The True Value of Solar

Measuring the Benefits of Rooftop Solar Power

Environment Illinois Research & Education Center

Frontier Group

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Written by:

Gideon Weissman
Frontier Group

Emma Searson and Rob Sargent
Environment America Research and Policy Center

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Executive Summary

Distributed solar energy is on the rise, generating enough electricity to power more than 6 million homes each year, and resulting in annual carbon dioxide emission reductions equivalent to taking 4.4 million passenger vehicles off the road.[1] Public policy has been a key factor in driving the growth of solar energy – recognizing the enormous benefits that solar power can provide both today and in the future.

To help develop smart public policy around solar energy, many public utilities commissions, utilities and other organizations have conducted or sponsored "value-of-solar" studies that attempt to quantify the monetary value of the benefits delivered, and costs imposed, by the addition of solar energy to the electric grid. Studies that include a full range of solar energy's benefits – including benefits to the environment and society – reliably conclude that the value of

Figure ES-1. The Benefits of Rooftop Solar Energy[2]

Benefit Category		Benefit
Grid	Energy	Avoided electricity generation
		Reduced line losses
		Market price response
	Capacity and Grid Investments	Avoided capacity investment
		Avoided transmission and distribution investment
		Reduced need for grid support services
	Risk and Reliability Benefits	Reduced exposure to price volatility
		Improved grid resiliency and reliability
	Compliance	Reduced environmental compliance costs
Societal	Environment	Avoided greenhouse gas emissions
		Avoided air pollution
		Health benefits
		Avoided fossil fuel lifecycle costs
	Economy	Local jobs and businesses

those benefits approximates or exceeds the compensation solar panel owners receive through policies such as net metering.

Many value-of-solar studies, however – especially those conducted by electric utilities – have left out key benefits of solar energy. Policymakers and members of the public who consult these studies may be left with a false impression of solar energy's value to the grid and society, with damaging results for public policy.

To make decisions that serve the public interest, policymakers should account for the full value of solar energy, including societal benefits to the environment and public health.

Rooftop solar energy brings a wide variety of benefits to the grid and to society.

- Rooftop solar power generally adds value to the electric grid. It not only reduces the need for generation from and investment in central power plants, but over the long lifetime of solar energy systems it also can increase price stability and grid reliability, and reduce environmental compliance costs.
- As a clean, emission-free energy source often located on private property and built with considerable private, non-ratepayer investment, rooftop solar brings valuable societal benefits. Solar energy reduces global warming pollution, and also reduces emissions of dangerous air pollutants such as nitrogen oxides, mercury and particulate matter.

Value-of-solar studies inconsistently account for solar energy's benefits, especially beyond the electric grid, resulting in dramatically different conclusions.

- Studies that include the benefits of solar energy beyond the grid generally find that its value exceeds the retail rate of electricity. Recent studies from states including Maine, Pennsylvania and Arkansas have found that solar energy brings substantial environmental benefits, and that rooftop solar owners would provide a net benefit to society even with net metering compensation.[3]
- Studies commissioned by electric utilities generally fail to account for benefits beyond the grid, resulting in far lower values of solar. A 2016 report published by Environment America Research and Policy Center and Frontier Group reviewed value-of-solar studies and found that, of 16 studies reviewed, only eight accounted for avoided greenhouse gas emissions, and no studies commissioned by utilities accounted for the value of solar energy beyond the grid. The studies that left out societal benefits valued solar, on average, at 14.3 cents per kilowatt-hour, compared to 22.9 cents for those studies that at least accounted for greenhouse gas emissions.

Value-of-solar studies should account for all of solar energy's benefits to the grid and society.

- Policymakers must account for the societal value of reduced power plant emissions, in particular the value of avoided greenhouse gas emissions and pollutants that contribute to the formation of smog and soot.
- Policymakers should also seek to account for broader societal impacts of solar energy, including "upstream" impacts of fossil fuel production and use, such as methane emissions from fracking, and local economic development impacts.

Public policy that fails to account for the full range of benefits may deter the addition of solar power to the grid, with ramifications for the environment, public health, and the operation of the electric grid.

Introduction

The electricity system that powers our homes, businesses and factories imposes heavy costs on our environment and our health. These costs accrue in a variety of ways. Particulate matter from burning coal harms our bodies, increases mortality rates and strains the health care system.[4] Fracking and coal mining degrade the environment, threaten water quality, and require expensive environmental rehabilitation.[5] Each new ton of global warming pollution – whether carbon dioxide from power plants, or methane leaked from natural gas wells – adds to the burden we and future generations will face from extreme weather, rising seas, and economic and societal disruption.[6]

Most of these costs are quantifiable, and all are vast. For instance, one U.S. Environmental Protection Agency study found that the impact of fossil fuel electricity generation on premature mortality, lost work days, and health care costs add up to hundreds of billions of dollars each year.[7] Per unit of energy, these health costs alone often exceed the price we pay on our electric bill.[8]

Policymakers have a variety of tools at their disposal to minimize the societal costs of electricity generation and minimize harm to our health and environment. But while many states aspire to least-cost utility planning, and some even incorporate the social cost of carbon into certain planning decisions, no state fully accounts for the external costs of electricity in pricing or investment decisions.[9]

In the 20th century, the vast majority of electricity was generated from fossil fuels at large, centralized power plants. Today, the availability of clean, affordable renewable energy, coupled with the potential to generate power close to where it is used, forces a rethinking of traditional ways of setting utility rates and comparing the value of various options for generating electricity. The ways in which we choose to assign value to various options for generating electricity will help to shape the electricity system of the future. It is critical that we get it right.

As the following pages show, one important step policymakers can take is to begin accurately assessing the costs and benefits of one of our most promising clean energy resources: rooftop solar energy. By doing so, they can adhere to sound policymaking principles, while putting the U.S. on a path to a cleaner, healthier and more prosperous future.

The Value of Solar Power Has Important Implications for Renewable Energy Adoption

What is the value of solar energy?

In recent years, as distributed solar energy has grown into an important piece of the American electricity system – now generating enough electricity to power more than 6 million homes each year –policymakers, utilities, solar energy trade organizations and other energy policy experts have grappled with the question.[10] Their attempts to calculate the cents per kilowatt-hour value of solar energy have had important ramifications – "value of solar" studies have been used as evidence for energy policymaking that affects the speed and quantity of solar energy adoption, which in turn affects the environment, public health, and the economy.

Authors of value-of-solar studies typically must contend with a variety of complex questions, but the most important question is really the simplest: What is the universe of benefits that will be included and quantified in the analysis? Their answer can determine whether policymakers ultimately view solar energy as bringing a net benefit to society, with consequences for energy rates and the compensation rooftop solar owners receive for excess energy they feed to the grid.

The difference can be dramatic. For example, a 2013 study by the Vermont Public Service Department found that the costs and benefits of solar energy were approximately equal when environmental benefits were ignored. When greenhouse gas emissions were accounted for, however, each kilowatt-hour of solar energy generated brought a societal benefit of 4.3 cents.[11]

The value attributed to solar energy – and how that value is integrated into ratemaking and investment decisions – has important implications for renewable energy adoption. Any homeowner or business owner considering installing solar panels needs to compare the upfront cost of the investment with the likely utility bill savings over time – including both avoided electricity purchases and any compensation paid by the utility for the excess solar power supplied to the grid. Differences in the valuation of those extra kilowatt-hours supplied to the grid can make or break a distributed solar power project from a financial perspective. This is reflected by the success of net metering policies, which value solar energy at the retail rate of electricity, in driving adoption of rooftop solar power. Of the 10 states that generated the most small-scale solar energy per capita in 2017, all but two had a state net metering policy.[12]

Solar Power Delivers Important Environmental and Public Health Benefits

Not all energy is created equal. Some energy – like electricity generated by burning coal – imposes enormous costs on the public and the environment, including air pollution, environmental degradation and adverse health impacts. Energy sources such as wind and solar power impose fewer environmental costs than fossil fuel sources, and can even reduce the cost of operating the grid.

The benefits of distributed solar power can be divided into two categories: benefits to the grid (which benefit utility ratepayers in their capacity as consumers) and benefits to the environment and society (which benefit ratepayers and others in their capacity as residents and taxpayers). The following describes many of those benefits in detail.

Figure 1. The Benefits of Rooftop Solar Energy[13]

Benefit Category		Benefit
Grid	Energy	Avoided electricity generation
		Reduced line losses
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		Avoided air pollution
		Health benefits
		Avoided fossil fuel lifecycle costs
	Economy	Local jobs and businesses

Grid Benefits

Energy generated using solar panels on rooftops of homes and businesses benefits the electric grid. Not only do solar panels reduce the need for electricity from central power plants, but the integration of distributed clean energy resources can also help create a more modern, resilient and efficient grid.

Energy

Avoided electricity costs: Solar energy sent to the grid reduces the amount of electricity that utilities must generate or purchase from 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: Distributed solar energy also reduces the amount of electricity lost as heat as it travels from large, centralized power plants to our sockets. The U.S. Energy Information Administration estimated that the United States lost about $21 billion worth of electricity in 2017, or 5 percent of the total amount of electricity generated that year.[14] These losses cause us to generate more electricity than we need, increasing costs for ratepayers.

Rooftop 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, with losses as high as 30 percent during the high-load hours when most solar output is delivered.[15]

Market price response: Distributed solar energy also reduces the price of electricity by reducing overall demand on the grid, which can suppress wholesale electricity prices.[16] In other words, 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.[17] These demand reduction-induced price effects can represent an important value to ratepayers.

Capacity and grid investments

Avoided capacity, transmission and distribution 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 often highest during the day when the sun is shining. By reducing overall and peak demand, expanding solar energy production helps ratepayers and utilities avoid the cost of investing in new power plants, transmission and distribution lines, and other forms of electricity infrastructure.

Reduced need for ancillary services: Solar energy may also reduce certain costs of keeping the grid running smoothly, including regulating voltage and reducing the need to keep backup power plants running ("spinning reserves"). Solar energy systems installed with "smart inverters" and other technologies that increase two-way communication with the grid, for example, have the potential to improve grid operation and reduce the need for centralized grid support services.[18] Without such equipment, solar energy may increase certain grid support costs.

Risk and Reliability Benefits

Reduced exposure to price volatility: Fossil fuel price volatility 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.[19] 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. Research has shown that the risk of fuel price volatility is primarily borne by ratepayers, rather than utility shareholders.[20] Some utilities also engage in fuel price hedging strategies to ensure that a portion of electricity costs are stable. Solar energy can help ensure price stability, a contribution with financial value for utilities and grid users.[21]

Improved grid resiliency and reliability: Solar panels create a more diverse and geographically dispersed energy portfolio, and generate energy close to the point of consumption. These attributes may help reduce congestion in transmission and distribution systems, and create a more reliable grid less prone to central disruptions, power outages or rolling blackouts.[22]

Compliance

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. Increasing distributed 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 energy also reduces the costs of compliance with regulations on criteria pollutants like sulfur dioxide and nitrogen oxides, as well as greenhouse gas reduction programs such as the Regional Greenhouse Gas Initiative in the northeastern U.S., California's cap-and-trade program for greenhouse gas emissions, and any future programs that may be adopted at the state or federal levels.

Societal Benefits

Solar panels provide valuable benefits to society beyond what is addressed by current electricity rates. Namely, solar energy reduces the need for the extraction, transportation and combustion of fossil fuels, which impose heavy costs on the environment and public health.

Environment

Avoided greenhouse gas emissions: In 2017, the electricity sector was responsible for 28 percent of all U.S. greenhouse gas pollution.[23] The generation of electricity with both coal and natural gas has a substantial climate impact. Although natural gas is less carbon intensive than coal at the point of combustion, the process of natural gas extraction and transportation results in vast emissions 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.[24]

Research suggests that every metric ton of carbon dioxide released into the air causes $37 of economic and social damage.[25] In 2017, the United States electric power sector emitted more than 1.7 billion metric tons of carbon dioxide emissions, equivalent to more than $64 billion in economic and social damages.[26] Solar energy, on the other hand, is renewable and emission-free, and avoids the costs of both future damage and future environmental compliance.

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.[27] Distributed solar energy can also be installed in a wide variety of urban settings, including on rooftops and parking lot canopies, making it well-suited for densely populated and energy-intensive regions.

Health benefits and avoided air pollution: Solar energy reduces emissions of dangerous air pollutants such as nitrogen oxides, mercury and particulate matter that harm public health.[28] Solar energy production can reduce emissions beyond the level required by environmental regulations, or address environmental and public health threats that are inadequately regulated, providing value such as reduced illness and mortality.

According to a 2018 report by the American Lung Association, 41 percent of Americans live in a county where air pollution often reaches dangerous levels.[29] 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.[30] 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.[31]

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.

Avoided fossil fuel lifecycle costs: Use of solar energy reduces the need for fossil fuels, which impose a steep cost on society not just at the point of combustion, but also during extraction and transportation.[32] Natural gas drilling uses vast water resources, and risks chemical contamination of drinking water. Coal mining puts coal-worker health at risk, and has caused environmental devastation including the loss of thousands of miles of streams.[33] Burning coal generates millions of tons of coal ash that are often stored on site at power plants, threatening groundwater and occasionally resulting in catastrophic spills. And thermoelectric power plants – coal, natural gas and nuclear – require water for cooling, and can have adverse effects on water resources and ecosystems.[34]

Economy

Local jobs and businesses: The solar energy industry has created thousands of new jobs and businesses across the nation. As of November 2017, the solar energy industry employed more than 250,000 people, a 168 percent increase from 2010.[35] The Bureau of Labor Statistics projects that solar installation jobs will be the nation's fastest growing occupation in terms of total employment through 2026.[36] There are more than 10,000 solar companies in the U.S., and in 2017 the solar industry generated $17 billion of investment in the U.S. economy.[37] Because rooftop solar installations take place in our communities, they generate local spending and opportunities for local businesses, and serve as visible reminders of the local economic benefits of clean energy.

Value-of-Solar Studies Should Account for All of Solar Energy's Societal Benefits

Good policymaking requires accurate information, and accurately valuing energy resources is a critical part of setting good energy policy. In Karl R. Rábago and Radina Valova's 2018 *Electricity Journal* article attempting to determine new principles for modern rate design, the authors contend that policymakers must work to "fully comprehend and reflect resource value in rates" through "conscious engagement with objective, data-driven valuation processes."[38] For policymakers to fully comprehend the value of solar, they must understand solar energy's full range of costs and benefits, including environmental, public health, and other societal impacts – and incorporate them appropriately into rate-setting and investment decisions.

Many states already incorporate solar energy's societal and environmental benefits in value-of-solar studies. In Maine, for example, the state Legislature required the public utilities commission to "determine the value of distributed solar energy generation" and in doing so to account for "the societal value of the reduced environmental impacts of the energy."[39]

The Interstate Renewable Energy Council, which works to provide energy regulators with best practices and other policy resources, has written that the "societal benefits of [distributed solar generation] policies, such as job growth, health benefits and environmental benefits, should be included in valuations, as these were typically among the reasons for policy enactment in the first place."[40]

Often, however, utilities present assessments of the value of solar that exclude key benefits to society, the environment, or the grid. In 2016, Environment America and Frontier Group published *Shining Rewards*, which assessed recent value-of-solar studies, mostly either commissioned by public utility commissions or submitted as evidence in ratemaking cases. Of 16 studies published, only eight accounted for avoided greenhouse gas emissions, and only three accounted for economic development benefits. No studies commissioned by utilities accounted for the value of solar energy beyond the grid.

The societal benefits of [distributed solar generation] policies, such as job growth, health benefits and environmental benefits, should be included in valuations, as these were typically among the reasons for policy enactment in the first place."

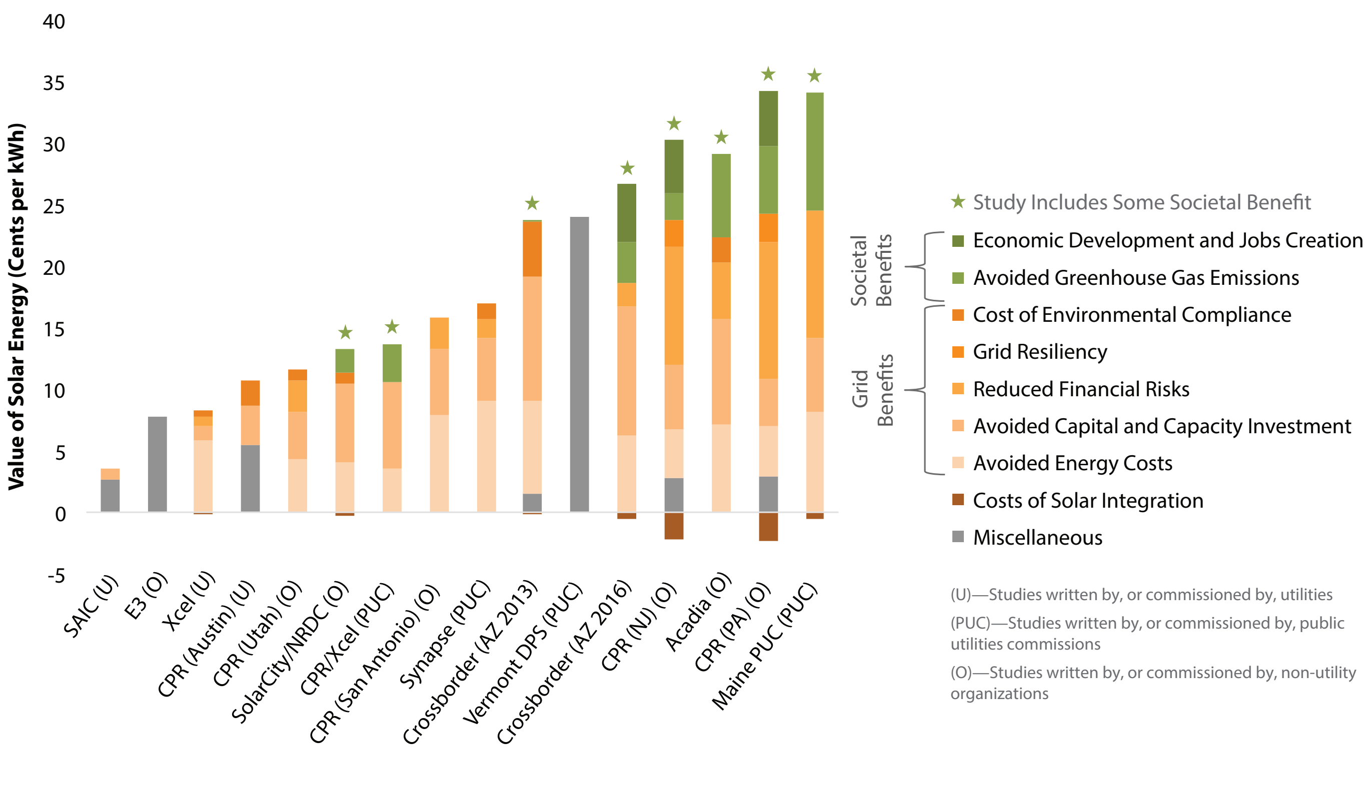
- Interstate Renewable Energy Council

Those studies that left out societal benefits valued solar power, on average, at 14.3 cents per kilowatt-hour, compared to 22.9 cents for those studies that at least included greenhouse gas emissions.[41] The difference is even starker when studies include public health, economic or other societal values.

More recent value-of-solar studies from 2017 and 2018 have also left out the societal value of solar energy. South Carolina utilities, using a state-determined methodology, reported that solar generation had zero value for avoided CO_2 emissions, since they only assessed avoided compliance costs.[43] Oregon utilities, also using a state-determined methodology, based avoided emission values on "anticipated environmental standards" – the estimated avoided cost of compliance with future greenhouse gas standards – and therefore did not include the full societal benefits of avoided emissions.[44]

Meanwhile, at least two recent utility value-of-solar studies have accounted for the societal value of solar energy. A value-of-solar study conducted by Austin Energy, a publicly owned utility that compensates rooftop solar owners based on its calculated value of solar, accounts for the avoided carbon dioxide emissions using the social cost of carbon (as estimated by the U.S. EPA).[45] And in Minnesota, Xcel Energy's 2019 value-of-solar tariff calculation includes avoided environmental costs that are based on the social cost of carbon, and externality costs for non-CO_2 emissions developed by the Minnesota Public Utility Commission.[46] Xcel Energy's calculation was made using a required, state-commissioned methodology.[47]

In both studies, despite only including a subset of societal benefits, those benefits were found to be significant: Environmental benefits accounted for more than 17 percent of the value of solar energy in Austin



Among 16 value-of-solar studies included in Environment America Research & Policy Center and Frontier Group's 2016 report Shining Rewards*, only eight accounted for any societal benefits, none conducted by or for utilities.*[42]

Energy's analysis, and more than 33 percent in Xcel Energy's.[48] Yet these substantial benefits are typically left out of utility analyses.

Failing to account for the full value of solar energy may have costly ramifications. Utility regulators, legislators and the public are keenly focused on ensuring that utility rate-setting and investment decisions do not impose undue burdens on ratepayers. Value-of-solar studies that fail to include key societal, environmental and grid benefits of solar power have been used to undermine support for policies such as net metering that compensate owners of distributed solar energy for the excess electricity they supply to the grid. For example, a solar cost-benefit analysis conducted for the Louisiana Public Service Commission that did not include social benefits informed legislation that severely restricted Louisiana's solar tax credit.[49]

Understanding the full value of solar installations can help policymakers develop and implement appropriate tools to compensate owners of distributed solar projects for the value they provide. The full range of benefits to society needs to be reflected in those policies.

Conclusion and Recommendations

As policymakers consider the future of America's energy system, they should seek to make decisions that serve the public interest. In his seminal and oft-cited work on utility ratemaking, *Principles of Public Utility Rates*, James Bonbright defined "the theory of rates" as "the systematic development of principles of ratemaking policy, the complete or qualified observance of which would subserve the public interest or the social welfare."[50]

In 2019, serving the public interest means considering the broad impacts of electricity generation, which is closely tied to many of America's most pressing environmental and public health challenges. In 2017, electricity generation accounted for 28 percent of U.S. global warming emissions, and as America moves toward the electrification of transportation and heating, the importance of clean electricity will only increase.[51]

When it comes to solar energy, that means basing policy decisions on studies that accurately and fully assess the impact of solar energy on the grid and society. Failing to account for solar energy's full range of benefits is not only unsound policymaking, but also risks putting America on a path to a less healthy, less sustainable, and less prosperous future.

To craft energy policy that accurately reflects the value of solar energy resources, policymakers should account for the societal as well as the grid benefits of solar energy, specifically including:

- The societal value of avoided greenhouse gas emissions.
- The societal value of other avoided pollutants, including criteria pollutants such as particulate matter, lead, and sulfur dioxide.

Policymakers should also seek to quantify and account for a broader set of societal impacts of solar energy, including:

- The local economic benefits of solar energy, including the creation of local jobs and businesses.
- The societal value of avoided costs imposed by fossil fuels throughout their life cycle, including:
  - Impacts from resource extraction, such as methane emissions associated with fracking.[52]
  - Health care and mortality costs associated with pollution from the entire fossil fuel lifecycle.
  - Potential impacts of accidents and spills associated with fossil fuels, including coal ash, fracking and pipeline spills.

After accounting for the full value of solar, policymakers should seek to ensure that electricity rates, investment decisions, and other energy policies fully reflect their findings. There is precedent for ensuring that electricity rates incorporate societal costs and benefits beyond energy costs, and doing so is both justifiable and necessary.[53] In some cases, legislators may need to ensure that state utility commissions have the authority to account for external costs and benefits in ratemaking decisions.

The decisions we make about our use of power not only impact the grid, but also our health, our quality of life, and our future. Energy policy should reflect that – after all, ratepayers are taxpayers and citizens too.

Notes

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