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A Brief Guide to On-Farm Solar

While, the agricultural sector was an early adopter of off-grid solar photovoltaic (PV) systems as a remote energy source, declining installation costs and various energy policies are now making net-metered systems more enticing for agricultural producers. According to the International Renewable Energy Agency (IRENA), the current levelized cost of energy (LCOE) for large-scale solar is around $0.068/kWh, compared to $0.378 in 2010. The cost fell 13.1% between 2018 and 2019 (IRENA, 2020). Considering these factors, many farms in Maryland are installing solar PV systems with an average projected breakeven timeframe of around 6.5 years (Gambone, 2021; SolarReviews, 2020).

Solar PV systems are generally compatible with many agricultural operations, either with rooftop installations on top of farm structures or with open land for ground-mounted systems. Many Maryland farmers support solar PV because it reduces the volatility of future energy costs, has low maintenance costs, and uses a free fuel resource. These attributes are particularly relevant for farmers with high electricity demands and utility rates.

The environmental impacts of solar PV are also substantial, particularly considering the average Maryland home consumes almost 12,000 kilowatt hours of electricity annually (EIA, 2019). Producing 50% of that demand with a solar PV system would offset the equivalent carbon dioxide emissions from over 85,000 pounds of coal burned, or about 26 tons of landfill waste, over a 20-year period based on calculations performed with the EPA's Greenhouse Gas Equivalencies Calculator (EPA, 2021). The total amount of water needed to generate solar electricity is also dramatically less than the manufacturing processes of more traditional electricity sources such as nuclear, natural gas, and coal-fired facilities.

Solar PV has many benefits, but investing in a system may not be for everyone. While the many benefits and

challenges of solar PV will need to be weighed on an individual and local basis, the continued growth of on-farm solar in Maryland is expected; particularly considering the declining installation costs and potential volatility in future electric rates.

The purpose of this report is to provide farmers with important information regarding the development of on-farm solar PV systems. We explore the opportunities, motivations, and benefits of installing solar PV for your home, farm or business. We describe the various types of systems currently available in the marketplace, as well as the financial, operational and environmental benefits of solar PV. This publication will help farmers understand the difference between grid-connected and off-grid systems, the difference between residential, commercial and utility-scale systems, and the common concerns associated with agricultural solar development in Maryland.

Diverse System Types are Compatible with Agriculture

Solar PV systems were once used almost solely for power in remote locations, with the agricultural sector being an early adopter of off-grid systems. Off-grid solar

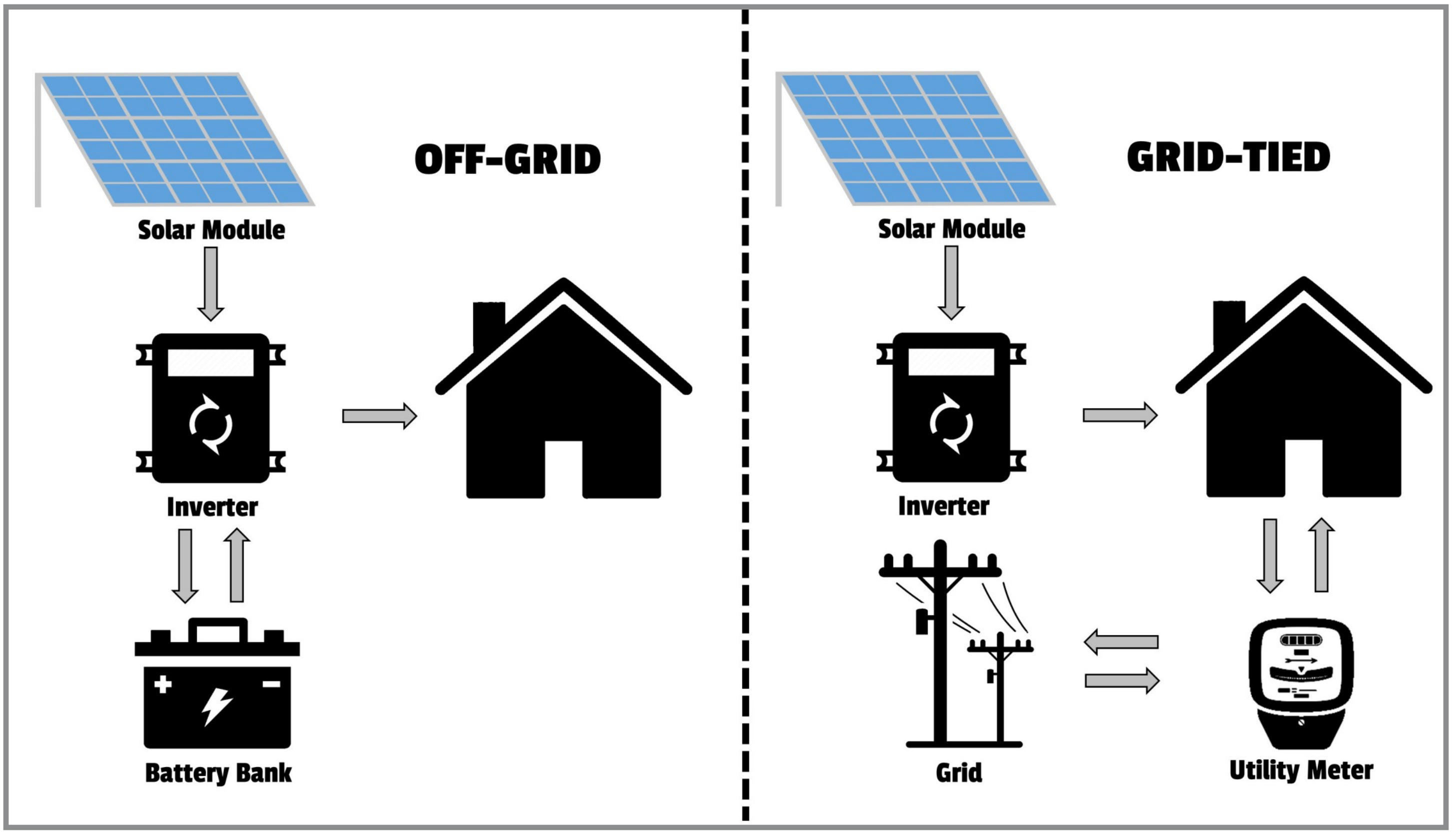

Figure 1. Differences between grid-tied and off-grid solar photovoltaic (PV) options

energy systems were not connected to the utility grid, whereas a grid-tied system is connected to the utility grid (Figure 1). The implementation of either an off-grid or grid-tied system will determine:

- how electricity is accessed;
- what equipment is needed for excess production;
- what happens when the utility grid goes down; and
- how electricity will be billed.

While residential, community, and utility grid-tied applications became more common in the early 2000's, widespread adoption remained somewhat limited within agricultural settings due to its high cost. In accordance with these market trends, solar PV installations are commonly classified as residential, commercial, or utility scale.

Residential systems are generally comprised of only a few solar panels and have system capacities of 5 to 20 kilowatts (kW). Commercial systems, which are often built by businesses on rooftops, parking canopies, or at ground level, generally range between 10 kilowatts (kW) and 2 megawatts (MW). Utility-scale systems are almost exclusively ground-mounted and have capacities exceeding 2 megawatts (MW). According to the Code of Maryland Regulations (Maryland PSC, 2019), the Public Service Commission (PSC) must approve applications to construct PV systems that are 2 MW and above.

In recent years, a combination of energy policy and significant price reductions in solar PV panels has made various sizes and capacities of solar electric systems more affordable to install on farms. Solar PV installed within an agricultural setting may fall into any of the three common classifications, depending on its system capacity.

In this document, '*agricultural solar*' or '*farm solar*' refer to smaller system sizes or capacities similar to residential or commercial solar. The energy produced by these agricultural or farm solar electric systems are generally used for various on-farm uses and applications. In contrast, the term '*solar farm*' refers to utility-scale systems in which the energy produced would predominately be transported and used off-site.

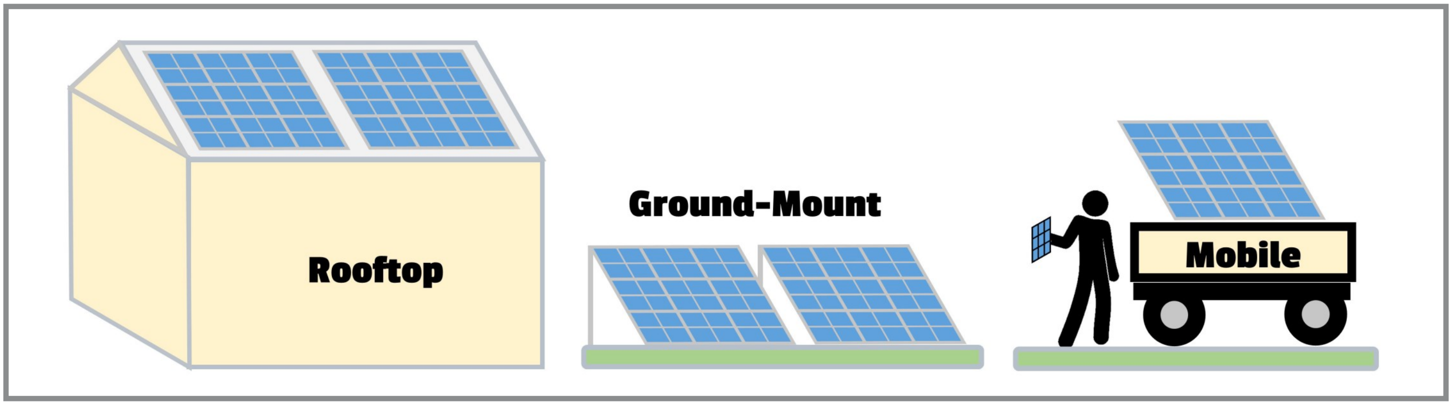

Figure 2. Broad categories of solar photovoltaic (PV) opportunities for installation.

Several Site Configurations Work with Agriculture

Rooftop Solar

Rooftop systems may be placed on the roofs of existing or newly-constructed buildings (Figure 2). These systems typically provide electricity to the same location as the system is installed, thereby reducing the site's utility load. The addition of a rooftop system may provide some structural benefit, potentially extending the lifespan of a roof. Solar PV can also serve as a structural component of new construction. These integrated systems are commonly referred to as Building Integrated Photovoltaics (BIPV) which generally have a strong aesthetic appeal and are architectural rather than simply utilitarian. They may provide multi-functional energy improvements for heating, cooling shade and noise because they're built into the structures. Common BIPV applications within Maryland include TESLA's Solar Roof (Crider, 2021; Lambert, 2021; Stoetzer, 2021) and GAF Energy's roof-integrated solar (Gorman, 2021; Jacoby, 2021), among other technologies. However, the higher cost and increased sophistication of BIPV make it less than ideal for most practical agricultural applications. More traditional applications of rooftop solar in agricultural settings include poultry housing, barns or workshops, and farm homes.

Ground-mounted Solar

Ground-mounted solar PV often has more time-intensive installation due to the more sophisticated and sizable mounting system. Permitting requirements for ground-mounted installations may also be different. While large ground-mounted installations may require a land use review, they're typically not subject to building or structural permits like rooftop installations. Local zoning laws could also impose different regulations for ground-mounted installations which could impact the permitting process, such as setback distances from neighboring properties and the height of the ground-mounted array. There are two basic types of ground-mounted solar panel systems:

- ***Standard ground mounts*** use metal framing driven into the ground to hold the solar panels up at a fixed angle.
- ***Simpler pole-mounted systems*** can support one or more solar panels on a single pole. Pole-mounted solar systems typically elevate panels higher off the ground than a standard ground-mounted system.

While some ground-mounted systems can be manually adjusted a few times a year to account for seasonal shifts of the Sun, others may incorporate more sophisticated tracking systems to automatically tilt the solar panels to capture the optimal amount of sunshine. Single-axis or dual-axis tracking systems can increase the production of solar panels by 25% or more (Kalogirou, 2014; Kelly and Gibson, 2009; 2011), but the sophistication of tracking technology comes at a higher cost and maintenance level.

Ground-mounted systems are a good fit for many remote applications on the farm such as well pumps and electric fencing. Ground-mounted systems also are a good choice when adequate land is available for solar installation. While innovative farming operations may incorporate solar PV and agricultural production on the same land, most ground-mounted applications are installed on unused land. Ground-mounted systems also are suitable for large utility-scale installations in brownfields or other uninhabitable sites.

Mobile Solar

Mobile solar systems are designed for portability. Mobile systems are replacing the use of diesel generators in many applications since the fuel source for solar PV does not need to be manually replenished as in systems using fossil fuels. Micro systems (around 20 to 200 watts) are common in outdoor recreational uses such as charging a mobile phone or GPS device in the field. Larger mobile systems, or deployable solar, are more moderately sized (around 1 to 3 kilowatts) and are used in construction, military applications, and disaster relief when the grid is down. Inverters are rarely needed with mobile systems since they are often connected to a battery for energy storage. A common application of mobile solar PV on farms includes relocatable livestock watering systems for grazing management.

Demand for Solar PV Increasing for Many Reasons

Maryland's Renewable Portfolio Standard (RPS) requires 14.5% of an electricity supplier's retail sales to come from solar power by 2030. As of May 2021, the solar PV industry in Maryland employed 4,565 individuals in jobs directly related to project development, manufacturing, installation, and sales of solar energy systems (SEIA, 2020). This represents a 52% increase over 2014 employment (SEIA, 2021a), with further growth in the solar workforce expected.

The demand for solar PV is growing in Maryland for many reasons, including declines in installation costs and the goal of reducing monthly energy bills. Solar PV is compatible with many agricultural operations since farmers generally have high electricity demands, as well as access to open land or roof space to host a solar installation. Solar PV can also be considered a "set-and-forget" solution with no moving parts and minimal maintenance. Many users appreciate an understanding of where their electricity comes from, particularly renewable, local, or alternative generating resources. Others may value independence or self-sufficiency in their electrical use.

Economic Factors

Considering the free fuel resource (i.e., sunlight), low maintenance costs, and positive environmental attributes, many farms in Maryland are installing solar PV systems with an average Return on Investment (ROI) of 19.7% and an average projected breakeven time of 6.5 years (Pickerel, 2019). While installation and equipment costs have fallen in recent years, solar PV may still represent a significant investment hurdle for many farming operations in Maryland due to the up-front capital or financing required.

Long-term savings can be achieved as more electricity is generated from the solar installation, thereby lowering monthly electric bills. Installing solar PV can also help protect against rising electric rates. To achieve positive financial returns, the monthly electric bill savings must exceed the system installation and maintenance costs. Financial returns from solar PV will be greater when kilowatt-hour (kWh) prices are high or when energy prices are expected to escalate rapidly. Solar PV, therefore, may play an important role in reducing energy cost volatility, particularly after the initial investment is recovered.

The Investment Tax Credit (ITC) currently allows recovery of 26% of the solar PV system's cost within the first year. Farms and other businesses can further recover installation costs by taking advantage of 100% accelerated depreciation, as well as the U.S. Department of Agriculture's REAP Grant (USDA, 2020) and others. See the Database of State Incentives for Renewables & Efficiency (DSIRE, 2021) for more information.

As with any investment, a good economic analysis weighs the potential savings against the associated maintenance costs, insurance, and taxes. If all of these economic criteria are met, the monthly electricity savings may allow for reinvestment into different aspects of the farm or business.

While various financial incentives can improve the investment performance of a solar electric system, specific financing options are dependent on who owns the system. Purchasing a PV system on a cash- or loan-basis will allow the customer to claim any relevant tax benefits as the owner of the system. System owners will also benefit from any savings they may experience on their electrical utility bill. Various loan options are available in Maryland, including home equity loans, solar loans from a credit union, and loans from a solar company among others.

Other financing options come in the form of third-party ownerships, including leases and power purchase agreements (PPAs). A solar lease generally involves a fixed monthly payment to owner of the solar electric system over the term of the lease, which is typically 20 years. This arrangement is cost-effective when the value of the electricity produced from the system is greater than the cost of the lease. A PPA is another financing arrangement in which the customer pays only for the electricity they use.

As of September 2021, the solar Income Tax Credit (ITC) provides a 26 percent tax credit to the owner(s) of residential and commercial systems installed in 2020-2022. The ITC is scheduled to decline in coming years, with a 22 percent credit slated for systems installed in 2023. While the commercial ITC drops to 10 percent for systems installed in 2024 or thereafter, the residential tax credit expires starting in 2024 unless congress renews it. Typically, a commercial PV system that is eligible for the ITC can also use an accelerated depreciation corporate deduction. More information on the solar ITC can be found on the U.S. Department of Energy website (DOE, 2021).

There are many incentives available for solar electric systems in Maryland, including the Commercial and Residential Clean Energy Rebate programs offered by the Maryland Energy Administration. More information on current incentives offered through the Maryland Energy Administration can be found on their website (MEA, 2021). Solar Renewable Energy Certificates (SRECs) are a performance-based incentive that allows the owner of a solar electric system to earn additional income from solar electricity generation. SRECs are created whenever solar panels generate electricity. One megawatt-hour (MWh) of solar electric generation equals one SREC. SRECs initially belong to the owner of the system; giving them the legal right to use or sell the energy to someone else.

Net metering is an electricity billing arrangement that credits solar customers for the electricity they add to the electricity grid beyond the amount they consume during a particular billing period. The customer's electric bill is credited for the power produced by their solar array as it flows to the electric utility grid. This credit is cashed in when the customer uses energy from the grid. Accounting normally occurs on a monthly and a yearly basis.

Environmental Drivers

Maryland's electricity comes from a diverse energy market including power plants which burn fossil fuels. Burning fossil fuels contribute to increased levels of air pollution and greenhouse gas (GHG) emissions such as carbon dioxide. GHG emissions are reduced by generating less electricity from fossil fuels. GHG emissions are the main cause of man-made climate change. Solar PV produces less life-cycle GHG emissions than conventional fossil fuel energy sources (NREL, 2013). While some GHG emissions may be produced during the manufacturing and recycling of solar electric systems, there are no GHG emissions and minimal environmental impacts with electricity generation from solar PV. Many businesses have also imposed operational goals to reduce their emissions and carbon footprint. Solar PV and other renewable energy systems are often implemented in order to meet these environmental goals. A business may further benefit from the potential marketing and awareness that green energy initiatives like solar PV can present to the public.

Self-Sufficiency

Solar PV can help farms and businesses become more energy independent or self-sufficient as they produce their own power. A solar PV system can enable farms and other businesses to continue operations when the utility grid goes down. Others may install solar PV because they are far from the power grid.

In any case, battery storage would be required to become completely independent of the grid. Off-grid systems will require battery storage for nighttime and inclement weather, while grid-tied systems will not function during an electricity outage due to safety regulations. For these reasons, farms may supplement their solar electric power with a battery storage option.

Solar PV can Present Challenges

Solar PV accounts for 93% of farms with on-farm renewable energy production (USDA, 2011). Challenges, however, include the need for backup power, available dedicated space, and proper permitting, as well as environmental and land use considerations.

Backup Power

Solar PV will generate electricity as long as the Sun is shining, but the system will produce little to no power on cloudy days or at night. During periods of low solar radiation, electricity is pulled from the grid rather than the solar panels. Installation of a rapid shutdown component is required by law for any grid-tied system to keep electricity from back-feeding into the grid. This safety regulation protects those who may be working on the electric lines. In the event of a blackout, the system will automatically shut-off to prevent energy being sent onto the power lines that could be damaged. In these situations, the power from a grid-tied system will be unusable without implementing some form of energy storage (e.g., battery) or otherwise disconnecting the system from the grid. An off-grid system (or a system that operates temporarily during grid outages) will require the additional expense and upkeep of batteries to store energy and deliver it when needed.

Space Requirements

Depending on the type of installation, roof or open ground space is required to install solar PV. Local ordinances and building codes may restrict the design and installation of systems. Although solar PV systems may utilize less land than a residential or retail development with similar energy capacity, agricultural solar may still require a considerable amount of farmland, typically five to eight acres of solar panels to generate one megawatt (MW) of electricity.

With the installed solar capacity in the U. S. increasing by over 10 GW annually (SEIA, 2021b), interest is growing in the use of undeveloped tracts of land to support solar installations. While much of the land that meets the requirements for solar is arable farmland, the amount of land that could be support agricultural production and solar energy is physically limited. For this reason, research and innovation is needed to combine solar arrays with active agriculture.

Agrivoltaics, or dual-use solar, combines agricultural production with solar photovoltaics (PV). With agrivoltaics, solar modules are typically raised 5-10 feet above the ground where plants or livestock are managed. If your crops require large equipment that needs to fit between the solar panel systems, you may need to limit your arrays to certain areas on your farm. Solar arrays are typically spaced a few feet apart to provide additional sunlight and space for farming equipment. Depending on the placement, type of panels used, and quality of the installation, solar systems can also impact the curb appeal of your farm or business.

Farming Operations

Agrivoltaics are compatible with many farming operations, including grazing pastures for sheep, pollinator habitats, vineyards, or with many other crops requiring partial sunlight (e.g., lettuce, tomato, corn). Crops requiring full sunlight (e.g., wheat) typically won't grow under the shade of solar modules.

Solar modules can improve the efficiency of photosynthesis, maintain soil moisture, and regulate temperature of some plants. With agrivoltaics, the strategic placement of solar modules can optimize the amount of sunlight reaching plants below. Some studies have shown that plants in agrivoltaic systems can produce more fruit and larger leaves to increase the surface area for photosynthesis (Barron-Gafford et al., 2019). With optimal agrivoltaic lighting, plants can reach their light saturation point without undergoing additional light stress. Any excess light will only dry the soil and require more water use.

Agrivoltaics can also create micro-climates with fewer temperature fluctuations between day and night. The efficiency of solar modules can be improved as they're cooled from plant evapotranspiration (when plants transfer water from soil to air). In addition to keeping plants relatively cool during the day, solar modules can also help keep plants warm at night.

Agrivoltaics have also been shown to work well with animals such as sheep because they generally don't disturb the solar modules and wiring (you can also install fencing to further protect your solar systems); the sheep can even use the solar modules for shade. However, cattle are prone to disturbing the solar systems and will likely not be able to safely roam among them.

Environment and Land Use

Depending on the design, size, and location of the solar electric system, the installation will typically undergo rigorous reviews and permitting from federal, state, and local authorities to ensure minimal impact to the environment and wildlife (Fraas et al., 2021). Larger, utility-scale installations require more extensive planning and studies during the design, permitting and commissioning stages. While solar panels are generally warranted for 25-years, their useful lifespan may be much longer before they are decommissioned.

Solar panels can be recycled or landfilled at the end of their useable life, while the land on which the system was built can be restored to its original use. Some Maryland farmers and landowners are leasing their land for solar development – as opposed to the land being permanently lost to commercial or residential development. Leasing can serve as an important "cash crop." Lease payments can help farmers retain ownership and the long-term usability of their land.

Permitting

Most solar installations in Maryland require various inspections and permits before the project can be developed. This may include county building and electrical permits, as well as city permits. An interconnection agreement and certificate of completion from the local electric is also required for grid-tied systems. Specific permitting requirements may vary across the state, with each county having its own solar guidelines. In Montgomery County, for example, an application must include:

- A copy of the solar panels' designs and specifications;
- Scaled blueprints of the installation; and
- Detailed schematics of electrical components, wire identifications, sizing, and grounding

County permits may also require a landscaping plan to minimize the project's environmental impact through various measures, including the replacement of plant materials. Commercial and utility-scale systems may pose unique permitting challenges related to grid stability and capacity. Most solar facilities in Maryland that generate over 2 megawatts (MW) of electricity must also apply for a Certificate of Public Convenience and Necessity (CPCN) from the Maryland Public Service Commission (PSC) before construction. Depending on the system design, and the requirements imposed by the local government, the permitting process may require significant time and cost. In August 2021, Montgomery County became one of the first jurisdictions in the U.S. to pilot Solar Automated Permit Processing (SolarAPP+) to reduce the review and processing time for solar installations (Montgomery County Government, 2021).

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