The True Cost of Solar Power
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Much of what is said here also applies to wind power.

The object of this paper is to divine how much solar power costs if you strip away all the subsidies and mandates that shift the cost to others.

It is straight forward to compute how much a solar farm costs to build. But that doesn't tell you how much the electric power from the farm would cost if the government actions supporting solar weren't present.

If there were a free market for solar electricity, we could just look up the current market price and that would be the true cost of solar power, what producers are willing to sell for and purchasers are willing to buy for. But electricity doesn't work that way. It's not like sugar or corn. Building a plant with any technology to generate electricity is a large capital investment and that is not an investment likely to be made without a good idea what the market for the electricity is going to be. For electricity, price is less important than reliability. That affects everyone's approach to building more generating capacity. Blackouts can easily cost billions and cause politicians to be voted out of office.

Lacking a market price, we revert to defining the price of solar as what the developers of solar have to charge to stay in busines and make a reasonable profit.

There would be either no solar or very little solar if it weren't for the multitude of government support programs. Companies like Apple or Duke Energy may build solar farms for virtue signaling or as show projects. People that live off grid often use solar to generate electricity, but those systems are not comparable to utility scale systems. The reason there is no free, or even somewhat free, market in solar electricity is that solar electricity is erratic because the rate of delivery depends on the weather. The cost is much higher under any scenario than using traditional sources like coal or natural gas. That is to say that the cost of solar is higher than the marginal cost generating a megawatt hour with the backup plants that are always present and ready to take over at night and when it is cloudy. The alternative to a solar megawatt hour is always to burn some fuel in a backup plant and make the megawatt hour for the marginal cost of generating that megawatt hour.

Utility scale solar is driven by renewable portfolio standards, otherwise known as mandates. Thirty states specify quotas for what percentage of their electricity should come from renewable sources. That usually means wind or solar. The quotas usually increase according to a schedule.

A utility under a mandate has to find a way to acquire more solar or wind. In sunny southwestern states solar is the usual path. A common method of acquiring solar is to request

bids for the cost of the solar electricity from a limited circle of companies with the wherewithal to build solar farms in the $100 million and up category. These companies have no interest in building and owning a solar farm unless they can be assured a market for the electricity. The consequence is that the relation between the developer and the utility always starts with a power purchase contract or PPA. The PPA is often for 25-years as the assumed life of the solar farm. Most often the price is a constant, so many dollars per megawatt hour of electricity for the life of the contract. The utility is expected to take all the solar electricity that appears when it appears. If it can't take the power for some reason it may still have to pay for the electricity it didn't take.

Once the developer has a PPA in hand he has eliminated market risk, having handed that risk off to the utility. Since the PPA is undoubtedly approved by the public utility commission, the utility in turn passes the risk off to its electricity customers from which it is entitled to get reimbursement in some way or another. Although if the public utility commission gets mad at the utility or is under pressure it may force the risk back to the utility.

Market risk can take different forms. If the authorities repeal the renewable power mandate, the power still has to be purchased for the length of the contract. If a better or more fashionable form of renewable power appears, the utility still has to buy the old-fashioned power for 25 years.

Then there is performance risk. If the farm isn't completed or doesn't work, then the developer loses the money invested. Since these developers are usually experienced and understand the risks, this should not happen too often. The Crescent Dunes thermal power plant in Tonopah, central Nevada, apparently failed because a tank holding molten salts failed persistently. The contract was cancelled. This was for power at $135 per megawatt hour, a very high price. The federal government also lost money on a $737 million loan guarantee.

The government mandates are a subsidy because risk is removed from the developer and transferred to the utility and its customers. With less risk the developer can proceed with a lower expected rate of return and thus a lower price for the electricity. Because a PPA is in hand much better financing arrangements can be made, such as low interest loans. Once the project is finished, working and collecting money, the developer has gotten past most of the performance risk. At that point he has the possibility of selling the farm as an infrastructure investment, perhaps to an infrastructure investment fund. If the developer develops the project with an 8 percent rate of return, he may be able to in turn sell the project at 5.5 percent as an infrastructure investment. This gives a substantial capital gain, because the price is higher if the rate of return is lower.

Infrastructure investors are organizations like pension funds, insurance companies, sovereign wealth funds or family offices. These investors seek investments that pay better than bonds but have bond-like security. These are things like toll bridges, sewer plants, or renewable energy plants. The investments may cost hundreds of millions. An infrastructure investment fund may buy these investments yielding 5.5 percent as an example and retail them to other investors

yielding more, perhaps 7 percent. The yield can be boosted by using leverage with money borrowed at a very low cost, say 2.0 percent.

One method of breaking a PPA contract is utility bankruptcy. Utilities can go bankrupt, but they can't go out of business because the government will ensure that the lights don't go out. The The large California utility PG&E has already gone bankrupt twice, in 2001 and 2019. The bankruptcies were a caused by government hostility toward the utility. In the 2001 bankruptcy the government refused to let the utility raise rates even as the price of wholesale electricity skyrocketed. In the second instance the government imposed strict liability for consequential damages when power lines started a forest fire. In the second instance the utility threatened to abrogate $40 billion of PPA contracts for renewable energy. This did not happen because it would have been deeply embarrassing to the California politicians, big supporters of renewable energy. Probably the threat enabled PG&E to settle the bankruptcy on better terms. If the contracts had been cancelled it would have been a fatal blow to the renewable energy business. Those projects no longer would have been considered secure investments.

The subsidizing effects of mandates is rooted in the fact that the PPA bestows on the developer a credit rating approaching that of the utility on the other side of the PPA contract.

There are two other important subsidies created by the federal government.

There is a federal tax credit, currently 26 percent of the project cost, but scheduled to decline to 10% by 2023. This is effectively a cash subsidy. The currently scheduled phase down of the tax credit might be suspended, depending on the political climate. Note: As of the end of December 2020 the president signed a 6,000-page bill presented at the last minute. That bill extended the solar investment tax credit as follows: 26 percent through the end of 2022, 22 percent through the end of 2023 and then 10 percent for utility scale projects, but zero percent for residential rooftop solar. By making a small start on a project the subsidy can be stretched into future years.

The second federal subsidy is regulations and law that enables something called tax equity financing. This allows project depreciation to be mobilized to reduce federal, and possibly state, corporate income tax. Essentially money that would have gone to the tax collectors is redirected to the project. These subsidies result in very complicated legal structures. In addition, the project may leverage with loans to provide part of the capital. A bank is often a partner in these transactions. My guess is that these subsidies together provide two thirds of the project capital, leaving one third as equity capital.

We know the price of electricity for many projects as the PPA's are public documents, or we can consult organizations that collect this information, like the Berkeley Lawrence Lab. The construction cost of and output of the solar farm can be estimated from information from the Energy Information Agency (EIA) or the National Renewable Energy Laboratory (NREL). These are federal organizations. Analyzing the various subsidies is more difficult because this

information is held by companies under no obligation to release it. Some advisory firms, like Woodlawn Associates, provide websites with considerable analysis.

My analysis assumes an initial rate of return of 8 percent and a sale of the project as an infrastructure investment for 5 to 6 percent. I assume federal subsidies and loans cover 64 percent of the capital requirement. Using these parameters and numbers from NREL I end up with the unsubsidized cost of solar power at about $72 per megawatt hour. The subsidized PPA price is about $31 per megawatt hour. This is for a one axis tracking system, with the axis pointing north south, and at a good desert location. The capital cost is $1680 per nameplate kW AC and $1380 per nameplate kW DC. A spreadsheet is here. In the spreadsheet I assume sale of the farm as soon as commissioned as a simplification to the calculations. Normally, several years would pass before the sale.

When a utility enters into a PPA it is using up part of its borrowing capacity. The more obligations it takes on the higher interest rate is going to have to pay to borrow money. The PPA is a real subsidy that costs the utility money.