SHINING REWARDS

The Value of Rooftop Solar Power for Consumers and Society

2016 Edition

ENVIRONMENT AMERICA
RESEARCH & POLICY CENTER

FRONTIER GROUP

SHINING REWARDS

The Value of Rooftop Solar Power for Consumers and Society

2016 Edition

Written by:

Gideon Weissman

Frontier Group

Bret Fanshaw

Environment America Research & Policy Center

October 2016

Acknowledgments

Environment America Research & Policy Center sincerely thanks Amit Ronen, Director of the GW Solar Institute, Sean Gallagher, Vice President of State Affairs for the Solar Energy Industries Association, and Jim Lazar, Senior Advisor for the Regulatory Assistance Project. Thanks also to Tony Dutzik and Elizabeth Berg of Frontier Group for editorial support.

This report is an update to *Shining Rewards: The Value of Rooftop Solar Power for Consumers and Society,* released in summer 2015 and written by Lindsey Hallock of Frontier Group and Rob Sargent of Environment America Research & Policy Center.

Environment America Research & Policy Center thanks the Tilia Fund, the Barr Foundation, the John Merck Fund, Fred & Alice Stanback, the Scherman Foundation, the Arntz Family Foundation, the Kendeda Fund, the Fund for New Jersey, the Falcon Foundation, Victoria Foundation and Gertrude and William C. Wardlaw for making this report possible. The authors bear responsibility for any factual errors. The recommendations are those of Environment America Research & Policy Center. The views expressed in this report are those of the authors and do not necessarily reflect the views of our funders or those who provided review.

Environment America Research & Policy Center is a 501(c)(3) organization. We are dedicated to protecting America's air, water and open spaces. We investigate problems, craft solutions, educate the public and decision makers, and help Americans make their voices heard in local, state and national debates over the quality of our environment and our lives. For more information about Environment America Research & Policy Center or for additional copies of this report, please visit www.environmentamericacenter.org.

Frontier Group provides information and ideas to help citizens build a cleaner, healthier, fairer and more democratic America. We address issues that will define our nation's course in the 21st century – from fracking to solar energy, global warming to transportation, clean water to clean elections. Our experts and writers deliver timely research and analysis that is accessible to the public, applying insights gleaned from a variety of disciplines to arrive at new ideas for solving pressing problems. For more information about Frontier Group, please visit www.frontiergroup.org.

Layout: Alec Meltzer/meltzerdesign.net

Cover photo: Courtesy of Jon Callas

Contents

Executive Summary

Solar energy is on the rise in the United States. Through September 2016, more than 31 gigawatts of solar electric capacity had been installed around the country, enough to power more than 6 million homes. The rapid growth of solar energy in the United States is the result of forward-looking policies that are helping the nation reduce its contribution to global warming and expand its use of local renewable energy sources.

One policy in particular, net energy metering, has been instrumental in the growth of solar energy, particularly on homes and small businesses. Net energy metering enables solar panel owners to earn fair compensation for the benefits they provide to other users of the electricity grid, and makes "going solar" an affordable option for more people. Net energy metering works by providing customers a credit on their electric bill that offsets charges for energy consumption. As solar energy has taken off in recent years, however, utilities and other special interests have increasingly attacked net metering as an unjustified "subsidy" to solar users.

A review of 16 recent analyses shows that individuals and businesses that decide to "go solar" generally deliver greater benefits to the grid and society than they receive through net metering. Decision-makers should recognize the great value delivered by distributed solar energy by preserving and expanding access to net metering and other programs that ensure fair compensation to Americans who install solar energy.

Net metering is not a new idea. It has been the policy in some states for more than 30 years. The concept has been tested in the courts and in regulatory proceedings in the states and at federal agencies like the Federal Energy Regulatory Commission and the Internal Revenue Service. Net metering is the law of the land in 41 states today.

Net metering has been critical to solar energy's rapid expansion in the United States.

- Net metering offsets costs for solar panel owners and credits them for providing excess power to the grid at a set price, usually at the same retail price they pay to buy electricity.
- Net metering is conceptually simple (it essentially allows consumers to run their electric meters backwards), easy to administer, requires a minimum of utility system investment, and ensures that customers receive compensation that tracks with electricity prices over time.
- Net metering also makes solar energy more economically attractive for residents and businesses, and accessible and affordable to low and middle income Americans.

Solar energy creates many benefits for the electricity grid.

- **Avoided energy costs**: Solar energy systems produce clean, renewable electricity on-site, reducing the amount of electricity utilities must generate or purchase from fossil fuel-fired power plants. In addition, solar photovoltaic (PV) systems reduce the amount of energy lost in generation, long-distance transmission and distribution, which cost U.S. ratepayers about $21 billion in 2014.

- **Avoided capital and capacity investment:** By reducing overall demand for electricity during high-load daytime hours that form the peak period for most utilities, solar energy production helps ratepayers and utilities avoid the cost of investing in new power plants, transmission lines, distribution capacity, and other forms of electricity infrastructure.

- **Reduced financial risks and electricity prices:** Because the price of solar energy tends to be stable over time, while the price of fossil fuels can fluctuate sharply, integrating more solar energy into the grid reduces consumers' exposure to volatile fossil fuel prices. Also, by reducing demand for energy from the grid, solar PV systems reduce its price, saving money for all ratepayers.

- **Increased grid resiliency:** Increasing distributed solar PV decentralizes the grid, potentially safeguarding people in one region from other areas that are experiencing problems. Emerging technologies, including smart meters and small-scale battery storage systems, will enhance this value.

- **Avoided environmental compliance costs:** Increasing solar energy capacity helps utilities avoid the costs of installing new technologies to clean up fossil fuel-fired power plants or meeting renewable energy requirements, and avoid the cost of emission allowances where pollution is capped.

Solar energy also creates valuable benefits for the environment and society at large.

- **Avoided greenhouse gas emissions:** In 2014, the electricity sector was the largest source of global warming emissions—responsible for 30 percent of all total U.S. greenhouse gas pollution. Generating energy from the sun provides a renewable source of energy that produces no greenhouse gas emissions. In 2015, distributed solar energy alone – just solar panels on households and businesses – averted approximately 8 million metric tons of carbon dioxide emissions.

- **Reduces air pollution that harms public health:** According to the American Lung Association, 44 percent of Americans live in a place where pollution often reaches dangerous levels. Expanding the nation's ability to obtain clean electricity from the sun reduces our dependence on fossil fuels, and lessens the amount of harmful emissions that flow into the air we breathe.

- **Creates jobs and spurs local economies:** The American solar energy industry is growing rapidly, creating new jobs and businesses across the nation. In 2015, the solar energy industry added jobs at a rate 12 times that of the overall economy, and as of November 2015 employed more than 208,000 people.

The benefits solar homeowners provide to the grid, and to society generally, are often worth more than the benefits they receive through net metering.

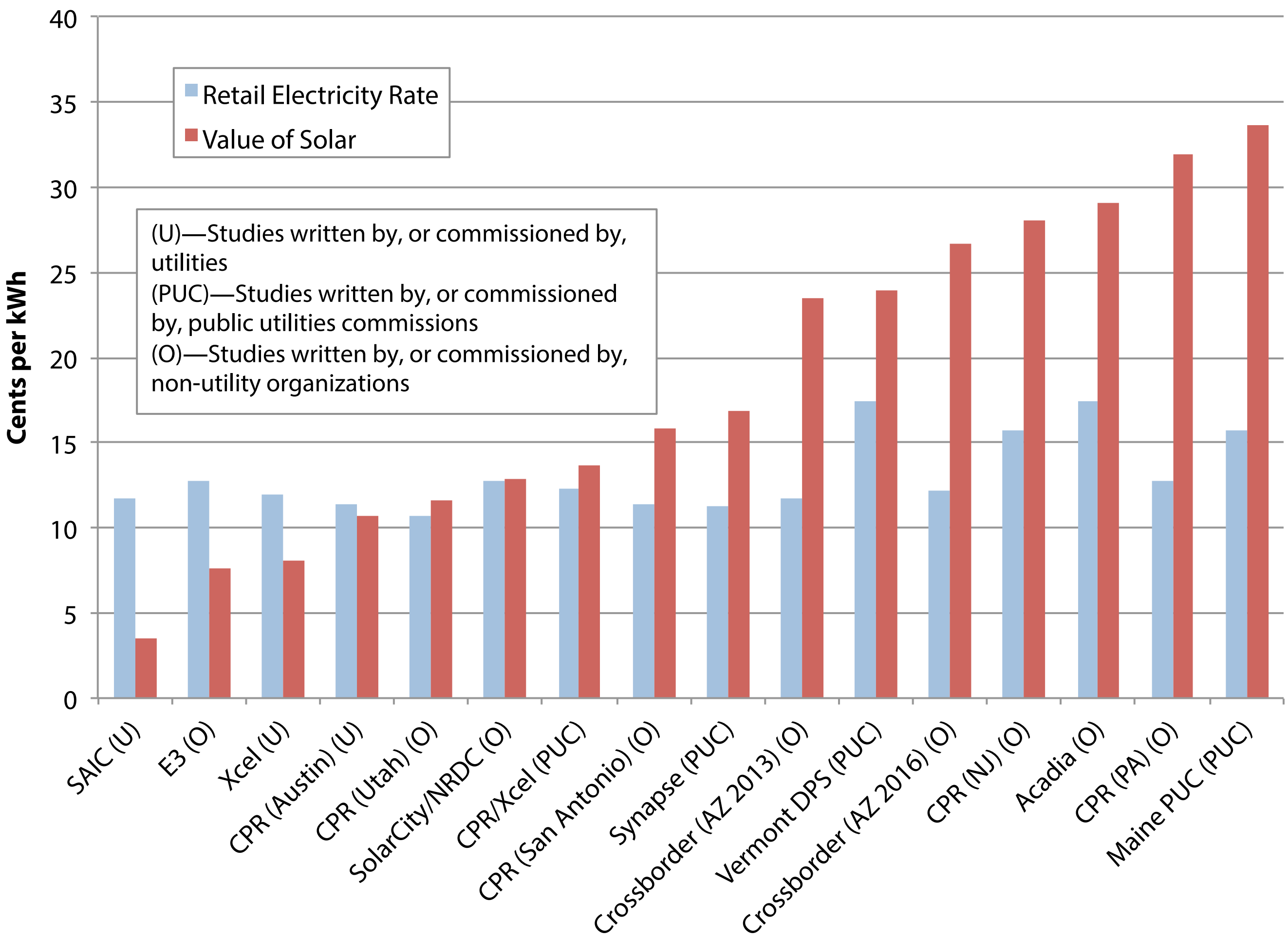
- All 16 analyses reviewed here found that solar energy brought net benefits to the grid.

- 12 analyses out of 16 found that the value of solar energy was worth more than the average residential retail electricity rate in the area at the time the analysis was conducted. Three of the four analyses that found different results were commissioned by utilities. (See Figure ES 1.)

- Of these 16 analyses, the median value of rooftop solar energy was 16.35 cents per kWh, while the average residential retail electricity rate in included states was 13.05 cents per kWh.

- The studies that estimated lower values for solar energy often undervalued, or did not include, important environmental and societal benefits that come from generating electricity from the sun.

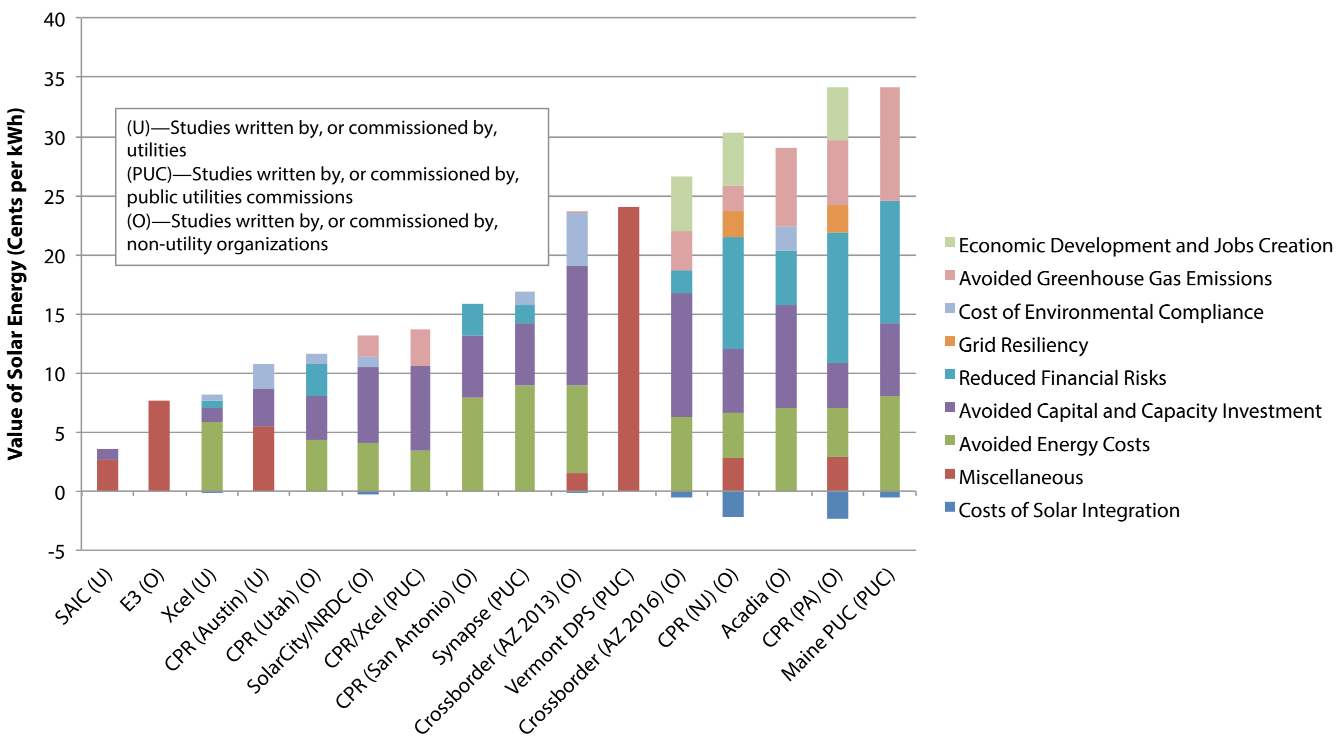
Figure ES-1: Retail Electricity Rates and the Values of Solar Energy in 16 Cost-Benefit Analyses.



Net metering policies have been critical to the growth of solar energy in the United States. To maintain America's momentum toward a clean energy future, policy-makers should continue and expand net metering policies. Specifically:

- States should lift arbitrary caps that limit availability of net metering in fast-growing solar markets.
- State or local governments that evaluate the benefits and costs of net metering should include a full range of benefits of solar energy, including environmental and societal benefits.
- State and local governments should consider the simplicity of net metering when evaluating programs that compensate customers for the solar electricity they provide to the grid.
- State and local governments should reject alternatives to net metering that do not provide residential and business customers full and fair compensation that reflects all the benefits that they provide.
- State and local governments should ensure that all people can take advantage of net metering policies, including multifamily homes or homes without sunny roofs, by implementing virtual net metering programs.

Figure ES-2: A Comparison of Cost-Benefit Analyses of Solar Energy by Study and Category.



Introduction

In 2015, America saw its 1 millionth solar installation. The vast majority of those installations were built on rooftops, parking lot canopies and for community solar gardens, and on homes, apartment buildings, businesses, farms, schools, government offices and more – a category known as distributed solar energy.

It is still the early days of America's transition to clean energy. Those who have "gone solar" so far are in the vanguard – and their decisions to invest time and money in solar projects are often driven by the desire to do their part in reducing the threat of global warming. Their efforts are working. In 2015, the energy generated by rooftop and other distributed solar energy averted 8.4 million metric tons of greenhouse gas pollution, equivalent to taking nearly 2 million passenger vehicles off the road, burning 20 million fewer barrels of oil, or shutting down two coal plants.[1]

Yet early solar adopters have done more than just reduce global warming emissions. They have also supported local jobs, improved public health, and paved the way for a future of cheaper and easier solar installations. And they have driven forward the American solar industry, which is creating jobs 12 times faster than the rest of the economy and now employs three times as many people as the U.S. coal-mining industry.[2]

This report reviews a growing body of research on solar energy's value to society, and to the electric grid in particular – and finds that those who have "gone solar" are likely not only fighting global warming, but also providing financial benefits to fellow utility ratepayers, even when accounting for support provided by state policies like net metering.

By realizing the full benefits provided by those who "go solar," and supporting homeowners and businesses that choose to invest in a cleaner and healthier future, America can continue to fuel the growth of clean solar energy for years to come.

Pro-Solar Policies Are Fueling a Solar Revolution in America

The United States has witnessed a decade of impressive growth in solar energy. By September 2016, the United States had 31.6 gigawatts of solar electric capacity, enough to power more than 6 million average U.S. homes.[3]

Solar power is growing exceptionally fast, but the United States is nowhere near the limit of its solar potential. The United States has the technical potential to install enough solar electricity capacity to meet the nation's electricity needs more than 100 times over.[4]

America's ability to tap that potential grows as solar energy prices continue to fall. The price of a typical solar PV system has declined an average of 6 to 8 percent annually since 1998, providing more Americans with the opportunity to generate their own electricity at home or at their business.[5]

Continued declines in the price of solar energy, coupled with Americans' increasing familiarity with this clean energy source, could lead to a continued boom in solar power. But that is only likely to happen if the United States retains stable public policies that provide a solid foundation for solar energy.

Net Metering Has Been Critical to the Expansion of Solar Energy

Net energy metering is a simple, easily understood, easy-to-administer system designed to ensure that solar panel owners are fairly compensated for the benefits they provide to the grid. Under net energy metering, solar panel owners are compensated for the extra power they supply to the grid at a fixed rate, normally the retail cost of electricity – the amount that a residential customer would pay to draw a unit of electricity from the grid. Stated simply, net energy means that the customer meter spins forward for every bit of electricity the customer uses, and spins backwards at times when solar power production exceeds on-site needs. The balance, or the "net," is what the customer is charged or credited for at the end of the month. As a result, over the course of a year, a customer with a solar photovoltaic system pays for only the *net* amount of electricity used over a 12-month period (electricity consumed minus electricity produced), plus utility service charges.

Net metering is not a new idea. It has been the policy in some states for more than 30 years, and is currently offered in 41 states and Washington, D.C.[6] Of the top 10 states with the most solar energy capacity per capita, all but one had a strong net metering policy through 2015.[7]

Historically, the relationship between power generators and consumers had been a one-way street. Utilities generated the power and customers bought it. Utilities simply sent customers a monthly bill for the amount of power they consumed. Utilities were granted a franchise and exclusive monopoly to serve an area in return for a reasonable opportunity to make a profit. The price of power was set at a level designed to recover the utility's cost of building and operating the power plants, power lines and distribution systems needed to supply electricity to consumers.

Technologies like solar panels, however, enable electricity consumers to also be electricity producers. Because solar panels generate more electricity than needed at certain times of day and less than is needed at others, most solar homeowners are both producers and consumers of electricity from the grid, depending on the time of day and season of the year.

Charging solar panel owners based on their net consumption of electricity is not the only possible option for compensating them for the power they supply to the grid. Even in the absence of net metering, federal law requires utilities to purchase any excess power from customer-owned solar photovoltaic systems at a state-regulated rate based on the "avoided cost" of the electricity the utility would have otherwise had to generate or purchase – a figure usually far lower than the retail rate.[8] Some states and localities have adopted other methods for calculating compensation, such as "value of solar" rates that attempt to pay solar panel owners based on the estimated value of the benefits they supply to the grid.

Unfortunately, net metering is often misunderstood as a "subsidy" to solar homeowners, rather than as a system for compensating them for the benefits they provide to the grid and to society. A series of studies in recent years has shown that those benefits are significant.

Rooftop Solar Energy Provides Clear Benefits to Electricity Consumers and to Society

Solar energy provides a wide variety of benefits for the grid and for society in general. These benefits can be divided into two categories: benefits to the grid (and, by extension, all electricity consumers) and benefits to the environment and society. The value of distributed solar power should not be compared to the cost of power from a fossil-fueled central generating station. A new, clean resource that produces all of its output during the high-load daytime hours and is delivered to the system at the distribution grid level is fundamentally different – and in some ways superior to – a fossil-fired power plant located far from the customer base.

Grid Benefits

Avoided Energy Costs

Of all the benefits that solar energy creates for electricity ratepayers, reduced expenditure for power generation is perhaps the most obvious. Solar energy systems produce clean, renewable electricity on-site, reducing the amount of electricity utilities must generate or purchase from fossil fuel-fired power plants.

The value of this avoided electricity consumption is often greatest in the summer months, when demand for electricity rises due to increased air conditioning demand and solar energy production is near its peak. Adding solar energy to the system reduces the need to power up expensive, often inefficient generators that run only a few times a year, or to purchase expensive peak power on wholesale markets, reducing the cost of electricity for all ratepayers.

Reduced Line Losses

Our nation's electricity grid was built around large, centralized power plants, with power transmitted over long distances to our homes and businesses. As it travels from the power plant to our sockets, a portion of the electricity is "lost" as heat and never arrives at its destination.

The Energy Information Administration estimated that the United States lost about $21 billion worth of electricity in 2014, or 5 percent of the total amount of electricity transmitted and distributed that year.[9] These losses cause us to generate more electricity than we need, increasing costs for ratepayers. Solar PV systems drastically reduce the amount of system losses by producing electricity on-site, thereby reducing the amount of electricity transmitted and distributed through the grid.

Solar power is particularly effective in reducing line losses because it reduces demand on grid infrastructure at times when line losses are highest. Line losses increase with the square of the load on the distribution system, so they are highest during the high-load hours when most solar output is delivered. On-peak losses can be as high as 30 percent, so the benefits of distributed solar energy may be disproportionately high.[10]

Avoided Capacity Investment

Expanding the amount of electricity we generate from the sun can defer or eliminate the need for new grid capacity investments, particularly because demand for energy from the grid is currently often highest during the day when the sun is shining (although this may change with increasing deployments of rooftop solar). By reducing overall demand, expanding solar energy production helps ratepayers and utilities avoid the cost of investing in new power plants, transmission lines, reserve capacity and other forms of electricity infrastructure.

Reduced Financial Risks and Electricity Prices

Price volatility in the fossil fuel market has long been a concern for utilities and ratepayers alike, but the risk has become greater as power companies have shifted from coal to natural gas – a fuel with a history of price volatility.[11] Because solar panels, once installed, do not incur fuel costs, integrating more solar energy capacity onto the electric grid can reduce exposure to sudden swings in the price of fossil fuels or wholesale electricity. Utilities commonly engage in strategies to hedge against fossil fuel price volatility – such as by securing long-term contracts, where possible, for fossil fuels or electricity – for which utilities are often willing to pay a premium. Solar energy can help meet these same needs to increase price stability, a contribution with financial value for utilities and grid users.[12]

In competitive energy markets, distributed solar energy also reduces the *price* of electricity by reducing overall demand on the grid. In these areas, ratepayers not only benefit when utilities must purchase less electricity to satisfy demand, but they also gain because each unit of electricity purchased becomes cheaper.[13] These demand reduction-induced price effects can represent an important value to ratepayers.

Grid Resiliency

The centralized nature of our power grid leaves it vulnerable to frequent and prolonged outages. In 2003, four downed power lines in Ohio left more than 50 million people in eight states and Canada without power and cost $6 billion in economic damage.[14] Increasing distributed solar PV capacity and energy storage options not only reduces the demand that combines to overload the system, but it also decentralizes our grid, potentially safeguarding people in one part of the country from other areas that are experiencing problems. Additionally, advances in smart inverter technology allow higher percentages of solar energy to be safely integrated into the grid, increasing grid resiliency and reliability.[15] This will be enhanced as distributed battery storage expands.

Avoided Environmental Compliance Costs

Adding solar energy to the grid allows local utilities and municipalities to avoid some of the growing costs of compliance with environmental regulations. Many states have air quality and water quality regulations and 29 states and Washington, D.C., have Renewable Electricity Standards that require states to source a certain percentage of their energy demand from renewable resources, including from the sun.[16] Increasing solar energy capacity helps utilities avoid or reduce the costs of installing new technologies to curb air and water pollution or installing renewable energy. Solar also assists with compliance with regulations on criteria pollutants like sulfur dioxide and nitrogen oxides, and also helps states to comply with the proposed federal Clean Power Plan.

Environmental and Societal Benefits

Taking on Climate Change

In 2014, the electricity sector was the nation's largest source of global warming emissions – responsible for 30 percent of all total U.S. greenhouse gas pollution.[17] Coal is the most carbon intensive of the fossil fuels we burn for electricity, accounting for 77 percent of carbon dioxide emissions from the electricity sector. The combustion of natural gas, while emitting less carbon dioxide than coal, has now been shown to emit large amounts of methane – a gas that traps approximately 86 times more heat in the atmosphere than the same amount of carbon dioxide, over a 20-year time frame.[18]

Conservative studies suggest that every metric ton of carbon dioxide released into the air causes $37 of economic and social damage.[19] In 2015, the United States electric power sector emitted nearly 2 billion metric tons of carbon dioxide emissions, equivalent to more than $70 billion in economic and social damages.[20] Solar energy, however, is a renewable source of energy that produces emission-free electricity.

Rooftop solar in particular is also fast and flexible to implement, making it an important tool for taking on climate change. Residential rooftop projects typically take just a few months from initial deposit to power generation, while utility-scale solar projects can take years.[21] Distributed solar energy can also be installed in a wide variety of urban settings, including rooftops and parking lot canopies, making it well-suited for densely populated and energy-intensive regions.

Reduced Public Health Threats

Solar energy will not only reduce greenhouse gas emissions and help to mitigate the worst impacts of climate change, but it will also reduce emissions of dangerous air pollutants such as nitrogen oxides, mercury and particulate matter that harm public health.[22]

According to a new report by the American Lung Association, 44 percent of Americans live in a place where air pollution often reaches dangerous levels.[23] Air pollution is linked to increased incidence of asthma and chronic bronchitis, and has also been shown to cause hundreds of thousands of premature deaths per year.[24] A typical coal-fired power plant without technology to limit emissions sends 170 pounds of mercury —an extremely harmful neurological toxin – into the air each year.[25]

Expanding the nation's ability to source clean electricity from the sun reduces our dependence on fossil fuels, and lessens the amount of harmful emissions that flow into the air we breathe.

Job Creation and Economic Development

The solar energy industry is rapidly growing, creating new jobs and businesses across the nation. In 2015, the solar energy industry added jobs at a rate nearly 12 times that of the overall economy, and now employs more than 208,000 people.[26] Many of these jobs are in installation and maintenance, jobs that cannot be sent overseas. In addition, these jobs are well-paid, with installation jobs paying a median wage of $21 per hour.[27] In Colorado, for example, the solar energy industry has added $1.42 billion to the state economy since 2007, while creating 10,700 full-time jobs.[28] Because rooftop solar installations take place in our communities, they create opportunities for local businesses, and serve as visible reminders of the local economic benefits of clean energy.

Solar Energy is Worth More than the Benefits from Net Metering

Net metering is intended to compensate the owners of solar energy systems for the value they provide to the grid. In recent years, however, as solar energy has spread across the United States, utilities and fossil fuel interests have begun to argue that net metering represents an unfair subsidy that shifts costs onto other electricity ratepayers.

This report reviews 16 of those analyses, and seeks to compare the studies by author, categories valued and perspective. It shows that all of the studies find that solar energy brings net benefits to the grid and to society. It also finds that non-utility analysts generally value solar energy at higher rates than utilities and public utilities commissions, that the majority of analyses find solar energy to be worth more than the credits offered to solar energy system owners through net metering, and that studies that find lower values for solar energy often exclude consideration of key benefits that solar panel owners provide to the grid and society.

Many factors can affect the value of rooftop solar, from the time of day when electricity is generated, to location-specific factors like peak demand rates and a region's generation capacity. The value of rooftop solar will also change over time as the grid evolves and as rooftop solar becomes a more substantial part of our energy system. Nevertheless, the evidence suggests that today, in the majority of cases, net metered rooftop panels provide a net benefit to electric ratepayers, and to the rest of society.

The Value of Solar Power Is More than Just Avoided Costs

A key difference between studies that valued solar energy at lower levels and those that valued it at higher rates concerned the types of benefits considered in the analysis: did the report consider the ways that solar created benefits that accrue to all of society, or did it only consider a limited number of direct benefits to the grid and the utility?

The most basic way to value solar, and the most commonly presented by electric utilities, is to calculate the avoided costs that result from its expansion.[29] In other words, what costs do ratepayers and the utility avoid or defer as more solar energy is integrated into the grid? The avoided costs most commonly used in a solar cost-benefit analysis are: avoided energy costs, avoided capacity and capital investment, costs of market price fluctuation and avoided environmental compliance costs. The majority of the studies reviewed in this report included all or most of these avoided costs. (See Figure 1)

Equating avoided costs with the value of solar, however, does not capture all of the benefits that solar energy creates, such as reduced greenhouse gas emissions, improved public health, increased job creation and economic development, and the potential for increased resiliency of local electric grids with greater levels of distributed generation. Analyses that considered these additional benefits consistently calculated higher values of solar energy than reports that did not.

Table 1: A List of Studies Reviewed in this Report (by Date Published)

Author	Abbreviation Used in Graphs	Organization that Commissioned the Report	Geographic Area Covered	Date
Clean Power Research	CPR (NJ, PA)	Prepared for the Mid-Atlantic Solar Energy Industries Association and the Pennsylvania Solar Energy Industries Association	Examined four different fleet locations and seven different locations in New Jersey and Pennsylvania	Nov 2012
Clean Power Research and Solar San Antonio	CPR (San Antonio)	Written by Clean Power Research, a consulting and research group, and Solar San Antonio, a non-profit	CPS Energy service territory	Mar 2013
SAIC Energy, Environment and Infrastructure, LLC	SAIC	Arizona Public Service Company, an investor-owned utility	Arizona Public Service territory	May 2013
Xcel Energy, Inc.	Xcel	Written by Xcel Energy, a local utility	Xcel Energy service territory in Colorado	May 2013
Crossborder Energy	Crossborder Energy (2016 AZ)	Written by Crossborder Energy, a consulting group.	Arizona Public Service territory	May 2013
Clean Power Research	CPR (Austin)	Commissioned by Austin Energy, the incumbent investor-owned utility.	Austin Energy service territory (Texas)	Dec 2013
Clean Power Research	CPR (Utah)	Utah Clean Energy, a non-profit group.	Rocky Mountain Power service territory	Jan 2014
Clean Power Research and Xcel Energy	CPR/Xcel (Minnesota)	Calculated by Xcel Energy using methodology developed by Clean Power Research for the Minnesota Department of Commerce.	Xcel Energy service territory in Minnesota	Apr 2014
Synapse Energy Economics, Inc.	Synapse	Prepared for the Public Service Commission of Mississippi	State of Mississippi	Sep 2014
Vermont Department of Public Services	Vermont DPS	Written by the Vermont Department of Public Services, as directed by Act 99 of the 2014 Vermont legislative session.	State of Vermont	Nov 2014
CPR (Maine)	Maine PUC	Prepared for the Maine Public Utilities Commission	State of Maine	Mar 2015
Acadia Center	Acadia	Written by Acadia Center, a non-profit research and advocacy group	State of Massachusetts	Apr 2015
Crossborder Energy	Crossborder Energy (2016 AZ)	Written by Crossborder Energy, a consulting group.	Arizona Public Service territory	Feb 2016
SolarCity and the Natural Resource Defense Council	SolarCity/NRDC	Written by SolarCity and the Natural Resource Defense Council.	State of Nevada	May 2016
Energy and Environmental Economics, Inc.	E3	Written by Energy and Environmental Economics, Inc. and requested by the Nevada Legislative Committee on Energy. This was a follow up to a 2013 value of solar study was commissioned by the Nevada Public Utilities Commission.	State of Nevada	Aug 2016

Table 2: Categories of Benefits and Costs Included in Each Solar Energy Cost-Benefit Analysis.*

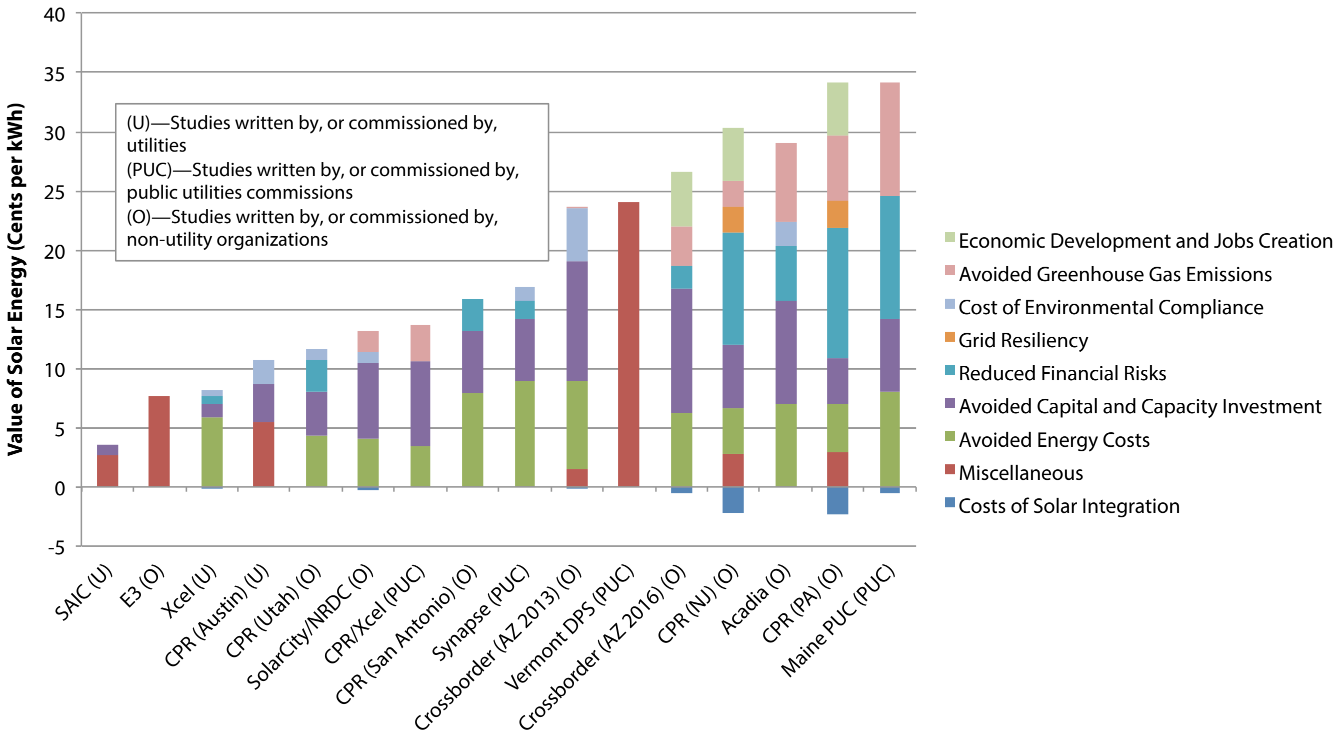
Author	Costs of Solar Integration	Avoided Energy Costs	Avoided Capital and Capacity Investment	Reduced Financial Risks	Grid Resiliency	Cost of Environmental Compliance	Avoided Greenhouse Gas Emissions	Economic Development	Total(cents per kWh)
SAIC		●	●			●			3.56
E3†		●	●			●	●		7.60
Xcel	●	●	●	●		●			8.04
CPR (Austin)		●	●	●		●			10.70
CPR (Utah)		●	●	●		●			11.60
SolarCity/NRDC	●	●	●			●	●		12.90
CPR/Xcel		●	●				●		13.64
CPR (San Antonio)		●	●	●					15.80
Synapse		●	●	●		●			16.90
Crossborder (AZ 2013)	●	●	●			●			23.50
Vermont DPS†		●	●	●		●			24.00
Crossborder (AZ 2016)	●	●	●	●			●	●	26.15
CPR (NJ)‡	●	●	●	●	●		●	●	28.10
Acadia		●	●	●		●	●		29.06
CPR (PA)	●	●	●	●	●		●	●	31.90
Maine PUC‡	●	●	●	●			●		33.60

*Colored cells represent categories that were included in the solar energy cost-benefit calculation.

† Reports do not list individual values for each of the values accounted for in avoided cost calculation.

‡ Reports include additional category "Long Term Societal Value," for details see Methodology.

Figure 1: A Comparison of Solar Energy Cost-Benefit Analyses by Report and Category.



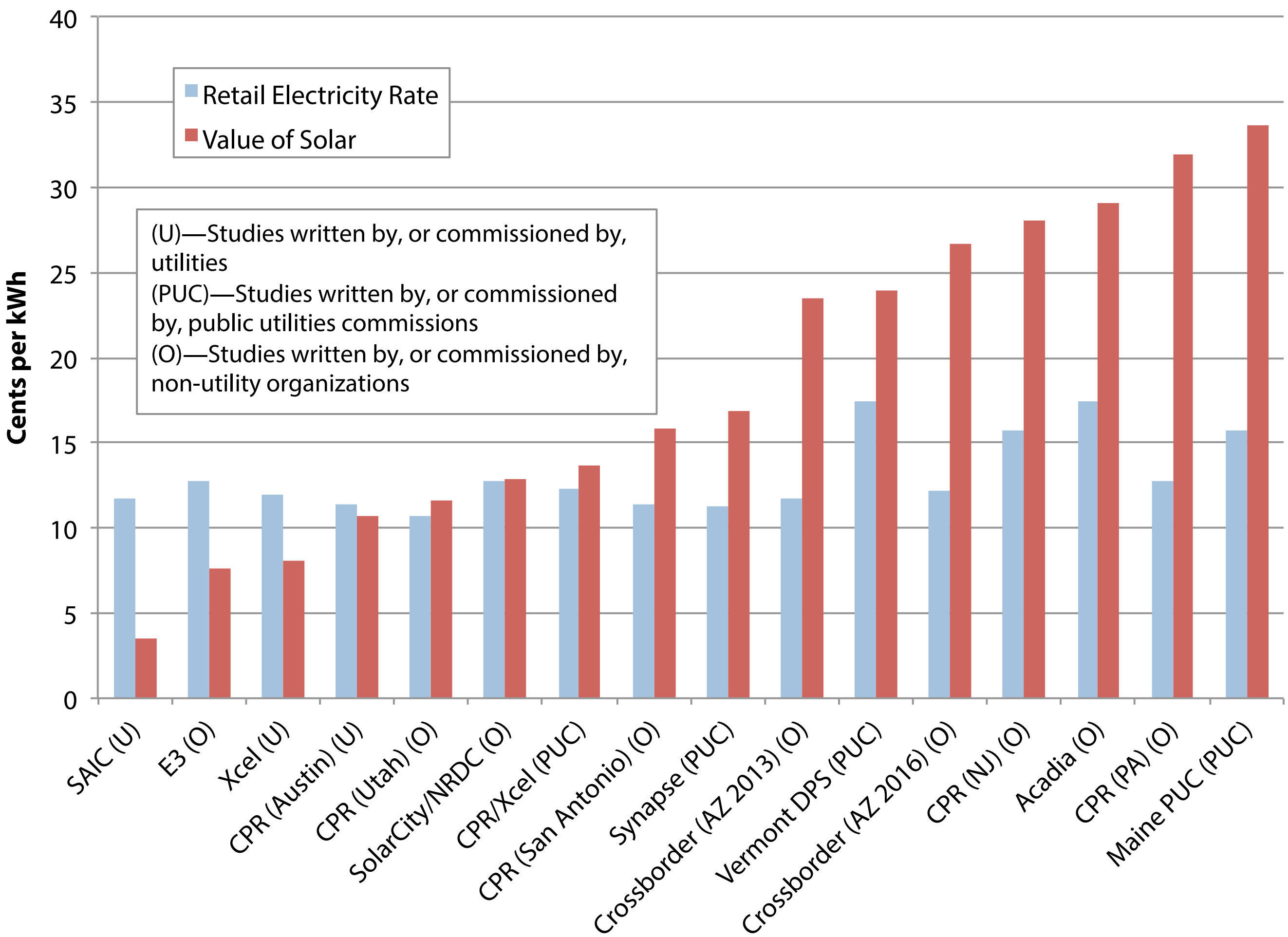
Value Provided by Solar Energy Usually Exceeds Benefits from Net Metering

Nearly all analyses that consider a full range of solar energy benefits find that the value provided by installing solar energy exceeds local retail electricity rates. In other words, far from being an overly generous subsidy, net metering often *under-compensates* solar energy system owners for the benefits they provide to all customers and to society. Of these 16 analyses, the median value of rooftop solar energy was 16.35 cents per kWh, while the average residential retail electricity rate in included states was approximately 13 cents per kWh.[30]

Non-Utility Analysts Value Solar Power at Higher Rates than Utilities

Studies of the value of solar conducted by utilities routinely arrive at estimates lower than those of studies conducted by public utilities commissions and other organizations. One reason for this is the tendency of utility-produced studies to exclude benefits of solar energy accruing to the environment and society by focusing only on costs and savings that affect the direct costs of operating the grid. Out of the 16 analyses reviewed in this report, those authored by non-utility groups consistently included valued environmental categories at a higher rate than utilities, while analyses conducted by public utilities commissions were inconsistent in this treatment. In fact, 12 of the 13 non-utility value-of-solar studies evaluated here found that solar energy delivered greater value than retail electricity rates, while none of the three studies commissioned by utilities came to that conclusion.

Figure 2: Average Retail Residential Electricity Rates Compared to the Values of Solar in 16 Cost-Benefit Analyses.[31]



Conclusion: A Clean Energy Future Depends on Full and Fair Compensation for Homes and Businesses that "Go Solar"

The benefits of increased solar energy capacity are clear: reduced greenhouse gas emissions, lower monthly electricity bills, and cleaner air, to name just a few. It is also clear that pro-solar policies, such as net metering, are critical to the success of solar energy.

Recently, however, net metering has come under attack. Utilities and fossil fuel interests, along with allied legislators and regulators, have sought to portray the program as an unfair subsidy to solar energy system owners.

Most analyses – especially those that consider the full range of benefits that solar energy delivers to the grid and to society – find that the value to all customers created by installing solar panels on a home or business generally exceeds the private benefits received through net metering by customers who invest in solar.

Net metering is a critical tool to ensure fair compensation for owners of solar energy systems and to continue to fuel the growth of solar energy. Public officials should support and strengthen net metering as sound public policy to stimulate private investment and job growth, and to encourage utilities to diversify and strengthen the grid. Specifically:

- States should lift arbitrary caps that limit availability of net metering in fast-growing solar markets.
- State or local governments that evaluate the benefits and costs of net metering should ensure that a full range of benefits is considered, including environmental and societal benefits. This isn't just good policy for solar energy – utility decision-making should fully account for the costs and benefits of all resource options.
- State and local governments should consider the simplicity of net metering when evaluating programs that compensate customers for the solar they provide to the grid.
- State and local governments should reject alternatives to net metering that do not provide residential and business customers full and fair compensation for the value they provide to the grid and society.
- State and local governments should ensure that all people can take advantage of net metering policies, even those who do not live in single-family homes, by implementing virtual net metering programs.

Local, state and federal governments should adopt other policies to encourage the growth of solar energy.

- State and local regulators should reject rate designs that incorporate high fixed charges or other rate design elements that shift costs to small users, including customers with solar installations.
- States should set aggressive goals for solar energy adoption, and implement policies that will encourage homeowners and businesses to meet them.
- States should remove other financial and regulatory hurdles to solar energy that slow down installation and discourage homes and businesses from investing in solar energy systems.
- The federal government should use its regulatory powers to promote solar energy, and should lead by example by rapidly adopting solar energy to meet its own energy needs.
- Local governments should ensure that every homeowner and business with access to sunlight can exercise the option of generating electricity from the sun, and should make "going solar" as easy as possible by removing unnecessary red tape, reducing fees, and speeding the permitting process.
- Local governments should set ambitious local clean energy goals, and should lead by example by installing solar energy systems on public buildings. They should also establish programs that help citizens and businesses get better access to solar power, such as solar co-ops or solarize programs.

Methodology

This report reviewed 16 analyses of the value of solar energy in states across the country. Each analysis is unique, using its own methodology and setting its own parameters. As such, in order to enable a fair comparison of the studies, we created a standard set of categories for the various benefits and costs of solar power addressed in the studies. A few analyses used categories that were not translatable into our categories, or for which individual costs were not available. In those cases, we created a "Miscellaneous" category, and the details of that can be found in the methodology of those analyses.

Details of how the benefits and costs of solar energy in each report were allocated are described below.

Acadia Center

Report Citation: Acadia Center, *Value of Distributed Generation: Solar PV in Massachusetts*, April 2015.

This study assessed the grid and societal value of six solar PV systems to better understand the overall value that solar PV provides to the grid. We used the 25-year levelized value of the system labelled "South Facing—Fixed, 35 Degrees." Other orientations of solar panels produce different estimates of value, ranging from 29.28 cents per kWh to 34.26 cents per kWh. The total value of solar found for this system is 29.06 cents per kWh.

A. **Avoided Energy Costs:** consists of the category "Avoided Energy Costs" (7.07 cents per kWh).

B. **Avoided Capacity and Capital Costs**: calculated by adding the category "Avoided Capacity Costs" (4.41 cents per kWh), the category "Avoided Transmission Costs" (2.43 cents per kWh) and the category "Avoided Distribution Costs" (1.81 cents per kWh). The total value for this category is 8.65 cents per kWh.

C. **Reduced Financial Risks and Electricity Prices**: calculated by adding the category "Demand Reduction Induced Price Effects-Energy" (3.66 cents per kWh) and the category "Demand Reduction Induced Price Effects-Capacity" (1.55 cents per kWh.) The total value for this category is 5.21 cents per kWh.

D. **Avoided Environmental Compliance Costs**: calculated by adding the category "Avoided CO_2 Compliance Costs" (2.04 cents per kWh) and the category "Avoided NO_x Compliance Costs" (0.0006 cents per kWh). The total value for this category is 2.0406 cents per kWh.

E. **Avoided Emissions Costs**: calculated by adding the category "Net Social Cost of CO_2" (3.11 cents per kWh), the category "Net Social Cost of SO_2" (2.86 cents per kWh) and the category "Net Social Cost of NO_x" (0.71 cents per kWh). The total value for this category is 6.68 cents per kWh.

CPR (Austin)

Report Citation: Thomas E. Hoff and Ben Norris, Clean Power Research, *2014 Value of Solar Executive Summary,* 12 December 2013.

This report is part of an annual update conducted by Austin Energy and Clean Power Research that calculates the value of solar in Austin Energy's territory and is used as input in decisions over the following year's

Value of Solar tariff. We used the Distributed PV Value for each category, which equals the "Economic Value (levelized $/kWh) times Load Match (%) (for capacity related components) times 1 plus Loss Savings (%)." As in the report, we then added each category together to arrive at a total value of solar of 10.7 cents per kWh.

A. **Avoided Energy Costs and Avoided Capital and Capacity Investment**: consists of the category "Guaranteed Fuel Value" (5.5 cents per kWh). In Figure 1 and Figure ES-2 this category is included under "Miscellaneous" because it includes both current *and* future avoided energy costs (which, in other cases, we put into the "Reduced Financial Risk and Electricity Prices" category).

B. **Avoided Capacity and Capital Costs:** calculated by adding the category "Plant O&M Value" (0.5 cents per kWh), the category "Generation Capacity Value" (1.7 cents per kWh), the category "Avoided Transmission Capacity Cost" (1.0 cents per kWh), and the category "Avoided Distribution Capacity Cost" (0.0 cents per kWh). The total value for this category is 3.2 cents per kWh.

C. **Avoided Environmental Compliance Cost:** consists of the category "Avoided Environmental Compliance Costs" (2.0 cents per kWh).

CPR (NJ and PA)

Report Citation: Richard Perez, Benjamin L. Norris and Thomas E. Hoff, Clean Power Research, *The Value of Distributed Solar Electric Generation to New Jersey and Pennsylvania,* November 2012.

This report analyzed the value of solar at seven different locations across New Jersey and Pennsylvania. The analyses represent the levelized value of PV for a "fleet" of PV systems. Four different fleet configurations were evaluated at each of the seven locations. We used the highest values from each state – Newark, New Jersey, and Scranton, Pennsylvania. Other orientations of solar panels produce different estimates of value, ranging from 25.6 cents per kWh to 31.5 cents per kWh.

Scranton, Pennsylvania:

A. **Cost of Solar Integration:** consists of the category "Solar Penetration Cost" (-2.3 cents per kWh).

B. **Avoided Energy Costs:** consists of the category "Fuel Cost Savings" (4.1 cents per kWh).

C. **Avoided Capacity and Capital Costs:** calculated by adding the category "O&M Cost Savings" (2.0 cents per kWh), the category "Generation Capacity Value" (1.7 cents per kWh), and the category "T&D Capacity Value" (0.1 cents per kWh). The total value for this category is 3.8 cents per kWh.

D. **Reduced Financial Risks and Electricity Prices:** calculated by adding the category "Fuel Price Hedge Value" (4.2 cents per kWh) and the category "Market Price Reduction Value" (6.9 cents per kWh). The total value for this category is 11.1 cents per kWh.

E. **Grid Resiliency:** consists of the category "Security Enhancement Value" (2.3 cents per kWh).

F. **Avoided Emissions Costs:** consists of the category "Environmental Value" (5.5 cents per kWh).

G. **Economic Development Value:** consists of the category "Economic Development Value" (4.5 cents per kWh).

H. **Miscellaneous:** this study contains a cost category "Long Term Societal Value" (2.9 cents per kWh), which the report defines as "potential value (defined by all other components) if the life of PV is 40 years instead of the assumed 30 years." In Figure 1 and ES-2 this category is included under the label "Miscellaneous."

Newark, New Jersey

A. **Cost of Solar Integration:** consists of the category "Solar Penetration Cost" (-2.2 cents per kWh).

B. **Not Specified:** consists of the category "Long Term Societal Value" (2.8 cents per kWh), which the report defines as "Potential value (defined by all other components) if the life of PV is 40 years instead of the assumed 30 years."

C. **Avoided Energy Costs:** consists of the category "Fuel Cost Savings" (3.9 cents per kWh).

D. **Avoided Capacity and Capital Costs:** calculated by adding the category "O&M Cost Savings" (1.9 cents per kWh), the category "Generation Capacity Value" (2.6 cents per kWh), and the category "T&D Capacity Value" (0.8 cents per kWh). The total value for this category is 5.3 cents per kWh.

E. **Reduced Financial Risks and Electricity Prices:** calculated by adding the category "Fuel Price Hedge Value" (4.4 cents per kWh) and the category "Market Price Reduction Value" (5.1 cents per kWh). The total value for this category is 9.5 cents per kWh.

F. **Grid Resiliency:** consists of the category "Security Enhancement Value" (2.2 cents per kWh).

G. **Avoided Greenhouse Gas Emissions**: consists of the category "Environmental Value" (2.2 cents per kWh).

H. **Economic Development Value:** consists of the category "Economic Development Value" (4.4 cents per kWh).

CPR (San Antonio)

Report Citation: Ben Norris, Clean Power Research, Nic Jones, Solar San Antonio, *The Value of Distributed Solar Electric Generation to San Antonio*, March 2013.

This report conducted analyses on four different solar PV systems, each facing a different direction and placed at different angles. We used the value from the analysis conducted on the system labelled "West-15."

A. **Avoided Energy Costs:** consists of the category "Fuel Cost Savings" (7.9 cents per kWh).

B. **Avoided Capacity and Capital Costs:** calculated by adding the category "O&M Cost Savings (2.7 cents per kWh), the category "Generation Capacity" (1.9 cents per kWh), the category "Transmission and Distribution Capacity" (0.4 cents per kWh), and the category "Reserve Capacity" (0.3 cents per kWh). The total value for this category is 5.3 cents per kWh.

C. **Reduced Financial Risks and Electricity Prices:** consists of the category "Fuel Price Hedge" (2.6 cents per kWh).

CPR (Utah)

Report Citation: Clean Power Research, *Value of Solar in Utah,* 7 January 2014.

We used the Distributed PV Value for each category from this report, which, according to the report, is the economic value modified using "Load Match" factors "to reflect the match between PV production profiles and utility loads." To arrive at the distributed PV value, the study then applied a "Loss Savings" factor "to reflect the distributed nature of the resource." The final value is 11.6 cents per kWh. This value is a levelized value representing all avoided costs over a 25-year assumed PV life.

A. **Avoided Energy Costs:** consists of the category "Fuel Value" (4.3 cents per kWh).

B. **Avoided Capacity and Capital Investment**: calculated by adding the category "Plant O&M Value" (1.3 cents per kWh), the category "Generation Capacity Value" (1.4 cents per kWh), and the category "Avoided T&D Capacity Cost" (1.1 cents per kWh). The total value for this category is 3.8 cents per kWh.

C. **Reduced Financial Risks and Electricity Prices**: consists of category "Fuel Price Guarantee" (2.6

cents per kWh).The total value for this category is 2.6 cents per kWh.

D. **Avoided Environmental Compliance Costs**: consists of category "Avoided Environmental Cost" (0.9 cents per kWh). The total value for this category is 0.9 cents per kWh.

Crossborder Energy (2013 AZ)

Report Citation: R. Thomas Beach and Patrick G. McGuire, Crossborder Energy, *The Benefits and Costs of Solar Distributed Generation for Arizona Public Service,* 8 May 2013.

The scope of this report is limited to assessing how demand-side solar will impact Arizona Public Service's ratepayers. The total value of solar found in this report is 23.5 cents per kWh.

A. **Costs of Solar Integration**: consists of the category "Integration Costs" (-0.2 cents per kWh).

B. **Avoided Energy Costs**: consists of the category "Energy" (7.5 cents per kWh).

C. **Avoided Capacity and Capital Costs:** calculated by adding the categories "Generation Capacity" (7.6 cents per kWh), "Transmission" (2.3 cents per kWh), "Distribution" (0.2 cents per kWh), and "Ancillary Services and Capacity Reserves" (1.5 cents per kWh). The total value for this category is 11.6 cents per kWh.

D. **Avoided Environmental Compliance Costs:** consists of the category "Avoided Renewables" (4.5 cents per kWh).

E. **Avoided Emissions Costs**: consists of the category "Environmental" (0.1 cents per kWh).

Crossborder Energy (2016 AZ)

Report Citation: R. Thomas Beach and Patrick G. McGuire, Crossborder Energy, *The Benefits and Costs of Solar Distributed Generation for Arizona Public Service (2016 Update),* 25 February 2016.

The scope of this report is limited to assessing how demand-side solar will impact Arizona Public Service's ratepayers. The total value of residential solar found in this report is 26.2 cents per kWh – the value of commercial solar was not included in this analysis.

A. **Costs of Solar Integration**: consists of the category "Integration Costs" (-0.2 cents per kWh).

B. **Avoided Energy Costs**: consists of the category "Energy" (6.2 cents per kWh).

C. **Avoided Capacity and Capital Costs:** calculated by adding the category "Capacity" (7.0 cents per kWh), the category "Transmission" (1.3 cents per kWh) and the category "Distribution" (2.4 cents per kWh). Values were averaged between South and West-facing orientations. The total value for this category is 10.6 cents per kWh.

D. **Avoided Emissions Costs**: consists of the category "Carbon" valued at 3.3 cents per kWh.

E. **Economic Development and Jobs Creation**: consists of the category "Local economic benefit." (4.7 cents per kWh.)

Maine PUC

Report Citation: Benjamin L. Norris, et al., *Maine Distributed Solar Valuation Study*, 1 March 2015.

This report calculated a 25-year Levelized Distributed PV Value for the Central Maine Power service territory. The total value of solar found in this report is 33.7 cents per kWh.

A. **Costs of Solar Integration**: consists of the category "Solar Integration Costs" (-0.5 cents per kWh).

B. **Avoided Energy Costs**: consists of the category "Avoided Energy Cost" (8.1 cents per kWh).

C. **Avoided Capital and Capacity Costs**: calculated by adding the category "Avoided Generation Capacity Costs" (4.0 cents per kWh), the category "Avoided Reserve Capacity Costs" (0.5 cents per kWh), and the category "Avoided Transmission Capacity Costs" (1.6 cents per kWh). The total value for this category is 6.1 cents per kWh.

D. **Reduced Financial Risks and Electricity Prices:** calculated by adding the category "Market Price Response" (6.6 cents per kWh) and the category "Avoided Fuel Price Uncertainty" (3.7 cents per kWh). The total value for this category is 10.3 cents per kWh.

E. **Avoided Emissions Costs**: calculated by adding the category "Net Social Cost of Carbon" (2.1 cents per kWh), the category "Net Social Cost of SO_2" (6.2 cents per kWh) and the category "Net Social Cost of NO_x" (1.3 cents per kWh). The total value for this category is 9.6 cents per kWh.

SAIC

Report Citation: SAIC Energy, Environment and Infrastructure, LLC, *2013 Updated Solar PV Value Report*, 10 May 2013.

We used the "present value" from this analysis. The present value, as calculated by the report, "is the 2025 nominal value using the APS discount rate of 7.21 percent." This report calculated the overall value using different categories than many other reports did, and aggregated many values that are separate in other reports. As a result, the review of this report has a category called "Miscellaneous" that makes up a large percentage of the overall value and includes many of the categories that were calculated separately in other reports. The total value of solar found in this report is 3.56 cents per kWh.

A. **Miscellaneous**: calculated by adding category "Fixed O&M, Gas Transportation" (0.13 cents per kWh) and category "Fuel, Variable O&M, Emissions, Purchased Power" (2.57 cents per kWh). The total value for this category is 2.7 cents per kWh.

B. **Avoided Capital and Capacity Costs:** calculated by adding the category "Generation" (0.72 cents per kWh), the category "Distribution" (0.0 cents per kWh) and the category "Transmission" (0.14 cents per kWh). The total value for this category is 0.86 cents per kWh.

Synapse

Report Citation: Elizabeth A. Stanton, et al., Synapse Energy Economics, Inc., *Net Metering in Mississippi*

Costs, Benefits, and Policy Considerations, 19 September 2014.

We used the "Levelized Avoided Cost Value," which levelized the value of solar over a 25-year period.

A. **Reduced Financial Risks:** consists of the category "Avoided Risk" (1.5 cents per kWh).

B. **Avoided Energy Costs**: calculated by adding the category "Avoided Energy Costs"(8.1 cents per kWh) and the category "Avoided System Losses" (0.9 cents per kWh). The total value of this category is 9.0 cents per kWh.

C. **Avoided Capital and Capacity Costs:** calculated by adding the category "Avoided Capacity Costs" (1.2 cents per kWh) and the category "Avoided Transmission and Distribution Costs" (4.0 cents per kWh). The total value for this category is 5.2 cents per kWh.

D. **Environmental compliance Costs:** consists of the category "Avoided Environmental Compliance Costs" (1.2 cents per kWh).

Xcel Energy

Report Citation: Xcel Energy, Inc., *Costs and Benefits of Distributed Solar Generation on the Public Service Company of Colorado System,* 23 May 2013.

This study examined the first 59 MW of distributed solar generation ("DSG") installed on the Public Service of Colorado system as of 30 September 2012, in addition to a projection of an additional 81 MW of DSG being installed by 31 December 2014, for a total of 140 MW. We used the levelized net avoided cost value calculated under the "Base Gas" scenario. The total value of solar found in this report is 8.04 cents per kWh.

A. **Avoided Energy Costs**: calculated by adding the category "Avoided Energy Costs" (5.21 cents per kWh) and the category "Avoided Line Losses" (0.62 cents per kWh). The total value for this category is 5.83 cents per kWh.

B. **Avoided Capacity and Capital Costs**: calculated by adding the category "Avoided Capacity & 7FOM (fixed operation and management) costs" (1.15 cents per kWh), the category "Avoided Distribution Upgrades" (0.05 cents per kWh), and the category "Avoided Transmission Upgrades" (0.02 cents per kWh). The total value for this category is 1.22 cents per kWh.

C. **Reduced Financial Risks and Electricity Prices**: consists of the category "Fuel Hedge Value" (0.66 cents per kWh).

D. **Avoided Environmental Compliance Costs**: consists of the category "Avoided Emissions Cost" (0.51 cents per kWh).

SolarCity and NRDC

Report Citation: SolarCity and NRDC, *Distributed Energy Resources in Nevada,* May 2016.

This study conducted a cost-benefit analysis of distributed energy that will be installed in Nevada during 2017-2019, using the *Nevada Net Energy Metering Public Tool* developed by Energy + Environmental Economics in July 2014.

A. **Costs of Solar Integration:** calculated by adding the categories "Program Costs" (0.1 cents per kWh) and "Integration Costs" (0.2 cents per kWh). The total value for this category is 0.3 cents per kWh.

B. **Avoided Energy Costs**: calculated by adding the category "Avoided Energy Costs" (3.7 cents per kWh) and the category "Line Losses" (0.4 cents per kWh). The total value for this category is 4.1 cents per kWh.

C. **Avoided Capacity and Capital Costs**: calculated by adding the categories "Generation Capacity" (2.6 cents per kWh), "Ancillary Services" (0.1 cents per kWh), "Transmission & Distribution Capacity" (2.8 cents per kWh) and "Voltage Support" (0.9 cents per kWh). The total value for this category is 6.4 cents per kWh.

D. **Avoided Environmental Compliance Costs**: consists of the category "CO2 Regulatory Price" (0.9 cents per kWh).

E. **Avoided Greenhouse Gas Emissions:** consists of the categories "Criteria Pollutants" (0.1 cents per kWh) and "Environmental Externalities" (1.7 cents per kWh). The total value for this category is 1.8 cents per kWh.

E3

Report Citation: Snuller Price et al., Energy and Environmental Economics, Inc., *Nevada Net Energy Metering Impacts Evaluation 2016 Update*, August 2016.

This study calculated the costs and benefits of renewable generation systems under Nevada's net metering law. The study calculated the avoided cost to be 7.7 cents per kWh. E3 accounts for the following components in its avoided cost calculation: distribution capacity, transmission capacity, system capacity, ancillary services, criteria pollutants, line losses, and carbon energy. The report does not provide costs for each component in its avoided cost calculation, therefore these costs are included under the label "Miscellaneous" in Figure 1 and Figure ES-2. The report does not include integration costs or RPS compliance value in its utility avoided costs calculation, although those values are accounted for in cost-benefit calculations elsewhere in the report.

Vermont DPS

Report Citation: Vermont Department of Public Service, *Evaluation of Net Metering in Vermont Conducted Pursuant to Act 99 of 2014 (revised)*, 7 November 2014.

This study conducted an evaluation of net metering and the value of solar in Vermont as directed by Act 99 of the 2014 Vermont legislative session. Data for the benefit of solar was taken from section *3.3.2.1 - 4 kW fixed solar PV system, net metered by a single residence*, which calculated the benefit of solar for such a system at 23.7 cents per kWh for ratepayers (the study provides a higher benefit provided to society as a whole). The study includes the following components in its avoided utility cost analysis: avoided energy, avoided capacity, avoided regional transmission, avoided transmission and distribution infrastructure, market price suppression, and potential future regulatory value. The report does not provide costs for each component in its avoided cost calculation, therefore these costs are included under the label "Miscellaneous" in Figure 1 and Figure ES-2.

Clean Power Research / Xcel Energy

Report Citation: Xcel Energy, submission to Minnesota PUC at Docket No. E002/M-13-867, *VOS Calculation Compliance*, 2 March 2015.

This value of solar estimate was calculated by Xcel Energy using a methodology created by Clean Power Research for Minnesota's Department of Commerce. The study calculated the value of solar as 13.6 cents per kWh in Xcel territory.

1. **Avoided Energy Costs:** 3.5 cents per kWh, from category "Avoided Fuel Costs."
2. **Avoided Capital and Capacity Investment:** 7.1 cents per kWh, from categories "Avoided Plan O&M – Fixed," "Avoided Plan O&M – Variable," "Avoided Gen Capacity Cost Avoided Reserve Capacity Cost Avoided Trans Capacity Cost" and "Avoided Distribution Capacity Cost."
3. **Avoided Greenhouse Gas Emissions:** 3.04 cents per kWh, from category "Avoided Environmental Cost."

Notes

1 Distributed solar generation data: EIA, *Electricity Data Browser*, accessed at eia.gov/electricity/data/browser/ on 14 September 2016; pollution calculation: EPA, *Greenhouse Gas Equivalencies Calculator*, accessed at epa.gov/energy/greenhouse-gas-equivalencies-calculator on 14 September 2016.

2 The Solar Foundation, *National Solar Jobs Census 2015,* January 2016.

3 SEIA, *U.S. Solar Market Insight Q3 2016 press release*, archived at http://web.archive.org/web/20160915043842/http://www.seia.org/research-resources/us-solar-market-insight.

4 This includes potential solar power generation from rooftop solar panels, large utility-scale solar installations, and concentrating solar power plants. Judee Burr and Lindsey Hallock, Frontier Group, Rob Sargent, Environment America Research & Policy Center, *Star Power: The Growing Role of Solar Energy in America*, November 2014.

5 National Renewable Energy Laboratory, *Photovoltaic System Pricing Trends: Historical, Recent, and Near-Term Projections, 2014 Edition*, 22 September 2014.

6 States with mandatory net metering rules: DSIRE NC Clean Energy Technology Center, *Net Metering policy map*, available at dsireusa.org/resources/detailed-summary-maps, July 2016.

7 In mid-2015, Nevada and Hawaii eliminated traditional net metering for newly installed solar energy systems. Top ten states for per capita solar capacity: Gideon Weissman, Frontier Group, Bret Fanshaw and Rob Sargent, Environment America Research & Policy Center, *Lighting the Way 4: The Top States that Helped Drive America's Solar Energy Boom in 2015,* July 2016.

8 The Public Utilities Regulatory Policies Act of 1978 (PURPA), which can be found at 18 CFR §292.303.

9 Line losses: EIA, *United States Electricity Profile 2014: Table 10. Supply and disposition of electricity*, 24 March 2016; average 2014 retail price of electricity was 10.44 cents per kWh: EIA, *Electric Power Monthly with Data for June 2016: Table 5.3. Average Price of Electricity to Ultimate Customers*, August 2016.

10 Lazar, J. and Baldwin, X., *Valuing the Contribution of Energy Efficiency to Avoided Marginal Line Losses and Reserve Requirements*, Regulatory Assistance Project, 2011.

11 Union of Concerned Scientists, *The Natural Gas Gamble: A Risky Bet on America's Clean Energy Future,* March 2015.

12 Thomas Jenkin et al, National Renewable Energy Laboratory, Ray Byrne, Sandia National Laboratories, *The Use of Solar and Wind as a Physical Hedge against Price Variability within a Generation Portfolio*, August 2013.

13 Paul Chernick, Resource Insight, Inc., John J. Plunkett, Green Energy Economics Group Inc., *Price Effects as a Benefit of Energy-Efficiency Programs*, 2014.

14 JR Minkel, "The 2003 Northeast Blackout–Five Years Later," *Scientific American,* 13 August 2008.

15 Herman K. Trabish, "Smart Inverters: The Secret to Integrating Distributed Energy onto the Grid?" *Utility Dive*, 4 June 2014.

16 Number of states with renewable portfolio standards: DSIRE, *Renewable Portfolio Standard Policies,* accessed at ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2014/11/Renewable-Portfolio-Standards.pdf, 1 June 2015.

17 EPA, *Sources of Greenhouse Gas Emissions*, archived at web.archive.org/web/20160915201031/https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions.

18 Gunnar Myhre et al., "Anthropogenic and Natural Radiative Forcing," in T.F. Stocker et al. (eds.), Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, 2013), 714.

19 Peter Howard, Environmental Defense Fund, Institute for Policy Integrity and the Natural Resources Defense Council, *Omitted Damages: What's Missing from the Social Cost of Carbon,* 13 March 2014.

20 Tons of carbon dioxide pollution multiplied by $37. Electric power carbon dioxide emissions: U.S. Energy Information Administration, *What Are U.S. Energy-related Carbon Dioxide Emissions by Source and Sector?,* accessed at: https://www.eia.gov/tools/faqs/faq.cfm?id=75&t=11, 15 September 2016.

21 SEIA, *Siting & Permitting*, archived at web.archive.org/web/20160916220218/http://www.seia.org/policy/power-plant-development/siting-permitting.

22 U.S. Environmental Protection Agency, *Air Pollutants,* accessed at: www.epa.gov/air/airpollutants.html, 1 June 2015.

23 American Lung Association, *State of the Air 2015,* 2015.

24 Ibid.

25 Union of Concerned Scientists, *Environmental Impacts of Coal Power: Air Pollution*, accessed at www.ucsusa.org/clean_energy/coalvswind/c02c.html#.VW5vus9Viko, 2 June 2015.

26 See note 2.

27 Ibid.

28 The Solar Foundation, *An Assessment of the Economic, Revenue, and Societal Impacts of Colorado's Solar Industry,* October 2013.

29 This methodology is the most common because many utility-commissioned reports only seek to calculate the costs of benefits of solar energy to the utility or to the non-participating ratepayer, and often only in the short-run of ten years or less.

30 Electricity rates are from the year the study was conducted in. For studies conducted in 2016, retail rates were used from 2015, the latest year rate information was available. Retail rates of electricity downloaded from: U.S. Energy Information Administration, *Electricity Data Browser,* accessed at www.eia.gov/electricity/data/browser, 14 September 2016. Several of the studies calculated values on a levelized basis, which makes comparing the value to a retail electricity rate from a single year problematic. This is, however, a way to show the comparison between current rates under net metering in most places, and the true value of solar.

31 Ibid.