Report for the Johnson County Kansas Board of Commissioners on Hazards and Dangers Associated with a Utility Scale Solar Photovoltaic Installation Including Battery Storage

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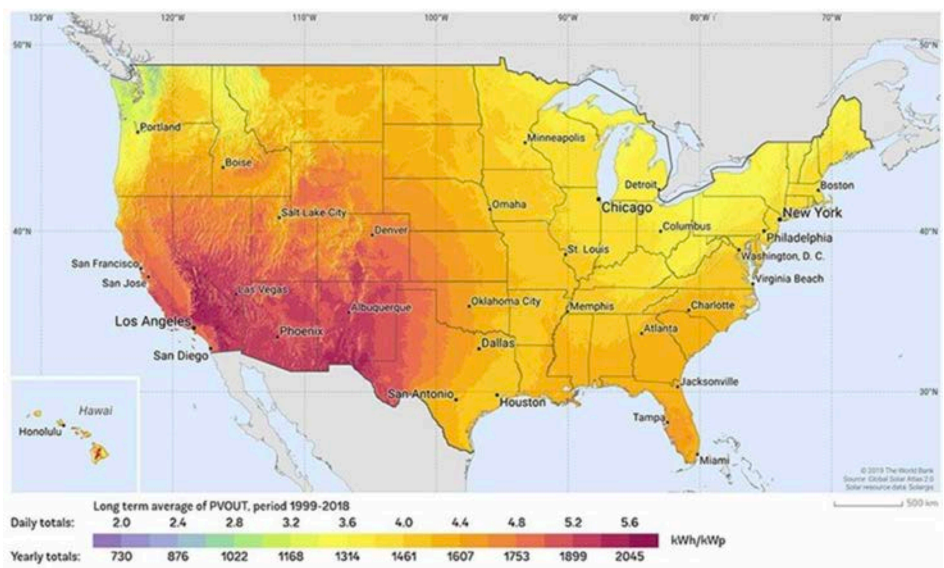
Photovoltaic Installation

The cost of photovoltaic (PV) electricity production has continued to decrease over time to the point now that in many locations it is the cheapest method for electrical power production. As with wind energy it is an intermittent energy source and so in many locations energy storage may be needed to provide power during times of no wind or solar production. Incorporation of storage is also dependent on the local grid balance of nuclear/fossil/hydro produced electricity and the local providers rate structure.



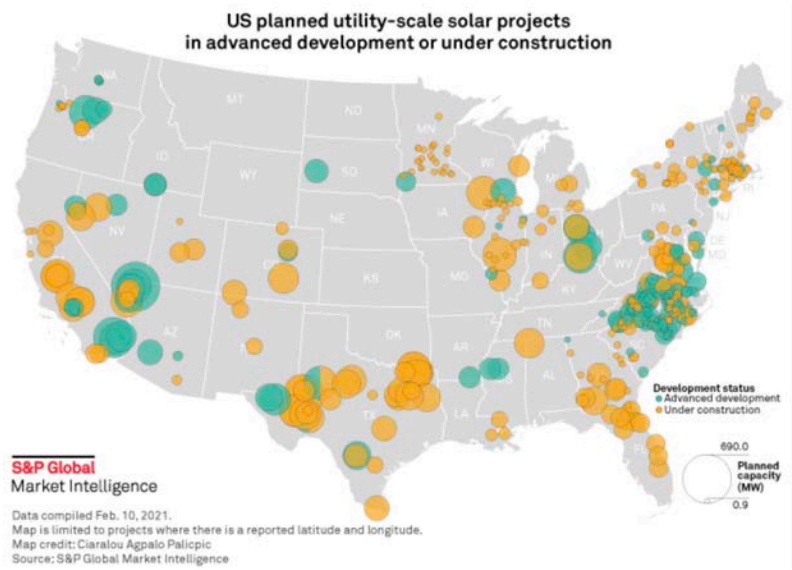
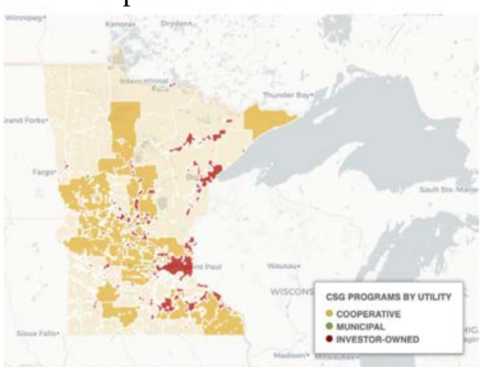


Figure 1 Johnson County has a quite favorable amount of solar PV potential. This potential is based on both latitude and cloud cover (above). The U.S. has a solar project pipeline of 96 GW through 2025 including 11,543 MW of projects under construction, 8,379 MW in advanced development, 68,374 MW in early development and 7,812 MW of announced projects (below).

Figure 1 shows that Johnson County has a favorable latitude with enough clear days to be a desirable location for implementing solar PV power production and that there is an increasing amount of solar PV development across the whole country. If there are high air conditioning loads during hot periods in the summer, solar PV is ideal for these peak loads given that it is providing the power exactly at that peak demand. Currently there are two main photovoltaic panel technologies that account for the large majority (>98%) of PV installations. These are crystalline silicon (Si) solar panels and thin film cadmium telluride (CdTe) panels. The silicon panels currently have 95% of the market and CdTe panels are primarily used in very hot desert locations since they do better than silicon in extremely hot environments and so I will assume that Johnson County installation will consist of Si solar panels. The silicon is nearly the same that is used in all computer and memory chips and is non-toxic and non-flammable. The individual cells that make up a panel are also weather sealed, and most panels have warranties for up to 30 years of operation with a stated minimal loss of production over that period. The only possible hazard is that if the cells are shattered, they can have sharp edges similar to glass but this is unlikely to be a problem since they are also sealed between an inert polymer film. For non-roof top installations, the posts and scaffolding materials are made mostly of either aluminum or steel and can be heavier or lighter duty depending on anticipated wind loads and are similar to metal posts for common fencing applications. Since Kansas is in "Tornado Alley" there would be considerable damage from a direct hit from even an EF1 tornado, but this would be true of virtually any energy infrastructure. Therefor these are common non-hazardous and recyclable materials. Most PV installations are fenced since there may be dangerous high voltages and to reduce theft of the panels where thieves would be particularly exposed to high voltages if they operated during daylight hours. The fences near population centers are usually common chain link fencing. This is not unusual since every community currently has high voltage transformers connected to the grid that are also protected by fencing albeit that the transformers usually occupy less space. A PV installation also needs inverters (needed to convert the DC power of solar panels into AC power for the grid) and transformers within the PV installation.

Photovoltaic installations have generally not been subject to fire hazards. A grass fire would be prevented by simple mowing periodically as is done for most community parks and boulevards. In Germany, that has the highest per capita installation of solar photovoltaics despite a rather northerly and cloudy location, has many PV installations on their farms and pastures where the support structures are higher to provide more space below and prevent any damage to the panels from large animals. The farmers love it since they get income from the power production and the cows and sheep love the shade and that the grass grows well in the shade. However recently there has been the introduction of the so-called bifacial solar modules that take advantage of reflected/diffuse light from the ground that then impinges on the back of the panels and so can increase the power output of the panels. This adds expense to the panels but the fact that the balance of systems (BOS) costs of a solar installation, things such as permitting, scaffolding, inverters etc., are now more than the price of the panels means that getting more output from the panels is worth a small increase in their cost. In this case having lighter ground such as sand or especially a white painted surface or concrete would significantly increase the power output of the solar facility without increasing its land area. The bifacial cells are recently increasing their market share and so should be considered when getting bids for the project. This is especially true where land values are high so that one gets more output per unit area.

In general community scale photovoltaic installations (a couple megawatts or less) are being installed all over the country. In particular Minnesota (a not particularly southerly or sunny location) partnering with Excel Energy has had an explosion of community solar installations due to government incentives and now has a total of 830 megawatts installed as of February 2022 with the first power produced only five years ago in January 2017 with about 425 separate installations with more being planned. This indicates that each installation averages about 2 megawatts (see: https://www.ag.state.mn.us/Consumer/Publications/CommunitySolarGardens.asp and https://ilsr.org/minnesotas-community-solar-program/). I have not heard of any serious problems associated with this program. Massachusetts, New York and Colorado have similar community solar programs with a total of about 2.2 gigawatts of US wide peak electricity production from state-tracked community solar. Note Massachusetts and New York also have considerably less solar PV potential than Eastern Kansas.



Left: A map of the distribution of community solar gardens in Minnesota. Right: a view of one such facility

Battery Storage

The daily, seasonal and cloud related intermittency of solar PV often makes the addition of battery storage to utility scale solar PV projects or off grid solar power installations. This adds considerable expense to the installation but can provide benefits especially if there is a large difference in the cost of peak electricity vs off peak electricity as determined by the local utilities.

The electrical grid operates with some sources that are considered baseline power that operate continuously 24/7. Currently these are mostly coal and nuclear plants and where available, hyrdo electric however hydro can have seasonal variations in output. In the future if current baseline power production sources, primarily coal and nuclear, are reduced or phased out there will be an increasing need for storage of intermittent wind and solar electricity. Battery storage is currently the most utilized electrical storage technology if pumping water uphill near a hydroelectric plant (currently the most cost-effective storage technology) and is not usually an option in flat areas such as Kansas. Electrolysis of water to produce hydrogen is a future technology for energy storage and decarbonization of other energy intensive technologies such as ammonia and steel is and is attracting billions of dollars of federal investment for development but is not currently a viable option. Therefor battery storage has been more common in utility scale PV installations. One example is the Slate Solar and Storage project a 300MW solar and 140.25-MW/561-MWh storage project located in Kings County, California. One needs to consider the local peak load and non-peak load electricity demands as well as the whether the utilities have different peak and non-peak rates to evaluate whether battery storage is worth the investment in a new PV installation. In addition, the battery capacity, in terms of both the hours of electrical energy storage and peak demand, needs to be matched with the load and time scale of demand when solar is reduced or not available. Often 4 hours of storage is all that is needed in order to accommodate the daily peak of electricity demand in the early evening when people return home and turn on their lights and appliances and would also be paying for peak electricity rates if the utility has such a rate plan. Longer storage times that require a greater investment with perhaps less usage would be needed for periods of extended clouds over multi-day long periods and is generally not cost effective unless there is limited or no access to the grid.

Currently there are three options for large scale battery storage, lithium batteries, lead acid batteries and redox flow batteries. Large scale lead acid battery storage is currently not being used partly due that most lead acid batteries do not tolerate many deep discharge cycles. Production of lithium batteries has been greatly increased due to both portable electronics and especially electric vehicles where the fact that lithium, being one of the lightest elements and having a high electrochemical potential, makes it attractive for these applications. This large scale-up of lithium battery production has also significantly reduced the cost of these batteries. The other competitive utility scale battery technology is the redox flow battery. A redox flow battery uses large tanks of water solutions of usually iron or vanadium salts that can store electrons when they are available by electrolysis at electrodes to produce electron rich and electron poor solutions during the charging cycle. The flow of the stored electron rich and poor solutions back across the electrodes recovers the electrochemical potential energy when needed. Since large tanks are used to store these solutions, they are not suited for portable applications but are very scalable since all you need is larger tanks to provide a longer discharge time. They are very safe since they are water-based electrolytes and so not flammable and iron and vanadium are not particularly toxic. Any mixing of the two solutions not through the battery would simply produce some hot electrolyte. Since the electrolytes are not nearly as energy dense as solid-state batteries the footprint of a large redox flow battery installation is quite a bit larger than for a solid-state battery of either lithium or lead acid. There are now a number of commercial suppliers of redox flow batteries at least one using cheaper and less toxic iron.

Typical redox flow batteries (in this case vanadium) available from 0.3 to 40 megawatt hours from stackable units with a claimed with a 2-12 hour discharge time and 25 year lifetime. Lithium batteries lose capacity over time and may only have up to 10 year lifetime with current technology.

Lithium batteries on the other hand do have the potential to produce fires if they are internally shorted or there is a short somewhere in the stack that is usually made up of many smaller batteries connected together. Some manufacturers have better safety records and different configurations of their batteries including the electrolyte and separators as well as composition of the anode and cathode electrodes that will result in more or less hazardous materials in case of a battery fire. A detailed discussion of the fire hazards associated with lithium batteries is available on the internet (https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/Hazardous-materials/rflithiumionbatterieshazard.ashx). There have been recalls of lithium batteries in electric cars due to fires in a very small percentage of the vehicles (in one case less than 1 in 5000) but electric vehicles are subject to more environmental stresses than stationary batteries. That said there have been several cases of battery fires in utility scale battery storage units that did produce hazardous products. Carbon monoxide is one of the most reported hazardous gas but it is also produced in most fires. The industry has learned from these incidents and large producers of utility scale lithium battery storage modules have extensive thermal monitoring of their battery stacks to detect any abnormal heating to then shut them down or isolate the section where the excess heating is occurring. Some lithium batteries chemistries for large stationary storage applications would not produce some of the hazardous products from combustion of their battery electrolytes but are a bit less energy dense than what is needed for electric vehicles where weight is a main issue.

The biggest early example of grid scale lithium battery storage is the Hornsdale Power Reserve in Australia installed by Tesla in 2017 with 129 megawatt hours of storage capacity and was expanded to 193 MWhr in 2020 (see figure below). The only problems that I could discover about this very large-scale project is that it didn't provide enough of the capacity needed during several major power outages. The Slate Solar and Storage project mentioned above is an even larger scale battery storage project integrated with a solar farm but is very new and so any long term safety concerns, if any, have not yet emerged.

The Hornsdale Power Reserve, a 100-megawatt battery storage facility in South Australia using Tesla lithium batteries.

In summary for this section, I would recommend a thorough study of the local energy demand and supply curves and utility and grid power availability and rates before investing in battery storage to go with the photovoltaic installation. Battery storage could easily be added later if needed since the cost of the batteries is still going down on a rather step learning curve and is projected to be about 2/3 of the present cost by 2025 in a recent study by the National Renewable energy Laboratory (https://www.nrel.gov/docs/fy21osti/79236.pdf).

In summary there are very few if any serious hazards associated with photovoltaic installations, a fact confirmed by the large number and scale of PV installations throughout the world and in the US operating for many years with no significant issues. There can be some disruptions of wildlife habitat and migration corridors but in the US these have been mostly mitigated by the environmental impact reviews that are required for permitting. Battery storage is now more commonly paired with PV installations and though there is a potential for fires with toxic by-products these have been rare and most lithium battery chemistries are safe and produce fewer if any toxic materials if they do fail. Redox flow battery storage is an even safer and potentially cost-effective alternative.