Solar panels cost benefit analysis

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Over the past decade,the cost of solar photovoltaic (PV) arrays has fallen rapidly. But at the same time, the value of PV power has declined in areas that have installed significant PV generating capacity. Operators of utility-scale PV systems have seen electricity prices drop as more PV generators come online. Over the same time period, many coal-fired power plants were required to install emissions-control systems, resulting in declines in air pollution nationally and regionally. The result has been improved public health -- but also a decrease in the potential health benefits from offsetting coal generation with PV generation.

Given those competing trends, do the benefits of PV generation outweigh the costs? Answering that question requires balancing the up-front capital costs against the lifetime benefits of a PV system. Determining the former is fairly straightforward. But assessing the latter is challenging because the benefits differ across time and place. "The differences aren"t just due to variation in the amount of sunlight a given location receives throughout the year," saysPatrick R. Brown PhD "16, a postdoc at the MIT Energy Initiative. "They"re also due to variability in electricity prices and pollutant emissions."

Brown notes that some generators may even bid negative prices. "They"re effectively paying consumers to take their power to ensure that they are dispatched," he explains. For example, inflexible coal and nuclear plants may bid negative prices to avoid frequent shutdown and startup events that would result in extra fuel and maintenance costs. Renewable generators may also bid negative prices to obtain larger subsidies that are rewarded based on production.

Health benefits also differ over time and place. The health effects of deploying PV power are greater in a heavily populated area that relies on coal power than in a less-populated region that has access to plenty of clean hydropower or wind. And the local health benefits of PV power can be higher when there"s congestion on transmission lines that leaves a region stuck with whatever high-polluting sources are available nearby. The social costs of air pollution are largely "externalized," that is, they are mostly unaccounted for in electricity markets. But they can be quantified using statistical methods, so health benefits resulting from reduced emissions can be incorporated when assessing the cost-competitiveness of PV generation.

The contribution of fossil-fueled generators to climate change is another externality not accounted for by most electricity markets. Some U.S. markets, particularly in California and the Northeast, have implemented cap-and-trade programs, but the carbon dioxide (CO2) prices in those markets are much lower than estimates of the social cost of CO2, and other markets don"t price carbon at all. A full accounting of the benefits of PV power thus requires determining the CO2emissions displaced by PV generation and then multiplying that value by a uniform carbon price representing the damage that those emissions would have caused.

Calculating PV costs and benefits

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To examine the changing value of solar power, Brown and his colleague Francis M. O"Sullivan, the senior vice president of strategy at ?rsted Onshore North America and a senior lecturer at the MIT Sloan School of Management, developed a methodology to assess the costs and benefits of PV power across the U.S. power grid annually from 2010 to 2017.

The researchers focused on six "independent system operators" (ISOs) in California, Texas, the Midwest, the Mid-Atlantic, New York, and New England. Each ISO sets electricity prices at hundreds of "pricing nodes" along the transmission network in their region. The researchers performed analyses at more than 10,000 of those pricing nodes.

For each node, they simulated the operation of a utility-scale PV array that tilts to follow the sun throughout the day. They calculated how much electricity it would generate and the benefits that each kilowatt would provide, factoring in energy and "capacity" revenues as well as avoided health and climate change costs associated with the displacement of fossil fuel emissions. (Capacity revenues are paid to generators for being available to deliver electricity at times of peak demand.) They focused on emissions of CO2, which contributes to climate change, and of nitrogen oxides (NOx), sulfur dioxide (SO2), and particulate matter called PM2.5 -- fine particles that can cause serious health problems and can be emitted or formed in the atmosphere from NOxand SO2.

The results of the analysis showed that the wholesale energy value of PV generation varied significantly from place to place, even within the region of a given ISO. For example, in New York City and Long Island, where population density is high and adding transmission lines is difficult, the market value of solar was at times 50 percent higher than across the state as a whole.

The public health benefits associated with SO2, NOx, and PM2.5emissions reductions declined over the study period but were still substantial in 2017. Monetizing the health benefits of PV generation in 2017 would add almost 75 percent to energy revenues in the Midwest and New York and fully 100 percent in the Mid-Atlantic, thanks to the large amount of coal generation in the Midwest and Mid-Atlantic and the high population density on the Eastern Seaboard.

Based on the calculated energy and capacity revenues and health and climate benefits for 2017, the researchers asked: Given that combination of private and public benefits, what upfront PV system cost would be needed to make the PV installation "break even" over its lifetime, assuming that grid conditions in that year persist for the life of the installation? In other words, says Brown, "At what capital cost would an investment in a PV system be paid back in benefits over the lifetime of the array?"

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