The economics of energy efficiency upgrades and residential solar PV installations

Background

Energy efficiency upgrades and distributed generation are two key ways that consumers can not only lower their electricity bills, but lower demand on the grid. Residential solar photovoltaic (PV) systems are one distributed generation technology that continues to fall in cost (Fu et al, 2017). Energy efficiency upgrades can be done on many different appliances throughout a home. Here, the replacement of a 25 year-old upright freezer will be analyzed in order to gain a better understanding of the value of efficiency upgrades. These types of upgrades and installations can also contribute to reducing carbon emissions as well since efficiency upgrades lower overall energy consumption and residential solar is a renewable technology.

The following sections contain an economic analysis of a potential residential solar PV system in Washington State and an efficiency upgrade of a 25 year-old freezer. These analyses utilize a levelized cost of electricity (LCOE) and a cost of saved energy (CSE) calculation. These will be used to determine potential impact on public policy and whether these actions would save the consumer money and benefit the grid, especially during peak hours. What this analysis does not fully address is the environmental benefits of these upgrades and installations.

Residential solar PV

The levelized cost of electricity (LCOE) can be used to determine what the price for power would be if the present value of revenue equaled the present value of the cost of production, meaning construction and generation. This is the hypothetical break-even price

for selling the electricity and we can use it here to determine the cost per kilowatt-hour (kWh) that their system would generate.

For a residential solar installation with an array capacity of 5.4 kW, the average annual production would be 5243 kWh (Cascadia Solar, n.d.). In Washington, the average cost of a solar project installation is $2.73/watt or $2730/kW (Parkman, 2021). The discount rate used in these calculations is 17%, or about the national average credit card interest rate (Dilworth, 2021). For this calculation, it was assumed that these solar panels would last about 25 years (Richardson, 2020). The annual cost of maintenance on solar panels is around $150 (HomeAdvisor, n.d.). Based on these assumptions, the LCOE of this system would be $0.51/kWh, or $516.32/mWh. In a later section, this will be compared to the retail price of electricity to determine whether this will make a good financial investment.

Energy efficiency upgrade

The cost of saved energy (CSE) is utilized here to give the consumer an idea of how much money they are going to spend per kWh in order to not consume that energy in the future. By completing this energy efficiency upgrade, the consumer must spend a certain amount of money now so that they do not consume energy in the future that would come from not installing the energy efficiency upgrade. For this efficiency upgrade, the CSE of a replacing a 25 year-old freezer will be modeled.

Because this is a freezer and not an appliance like a light bulb, we can assume that it will be in use all of the time. In a year, that is approximately 8760 hours. An old upright freezer between 16 and 18 cubic feet from the 1990s might use about 1481 kWh annually

(EnergyStar, n.d.). A new freezer of similar size today uses about 489 kWh a year. Utilizing the same discount rate as the solar panels (17%) and assuming the new freezer lasts 20 years (Consumer Reports, 2019) and costs $879 up front (Home Depot, n.d.) the cost of saved energy would be $0.16/kWh.

This demonstrates that the consumer here will spend $0.16/ kWh to not use this energy in the future. Other energy efficiency updates that may not be turned on all of the time would have a different savings associated with them, especially if they saved energy during peak hours. This would potentially hold a higher value because it would lower the overall demand on the grid. A freezer efficiency upgrade on the other hand, would save energy during all hours of the year. This CSE will be compared in the next section to the alternate cost of additional generation in order to determine whether this is a good investment for the homeowner and the grid.

Costs and Benefits

For the residential solar installation, the LCOE was $0.51/kWh, which is fairly high compared to the average retail price of electricity, which is between $0.10 and $0.25/kWh nationally (Energy Information Administration, n.d). One of the reasons this cost is much higher is because of the high discount rate, which would force the cost of electricity up in order for the present value of revenues to equal the present value of costs. Because this is so expensive, it is prudent to consider if the benefits outweigh the high costs for this installation. Assuming that the homeowner would be compensated for their solar generation utilizing net metering, this would be a relatively expensive approach to generating electricity. Net metering looks at how much electricity a homeowner used and generated in a period, and then they are charged for the difference by the utility. Because

the price of energy from this solar installation is so high, the homeowner in this case would be generating expensive electricity, and getting paid a much lower retail rate.

The Energy Information Administration (EIA) also estimates LCOE of new utility scale solar generation to be around $0.03/kWh, which is significantly cheaper than the costs of this residential solar generation (Energy Information Administration, 2021). However, if the residential solar generation ended up being less than the retail price of electricity with a different installation project, then that would make financial sense for the homeowner to undertake.

In addition, the levelized avoided cost of electricity (LACE) is utilized by the EIA to determine the cost of generating that electricity with other sources if the one you were assessing did not exist. For a utility scale solar generation, the capacity-weighted average LACE, which takes into account how much generation solar panels will actually produce, was $0.03/kWh (Energy Information Administration, 2021). We can use the LACE here to compare to the LCOE of this installation. Because the LACE is much smaller than the LCOE, then it would not be financially beneficial to install this for the grid, since the financial value of the construction does not outweigh the costs.

One benefit that residential solar can have is reduction on demand for the grid. Depending on the region, this may happen during off-peak hours, when the grid is not as constrained but the sun is shining. This is during the day, but peak demand often occurs in the evening. Therefore, residential solar combined with battery storage is a much more effective approach to reducing demand on the grid during peak hours. Battery storage would allow the homeowner to charge their batteries during the day when demand is lower on the grid and the sun is up, and then discharge the batteries in the evening when

there is peak demand on the grid. This can help reduce peak demand as well as potentially lower costs for the homeowner if there is a higher price of electricity during peak hours.

The freezer upgrade also has various costs and benefits. The efficiency upgrade's CSE was $0.16/kWh. If we were to compare the CSE and LCOE of both of these projects directly, we would see that CSE of the freezer upgrade is much cheaper than the LCOE of the rooftop solar. This has implications for what would be the more financially appropriate route for a homeowner to take, since the CSE was much cheaper than the LCOE. In this case, the efficiency upgrade would be a cheaper project to undertake by the homeowner since it would reduce electricity demand from the grid at a lower price. However, we can also compare this to the cost of additional generation, specifically the utility scale solar estimate from earlier. This cost for this was $0.03/kWh, which is much cheaper than both of these estimates. So, these would not be financially beneficial to the grid and, in the end, it would be cheaper to build additional generation.

Two more aspects to consider with efficiency upgrades is the time value and rebound effect. The time value of upgrades is the idea that appliances that are upgraded that are typically used during peak hours, like an air conditioner, would have a higher overall value because it would reduce load on the grid during peak hours. This was briefly mentioned in the calculation section above. However, an upgrade like a freezer, which is not utilized more during peak demand, would not have as large of a time value as other appliances might.

Rebound effect is sometimes mentioned with energy efficiency upgrades as a potential byproduct. This is when an upgraded appliance is used much more than it was before the upgrade and so the savings on energy are not as high as predicted. This happens

because it is now cheaper to use, and so homeowners are incentivized to utilize it more. Because this upgrade is a freezer that is typically turned on or plugged in at all hours of the day, this does not apply here as a potential concern. However, this is something to keep in mind for other efficiency upgrades.

Recommendations

Based on the above information and the LCOE calculation for the solar panels, it is recommended that a homeowner in this situation work to find a better discount rate or a better deal on the cost of solar panels in order to lower the $/kWh costs to be closer to the retail price of electricity. Because the discount rate used was the average credit card rate, a better approach would be to get a loan for this installation, rather that putting it on a credit card. Average national loan rates can be as low as 6%, which would significantly improve the LCOE (Millerbernd, 2021). Distributed generation compensated through net metering has a lot of benefits, but here it is clear that this would be an expensive project with the current assumptions.

In regards to how this compares to utility scale solar generation costs, it is clear that utility scale generation is much cheaper than distributed and it would be beneficial for a utility to invest in solar. However, it would also be financially reasonable to push for public policies that incentivized rooftop solar if they were at or lower than the retail cost of electricity in order for that generation to be mutually beneficial to the homeowner and the utility. Distributed generation would also lower the demand on the grid. If this were combined with battery storage, then distributed solar would be very beneficial to the grid at constrained peak hours when batteries could be discharge to lower the peak. Renewable

generation can also help utilities and states meet their Renewable Portfolio Standard (RPS) goals.

The freezer efficiency upgrade would be beneficial for the homeowner to undertake because it would save them money and would contribute to overall improvements in energy efficiency and lower demand on the grid. Energy efficiency not only helps lower carbon emissions, but also is one of the Northwest's biggest resources in meeting demand in the coming decades (Northwest Power and Conservation Council, 2016). Public policy that pushes for efficiency upgrades across various appliances and housing stock would greatly benefit the grid and homeowners both.

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