Carroll Electric Cooperative Corporation

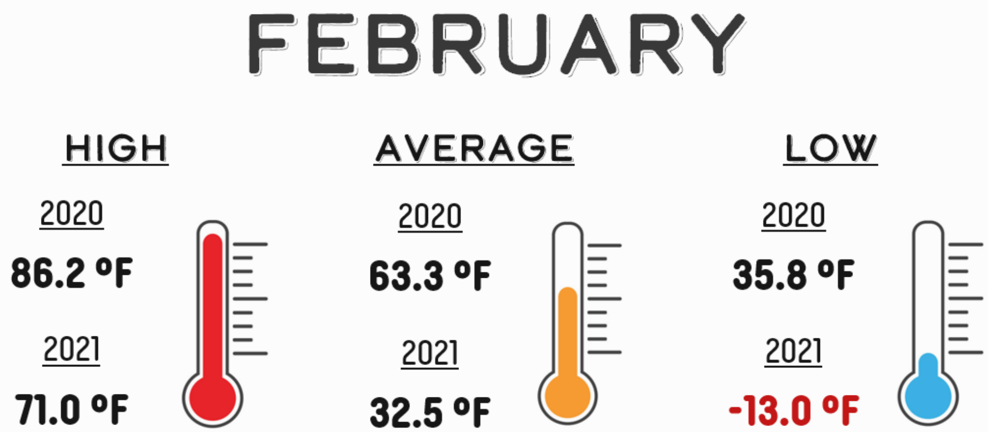
Case Study

Why Not Batteries?

Can a solar system coupled with battery storage replace traditional baseload generation?

During the February 2021 winter storm event, both northwest Arkansas and southwest Missouri experienced abnormally low temperatures (see Figure 1).

(Figure 1)



Source: Northwest Arkansas Regional Airport Station

As a rule, utility customers will demand (use) higher volumes of electricity during periods of extremely cold or hot temperatures.

During the winter storm event (which ran from Feb. 15 thru Feb. 19, 2021), the high temperature across northwest Arkansas only averaged **24°F**, which is well below freezing. The lowest temperature during that period was reported on Tuesday, February 16, 2021, at **negative 13°F**, (45° below freezing).

Carroll Electric Cooperative set a record high system-wide peak demand of 628,841 kilowatts on that same Tuesday morning. To put that in perspective, the Cooperative's previous peak demand registered during the previous February was 433,734 kilowatts. That is a 45% increase from the same month in the previous year. A small portion of that increase was attributable to customer growth but was primarily the result of extremely low temperatures experienced throughout the Cooperative's service area.

At certain times over that five-day period of extremely cold temperatures, there was an imbalance between the supply and demand of electricity. This imbalance of power eventually led to rolling power interruptions across the region.[1] Regional transmission organizations (RTOs), including Southwest Power Pool (SPP) and the Midcontinent Independent System Operator (MISO), were calling on all available power plants to generate and feed power to the grid. Unfortunately, those

[1] Carroll Electric's wholesale power supplier, Arkansas Electric Cooperative Corporation, at the request of Southwest Power Pool (SPP), ordered Carroll Electric twice to implement controlled power interruptions across its service area. Fortunately, both of those orders were rescinded. Other utilities in northwest Arkansas were not so fortunate. Some utility customers in Arkansas experienced rolling blackouts and were temporarily out of power during the extremely cold temperatures.

efforts at times still came up short. Controlled power interruptions were the result. Forcing customers to go without power when temperatures are well below freezing is never a good solution to solving an electricity supply shortage.

When renewable energy sources such as solar and wind generation do not optimally perform, traditional baseload generation – nuclear, coal, natural gas, and oil plants – are critical to sustaining the reliable delivery of electricity to end-use consumers, especially during extreme weather events.

Often the question gets raised, ***"Can a solar system coupled with battery storage replace traditional baseload generation?"***

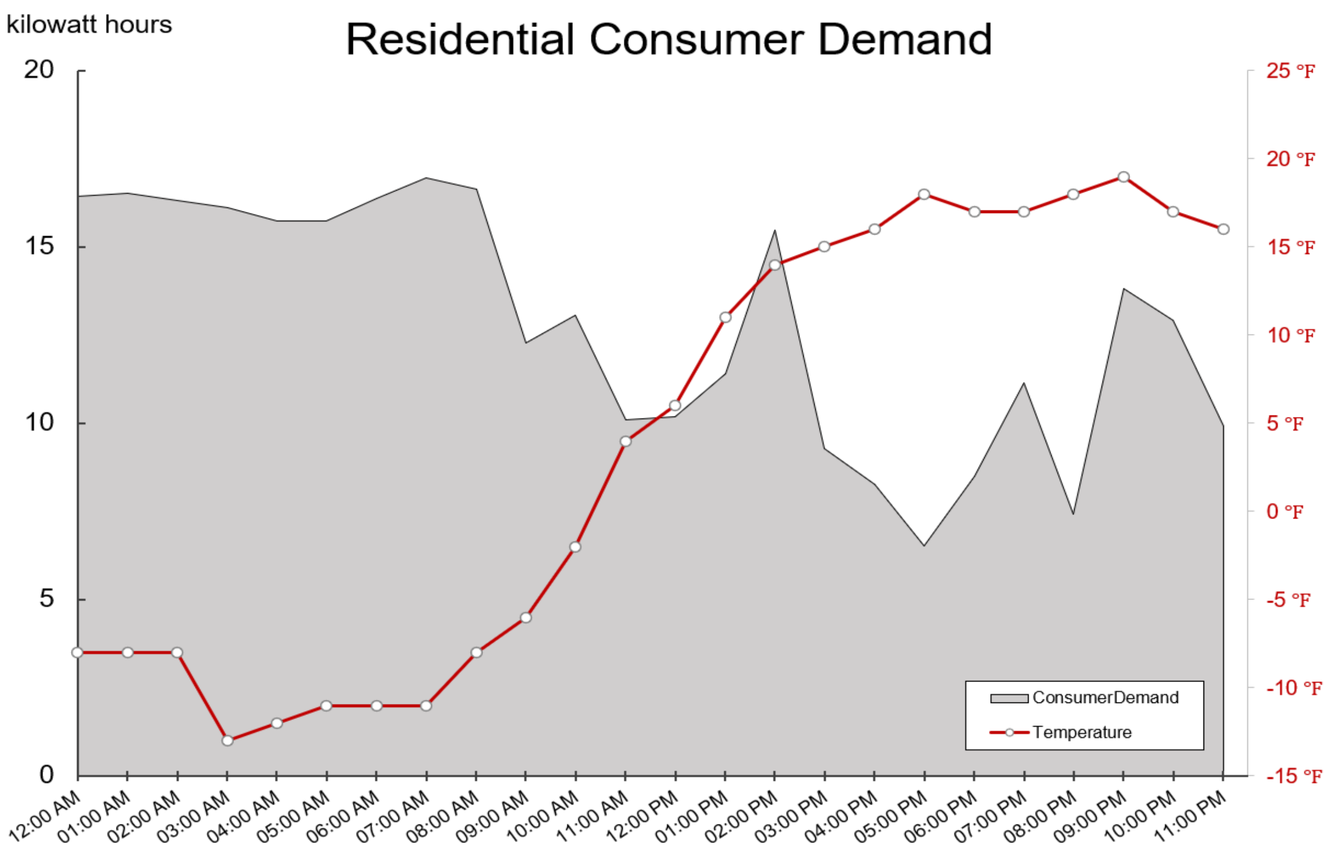
The extreme weather event of February 2021 yields a good case to ascertain whether solar and battery storage could have effectively and efficiently replaced traditional baseload generation.

Case Study

Off-Grid Solar System and Battery Storage Solution

The following chart (Figure 2) represents an actual customer of Carroll Electric Cooperative and their electricity requirements (in kilowatt-hours) that occurred on February 16, 2021. As would be expected, this customer required more electricity than under normal conditions and required the most electricity during those intervals of extremely cold temperatures (i.e., between 1 and 8 am).

(Figure 2)

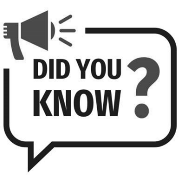


For this example, let's assume this customer is not connected to the electric grid but instead relies completely on a residential off-grid solar system coupled with battery storage to supply all his or her energy needs.

The total electricity required by this customer over this 24-hour period on February 16, 2021, was 307 kilowatt-hours. Keep in mind, this customer's average daily energy requirement during February 2020 (i.e., the same month in the previous year) was only 82 kilowatt-hours. In other words, the electricity used by this customer on the coldest day during the 2021 extreme weather event was almost 4 times more than what this customer typically uses over a single day in February.

Because this customer is depending on his or her solar facility to supply all their electricity needs, it is imperative the solar facility is appropriately sized to do so. If the facility is not appropriately sized, the customer will either be forced to conserve energy (i.e., forfeit some of the comforts they would normally or otherwise enjoy), or the reliable operation of their power system will be at risk.

As a side note, the supply and demand of electricity must always balance in real-time, or operational problems and outages can occur.[2]



The average rooftop solar facility size generally ranges from 5-10 kilowatts in DC capacity. A 75-kilowatt (kW) Direct Current (DC) solar facility would be required to effectively produce 307 kilowatt-hours in a single day under optimal (i.e., near perfect) conditions in February.[3] That may not register with most people, but a 300-watt solar panel takes up approximately 16 ½ square feet. A 75 kW DC system would require somewhere around 4,125 square feet of space.[4] This does not include the space needed for batteries or any needed buffer to prevent solar panel shading. Assuming the average sized roof is 3,000 square feet and the customer could utilize every square inch of his or her roof (which is unlikely), that leaves 1,125 square feet of solar panels to contend with. According to *EnergySage*, the average cost per watt ($/Watt) for solar panels in 2022 is projected at $2.77/Watt after applying the federal solar tax credit.[5] Based on those prices, the solar panels alone for a 75 kW DC system would cost somewhere around $205,000.

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[2] U.S. Energy Information Administration - *Electricity Explained. How Electricity is Delivered to Consumers*. https://www.eia.gov/energyexplained/electricity/delivery-to-consumers.php

[3] https://diysolarshack.com/solar-panel-sizing-calculate-solar-system-size/

*(74.1 DC kW * (1 - 23.8% system losses) * 96% inverter efficiency) * (24 hours x 23.6% average capacity factor)*

Optimal conditions were based on the highest hourly capacity factors in February as indicated on a PV watts model for a photovoltaic solar system in Bentonville, Arkansas.

[4] *75 kW DC x 1,000 watts ÷ 300-watt panels x 16.5 square feet = 4,125 square feet*

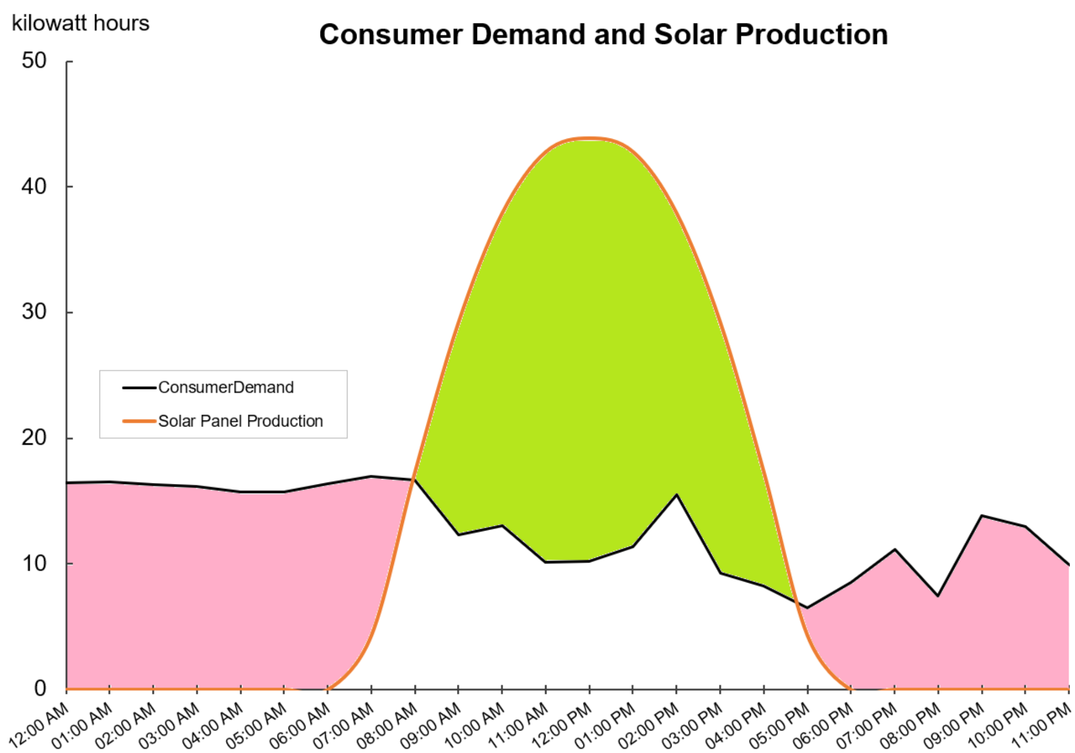
[5] *How Much Does a Solar Panel Installation Cost?* https://news.energysage.com/how-much-does-the-average-solar-panel-installation-cost-in-the-u-s/#cost

For this example, let's also assume the customer's solar facility experienced ideal sunlight on this particular day in February and performed almost perfectly (refer to Figure 3).

Observations

- Between 12 and 7 am the solar panels were not producing electricity because the sun simply does not shine during those intervals of the day. However, the customer still required 113 kWh of electricity during that time.
- Between 7 and 8 am, the solar panels were generating electricity (4 kWh), yet they did not produce enough electricity to meet the customer's overall demand (17 kWh). Instances like these, where the solar panels failed to meet the customer's energy needs, are represented by the **red** area of the chart in Figure 3.
- Between 8 am and 5 pm, the solar panels generated more electricity (299 kWh) than what the customer actually used (106 kWh). This is commonly referred to as "excess generation" and is represented graphically by the **green** area of the chart in Figure 3.[6]
- Between 5 and 6 pm the solar panels were generating electricity but once again failed to meet the customer's energy needs.
- Between the hours of 6 pm and 12 am, the solar panels did not produce electricity at all.

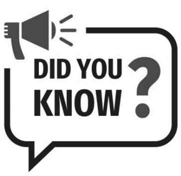
(Figure 3)



[6] The supply and demand of electricity must balance in real-time or electrical equipment, components, and conductors can malfunction. Under these conditions the "excess generation" would either need to feed a battery or it would need to be curtailed to possibly avoid power disruptions or impairing the quality of electric service. Curtailment refers to the act of reducing or restricting energy delivery from a generator. Curtailed energy is energy wasted.

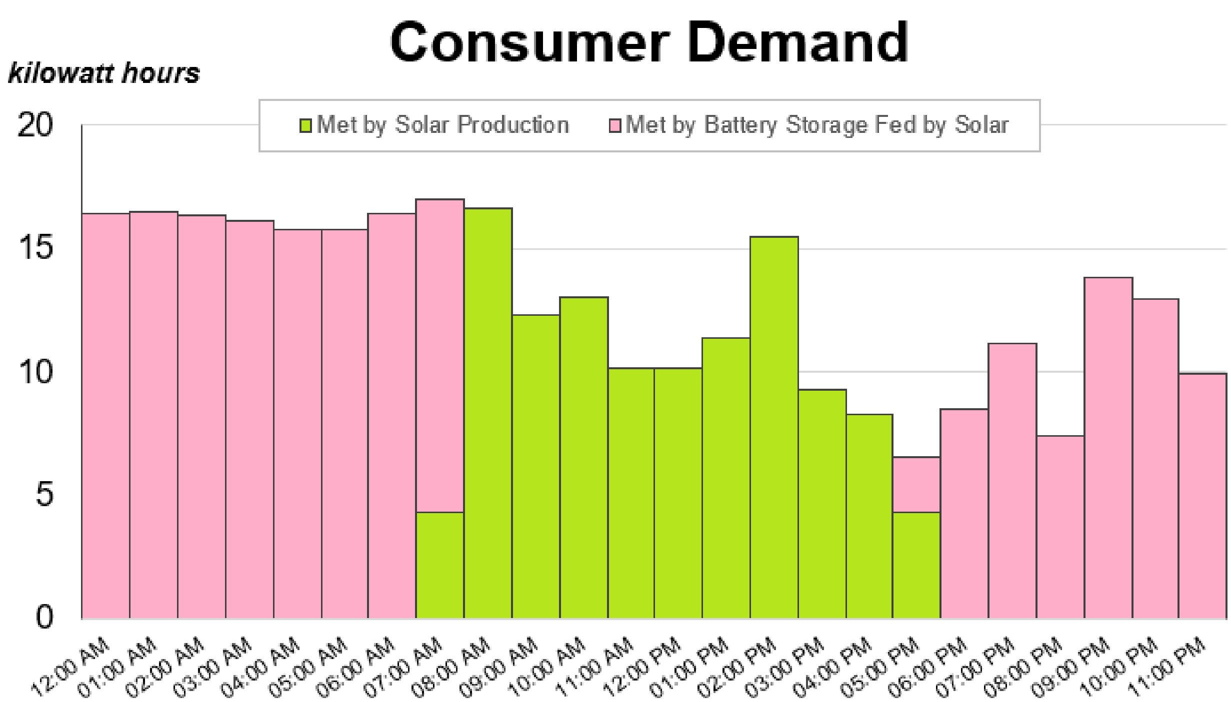
For this solar system to effectively supply all the customer's energy needs, the solar panels would need to charge a battery (or a group of batteries) during those intervals where the solar panels produced more energy than what was needed by the customer (as shown by the **green** area in Figure 3).

During those periods where the solar panels are not producing electricity (e.g., at night) and during those times the panels are producing electricity but cannot meet the customer's energy needs (e.g., early mornings and late evenings), energy stored in a battery must be dispatched (as shown by the red areas in Figure 3 and Figure 4) to account for the difference.



According to the U.S. Energy Information Administration, the roundtrip efficiency for battery storage in 2019 was 82%. Round-trip efficiency is the percentage of electricity placed into a storage device that can later be retrieved.[7] Because 18% of the electricity initially fed into the battery is lost during the conversion process, a solar facility larger than 75 kW would actually be needed to sustain the reliable delivery of electricity in this example.

(Figure 4)



7 https://www.eia.gov/todayinenergy/detail.php?id=46756

So, what happens on those days where the solar panels do not perform optimally and cannot effectively charge a battery?

Unfortunately, that is precisely what happened during the February 2021 winter storm event.

The Solar Lab

Before we endeavor to answer this question, let's hit pause and rewind to 2015. In 2015, Carroll Electric installed a Solar Demonstration Lab (Solar Lab). Prior to 2015, the Cooperative saw a growing interest in solar power among its members. Providing education, training, and information to the membership is one of the seven Cooperative Principles. Consequently, the Cooperative began to educate itself about solar power so it could, in turn, effectively educate its members on the subject.

The primary goal of the Solar Lab has always been to provide members with accurate information and a better understanding of solar power. The ultimate objective was to let members decide what is best for their individual situations, particularly as it relates to whether they choose to install a solar facility.

As you can read in **On the Record**, some have called for the country's entire generation portfolio (including traditional baseload generation) to be replaced with 100% renewable energy. Others have asked what a portfolio of this nature would physically look like or what it might cost. By utilizing the Cooperative's Solar Lab, Cooperative and individual member data, as well as making reasonable assumptions where necessary; the following narrative will outline what a 100% solar powered micro grid would potentially look like and what concessions would have to be made in order to sustain the reliable delivery of electricity during the February 2021 extreme weather event.

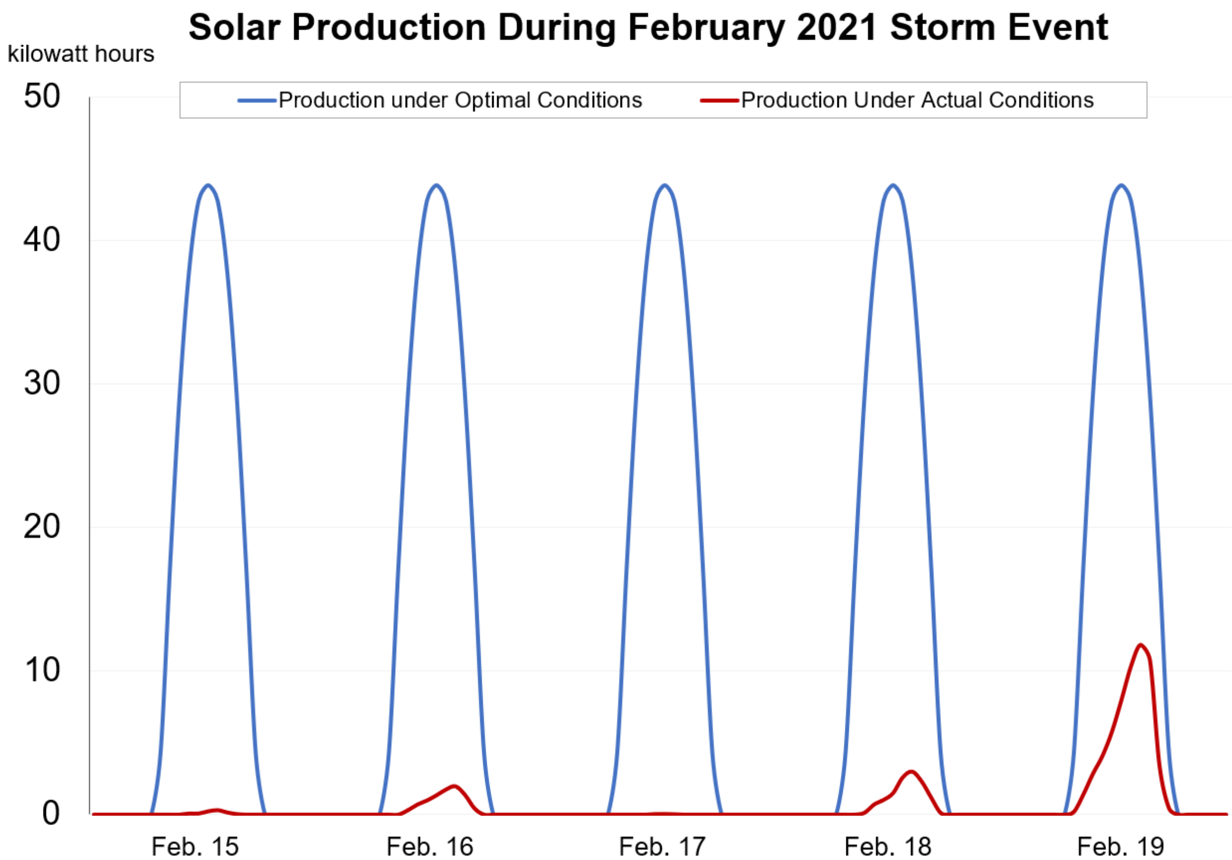
Now, back to the question at hand.

Under optimal sunlight conditions, a 75 kW DC solar facility could have produced around 1,536 kilowatt-hours of electricity over a five-day period in February. That's enough energy to satisfy the customer's actual demand of 1,419 kilowatt-hours over that period and the highest daily demand of 307 kilowatt-hours experienced on February 16. Again, these estimates are based on near (if not) perfect conditions.

The truth is, between February 15 and February 19, 2021, solar production in northwest Arkansas and southwest Missouri was minimal because of the poor weather conditions, which included a constant mix of snow and ice in addition to consistent cloud cover.

The chart on the following page (Figure 5) depicts the difference between what the 75 kW DC solar facility could have produced under optional conditions *versus* what the solar facility would have produced under the actual conditions experienced during the February 2021 winter storm event.

(Figure 5)



Under these poor weather conditions, the solar facility would NOT have produced enough electricity to supply all the customer's energy needs (see Figure 6 on the next page). The customer would have experienced a power interruption (outage) at approximately 7 am on February 15 when the customer's battery storage was completely depleted, and the customer's solar production was close to zero. As indicated in Figure 6, the solar system would have produced minimal power over the 5-day winter storm event.

To avoid sustained power outages, this customer would have either needed to (**Option 1**) size a solar/battery system large enough to satisfy the customer's abnormally high electricity requirements during a time there was minimal solar production[8] or (**Option 2**) deploy a backup or failsafe source of generation (e.g., diesel generator) capable of meeting the customer's energy requirements when the solar panels and battery storage failed to do so.[9]

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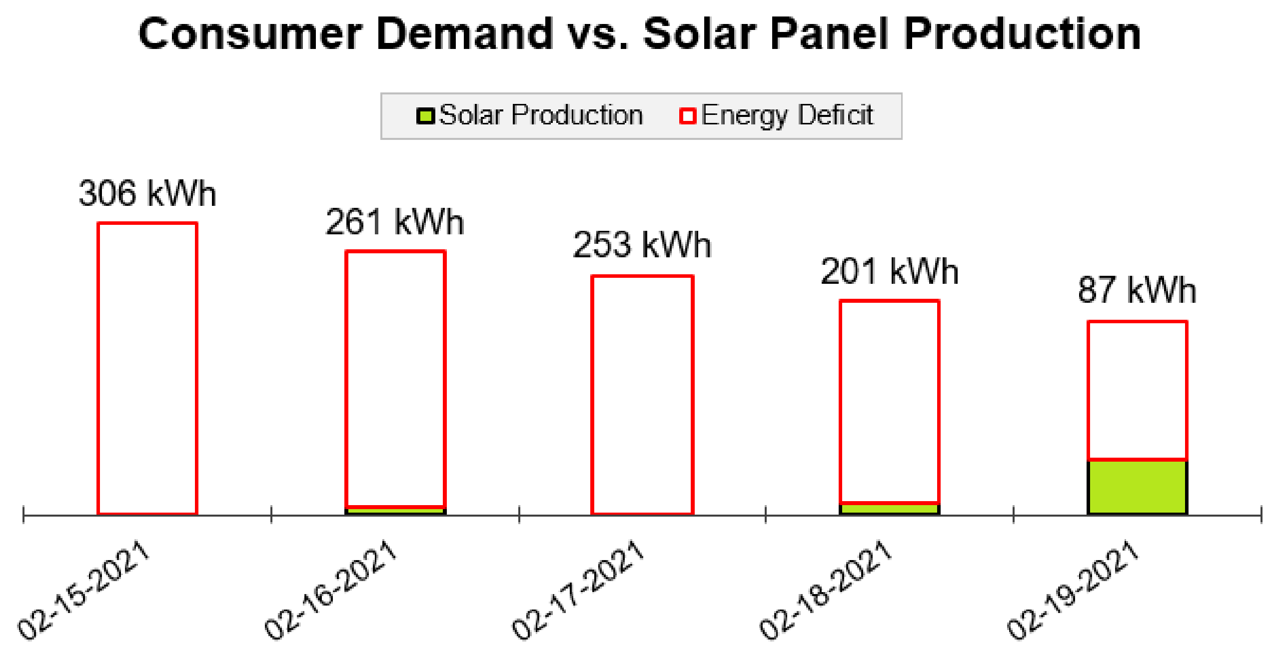
[8] Oversizing a photovoltaic solar/battery system for a five-day inclement weather event would result in forced curtailments of energy (i.e., wasted energy) for a considerable portion of the year.

[9] Any backup or failsafe generation would add additional cost besides that of the solar panels and the batteries. The value of electricity produced depends on its ability to serve demand, and solar power is only available when the sun shines. Even when coupled with battery storage, solar energy cannot be scheduled to operate under certain conditions, whereas traditional power plants that depend on fuel (i.e., natural gas, nuclear, oil, and coal) generally can. Some

(Figure 6)



So, let's look at Option 1.

If the customer strictly relied on solar power to provide all their electricity needs (and avoid the energy deficits shown in Figure 6), the answer seems simple – just add more solar and more batteries, store the additional energy, and dispatch it when there is minimal solar production.

Simple? Definitely not. Costly? Without question.

Instead of a 75 kW DC solar panel system, the customer in our example would have actually needed a much larger system. For example, a 1,300 kW DC (1.3 Megawatt) system under the actual February 2021 conditions could have produced an estimated 1,419 kilowatt-hours.[10]

That's a solar system **17 times larger**, and it would take up (at least) **1.6 acres** of total space (i.e., rooftop space *plus* land). It should be noted, that footprint does not include the additional space needed for batteries or to avoid solar panel shading.[11]

customers would be more than willing to pay the additional cost of having a failsafe source of generation to support renewable energy goals. Others simply cannot afford to.

[10] 1,419 kilowatt-hours were the customer's electricity requirements from Feb. 15 thru Feb. 19.

*1,491 kWh = (1,282 DC kW * (1 - 23.8% system losses) * 96% inverter efficiency) * (120 hours x 1.26% average capacity factor)*

The average capacity factor is based on actual Carroll Electric Solar Lab results from Feb. 15 thru Feb. 19.

[11] To provide the appropriate spacing of panels, is common for a 1-Megawatt solar array to occupy 4-7 acres of land.

As mentioned earlier, *EnergySage* states the average cost per solar panel watt ($/Watt) in 2022 is around $2.77/Watt. Even if prices were presently much lower, say at $1.00/Watt, the solar panels alone would cost an **additional $1.2 million**, and that estimate does not include the additional cost of the land or battery storage. To put it plainly, the average person cannot afford something on this scale.

That's a substantial increase in cost just to (1) supply all the customer's electricity requirements with 100% solar power and (2) avoid a power outage during extreme weather conditions. And let's not forget, because we are building a solar/battery system to accommodate the worst possible conditions, the solar system's production must be curtailed considerably under normal operating conditions throughout the remaining times of the year. In other words, a great deal of energy will be wasted throughout the year.

What about Option 2?

A 45 to 50-kilowatt generator should have the ability to support an underperforming residential solar system for the customer discussed in the above example. When the solar/battery system was unable to meet the customer's electricity requirements, the generator could be dispatched to satisfy the customer's energy demands (i.e., ride through the storm). Generator costs vary (e.g., $10K to $25K), but they are far less expensive and more practical than oversizing a residential solar system. Furthermore, the cost of fuel needed to run a generator over a 5-day window would be marginal compared to the alternative outlined in Option 1.

So back to the original question:

Can a solar system coupled with battery storage replace traditional baseload generation?

Although the above example represents the challenges of solar energy on a micro scale, this would be a very similar dilemma the U.S. would face if the entire electric grid were at present to move to 100% solar energy.

So…

- ✓ ***Could it be done…POSSIBLY, BUT NOT LIKELY.***
- ✓ ***Does it make the electric grid more difficult to operate…WITHOUT QUESTION.***[12]
- ✓ ***Without a failsafe, would the reliability of the electric grid be in jeopardy…YES.***
- ✓ ***Would it add unprecedented cost to both utilities and consumers…ABSOLUTELY.***

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12 MISO's "The February Arctic Event" states, "*The electricity system is in a constant state of change shaped by existing generation and emerging technologies like battery storage and solar power. Retirements, aging thermal units, and the addition of intermittent wind and solar resources dramatically change the characteristics of the MISO resource fleet. While grid operators have managed variability and uncertainty in the system for decades, MISO expects this variability and uncertainty to become more profound, making it more challenging to manage supply, load, and reserves.*"

<u>On a Much Larger Scale</u>

As mentioned earlier, Carroll Electric's peak during the winter storm of 2021 was 628 Megawatts. It is impossible to know when a peak will happen or for how long it will be sustained. These situations are almost completely weather dependent.

Keep in mind, if consumers want to maintain the comforts that come from the reliable delivery of electricity, a solar panel/battery array would have to be oversized to accommodate the less-than-optimal conditions that can and do occur.

A few points to consider…

- The size of a standalone solar system capable of generating enough electricity to satisfy the Cooperative's consumer demand between February 15 and February 19, 2021, simply doesn't exist.[13]

- <u>**The cost of such a system would be profound.**</u>

- If Carroll Electric were to size a utility-scale solar photovoltaic system large enough that it could have ridden through the worst conditions of February 2021, it would take a solar array that would occupy approximately <u>**273,000 acres of land.**</u>[14] <u>This estimate does NOT include the space needed for batteries.</u>

  To put this in perspective, Carroll Electric's largest concentration of accounts is in Benton County, Arkansas. Benton County covers approximately 566,000 acres. 24,000 acres are covered by water. In other words, sizing a solar system large enough to accommodate the worst possible conditions experienced in February 2021 would require ½ of Benton County's actual land mass.

- Relying on any single source of power generation creates a risk to reliability, whether the source is renewable or not. It's like the old saying goes, "<u>*Don't put all your eggs into one basket.*</u>"

Now fast forward to Spring. The sun is shining, and the weather is nice. Air conditioners and furnaces are both turned off. There is very little demand for power, but the solar array is generating under optimal or much closer to optimal conditions. Consequently, the batteries coupled with the solar panels have reached their maximum charge. There is nowhere to send the excess solar power. If all other utilities have operated in a similar manner to prepare for the worst conditions, they too have excess power and nowhere to send it. The only option…curtail (waste) solar generated electricity, to the extent necessary, until it is needed.

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[13] The largest solar farm in the United States is located in California. It has 1.7 million solar panels spread out over 3,212 square miles in Kern and Los Angeles Counties, California. The facility can generate <u>579 Megawatts</u> of total energy.

[14] The Cooperative purchased 56 million kilowatt-hours between Feb. 15 and Feb. 19. A 50,653-Megawatt Facility at 5.4 acres per Megawatt comes to circa 273,000 total acres.

*56 million kWh = (50,653,340 DC kW * (1 - 23.8% system losses) * 96% inverter efficiency) * (120 hours x 1.26% average capacity factor*

Conclusion

Eliminating traditional baseload generation entirely from the U.S. electric sector imposes substantial risk to the electric industry. Due to their intermittent nature, solar energy requires a backup or failsafe source of generation. Despite overly optimistic goals of reaching 100% renewable power generation, as things exist now, this can only occur if consumers are willing to accept compromised reliability and substantially increased costs. Abandoning traditional baseload generation in favor of resources that require energy storage at a scale that simply does not yet exist, is uncharted territory. Many traditional sources of electricity, such as coal plants, have or will exit the industry on account of renewable energy subsidies and their impacts on wholesale electricity markets. Rising concentrations of renewables can endanger the reliable delivery of electricity. This has already been seen in states that rely on large amounts of renewable energy, specifically in California, New York, and Texas. The *Electric Cooperatives of Arkansas* have fought hard to maintain affordable electric rates and provide sustainable electricity from diverse generation sources. This diverse mix of generation includes a balance of both traditional generation and renewable energy and has proven itself over time. Arkansas remains one of the lowest cost providers of electricity in the nation, largely in part to having a diversified generation portfolio.

For more information on the *Electric Cooperatives of Arkansas* and its **Balance of Power** campaign, click here.