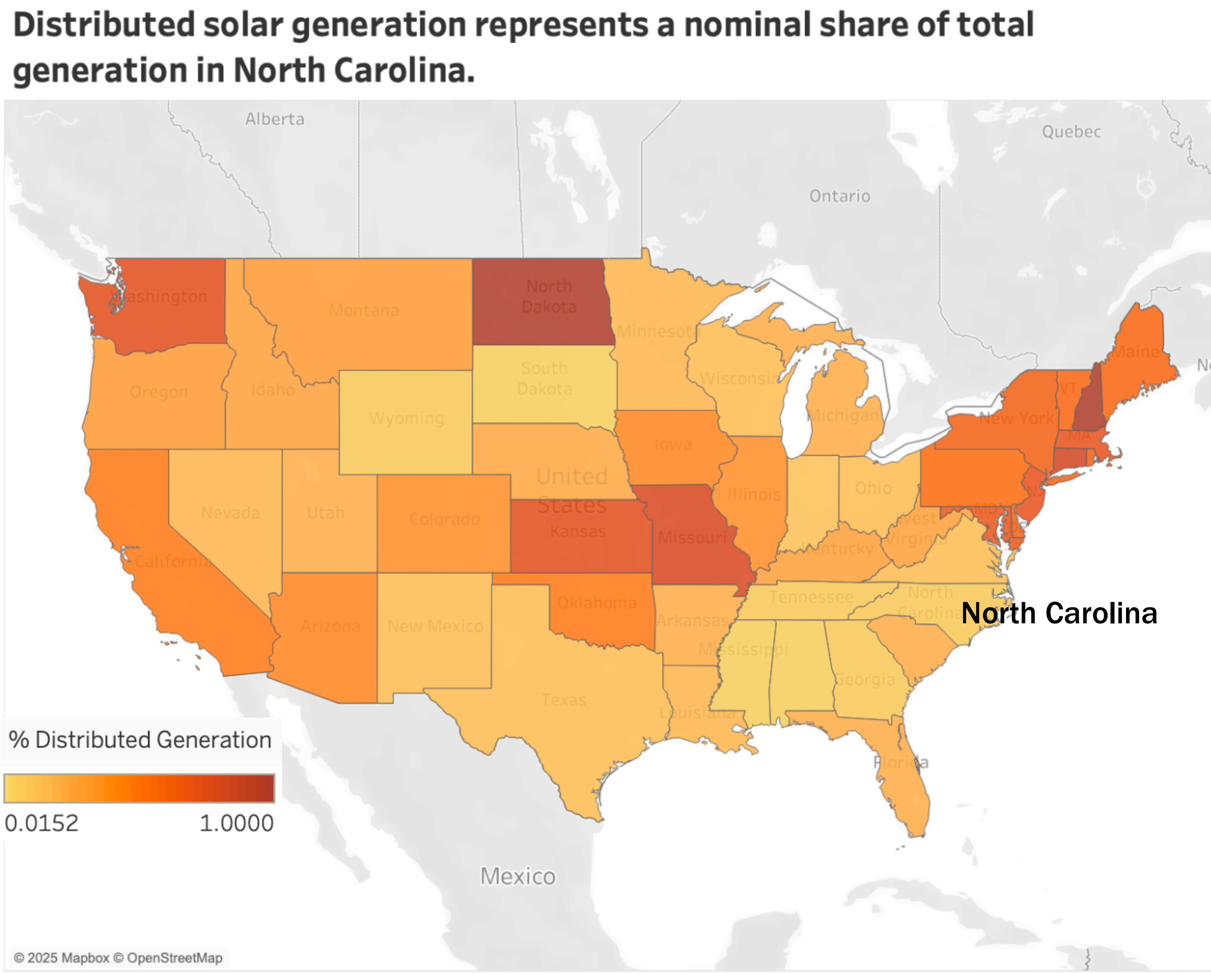
Distributed Solar Adoption Varies Over Time and Space

The U.S. generates ten times the power from rooftop solar today as it did in 2012.[15] Nonetheless, only 7% of homes in the U.S. have solar installations as of 2024.[16] Within the U.S., solar adoption rates vary considerably by geography, with Hawaii at a more than 24% adoption rate while several states have nearly 0% adoption. [17] Some of this discrepancy is attributable to available solar resources, though other policy and consumer barriers are at play.

North Carolina is the fifth largest market in the U.S. for utility-scale solar projects, with more than 7,284 megawatts (MW) installed. However, only 7.7% of this solar is from distributed resources, and less than 0.22% of these solar systems are paired with storage.[18] In total, there are 181 solar plus storage systems in the state out of the 47,000 residential solar installations.[19]As a result, North Carolina falls to 17th in terms of small-scale, distribution solar generation.

Figure 2 illustrates how North Carolina's percentage of distributed solar generation lags most of the country. This paper seeks to understand the policy levers, regulatory environment, and consumer behavior that have led to this discrepancy in utility-scale versus distributed solar adoption given North Carolina's generous solar endowment.

Figure 2: Map of distributed solar as a percentage of total solar generation by state, as of November 2024. Data sourced from EIA



General Barriers to Rooftop Solar Adoption

Several barriers to distributed solar adoption affect most of the country, including incumbent utilities, interconnection processes, high costs, and public education.

1. **Utility business models:** Investor-owned utilities' business models rely on investment in traditional, centralized generation in which they receive a set return through customers' rates. Distributed generation allows consumers to generate their power, which results in less power purchased from the grid and reduced utility revenue. As a result, the utility industry has advocated for policies that create new barriers to distributed solar adoption.[20]

2. **Interconnection time and costs:** Another barrier to rooftop solar adoption is the interconnection process, or the process of connecting a solar system to the grid. Policies vary among states, and each utility can have a unique timeline, process, and cost for interconnection. At a minimum, most residential solar projects must also apply for building permits and get local utility approval. The lack of a streamlined or standardized

interconnection process is slowing the pace of distributed solar. in the U.S. The soft costs, including permitting and interconnection, comprise two-thirds of the total cost of residential solar systems.[21]

3. **Rising costs and interest rates:** Since 2017, residential solar installations have been growing at an average rate of 26% per year.[22] However, 2024 marked the first annual decrease in installations. This decrease is a side effect of a return to normalcy after the dramatic increase in solar installations in 2022 with the passage of the Inflation Reduction Act, combined with rising soft costs and interest rates. High upfront costs remain a key barrier to residential adoption.

4. **Lack of public education:** A final barrier to distributed solar adoption is a lack of public education. As of 2023, 56% of Americans are unfamiliar with the benefits of residential solar plus storage systems.[23] This is especially prevalent in low-income and disadvantaged communities, where residents do not have reliable information about the benefits of distributed solar.[24]

Distributed Solar Policies in North Carolina Have Weakly Encouraged Adoption

Residential solar adoption in North Carolina is well below the national average of 7%, with 1.64% of owner-occupied housing units having installed solar.[25] There are additional geographic discrepancies within the state, with only 20% of rooftop solar adoption occurring in rural counties and most installations in urban and suburban counties.[26] Several policy, regulatory, and consumer levers have resulted in the relatively low adoption of rooftop solar, though a few policies have weakly encouraged adoption in the state.

Passed in 2007, North Carolina's Renewable Portfolio Standard (RPS) has encouraged renewable energy adoption, requiring 12.5% of the state's electricity to come from renewable resources after 2021. The RPS requires 0.20% of electricity come from solar generation, though it mainly incentivizes utility-scale projects as it does not include a specific mandate for distributed solar. [27]

Table 1 outlines the current and historical residential solar incentives available in North Carolina, including state- utility-level programs.

Table 1: Current Residential Solar Incentives in North Carolina

Policy	Description	Availability
Federal Renewable Energy Investment Tax Credit	The ITC covers up to 30% of the installation cost for a rooftop solar system.[28]	2022 – 2033
Property Tax Exemption	Property tax exemption of 100% of the value of a solar system, limiting the tax increase from the value-add of solar panels.	2008 – present
Duke Energy NC Solar Rebate Program	Duke Energy offers a one-time solar rebate to reduce the upfront cost of solar. Residential customers receive $0.40/W, up to $4,000.[29] The program is capped at 20 MW of applicants per year and is fully subscribed and does not accept new participants.[30]	2018 – 2022
Duke Energy PowerPair Program	Duke Energy's PowerPair Program provides one-time compensation of $0.36/W for solar and $400/kWh for battery storage installation.[31] The total compensation is capped at $9,000 per household. Maximum participation is set at 30 MW of solar panels.	2024 – present
Duke Energy PowerPair + Power Manager Program	Launched in mid-2024, Power Manager provides PowerPair customers up to $92 a month if Duke Energy is allowed to call upon their battery power up to 36 times a year.[32]	2024 – present

A non-financial solar policy in North Carolina is the state's interconnection process which includes a "fast-track" for residential solar systems under 20 kilowatts (kW).[33] Interconnection refers to the process of connecting a distributed energy resource to the grid. The NCUC established an expedited interconnection process in which homeowners submit a schematic of the proposed solar system, pay a $200 fee, and provide proof of insurance. This avoids the lengthy and more costly interconnection study process, which can cost between $20,000 to $120,000. [34] A recent update further streamlined the process by allowing previously interconnected solar systems to add energy storage without repeating the interconnection process.[35] The fast-tracked interconnection process saves owners thousands in installation costs.

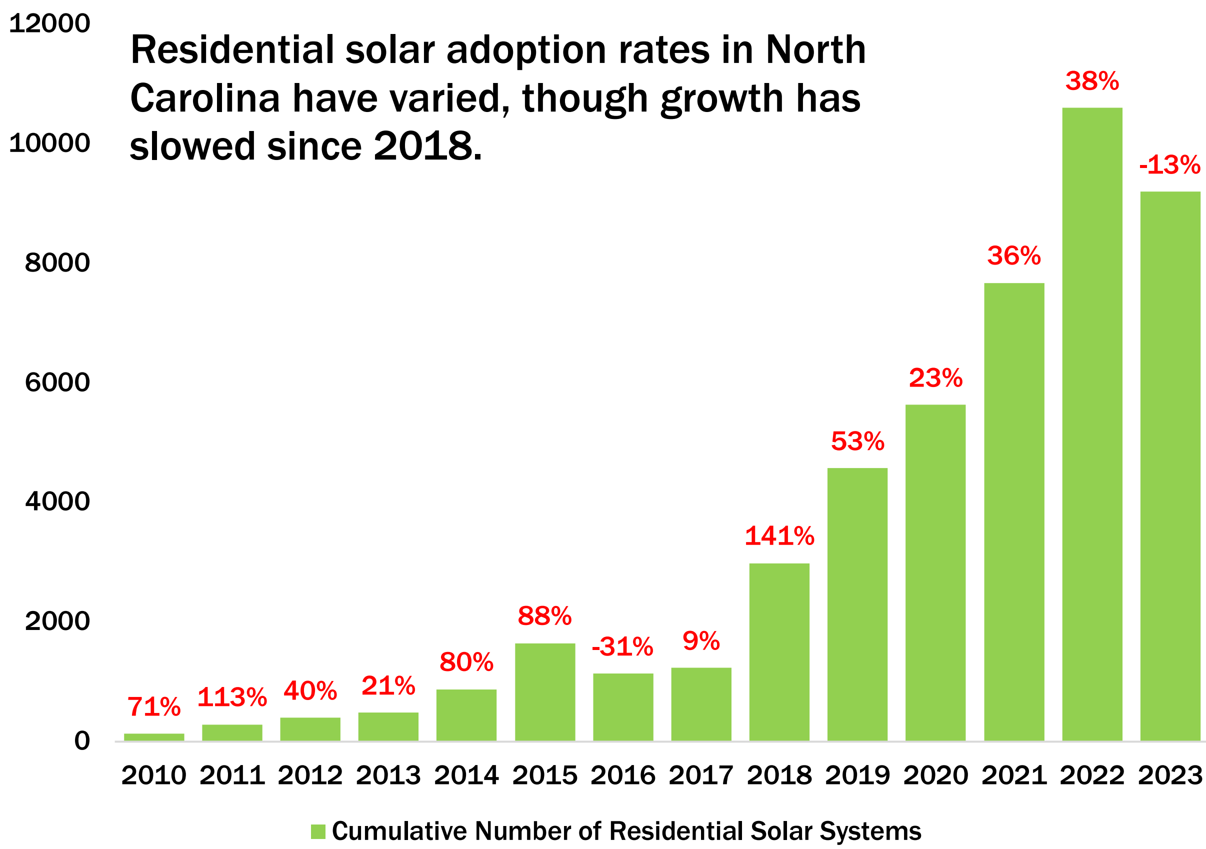
Changes to Distributed Solar Policies in North Carolina are Slowing Adoption

While these incentives have likely increased residential solar adoption relative to the baseline, recent policy changes have undermined these programs. In 2023, the NCUC approved changes to the state's net metering policy in response to utility concerns about the need for distributed solar owners to fund grid maintenance and upgrades.[36] The NCUC introduced a new minimum monthly bill charge and a grid access fee, despite evidence that charging additional fees for solar customers undermines their benefits.[37]

Under the previous net metering regime, solar participants received a bill credit equal to the full retail rate of electricity, or around $0.12 per kWh.[38] Most significantly, the new policy credits solar owners at the utility's avoided cost rate of $0.03 per kWh, dramatically reducing the financial returns.[39] The state also switched all net metering to a Time-of-Use (TOU) rate to provide the highest compensation during periods of high demand, such as the early evening hours of 6:00 to 9:00 PM. This greatly reduces compensation for customers without battery storage, as solar systems produce the most energy mid-day during the lowest periods of demand and do not produce electricity during peak hours for much of the year.

Coupled with the expiration of the state's residential tax credit of up to 35% of the cost of the solar system in 2015, North Carolina provides minimal incentives for distributed solar adoption.[40] As a result, the anticipated payback period for a residential solar system has increased for North Carolinians, significantly disincentivizing solar adoption.[41] This might contribute to the marked decrease in year-over-year adoption rates. The average growth in residential solar adoption in North Carolina was 69% per year from 2010-2015 but dropped to an average of 32% after 2015.

Figure 3: Residential solar adoption rates in North Carolina decreased from an average of 69% per year from 2010-2015 to 32% from 2016-2023. [42]



V. LITERATURE REVIEW

Net Benefits of Distributed Solar in the U.S.

Most studies have found that distributed solar paired with battery storage benefits the U.S. grid.[43] During peak demand, residential solar plus storage customers can sell excess electricity to the grid, reducing the need for natural gas peaker plants which are often more expensive, less efficient, and produce higher GHG emissions.[44]

Additionally, distributed solar plus storage has reliability implications by preventing blackouts or outages during peak demand. Distributed generation can be more cost-effective than hardening traditional infrastructure to boost climate resiliency in extreme weather events.[45] The economic ramifications of outages cost the U.S. an average of $150 billion a year.[46]

One of the largest savings for the grid is the potential to reduce or eliminate the need to construct new power plants. This will reduce capital costs for the utility and assist in lowering utility rates for customers. Further reductions will come from the lack of operating and fuel costs for power plants. Distributed generation closer to the end-user also reduces the amount of energy lost in the transmission, distribution, and generation processes. According to the EIA, around 5% of electricity is lost during transmission and distribution.[47]

Quantifying the Costs and Benefits of Distributed Solar

Over the last decade, studies have attempted to quantify the costs and benefits of distributed solar energy. With no standard methodology, these studies have conflicting conclusions about the impacts of distributed solar on the grid. A study sponsored by the solar industry found that the benefits of distributed solar are as high as $0.35 per kWh.[48] Meanwhile, reports commissioned by the utility industry have found costs as high as $0.09 per kWh.[49] Solar advocates tend to overestimate the benefits and ignore potential costs to the system. Likewise, the utility-sponsored reports focus primarily on the costs and fail to consider environmental or social benefits.

Rocky Mountain Institute (RMI) is an independent, non-partisan think tank that advances market-based sustainability solutions and has long advocated for distributed energy resources. In 2017, RMI compared the different methodologies for sixteen cost-benefit analyses of distributed solar and found the selective inclusion of variables and rate of solar adoption greatly affected the results.[50] RMI found that no study has objectively and comprehensively evaluated the costs and benefits of distributed solar.

Most researchers have found that when considering the emissions reduction benefits, distributed solar has a net positive benefit.[51] However, most of these studies were conducted before 2015, and rooftop solar adoption and electricity demand have grown considerably, which may increase the reliability potential of distributed solar plus storage. For example, a 2013 study in North Carolina found that ratepayers could see $26 million in annual energy savings with an increase in both utility-scale and distributed solar and the benefits exceed costs by up to 40%.[52] The expected benefits are even higher today, and this report builds upon existing analyses to provide more objective, quantitative, and granular research on the value of distributed solar generation in North Carolina.

Quantifying the Benefits of Virtual Power Plants

Even less research has been done into the benefits of aggregating solar plus storage systems into VPPs. In 2023, the Brattle Group found that VPPs could provide backup electricity at a lower cost than firing up a natural gas plant.[53] Their analysis modeled a VPP comprised of 3,500 distributed solar with battery-storage participants. They found that the total cost to call upon this generation would be $2.2 million, which is $41.1 million less than the natural gas plant when including the economic and social costs. Even when excluding the social benefits of the VPP, the VPP reduces costs by 40 to 60% compared to the natural gas plant.[54] Nationwide, the U.S. Department of Energy found that an 80- to 160-gigawatt (GW) VPP could save $10 billion in grid maintenance and upgrades annually by 2030.[55] RMI analysis estimates that VPPs will lead to $17 billion in savings in 2030 alone.[56] As such, the economic impact of an expanded distributed solar plus storage and VPP program in North Carolina is expected to be considerable.

VI. RESULTS AND CONCLUSION

Survey Findings

A national web-based survey of 1,229 likely U.S. voters was conducted to gauge baseline awareness of rooftop solar, its benefits, and support for solar-related policies. The largest geographic location for respondents was the South Atlantic region, which includes Delaware, Florida, Georgia, Maryland, South Carolina, Virginia, West Virginia, the District of Columbia, and North Carolina. The following findings will reference the national results.

Nearly half (47%) of respondents have seen or heard about rooftop solar in their community, though 38% have heard nothing at all. Awareness of virtual power plants is even lower, with 63% unfamiliar with the term. This highlights the importance of public education about the process and benefits of installing rooftop solar.

Regarding personal solar adoption, 8% of respondents have already installed solar panels.[57] The highest solar installation rates were in the Middle Atlantic (14%), New England (11%), Pacific (14%) and South Central (10%).

When asked how they expect residential solar plus storage would impact the frequency of blackouts and outages, most respondents said it would improve reliability (63%), with only 5% believing it would decrease reliability. Similarly, a majority (65%) say residential solar plus storage would reduce their electric bill, though 15% report it would have no impact, and 11% were unsure. This suggests that while many voters are aware of the benefits of solar, lack of education remains a barrier.

When asked how likely they are to install solar panels in the next five years, 47% of respondents say they are likely to do so, broken down by partisanship and age in **Figure 4.**

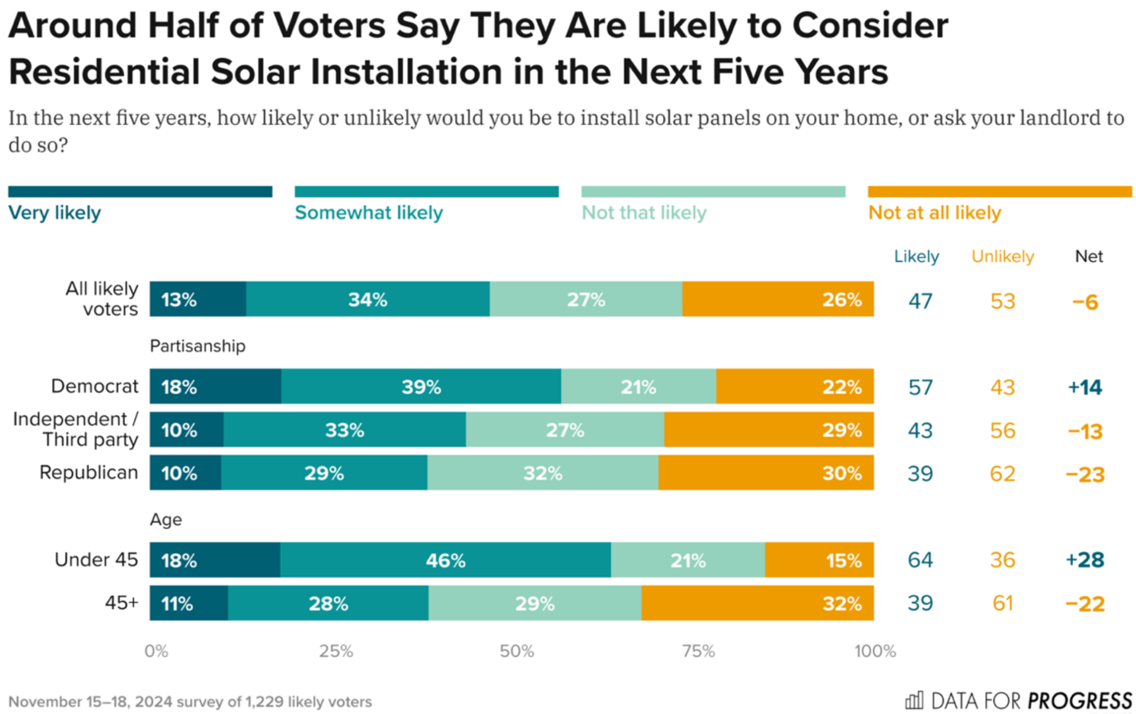


Figure 4: 47% of voters say that they are likely to install solar panels or ask their landlord to do so in the next five years.

The next question in **Figure 5** was to understand why voters support solar. Nationwide, the primary reason voters would install solar is to lower their electricity bill (43%), followed by having backup energy in the case of extreme weather (19%), and to remain independent from the electric grid (17%). These results drive home how the lack of awareness about the cost savings and reliability benefits of solar systems is a key barrier, as they are the primary motivations to install solar. Improved education about these attributes of residential solar could greatly increase solar adoption rates.

In the South Atlantic, which includes North Carolina, an even larger percentage of respondents were primarily motivated by lowering their electric bills (48%), followed by greater independence from the grid (22%), and backup energy for extreme weather events (19%). Only 5% of voters were primarily motivated to reduce their carbon footprint, showing how environmental reasons are becoming less important to consumers. Notably, the South Atlantic has relatively low residential electricity rates compared to the rest of the country, at $0.15 per kWh, compared to $0.28/kWh in New England.

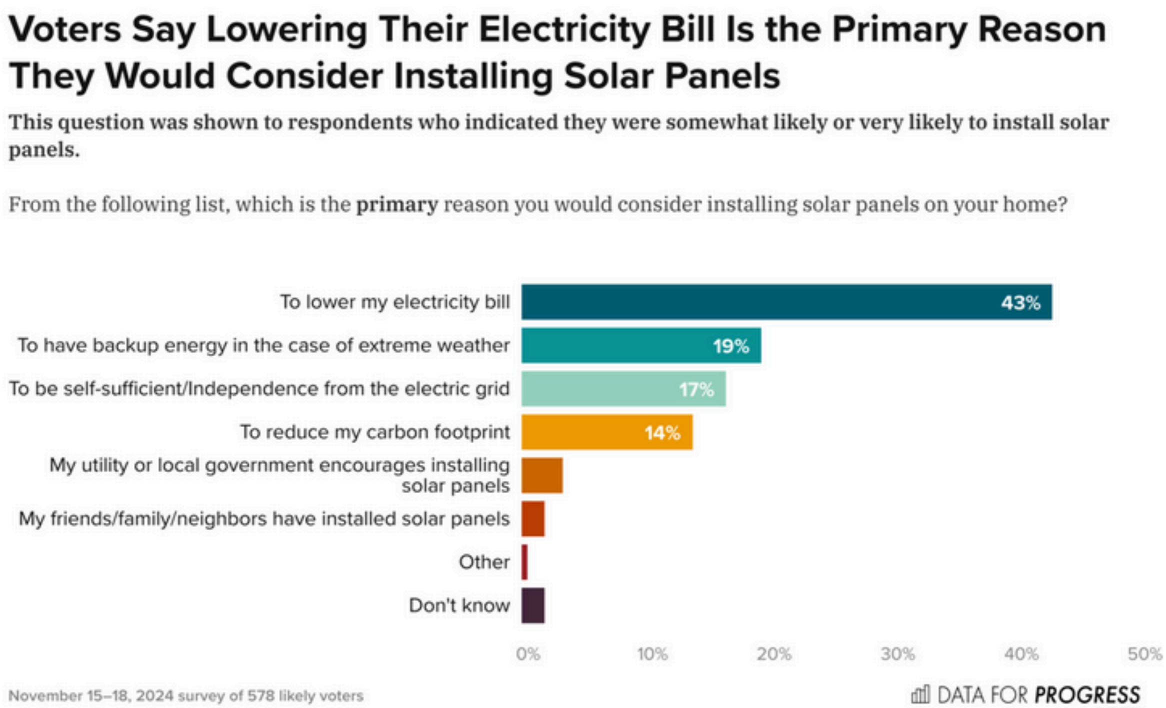


Figure 5: The primary reason voters would install solar is to lower their electricity bill (43%), followed by backup power during extreme weather (19%), and independence from the grid (17%).

Among voters who are not considering installing residential solar, when asked why they are not considering solar the most common reason is the high upfront cost (39%), followed by an inability to make permanent changes to their homes (26%) as shown in **Figure 6**. This suggests that more voters might be interested in solar if they were aware of incentives to bring down costs and temporary solar solutions, or if landlords were encouraged to install solar.

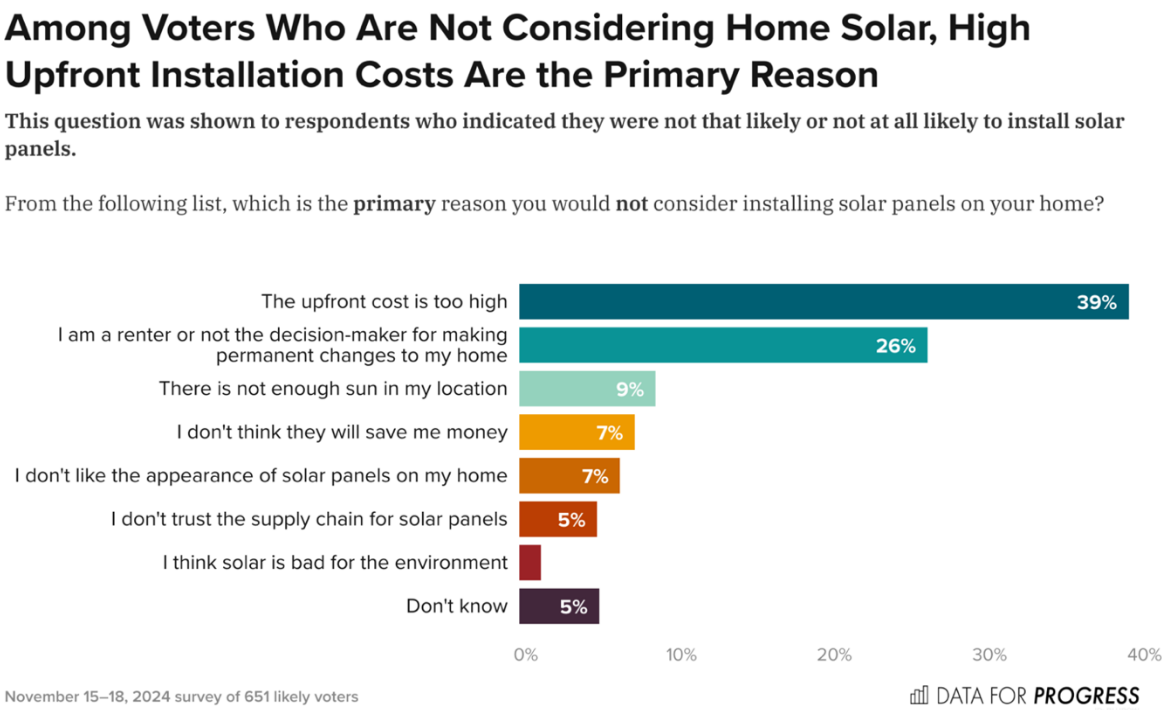


Figure 6: The top reasons respondents have not considered installing solar on their homes is the high upfront cost (39%) and the lack of authority to make permanent changes to their homes (26%).

To identify strategies to encourage more solar adoption, voters were then asked which factors would most increase their likelihood of installing solar. As shown in **Figure 7**, the most popular factor to increase adoption nationwide is an assurance that their electric bill will be lower (19%), followed by receiving subsidies to reduce the upfront cost (17%). In the South Atlantic region, the most common responses are flipped, with voters stating their top factor is receiving a subsidy to lower the upfront cost (20%), followed by an assurance that their electric bill would be lower (16%).

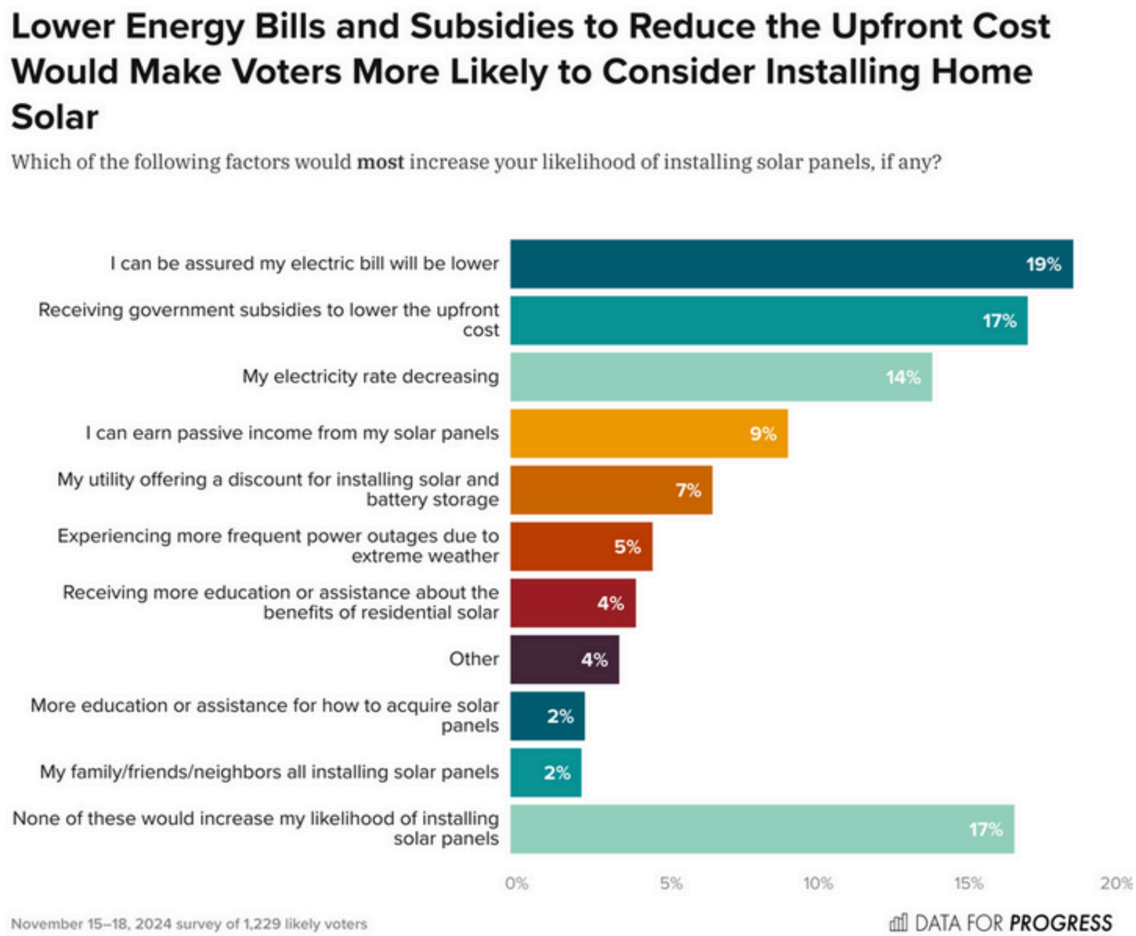


Figure 7: Nationwide, the factor most likely to increase solar adoption is an assurance of a lower electric bill (19%), followed by a subsidy to reduce the upfront cost (17%).

Digging into the issue of high upfront costs, voters were asked about their awareness of tax incentives for residential solar. Only one-third of voters were aware of any state or local tax credits or rebates available to them. However, a subsequent question found that if tax credits were available, 55% of respondents would take advantage of them.

Finally, voters were asked about their support or opposition to several distributed solar policies. **Figure 8** reveals that 68% of voters support net metering policies that provide greater compensation to solar owners when they sell excess power back to the grid, and 80% of voters support a virtual power plant program to compensate solar plus storage owners for making their system available to the grid during high demand.

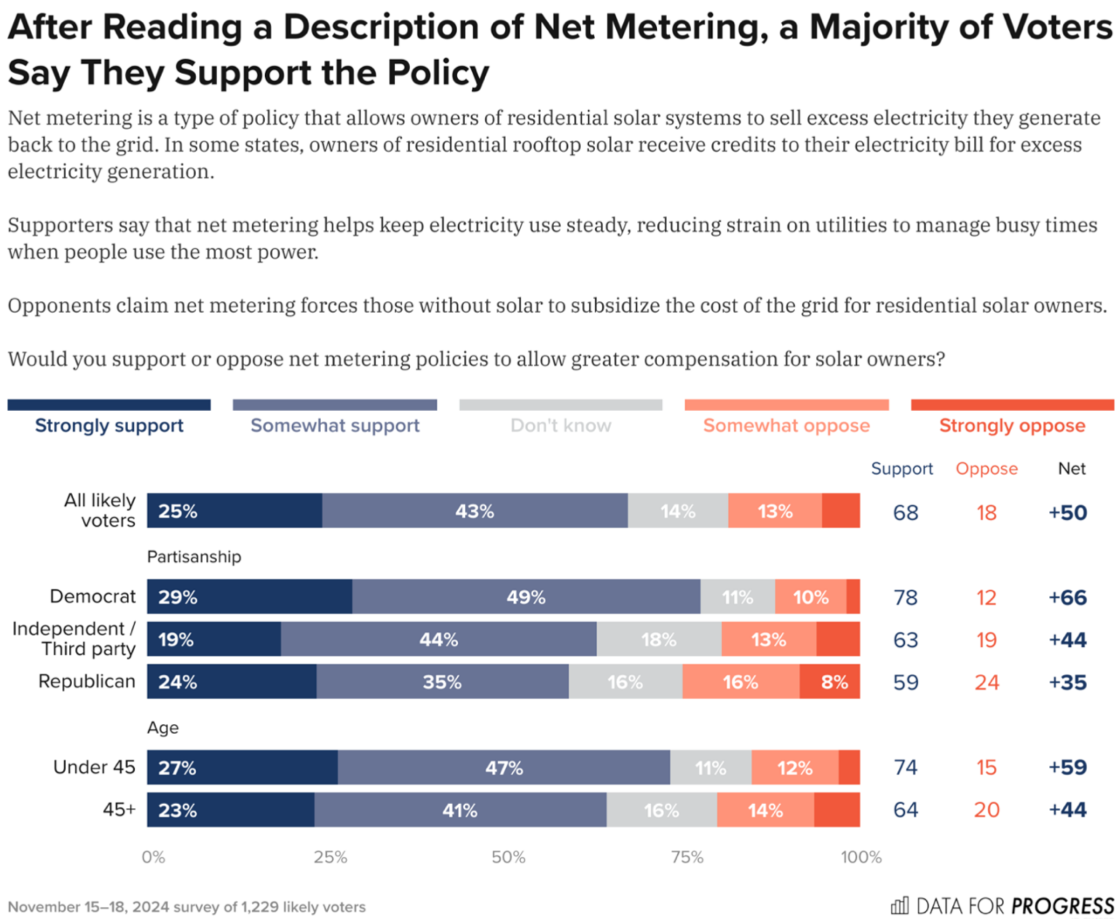


Figure 8: 68% of voters support a net metering policy to compensate solar owners who sell excess generation to the grid.

Voters were more mixed in their support for residential fixed charges, which disincentivize solar adoption by setting a minimum billing requirement for all users connected to the grid. 53% of voters support fixed charges, with one-third of respondents opposed.

Case Studies

States have experimented with other policy and regulatory approaches to shape distributed solar adoption in their jurisdiction. Arizona, Massachusetts, Hawaii, and Puerto Rico policies were examined to determine their success in increasing distributed solar adoption relative to other states. A more in-depth case study of Arizona was conducted, as it is more similarly situated to North Carolina given its regulatory environment, solar potential, and population growth.

Arizona

Key Takeaways:

- **Distributed energy resource mandates are important,** with Arizona's RPS requiring 30% of renewable energy come from distributed resources, like rooftop solar.
- **State- and utility-level incentives are necessary to reduce cost barriers,** which is the largest barrier to distributed solar adoption.
- **Enhanced transparency and education can address non-cost barriers,** such as the lack of awareness of available incentives or the reliability and cost-saving benefits of solar.
- **Incentives for battery storage should accompany any shift to net billing,** as solar plus storage systems are more economical for consumers in a net billing scenario.
- **Policy stability is critical for long-term solar growth,** as the shifts in Arizona's solar policies precipitated a significant decline in residential solar adoption.

Arizona was selected for the case study due to its high distributed solar adoption relative to North Carolina. Arizona is similarly situated to North Carolina as one of the top seven states with the fastest growing population.[58] Arizona has substantial rooftop solar potential, with 15,000 MW, though it falls short of North Carolina's 23,000 MW of potential.[59]

Of the 7,617 MW of current solar generation in Arizona, 38% is from distributed solar, while only 7.7% of solar generation in North Carolina is distributed.[60] This is due to Arizona's generous distributed solar plus storage programs and incentives, resulting in the state being ranked 5th in the country for distributed solar generation.[61] Arizona's distributed solar generation per capita is 329 W, compared to North Carolina's 47 W.[62] **Figure 9** compares the potential and actual generation of distributed solar in each state.

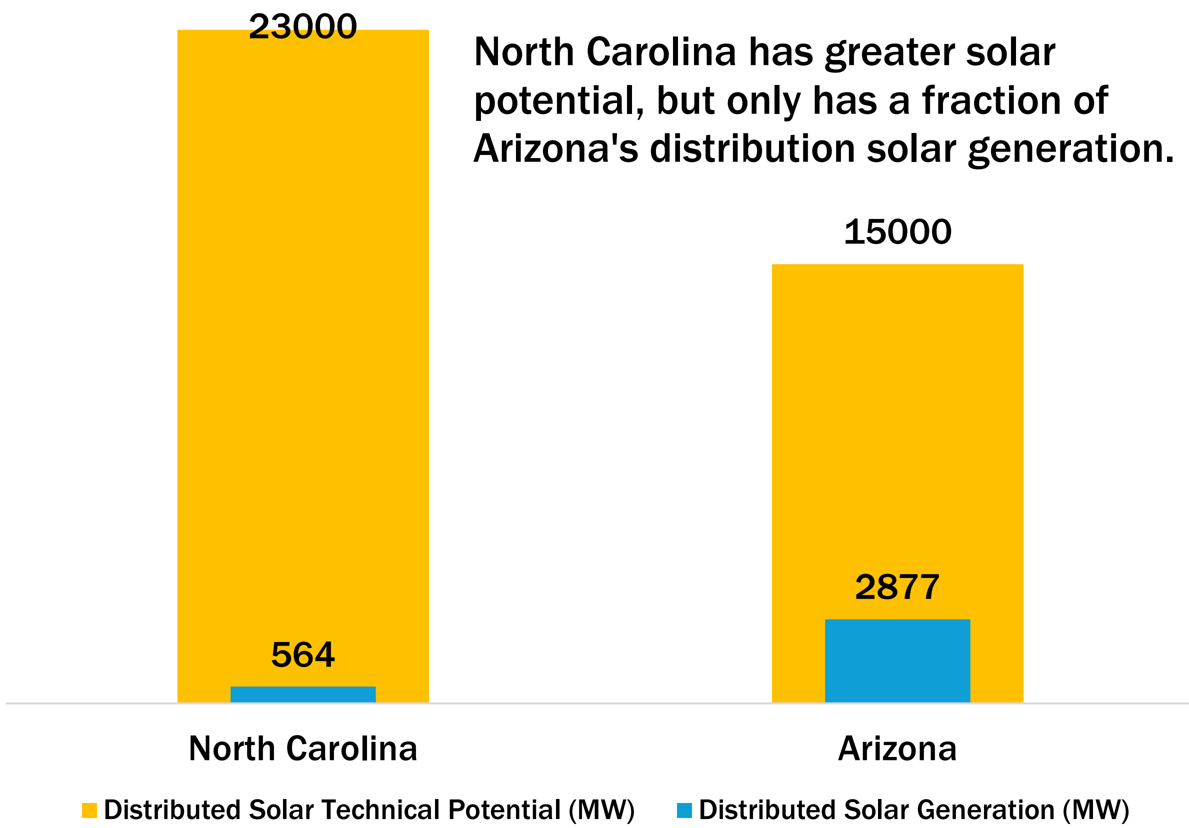


Figure 9: Technical potential and actual installed capacity for distributed solar in North Carolina and Arizona.

Like North Carolina, Arizona is also a regulated utility state operating outside of a regional transmission operator. Arizona has three primary investor-owned utilities (IOUs): the Arizona Public Service Company, Tucson Electric Power Company, and UniSource Electric.[63] Additionally, the Salt River Project is a government-owned, public power electric utility that services the Phoenix metropolitan area. In North Carolina, most of the state falls into Duke Energy Progress or Duke Energy Carolina's service territory, with the other major IOU being Dominion Energy.

This case study illustrates the successful implementation of Arizona's distributed solar program, the benefits to the state, and the necessary policy environment to enable these programs. These best practices may be replicated in North Carolina, subject to the state's unique political, economic, and social context.

Distributed Solar Policies in Arizona

In 2006, Arizona adopted a Renewable Portfolio Standard (RPS) requiring utilities to procure at least 15% of their energy from renewable sources by 2025, with 30% from distributed energy technologies.[64] Of this distributed generation, half must come from residential customers.[65] Utilities must provide annual filings detailing how they intend to comply with the RPS over the next five years. As a result of this mandate, utilities encouraged residential solar adoption through generous subsidies from 2006 to 2010.

The Arizona Corporation Commission (ACC) is the state's public utilities commission. The ACC and its regulated utilities have been instrumental in the push for greater solar adoption in Arizona. For example, the "Arizona Goes Solar" initiative is a collaboration between the ACC and utilities to educate consumers. The website publishes regular information on new solar installations to increase transparency and information-sharing between installers and customers. It also lists local, state, and federal incentives available for solar installation.

To encourage distributed solar adoption, Arizona offers several solar tax incentives. The largest incentive is Arizona's Residential Solar and Wind Energy Systems Tax Credit, which provides a tax credit of 25% or up to $1,000 for the solar system.[66] Since 2006, the state also provides a 100% property tax exemption for any additional value added to a commercial, industrial, or residential building that installs solar.[67] Solar is also exempt from all sales tax, which applies to the installation of solar, excluding batteries. [68]A 2012 revision applies the sales tax exemption to electricity sales through net metering. Additional policies in Arizona include incentives for battery storage, with the Salt River Project providing up to $3,600 per customer for co-installation of battery storage, limited to 4,500 subscribers.[69]

Table 2: Current Residential Solar Incentives in Arizona

Policy	Description	Availability
Federal Renewable Energy Investment Tax Credit	The ITC covers up to 30% of the installation cost for a rooftop solar system.[70]	2022 – 2033
Arizona Residential Solar and Wind Energy Systems Tax Credit	A tax credit of 25% or up to $1,000 for the solar system.[71]	2006 – present
Property Tax Exemption	A 100% property tax exemption on the additional value added for installing solar. [72]	2006 – present
Sales Tax Exemption	100% sales tax exemption for solar system and the installation of solar, not including battery storage. [73] In 2012, the sales tax exemption was expanded to cover electricity sales through net metering.	1997 – present
Salt River Project Battery Storage Incentive	The Salt River Project provided up to $3,600 per customer for co-installation of battery storage, though this program was limited to 4,500 subscribers.[74]	2018 – 2024

Finally, like North Carolina, Arizona regulators eased the interconnection process for distributed solar and storage systems via a fast-track approval process tiered by system size.[75] This helps remove a non-cost barrier to rooftop solar.

Despite these positive drivers for distributed solar adoption, policy changes in the last decade have hurt solar adoption in Arizona. The last decade has seen utilities end subsidy programs, and the Arizona Corporation Commission (ACC) has reduced incentives for solar owners, slowing annual growth in residential solar adoption as shown in **Figure 10.** Arizona saw a peak in solar adoption with the passage of the Inflation Reduction Act in 2022, however, policy developments in 2023 and 2024 have chipped away at the increase, with nearly half as many new installations in 2024.

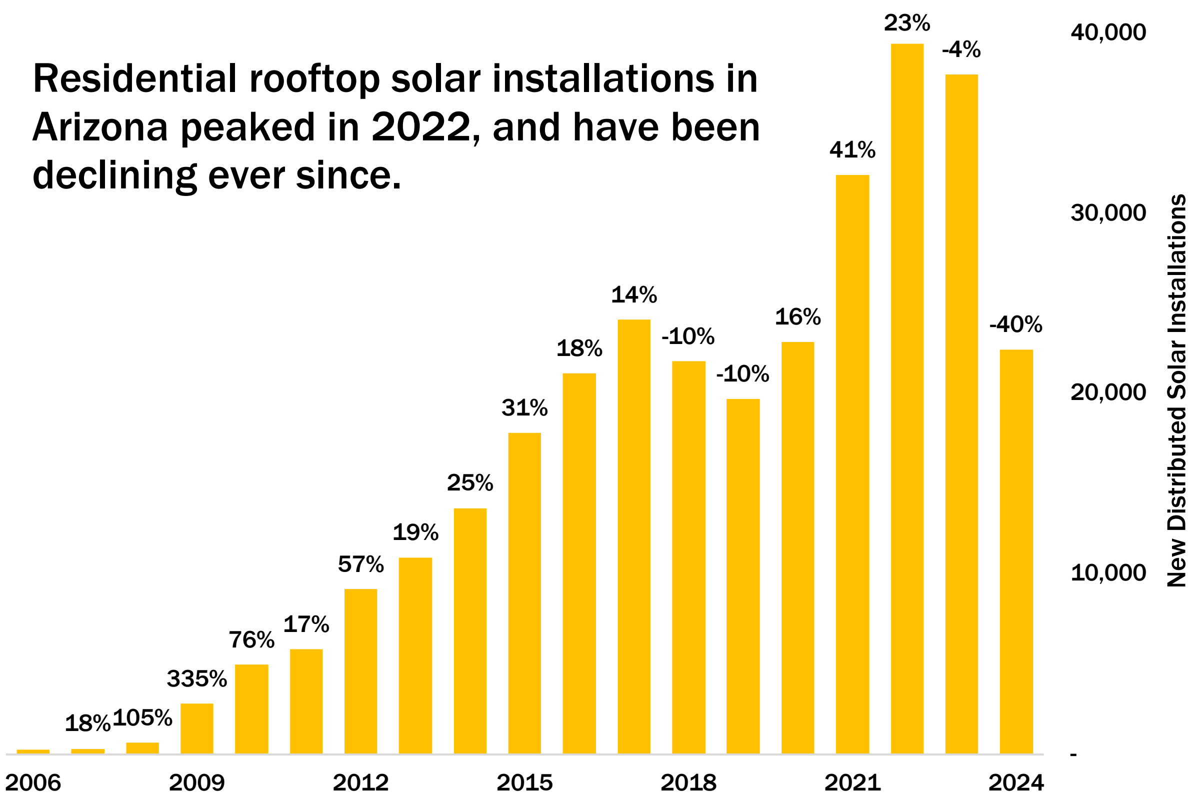


Figure 10: Source: Data from Lawrence Berkeley National Laboratory, Tracking the Sun 2024.[76]

In 2016, the ACC repealed the state's net metering policy, adopting net billing instead.[77] Through net billing, solar owners earn credits for selling excess electricity to the grid, which is applied to their bills at a rate equivalent to the utility's avoided cost rate--or the cost the utility would have incurred to provide that electricity. Under the existing policy, the credit was based on the retail rate of $0.13/kWh, with the new compensation rate being around $0.06/kWh, a 54% reduction.[78] As a result, the credits are worth significantly less than the credit accrued via net metering and will not have as large of an impact on customers' electric bills. The shift to net billing encourages battery storage adoption, as selling electricity to the grid is less lucrative than storing energy for personal use. Customers with solar plus storage can avoid receiving bill credits below the retail rate.

A final blow to the residential solar industry came in 2024 when the ACC removed the RPS requirement for utilities to procure 15% of generation from renewable energy by 2025. Rather than increase or extend the target, the ACC voted to repeal the target altogether.[79] This contrasts with most other states in the U.S. that are raising RPS targets. The decision was in response to Commission concerns that the RPS was placing a cost burden on ratepayers. Opponents of this decision argue the ACC failed to acknowledge the benefits of deferred generation investments, energy efficiency improvements, emissions reductions, reduced water usage, and increased private investment. The ACC also approved a grid access charge for rooftop solar owners in the Arizona Public Service Company (APS) service territory.[80]

Amid these policy changes, Arizona has backtracked from one of the most progressive distributed solar states to one of the most restrictive. This case will provide important lessons to future policymakers on the importance of a favorable regulatory environment for solar. With the changes being so recent, the full impacts of the policy changes have yet to be realized, though monthly permitting for rooftop solar in Arizona has dropped by one-third and APS saw a 50% decrease in rooftop solar installations in 2024.[81]

Quantifying the Benefits of Distributed Solar Plus Storage in Arizona

In general, utility-scale solar has a lower cost per kWh, however, factoring in the unique benefits of rooftop solar plus storage can partially or fully offset the utility cost advantage. Additional benefits include avoided electricity cost, faster renewable deployment, avoided line loss, avoided transmission and distribution capacity, and increased reliability if paired with storage.[82] With these benefits incorporated, one study estimates the value of rooftop solar in Arizona to be between $0.157 to $0.182 per kWh.[83] Arizona currently generates 11,519,508 MWh of distributed rooftop solar per year. Assuming the lower value of $0.157/kWh, Arizona ratepayers see at least $1.8 billion in benefits per year. [1]

Under the current net billing policy, Arizonians receive a fraction of this value at $0.06/kWh. PUCs typically attempt to value distributed solar equivalent to the costs avoided from an alternative electricity source, which explains the significant difference between the value of solar and the net billing rate. Many PUCs have the latitude to consider environmental and social benefits that would otherwise not be reflected in the avoided cost, though it is up to the PUC to determine if this should be factored into the net metering rate or compensated via another mechanism, such as higher consumer incentives.

Key Takeaways for North Carolina

In North Carolina, House Bill 951 requires the state to reduce carbon emissions in the electricity sector by 70% by 2030. Arizona can serve as a model for fostering greater distributed solar

[1] Calculation based on 2,877 MW of distribution generation in 2024, an average of 11 hours of sunlight per day, for 364 days of the year.

adoption to meet state renewable energy goals. Arizona's explicit requirement for utility procurement of distributed solar, net metering policy, state-level tax incentives, and the "Arizona Goes Solar" educational initiative encouraged some of the highest distributed solar adoption rates in the country.

Arizona also serves as a cautionary tale of the negative impact of policy reversals. The shift to net billing, oversubscription or cancellation of utility incentive programs, implementation of grid access charges, and the repeal of the RPS has led to a drop in distributed solar adoption in the state.

Overall, the main lessons from Arizona's experience include:

Distributed energy resource mandates are important, as Arizona's RPS was one of the primary drivers for the state's early lead in distributed solar adoption. From 2006 to 2010, utility- and state-level initiatives to comply with the 30% distributed energy mandate created a favorable environment for consumers. Utilities and the state educated the public on the advantages of solar energy and how to install it. North Carolina's renewable energy goal does not have explicit distributed energy targets, providing no incentive for utilities to encourage distributed solar adoption. Without targeted policies to encourage distributed solar, North Carolina will likely continue to see the dominance of utility-scale projects. North Carolina policymakers might explore a comparable distributed solar carve-out.

State and utility incentives are necessary to reduce cost barriers. Arizona offered numerous state-level tax credits, in addition to utility-level incentives. With survey results revealing the number one stated barrier to solar adoption is the high upfront costs, incentives significantly alleviate this barrier. North Carolina does not offer any tax credit for the purchase or installation of a residential solar system and might explore expanding incentives for solar plus storage to enhance grid reliability and reach the state's emissions targets. To fully internalize the positive externalities of distributed solar, states and utilities should encourage adoption through incentives and net metering programs that fully value the benefit of solar.

Enhanced transparency and education can address non-cost barriers, such as the lack of awareness of available incentives or the reliability and cost-saving benefits of solar. Arizona's "Arizona Goes Solar" platform provides a transparent source of public information and identifies available incentives for consumers. North Carolina does not offer a comparable coordinated program between the PUC and utilities to provide a single source of information for reputable solar installers and available incentives.

Incentives for battery storage should accompany any shift to net billing, as solar plus storage systems are more economical for consumers in a net billing scenario. Because net billing greatly reduces financial compensation, Arizona has seen a decline in installations. To avoid further disincentivizing adoption, Arizona and North Carolina might consider encouraging more battery storage to reduce the need to sell electricity back to the grid at below-residential rates.

Policy stability is critical for long-term solar growth, as the shifts in Arizona's solar policies--including the elimination of the RPS requirement, shift to net billing, and new grid access charge—precipitated a significant decline in residential solar adoption. Arizona's initial solar policies drove substantial growth for the distributed solar industry, and North Carolina policymakers should avoid such policy reversals to grow consumer and private-sector confidence in the industry.

Limitations to Applicability in North Carolina

The successes and failures of various policies in Arizona are not a guarantee for a similar outcome in North Carolina. As such, there are various limitations to applying the findings of this case study to the North Carolina context, including:

Utility market: Arizona is home to multiple investor-owned utilities and public power providers, unlike North Carolina which is dominated by Duke Energy, which could limit competition and innovation in distributed solar programs.

Political landscape: In Arizona, the ACC is an elected body, of which regulators are likely more receptive to public sentiment or the political ramifications of their actions. In contrast, the North Carolina Utilities Commission is appointed by the Governor, who since 2017 has been a Democrat. These political dynamics may impact the feasibility of a policy succeeding in North Carolina, though could bode well for greater commission support for distributed solar plus storage than Arizona.

Massachusetts

Key Takeaways:

- **Long-term policy stability for distributed solar is necessary,** with Massachusetts' expansion of its net metering program, Renewable Portfolio Standard and Clean Energy Standard creating a stable, pro-solar policy environment.
- **A solar carve-out for renewable energy targets is a guaranteed way to secure utility buy-in,** as Massachusetts mandates that a portion of its RPS specifically comes from distributed solar.
- **Generous state and utility incentive programs encourage distributed solar plus storage,** as seen in Massachusetts' Solar Massachusetts Renewable Target (SMART) program, which after passage the state saw a 144% increase in distributed solar plus storage.
- **Preserving net metering programs improves the economics of installing residential solar.** Massachusetts recently expanded eligibility for net metering at nearly the full retail rate.

For the last decade, Massachusetts has ranked fourth in the country for distributed solar generation, lagging only behind California, New York, and Texas—all of which have considerably larger populations. Massachusetts has the second highest amount of distributed solar per capita at 515 watts, though Hawaii leads with 588 W and one-fifth of the population.[84] As of 2024, Massachusetts has 2,972 MW in distributed solar generation and continues to see rapid uptake in residential solar.[85]

Of all solar generation in the state, more than 68% comes from distributed resources. Overall, Massachusetts has harnessed almost 11% of its total rooftop solar generation potential, one of the highest penetration rates in the country.[86] The popular support for solar can be attributed to a favorable policy environment in Massachusetts, which includes solar incentives, net metering, and a solar-focused renewable portfolio standard.

Distributed Solar Policies in Massachusetts

Massachusetts has established a stable policy environment with long-term commitments to the solar industry. The state's distributed solar market is shaped by generous state and utility incentives, net metering, and a renewable portfolio standard. In 2003, Massachusetts passed an RPS requiring a minimum of 1% of all retail electricity sales to come from renewable resources, increasing to reach 40% by 2030.[87] After 2030, the standard will increase by 1% every year. A 2010 update requires that a set percentage of generation comes from solar. As of 2025, this solar carve-out is set at 3.16% of total retail generation.[88]

In 2018, the Massachusetts Department of Environmental Protection passed a separate Clean Energy Standard (CES), which also sets a minimum percentage of retail electricity sales that must come from clean energy.[89] The stringency increases by 2% each year, reaching an 80% clean energy mandate by 2050. The CES requirements are set slightly above the RPS target, requiring that utilities comply with both. For example, the RPS target for 2025 is 27%, while the CES target is 30%.

Also in 2018, Massachusetts created the Solar Massachusetts Renewable Target (SMART) program with long-term incentives to promote solar adoption. The SMART program specifically incentivizes solar plus storage, providing an estimated $500 annually to customers. The original program also provided compensation at a fixed rate per kWh for solar generation without storage, but that program is fully subscribed. The incentive is paid by one of the three investor-owned utilities in the state, Eversource, National Grid, or Unitil, based on the amount of electricity produced.[90] Most customers are eligible to receive the incentive payments for 10 years.[91] From 2017 to 2022, the state has seen a remarkable 144% increase in solar adoption, largely attributed to the SMART program.[92] The SMART incentive bolsters the existing Massachusetts residential solar income tax credit, which provides a credit of 15% of the total cost of the solar system, up to $1,000.[93] In addition, the state provides a solar sales tax exemption and property tax exemption.

At a time when several states have repealed or reduced net metering policies, Massachusetts expanded eligibility for its net metering program in 2024. Customers with solar systems under 25 kW are eligible to sell excess power to the grid at almost the full retail rate.[94] The net metering credit for systems less than 60 kW is the sum of the basic service, distribution, transmission, and transition charge and varies by electric provider and system size.[95]

Finally, Massachusetts has been a frontrunner in advancing the use of virtual power plants. Massachusetts encourages battery installation through the SMART program, in addition to a demand response program called ConnectedSolutions. Participation in ConnectedSolutions allows a utility to call upon a customer's battery during periods of peak summer demand, from June to September, from 3-8 pm, in exchange for $275/kW.

Key Takeaways for North Carolina

Long-term policy stability for distributed solar is necessary, with Massachusetts recommitting to distributed solar in 2024 with the expansion of the state's net metering program. The state's Renewable Portfolio Standard and Clean Energy Standard have created a stable policy environment with long-term commitments to distributed solar, driving utility, investor, and consumer support. In North Carolina, House Bill 951 sets an emissions reduction target for the electricity industry but leaves the mechanism up to the utilities without explicit support for distributed resources. Implementing policy commitments specific to distributed solar could encourage greater adoption in North Carolina.

A solar carve-out for renewable energy targets is a guaranteed way to secure utility buy-in, as Massachusetts mandates that a portion of its RPS specifically comes from distributed solar. As of 2025, the carve-out requires that 3.16% of retail generation comes from solar. North Carolina's current RPS requires 12.5% of the state's electricity to come from renewables after 2021, with a 0.20% carve-out for solar.[96] It does not include a specific mandate for distributed solar, focusing instead on utility-scale projects. Introducing a larger distributed solar carve-out in North Carolina's policy framework could create stronger incentives for rooftop solar adoption.

Generous state and utility incentive programs encourage distributed solar plus storage, as seen in Massachusetts' Solar Massachusetts Renewable Target (SMART) program which provides compensation for solar generation plus additional incentives for battery storage paid by the utility. In the first five years of the SMART program, Massachusetts saw a 144% increase in distributed solar plus storage adoption. Massachusetts also offers a $1,000 solar tax credit, property tax exemption, and sales tax exemption. North Carolina's incentives are limited to a property tax exemption and limited utility-level rebates. Expanding financial incentives, particularly for solar-plus-storage systems, could accelerate adoption in North Carolina.

Preserving net metering programs improves the economics of installing residential solar. Unlike many states that have reduced net metering benefits, Massachusetts recently expanded eligibility for net metering at nearly the full retail rate. In contrast, North Carolina's net metering policies have become less favorable following the shift to avoided cost and time-of-use rates. In the absence of new state-level incentives for battery storage to encourage battery storage to help insulate customers from a reduction in net metering, net metering provides significantly greater value to distributed solar customers to incentivize adoption in North Carolina.

Limitations to Applicability in North Carolina

Massachusetts provides a strong example of how policy stability, targeted incentives, and net metering expansions can drive high levels of distributed solar adoption. However, differences between the state's political climates, utility market structure, and economic factors must be considered when adapting these policies in North Carolina.

Political landscape: Massachusetts is a solidly Democratic state with a historical commitment to renewable energy and sustainability. North Carolina's political composition is much different, with a Republican-controlled legislature and a Democratic executive branch. The North Carolina policy status quo has been focused on utility-scale solar and has been less receptive to distributed solar. Implementing the generous Massachusetts-style policies may require overcoming significant regulatory and political hurdles.

Utility market: Massachusetts is home to several IOUs and is in a deregulated electricity market with greater competition among generators and oversight by a regional transmission organization, ISO-New England. Instead, North Carolina's electricity market favors centralized utilities with vertically owned generation, transmission, and distribution systems. Adopting Massachusetts' distributed solar incentives would require greater cooperation from Duke Energy.

Electricity costs: Massachusetts' higher electricity rate of $0.30/kWh makes solar a more attractive financial investment compared to North Carolina's lower rate of $0.12/kWh.[97] Massachusetts also has the highest median household income out of all states at $99,858, potentially making distributed solar adoption more affordable and accessible for a greater number of homeowners.[98] North Carolina's median household income is significantly lower at $70,804 as of 2023.

Hawaii

Key Takeaways:

- **Long-term renewable energy targets create market certainty for distributed solar,** providing a clear signal to the utility and solar industries.
- **State tax credits can significantly increase solar adoption,** with Hawaii offering one of the most generous credits of up to $5,000 for distributed solar.
- **A shift away from retail-rate net metering dampens solar adoption,** and states should avoid reducing net metering incentives. After Hawaii shifted from retail-rates to a reduced, time-of-use rate, annual growth in solar adoption dropped from 39% to 7%.
- **Battery incentive programs are needed to encourage battery co-installation,** and provide the resiliency benefits during outages and enable VPPs.
- **Targeted programs can deploy solar plus storage in regions most susceptible to outages.** High electricity costs and the phase-out of coal plants presented Hawaii with an opportunity to push residential solar plus storage adoption to ensure continued reliability.

Compared to Massachusetts, Hawaii is a more conventional location for rooftop solar with its abundant sunlight throughout the year. Nearly the opposite of North Carolina, where utility-scale dominates, 66% of solar generation in Hawaii comes from small-scale distributed resources.[99] The island has long been a frontrunner in solar adoption, being one of the first states to offer a net metering program. Paired with the state's financial incentives and state-level solar goals, Hawaii presents a strong case for how to encourage high residential solar plus storage adoption, with 43% of single-family homes having rooftop solar within the Hawaiian Electric service territory. [100]

However, a key distinction for Hawaiian solar adoption is that in addition to the island's robust solar potential, a large driver for distributed solar in Hawaii is the island paying the nation's highest electricity rates, averaging over $0.40 per kilowatt-hour. This is due to the reliance on imported electricity, largely from petroleum.

Distributed Solar Policies in Hawaii

Hawaii has an increasingly stringent renewable portfolio standard, which was amended in 2015 to require 100% renewable energy by 2045. In the interim, the state set a target to cut carbon emissions from electricity by 70% by 2030.[101] The Hawaiian legislature explicitly encourages distributed solar to reach this goal. As a result, much of the state's current solar generation comes from distributed systems due to tax credits, net metering, and utility incentives. Hawaii has one of the most generous state solar tax credits in the country, providing 35% of the purchase of a solar system, up to $5,000. The state also provides a property tax exemption for the added property value from the system.[9]

From 2001 until 2015, Hawaii's net metering program paid solar owners the full retail rate of the electricity they sold to the grid. In 2015, Hawaii became the first state to move away from retail rate net metering. As shown in **Figure 11,** this had a dramatic effect on residential solar adoption, with solar installations growing at an 82% slower pace.

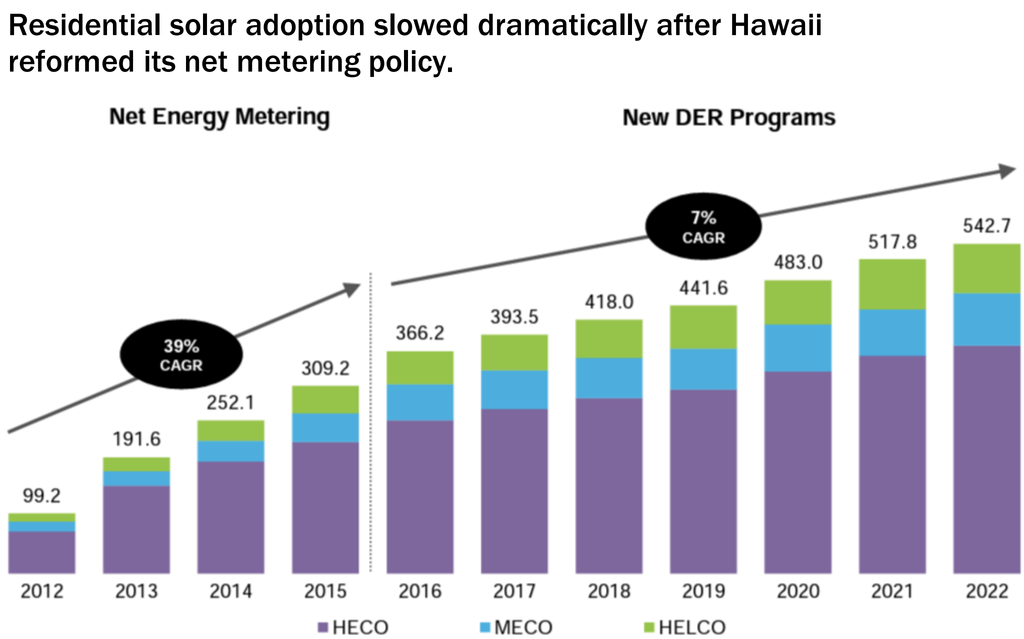


Figure 11: After the change to net metering, Hawaii's rate of residential solar adoption dropped by 82%.[102]

Existing net metering customers were grandfathered in under the retail rates. However, new solar customers fell under the Smart Export program, with rates based on the 12-month average of the avoided cost during peak demand for each island.[103] For some customers, this could result in a 75% decrease from the retail rate payment of $0.40/kWh.

In 2024, Hawaiian Electric once again revised the Smart Export program. The new Smart Renewable Energy Export program requires customers to enroll in the Distributed Energy Resource Management System. The new compensation rate varies by time of use and geographic location in Hawaii, ranging from $0.066 during the day in Maui to $0.408 during the evening peak in Lanai.[104]

Hawaiian rooftop solar plus storage adoption saw a surge in 2023 that might be attributable to the state's new Battery Bonus program. The Battery Bonus program incentivized co-installation of battery storage through a $4,250 upfront credit in addition to monthly bill credits. However, the program was short-lived and replaced with the less popular Bring Your Own Device (BYOD) program in 2024. The BYOD program provides an upfront $500 payment plus $5/kW per month if customers agree to dispatch during evening peak demand to stabilize the grid.[105] Both the Battery Bonus and BYOD programs were launched in response to the retirement of a major coal plant on Oahu to replace the generation.

Despite the changes to solar policies in the state, the Hawaiian government is still all-in on distributed solar adoption. In early 2025, Governor Josh Green announced an ambitious plan to install 50,000 new rooftop systems by 2030, for a pace of 10,000 installations a year.[106] To put that number in perspective, the highest annual installation rate to date in the state has been just under 6,500 in 2023. To continue to encourage battery storage and facilitate VPP programs, the Hawaiian legislature introduced H.B. No. 513 in 2025 to allow the 35% renewable energy tax credit to cover the cost of a battery storage system retrofitted to an existing solar system.[107]

Key Takeaways for North Carolina

Long-term renewable energy targets create market certainty for distributed solar. In 2015, Hawaii set a goal for 100% renewable energy by 2045, providing a clear signal to the utility and solar industries. Due to the land constraints in Hawaii and natural solar radiation, the state is well-positioned for distributed solar. North Carolina could consider setting a more ambitious target than its current RPS of 12.5%, which would force a more all-of-the-above approach to renewables, rather than relying on the preexisting nuclear and renewable resources, which already account for 33.1% and 9.9% of state generation.[108]

State tax credits can significantly increase solar adoption, with Hawaii offering one of the most generous credits of up to $5,000 for distributed solar. North Carolina could reintroduce a state tax credit for residential solar and introduce a new credit for battery storage.

A shift away from retail-rate net metering dampens solar adoption, and states should avoid reducing net metering incentives. After Hawaii shifted from retail rates to a reduced, time-of-use rate, annual growth in solar adoption dropped from 39% to 7%. Under a reduced rate, solar owners are disincentivized to sell to the grid for a lower rate, when that same energy is worth more to keep and consume themselves. North Carolina should assess the long-term impacts of potential net metering reforms and avoid sudden reductions that could discourage solar investment.

Battery incentive programs are needed to encourage battery co-installation to provide resiliency benefits during outages and enable VPPs. Hawaii's Battery Bonus and Bring Your Own Device (BYOD) programs incentivize storage adoption and help to stabilize the grid. Duke Energy's PowerPair and Power Manager similarly compensate homeowners for battery installation, and North Carolina could require a larger-scale program to encourage battery storage adoption, particularly in areas prone to grid congestion, outages, or extreme weather.

Targeted programs can deploy solar plus storage in regions most susceptible to outages. High electricity costs and the phase-out of coal plants presented Hawaii with an opportunity to push residential solar plus storage adoption to ensure continued reliability. Similarly, North

Carolina could consider region-specific incentive programs to install distributed solar where it can provide resilience and other consumer benefits.

Limitations to Applicability in North Carolina

Hawaii’s policies demonstrate the potential for North Carolina to pursue a state-led approach to distributed solar. However, given North Carolina’s different economic and market conditions, adopting tailored versions of Hawaii’s tax credits, battery incentives, and net metering adjustments would be necessary.

Electricity rates: One of the most significant limitations of applying Hawaii’s success in residential solar plus storage to North Carolina is the significantly higher electricity rates on the island. Hawaii’s high retail electricity rate of more than $0.40/kWh makes rooftop solar particularly cost-competitive compared to North Carolina’s average rate of $0.12/kWh. Without as high of electricity prices to drive demand, North Carolina may need additional policy incentives to encourage residential solar adoption.

Utility market: A key facet of Hawaii’s electric grid is its reliance on imported fuels, driving high electricity rates. As a result, the isolated grid benefits from distributed generation due to the inability to import excess generation from neighboring states and reduced dependence on imported fuels. Because North Carolina is in the continental U.S., centralized generation may remain more economically favorable in some cases and allow the importation of electricity from neighboring states during extreme events. Additionally, North Carolina’s regulatory environment favors utility-scale projects over distributed solar generation, with strong utility incentives.

Puerto Rico

Key Takeaways:

- **Distributed solar plus storage enhances grid resilience and reliability.** Puerto Rico’s experience with an unreliable grid and frequent natural disasters demonstrates the role of distributed solar plus storage and VPPs in enhancing grid resilience.
- **Additional assistance for low-income households in outage-prone areas will enhance resilience and equity,** with Puerto Rico’s targeted programs to assist low-income residents in installing solar plus storage.

The case of Puerto Rico drives home the reliability and resilience benefits of residential solar plus storage. For decades, Puerto Rico’s electrical grid has been defined by poor reliability, long-duration outages, and vulnerability to extreme weather. Frequent outages also occur outside of extreme weather events, caused by insufficient generation and a failing transmission and distribution system.[109] In 2021, power outages were seven times more frequent in Puerto Rico than in the rest of the U.S.

While Puerto Rico has employed numerous policies to facilitate a friendly environment for residential solar, many consumers in Puerto Rico are motivated to adopt solar due to the economics and desire for independence from the unreliable Puerto Rican grid and resilience during natural disasters. As a result, more than 10% of all households in Puerto Rico have installed rooftop solar, and around 80% have battery storage.[110] The adoption of rooftop solar allows much faster buildout of the additional generation needed to improve electric reliability on the island. As a result, 84% of solar generation in Puerto Rico comes from small-scale distributed solar. [111]

Distributed Solar Policies in Puerto Rico

Policies are an important driver of solar adoption in Puerto Rico, though most analysts suggest the sheer unreliability of the electrical grid is the primary driver of residential solar plus storage installations.[112] This contributes to the high co-installation of battery storage with solar systems, as standalone solar systems would not be beneficial during an outage. In addition to poor grid reliability, Puerto Ricans also face above-average electricity rates, paying an average of $0.20/kWh.[113]

In 2019, Puerto Rico adopted a goal for renewable energy to meet 40% of total generation by 2025, 60% by 2040, and 100% by 2050. With the slow buildout of utility-scale renewable generation, the territory has increasingly relied on distributed solar to meet the interim 40% by 2025 target. The bill, known as the Puerto Rico Energy Public Policy Act, also specifically mandates an increase in distributed generation systems.[114] As shown in **Figure 12,** residential solar adoption tripled from 228 MW to 680 MW from 2021 to 2023.[115]

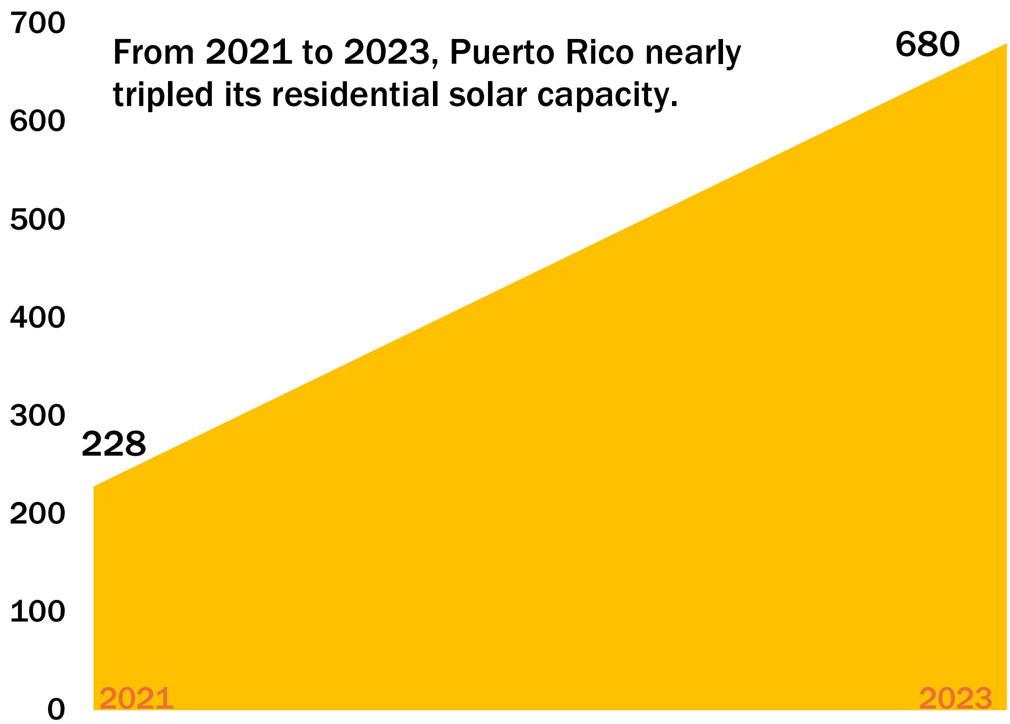


Figure 12: Puerto Rico has seen rapid growth in residential solar since the adoption of the Puerto Rico Energy Public Policy Act in 2019.[116]

In 2024, Puerto Rico extended its net metering program through 2031, providing solar plus storage owners the full retail rate of electricity. Puerto Rico does not offer a state tax credit for solar installation, though it does provide a sales and property tax exemption.[117] Instead, until 2020, Puerto Rico's Green Energy Fund (GEF) provided rebates for small-scale solar systems, up to 40% of the cost. The GEF was government-funded through an excise tax on motor vehicles and fines for RPS non-compliance.[118] The rebate is on a first-come-first-served basis, with a maximum of $20 million allocated annually.[119] The GEF ended in 2020 and has not been renewed.

Puerto Rico has targeted distributed solar plus storage adoption for low-income households. In 2023, the Puerto Rico Department of Housing created a Solar Incentive Program to provide incentives to 6,000 eligible, low-income households to purchase a solar plus storage system, or just storage if they already had solar PV.[120] The incentive provided a grant of 30% of the cost of the system, up to $15,000. The U.S. DOE offers a similar program in Puerto Rico through the Solar Access Program to provide solar plus storage with zero upfront costs to low-income residents living in areas that experience frequent power outages.[121] In addition to government initiatives, private companies have spurred distributed solar adoption. In 2023, Sunrun established a VPP on the island that has provided up to 15 MW of power during emergency power events.[122]

Key Takeaways for North Carolina

Distributed solar plus storage enhances grid resilience and reliability. Puerto Rico's experience with an unreliable grid and frequent natural disasters demonstrates the role of distributed solar plus storage in enhancing grid resilience. Puerto Rico's VPP initiatives showcase how aggregating residential solar plus storage provides additional grid benefits. North Carolina faces increasing risks from hurricanes and extreme weather, making solar plus storage an attractive option for improving grid reliability, especially in vulnerable areas.

Additional assistance for low-income households in outage-prone areas will enhance resilience and equity, with Puerto Rico's targeted programs to assist low-income residents in installing solar plus storage. North Carolina could adopt similar targeted incentive programs for low-income households or areas especially prone to power outages to increase energy equity and resilience.

Limitations to Applicability in North Carolina

Grid reliability: Compared to North Carolina, Puerto Rico has suffered from a much more unreliable grid, which has been a major driver of solar plus storage adoption. In 2021, Puerto Rico experienced 11.5 times the U.S. median number of minutes of outages and 7.1 times the number of interruptions.[123] North Carolina's grid is more stable, reducing the immediate economic justification for widespread residential solar plus storage purely for resilience. While North Carolina experiences hurricanes, it does not face the same level of prolonged outages as

Puerto Rico. This reduces the immediate demand for solar plus storage as an emergency energy source, though future climate risks could change this dynamic.

Federal and nonprofit support: It is important to note that Puerto Rico's rooftop solar adoption has experienced considerable federal and nonprofit support that is not available in North Carolina. In 2023, Congress allocated $1 billion for the Puerto Rico Energy Resilience Fund, which includes up to $450 million for residential solar plus storage installations.[124] This has directly allowed for the Solar Access Program and other means of improving energy resilience in Puerto Rico. As of mid-2024, an estimated 5,000 of the 117,000 solar installations in Puerto Rico were financed by the Puerto Rico Department of Housing and DOE programs.[125] North Carolina lacks this level of direct federal support, meaning incentive programs would require state or utility funding.

Electricity rates: Puerto Rico's high electricity rates--over $0.20/kWh--make solar plus storage financially attractive for utility customers. North Carolina has a retail rate of $0.12/kWh, well below the national average of $0.15/kWh, which may limit the financial impetus for rapid adoption.

Utility market: Puerto Ricans also have a greater affinity for reliable electricity because of their poor experience with the island's government-owned utility, the Puerto Rico Electric Power Authority (PREPA). Puerto Rico has experienced frequent outages due to natural disasters, damage from tree limbs or animals, and mechanical problems. Following the devasting blackout from Hurricane Maria, it took 11 months to restore power to the island fully.[126] During this period, many customers found alternative electricity sources, such as generators and residential solar plus storage. Combined with the island's high electricity rate and poor reliability, residential solar plus storage is particularly favorable for residents. Despite this shift, Puerto Ricans continue to face high power bills and frequent outages. North Carolina's regulated utility market, dominated by Duke Energy, may be less accommodating of widespread rooftop solar. However, there is growing support for residential solar plus storage across the country amid rising electricity rates, which have increased 32% since 2019, and growing reliability concerns.[127]

Economic Benefits for North Carolina

Faced with a suite of policy options to increase residential solar adoption, North Carolina policymakers and solar advocates need to understand the potential value of distributed solar to the state. This quantitative analysis models under what scenarios residential solar is cost-competitive with utility-scale generation, with a specific examination of the Value of Lost Load (VOLL) during blackouts.

Existing analyses have attempted to quantify the value of solar, though methodologies and findings vary greatly. In general, past studies calculate the costs of solar integration, avoided energy costs, avoided capital costs, and avoided emissions costs to value solar. In a literature review of 16 cost-benefit studies, only one included the metric of grid resiliency, called a "security enhancement value."[128] This report quantifies the reliability metric by calculating the Value of Lost Load savings provided by distributed solar plus storage during power outages in North Carolina. VOLL quantifies the economic cost to customers due to an outage, including lost economic revenue, equipment damage, and inconvenience to utility customers.

This analysis calculates the VOLL to assess how the adoption of distributed solar plus storage systems might prevent economic loss of that magnitude. Given the increasing frequency of power outages driven by extreme weather, the economic impacts for North Carolina are significant. More than 3.91 million customers are served by North Carolina's regulated electric utilities, 90% of which are residential.[129] In North Carolina, a power outage event lasts an average of 167 minutes. The Lawerence Berkeley National Laboratory interruption cost calculator was used to estimate the cost per interruption event. This relatively brief interruption has an estimated economic cost to the residential sector of more than $46 million. The cost of interruption balloons to more than $1.24 billion when including the impact on the commercial and industrial sectors. **Table 3** breaks down the costs, with the average cost being $2.12/kWh, or $2,120 per every 1 MWh of outage. If just 10% of residential customers installed a solar plus storage system capable of meeting their demand during an outage, the cost savings from the avoided lost load would be more than $4.65 million during an outage.

Sector	# of Customers	Cost Per Event ($)	Cost Per Avg kW	Cost Per Unserved kWh	Total Cost ($)
Residential	3,519,000	8.79	5.92	2.12	46,539,622
Small C&I	371,551	1,412.70	461.76	165.51	789,961,678
Medium and Large C&I	19,449	13,985.64	67.50	24.20	409,370,007
Total	**3,910,000**	**211.72**	**79.69**	**28.56**	**1,245,871,308**

Table 3: An estimate of the economic costs by sector (residential, commercial, and industrial) from a power outage in North Carolina.

As a baseline, the levelized cost of energy (LCOE) of distributed solar plus storage was compared to utility-scale solar. For simplicity, only the cost of retail service provided by utility-scale and distribution-scale solar was considered in this calculation. Based on National Renewable Energy Laboratory assumptions, the LCOE of utility-scale solar plus storage in North Carolina is $92.2/MWh, which is almost half the LCOE of a residential solar plus storage system at $175.1/MWh. This is in line with an existing Brattle Group analysis, which found that 300 MW of utility-scale solar is roughly one-half the cost of 300 MW of 5kW residential-scale systems in Colorado.[130]

The Brattle report fails to quantify the additional benefits of residential solar systems, such as faster interconnection and deployment, avoided transmission costs, less land use, avoided capital costs, and the VOLL. Of note, the study was commissioned by First Solar, the largest utility-scale solar developer, and the Edison Electric Institute, a major utility trade association. The authors did acknowledge residential cost advantages under certain scenarios and locations, particularly in extreme conditions. Residential solar plus storage might see a lower LCOE than utility-scale solar in scenarios with high electricity costs, high transmission congestion costs, or frequent reliability issues, as seen in Puerto Rico.

Ultimately, LCOE does not consider the VOLL, even though a generator's ability to provide reliable power during peak demand or extreme events increases its overall value to the grid. While residential solar plus storage has a higher LCOE, it might still be a better investment overall due to the value it provides the grid by avoiding costly outages.

In North Carolina, the LCOE of $175.1/MWh for residential solar plus storage systems is minimal, considering the alternative of losing $2,120/MWh during an outage event. Additionally, the VOLL is expected to increase over time due to an increasing frequency of extreme weather events and a growing population in the state to be impacted. Solar plus storage owners can alleviate some of the economic damages from an outage. Customers who experience more frequent or longer-duration outages and have a higher VOLL will be more likely to have benefits that exceed the cost of a residential solar plus storage system. An analysis in the Midwest found that the average residential solar plus storage system saw resilience benefits that comprised 20% of the total system cost, and up to 83%.[131]

CONCLUSION

Distributed solar plus storage presents an opportunity for North Carolina to meet rising electricity demand, decarbonize the grid, and improve grid reliability and resilience in the face of increasingly frequent extreme weather events. This report demonstrates that while upfront costs and limited consumer awareness remain key barriers, the economic, environmental, and resilience benefits of solar storage are significant and broadly supported by consumers. Case studies in other states and territories demonstrate the importance of policy stability, targeted incentives, and public education in increasing adoption rates. North Carolina should consider the adoption of key policy levers, including battery incentives, favorable net metering, and a virtual power plant goal for utilities, to harness the full potential of distributed solar plus storage to empower communities and strengthen the grid.

APPENDIX

Appendix A: Definitions and Key Terms

Distributed energy resource (DER)- small energy generation and storage technologies that provide electric capacity or energy near where it will be consumed

Distributed generation (DG)- generation technologies that generate electricity at or near where it will be used

Distributed power plant (DPP)- interchangeable terminology with virtual power plant

Distributed solar- a type of DER and DG that generates solar at or near where it will be used, typically on a residential, commercial, or industrial rooftop

Distributed solar plus storage- a battery system that is charged by a connected solar system

EIA- U.S. Energy Information Administration

GW- Gigawatt

Integrated Resource Plan (IRP)- a utility's regularly prepared plan to meet future energy demand and maintain reliability based on forecasted supply and demand resources.

ITC- investment tax credit, which allows taxpayers to subtract the amount of the credit from their taxes owed.

kW- Kilowatt

LBNL- Lawrence Berkeley National Laboratory

Levelized Cost of Energy (LCOE) – an estimate of the average cost of electricity generation over the lifetime of a generator, expressed as a cost per unit of electricity produced.

MW- Megawatt

NREL- National Renewable Energy Laboratory

PTC- production tax credit, which includes the federal Clean Electricity Production Credit that provides an incentive for every kWh of electricity generated from clean energy resources.

PV- photovoltaics

Renewable Portfolio Standard (RPS)- a voluntary or mandatory requirement for a certain percentage of electricity to be generated from renewable energy resources.

Residential solar- also known as rooftop solar, a small solar system that generates electricity for a single home

Value of Lost Load (VOLL)- the estimated amount electricity customers would be willing to pay to avoid a disruption in service from an outage event

Virtual power plant (VPP)- an aggregation of distributed energy resource (DER) technologies, like distributed solar plus storage, that work to balance supply and demand like a traditional power plant

Appendix B: Methodology

To quantify and describe the benefits of distributed solar plus storage, a multiple methodology framework was used that combines survey-based research, qualitative, and quantitative analysis.

Survey-based research to inform messaging and feasibility

SUN needs to understand public opinion to encourage the adoption of distributed solar plus storage. Survey-based research can contextualize why residential customers are not as receptive to solar. The non-profit think-tank and polling firm, Data for Progress (DFP), fielded a national survey of approximately 1,200 likely voters. The survey was administered as a part of DFP's omnibus survey fielded twice weekly. The questions comprise closed-ended questions to avoid inconsistencies or difficulty in interpreting the results. The survey was administered to homeowners and renters to compare perceptions of distributed solar across these groups.

Due to time and resource constraints in recruiting participants, a survey of only North Carolina was not feasible. To make the survey insights more applicable to North Carolina, the South Atlantic census tract responses were more heavily weighted. The survey questions are outlined in Appendix B. The results reveal barriers to solar adoption and guide the policies SUN can advocate for to lower barriers to adoption. The survey also tested various policy proposals for distributed solar plus storage and VPPs to inform their political and cultural feasibility. The survey results will inform policy recommendations to expand residential solar plus storage adoption in North Carolina.

Case studies to identify the benefits of distributed solar plus storage

The benefits of solar are examined through a case study of distributed solar plus storage implementation in states with higher adoption than North Carolina. A state-level unit of analysis was selected, as SUN hopes to maximize the passage of distributed solar policies through its state advocacy work. Arizona, Massachusetts, Hawaii, and Puerto Rico were chosen due to their higher distributed solar adoption relative to North Carolina. For example, more than 38% of solar in Arizona is from small-scale distributed solar projects compared to 7.6% in North Carolina.[132] Arizona is similarly situated to North Carolina in the top seven states with the fastest growing population.[133] Like North Carolina, Arizona is also a regulated utility state.

Case studies illustrate the precedent of successful distributed solar plus storage programs. The longer case study of Arizona will demonstrate the benefits of distributed solar and storage and the necessary policy environment to enable these programs. These best practices may be replicated in North Carolina subject to the state's unique political, economic, and social context.

The case studies highlight effective policies to spur distributed solar plus storage. The effectiveness of these policies is based on the adoption of distributed solar plus storage.

Quantitative analysis to measure the economic benefits for North Carolina

A limitation of this study is the external validity of generalizing the results of case studies of the benefits of distributed solar plus storage in other jurisdictions to North Carolina. The economic benefits of solar can vary greatly depending on the utility, electricity rates, and solar radiation in that jurisdiction. That is why quantitative analysis modeled the true benefits based on the unique parameters of North Carolina to support the results of the survey and case studies.

This analysis evaluates the Levelized Cost of Electricity (LCOE) for residential solar plus storage versus utility-scale solar plus storage and a conventional combined cycle natural gas facility in North Carolina. The utility-scale installation is a 100 MW solar photovoltaic (PV) system with 60 MWs of battery storage per National Renewable Energy Laboratory (NREL) standards. The LCOE also incorporates the 30% federal investment tax credit. The residential solar plus storage system includes a battery at 20% of the solar capacity and incorporates the federal investment tax credit. This analysis assumes no distribution upgrades are necessary to accommodate residential solar plus storage.

The goal is to show under what conditions a residential solar plus storage system would be cost-competitive with utility-scale generation. This can provide many benefits to the state, including the avoidance of transmission necessary for utility-scale generation and the Value of Lost Load (VOLL) savings during extreme weather events. Assumptions are sourced from the moderate scenario in the NREL's 2024 Annual Technology Baseline. The analysis will be based on Tyler H. Norris's existing LCOE model of commercial versus transmission-scale solar arrays for North Carolina. The following equation will be used to calculate the LCOE.[134]

$$LCOE = \frac{Fixed\ Charge\ Rate \times\ CAPEX + Fixed\ Cost}{Capacity\ Factor\ \times\ 8760\ hours/year} + Variable\ Cost + Fuel\ Cost$$

It is expected that, except for extreme scenarios, the LCOE of utility-scale solar and storage and natural gas facilities will be less than a residential system. However, the LCOE does not include the benefit of the Value of Lost Load (VOLL).

The VOLL can vary greatly even within a utility's service territory, as it depends on the composition of the customer base, the time of day, the season, the duration and frequency of the outage, and the probability of an outage, among other factors.[135] To measure the VOLL, the costs incurred when service is interrupted in North Carolina are estimated using the Lawrence Berkeley National Laboratory's ICE Calculator. The ICE calculator estimates the direct costs to customers from power interruptions lasting 24 hours or less.[136] Reliability metrics were sourced from the U.S. Energy Information Administration.

Appendix D: Survey Questions

DEMOS:

[dfp_housing_status]

1. Which of the following best describes your current housing status? **[randomize]**
   - Own
   - Rent
   - Other housing arrangement **[anchor]**

[dfp_climate_monthly_electric_bill]

1. How much is your average monthly electric bill?

[flip scale]

a. Less than $100
b. Between $100 and $150
c. Between $150 and $200
d. More than $200

e. I don’t pay for my own utilities **[anchor]**
f. Don’t know **[anchor]**

GENERAL AWARENESS OF SOLAR

[dfp_climate_rooftop_solar_heard]
2. How much have you seen or heard about rooftop solar in your community?
[flip scale]
- A lot
- A little
- Nothing at all

[dfp_climate_heard_two_split_alpha_vpp]
2. How familiar are you with the term “virtual power plant,” if at all?
[flip scale]
- Very familiar
- Somewhat familiar
- Only a little familiar
- Not at all familiar

[dfp_climate_heard_two_split_alpha_dpp]
3. How familiar are you with the term “distributed power plant,” if at all?
[flip scale]
- Very familiar
- Somewhat familiar
- Only a little familiar
- Not at all familiar

[dfp_climate_residential_solar_own]
4. Do you have installed solar panels for your home or rental?
[randomize]
- Yes
- No
- Not sure **[anchor]**

[dfp_climate_residential_solar_reliability_impact]
3. Pairing a battery with solar panels allows the storing of excess electricity, rather than it being wasted. This stored electricity can be used when the sun is not shining, can provide electricity during a power outage, and in some places can provide power to the rest of the grid.

How do you think residential solar plus battery storage on your rental or home would impact the reliability of the electrical grid, if at all?

[randomize]
a. Improve reliability (e.g., fewer blackouts and outages)
b. Decrease reliability (e.g., more frequent blackouts and outages)

c. No impact **[anchor]**
d. Don’t know **[anchor]**

[dfp_climate_residential_solar_cost_impact]
4. How do you think residential solar plus battery storage on your rental or homewould affect your electricity bill, if at all?

[randomize]
- Increase electric rates
- Decrease electric rates
- No impact **[anchor]**
- Don’t know **[anchor]**

OPINION OF SOLAR ADOPTION
[dfp_climate_solar_install_likelihood]
5. How likely would you be to install solar panels on your home, or ask your landlord to do so?
[flip scale]
a. Very likely
b. Somewhat likely
c. Not sure
d. Not that likely
e. Not at all likely

[dfp_climate_solar_install_primary_motivation]
6. If you were to install solar panels on your home, what would be your **primary** motivation for doing so?

[randomize]
a. Lowering electricity bill [skip next question]
b. Reducing carbon footprint [skip next question]
c. Self-sufficient/Independence from the electric grid [skip next question]
d. Backup energy in the case of extreme weather [skip next question]
e. I would **not** adopt solar panels [go to next question] **[anchor]**

7. What is the **primary** reason you would **not** consider installing solar panels on your home?

[randomize]
a. There is not enough sun in my location
b. The upfront cost is too high and I don’t think they will save me money
c. I don’t like the appearance of solar panels on my home
d. I think solar is worse for the environment
e. I don’t trust the supply chain for solar panels
f. I am a renter and can’t make permanent changes to my home

g. Don't know **[anchor]**

8. What factor would **most** increase your likelihood of adopting solar panels?

[randomize]

a. Government subsidies lower the upfront cost
b. My utility offers a discount for solar plus storage
c. More education or assistance for how to acquire solar panels
d. I can be assured my electric bill will be lower
e. My electric rate increases
f. More frequent power outages due to extreme weather
g. I will earn passive income from my solar panels
h. My neighbors all adopt solar panels
i. Other **[required text box] [anchor]**
j. I would **not** adopt solar panels **[anchor]**
k. Don't know [anchor]

TESTING POLICIES FOR SOLAR ADOPTION

9. How motivated, if at all, are you to take advantage of new tax incentives and rebates to install rooftop solar panels?

[flip scale]

a. Very motivated
b. Somewhat motivated
c. Not very motivated
d. Not motivated at all [**anchor]**

10. Net metering allows owners of residential solar to sell excess electricity they generate back to the grid. In some states, owners of residential rooftop solar receive credits to their electricity bill for excess electricity generation.

Supporters claim net metering policies create a smoother demand curve for electricity and allow utilities to better manage their peak electricity loads.

Opponents claim net metering forces those without solar to subsidize the cost of the grid for solar users.

Would you support or oppose the expansion of net metering policies to allow greater compensation for solar owners?

[flip scale]

- Strongly support
- Somewhat support
- Somewhat oppose
- Strongly oppose
- Don't know [**anchor]**

11. Residential fixed charges are minimum billing requirements that all users connected to the grid are charged, including residential solar owners.

Would you support or oppose residential fixed charges on utility bills for residential solar customers?

[flip scale]

a. Strongly support
b. Somewhat support
c. Somewhat oppose
d. Strongly oppose
e. Don't know **[anchor]**

12. A Virtual Power Plant is a group of many small energy sources, like solar panels and batteries on rooftops, that work together to supply electricity like a traditional power plant. They can meet electricity demand in a more affordable and eco-friendly way than fossil fuel power plants.

Based on what you know now, if you owned a solar plus battery storage system, would you support a program that would compensate you for making your system available when needed?

[flip scale]

a. Strongly support
b. Somewhat support
c. Somewhat oppose
d. Strongly oppose
e. Don't know **[anchor]**

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