# Prime Locations for Nine Megawatts of Solar Energy on Ohio State's Main Campus

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THE OHIO STATE UNIVERSITY

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## Executive Summary

Trying to limit and/or reverse the effects of climate change is an important issue around the world. One important strategy for reducing CO2 emissions is by expanding the use of solar energy. The Ohio State University has an excellent opportunity to not only substantially increase its use of solar power, but to also set an example for universities around the country. Through this research project, we have identified 30 sites, all of which are on the main campus, that would all be ideal for solar panel installations.

The goal of this research was to provide The Ohio State University with the best locations across campus that could house enough solar panels to generate 9 megawatts (MW) of electricity. Adding those 9 MW to what the university already has installed, or plans to install,

would bring the total to 10 MW. In order to develop a list of best locations, we focused our research on three objectives:

1. **Level of Solar Irradiance** - Our first research topic was to obtain information on the levels of solar irradiance on campus in order to highlight areas with ample amounts of sunlight.
2. **Determine Off-Limit Sites** - Our second research objective was to look at the university's Framework 2.0 document in order to learn which potential ground mount sites would be off limits due to future building plans in the area.
3. **Evaluate Surface Areas of Sites** - Our final objective was to gather and interpret GIS information that allowed us to measure the surface areas of roofs and open ground space and select/highlight desired building locations (while deleting the undesirable locations). We used this information to create an easy-to-read visual of outcomes. Notably large rooftop sites are preferable to smaller ones owing to economy-of-scale in installation costs.

Using the above criteria and research, we determined that there were 30 highest priority sites located on campus that can house enough solar panels to generate more than the desired amount of 9 MW. There are other locations on campus that would also be suitable for solar panel installation if the university wanted to expand in the future, but we focused on the highest value sites in order to meet the goal of 9 MW. The 30 sites consist of 27 roof mount sites, two ground mount sites, and one parking lot canopy site. Our research also revealed that with a total of 10 MW of solar generation on campus, The Ohio State University would become one of the largest solar energy users among other universities in the country.

We believe that implementing solar panels in the locations that we have selected will be very beneficial to the university. Ohio State has the opportunity to become a best-in-class example for universities to emulate when it comes to using solar power to help combat climate change. Implementing solar on campus will also provide an excellent learning example for students. Students can read meters for the panels placed in buildings and dorms to see the amount of electricity being produced by the solar panels. CFAES (College of Food, Agricultural, and Environmental Sciences) and other students can see (in relatively close proximity) how the panels work, and they can get a chance to learn about planting pollinator plants in conjunction with the ground mounted panels.

Next steps for Ohio State solar should include implementing a timeline of when the panels can be installed and determining if it is desirable and feasible to add even more panels across campus.

# Introduction

The Ohio State Sustainability Institute in conjunction with ENGIE, the energy provider of Ohio State, has a goal of installing 10 MW of solar energy on Ohio State's main campus. As of now, Ohio State already has plans to construct a 1MW solar project on campus at the Woody Hayes Athletic Center. Implementing large-scale solar projects in urban settings can be very complex. The primary challenge and goal involved in this solar project was finding the most suitable locations to place enough solar arrays to achieve 9 MW of capacity, as described in the request for proposal documentation.

The motivation for this research is not solely to find ideal locations, but also to establish Ohio State as a leader in on-campus solar among the Big 10 and other universities across the nation. While 10 MW of energy is relatively small in the big-picture of Ohio State's total energy usage, the installation of this project will show that the university places an importance on environmental sustainability. The successful completion of this project would aid in developing future renewable energy projects at Ohio State. Additionally, this project would create learning opportunities for students and for the community regarding the role that solar energy can have in urban settings, contradicting the common perception that solar energy is only harvested in large fields in rural areas. Finally, the transition to solar power will result in a decrease of the university's scope 2 carbon emissions due to a transition from traditional energy sources to solar (The Ohio State University, 2020). Our team established the following objectives for this project:

- Research solar irradiance levels on campus to determine areas of ample sunlight
- Research and collect information pertaining to Ohio State's "Framework 2.0" documentation, as this will allow us to determine future building locations and other changes to campus layout and land use
- Conduct a benchmarking analysis of solar projects at other Big 10 and similarly sized universities to determine best practices for on-campus solar installation
- Gather and interpret GIS data in order to find/select desired building locations

From these objectives and the concurring research conducted, our team located 30 viable sites for solar panel installations. While it was determined that 9MW of solar power would require 545,455 sq. ft. of space, these 30 sites resulted in 572,000 sq. ft. of viable space. Our team determined it was necessary to find more space than what is needed because it is possible that some sites may be deemed not suitable in the future. We do not expect any reclassification of sites to be significant enough to offset the 4.6% cushion we have developed. The goal would still be met even if 26,545 sq. ft. were declared ineligible.

# Methods

Solar generation on campus is in the early stages of planning. This presented the challenge of not having a significant amount of related information already developed and available. Fortunately, we had an excellent project sponsor and contact, Mike Shelton, the Associate Director at Ohio State's Sustainability Institute. He played an important role in helping us narrow our scope to site suitability, provided significant portions of data that we needed, and gave us guidance as to how much time should be spent benchmarking with other colleges while determining best practices.

Initially, we considered calculating figures related to economics such as anticipated costs, return on investment, and the Production Tax Credit (PTC). After communicating with representatives of Ohio State and ENGIE, it became clear that our research should be focused mainly toward implementation and discovering whether a location is physically capable of harnessing energy. The term "capacity factor" is the ratio between the nameplate capacity of an installation and the actual amount of energy generated. It is a critical measure of the economics of energy production by a solar array. (e.g. all else being equal a solar array that has twice the capacity factor of another facility has one-half the costs of electricity in $/kwh). Every location is unique, therefore the exact capacity factor for Ohio State and individual sites on campus is not yet precisely defined. Capacity factors will only become better known when installations have accrued at least a full year's worth of operating data. Trial installations at several sites could allow this data to be obtained allowing the relative economics to be better understood before constructing large-scale arrays.

We also learned that Ohio State is a tax-exempt organization and would not qualify for any Production Tax Credits. Further, even if a third party could qualify for the PTC (and pass these savings on to Ohio State in the purchase cost) the time frame for starting construction likely means that many of these benefits will be phased out. As of now, the project is not scheduled to be completed until around the year 2025. While this may seem like a slow-moving project, the timeframe is actually fast when compared to many other capital projects on Ohio State's campus that can take up to a decade to complete.

One of the first tasks we needed to accomplish was to learn the details about the solar panel model that Ohio State has chosen to utilize. Specifications related to the dimensions and power rating allowed us to determine the square footage required for 9 MW. This topic will be discussed in greater detail later in the report.

Next, the greatest challenge was to find available space on campus to install solar arrays across the calculated 545,455 sq. ft. of property. With practically all ground cover designated for future development, it became clear that rooftops would be the most effective way to reach this capacity. By using Ohio State's GIS map of campus, we were able to identify 27 buildings and 3 ground level locations. The software provided us with the ability to determine specific square footages by drawing desired outlines on top of satellite images. With the help of Tony Gillund, the Sustainability Manager for Ohio State's Facilities Operations and Development (FOD), we were able to obtain blueprints and ensure that all of these rooftops were structurally sound enough to hold the weight of the panels, the required mounting infrastructure, and any potential snowfall that could accumulate.

Buildings and dormitories located along the North Residential district proved to be well-suited for solar because many of them were recently constructed. Their rooftops are new, have structural integrity, and have large amounts of open space due to many heating, ventilation, and air conditioning (HVAC) units being installed inside the buildings. Athletic buildings also visibly presented an abundance of rooftop space, and large facilities such as these made it possible to fulfill almost half of the demand for space. The remaining solar square footage came from an assortment of smaller locations. Once we determined our list of sites, we returned to the GIS software to create a color-coded map of the selected buildings and the results. We also used the data we collected to compile a table of sites that faced immediate disqualification, as well as a table of sites that are not currently a first priority but could prove to be desirable if the university decides to expand its capacity beyond 10 MW.

## Benchmarking

We decided that the best schools to benchmark against were other universities in the Big Ten athletic conference. The Big Ten is the Midwest's largest collegiate sports conference and contains 14 schools. Benchmarking versus other Big Ten schools makes sense in that it provides comparable data from a number of other large universities which are all located along the same relative latitude (an important consideration for solar). At first, we tried contacting staff and students from the universities to see what types of solar projects may be operating, but contacts were difficult to reach. Fortunately, most universities with solar on campus have generally posted about it on their websites. Based on this, there are five schools, including Ohio State, that have solar in some capacity. Of these five, Ohio State would be the largest on-campus solar energy producer with 10 MW.

Benchmarking was performed as a means of discovering how universities comparable to Ohio State rank in their total solar energy capacity. The 14 universities in the Big Ten athletic conference were analyzed because they all have similar enrollments averaging between 40,000 to 60,000 students, most are public, state universities, and all have similar degrees of latitude as

Ohio State (Collegexpress, 2020). While benchmarking is not a required step in the installation of solar energy, it does serve as an important tool in discovering new possible solar innovations.

The first action we took to benchmark was to discover how many megawatts each university is producing and the types of solar arrays and installations. We reached out to five universities and received a response only from Northwestern University. Therefore, most data were found from online sources. We discovered that four other Big Ten universities have solar energy projects, those being: Michigan State University, Northwestern University, Rutgers University, and the University of Maryland. Both Rutgers and Michigan State operate and maintain solar farms that exist off-campus and provide 17 MW and 20 MW, respectively (Rutgers University, 2008). These are expansive farms that are over 100 acres in size and contain nearly 100,000 square feet of panel space. Michigan State's project has not yet been fully constructed but will eventually produce enough electricity to power 4,400 homes (Michigan State University, n.d.). Northwestern and Maryland are much smaller in scope, and each project only provides power to a few select buildings. Northwestern's solar array sits on top of the McCormick School of Engineering and provides approximately 2 MW of solar energy to that building (Solar Power Authority, 2020). The University of Maryland also has 2 MW that they produce on top of three parking garages and transmit to nearby classrooms (University of Maryland, n.d.). Ohio State will be using a combination of practices and installations that are similar to rooftop arrays at Northwestern and parking canopies at the University of Maryland.

## Key Findings

One of the most critical pieces of data required to perform this research included information regarding the photovoltaic (PV) panels Ohio State will utilize in the construction of the arrays. The model's specifications ultimately determined how many square feet of space were required. This is due to the fact that the higher the efficiency of the panels, the less space that will be necessary to attain the full 10 MW the university desires. There are three basic types of PV technology that exist: monocrystalline, polycrystalline, and thin film technologies. Monocrystalline is known for being the oldest and most developed out of the three varieties (Sendy, 2020). For the 1 MW already planned to be installed on the Woody Hayes Athletic Center, the Trina Solar TSM-345DD14A(II) 345W monocrystalline silicon model is slated to be the final choice (See Figure 1 below).

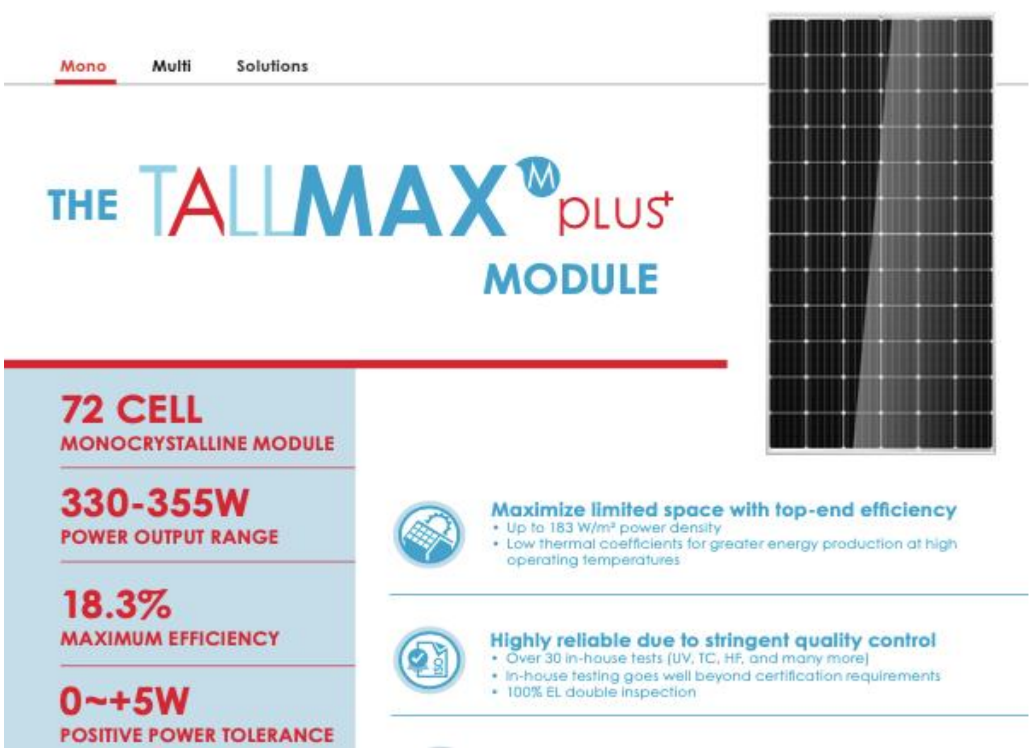


*Figure 1: PV model selected for installation (Trina Solar, 2016)*

After communicating with Mike Shelton, we were advised that this will be the same model chosen for all subsequent arrays. Data related to this panel can be found on the manufacturer data sheet on Trina Solar's website (Trina Solar, 2016). Some of the most important information from this sheet pertains to panel dimensions, weight, and the power rating. The number of square feet required (545,455 sq. ft.) was determined by dividing the total power desired (9 MW) by the power rating of one panel (16.5 W/sq. ft.). Then, by dividing the total square footage by each panels' dimensions (20.91 sq. ft.), the result is that 26,086 panels will be required to obtain 9 MW of total capacity. The model has a 25-year warranty; therefore, it is expected that each installation will remain in place for at least the length of this period. The angle of solar panels should always be adjusted according to the latitude of a location. Panels installed in lower latitudes do not need as large of an angle to optimize their collection, while higher latitudes need to be angled more so that they face the general direction of the sun. In the northern hemisphere, panels need to be southward facing, and in the southern hemisphere they need to be angled north.  With this data, we were able to determine whether a certain location/building was a feasible option.

Table 1 below is a list of all the potential solar array sites on the main campus in Columbus, Ohio. It can be broken down into two categories: rooftop and ground installations. We placed a higher priority on finding sites that would be located on rooftops for several reasons. Mainly, rooftop space would not encroach on land that could one day be used for future buildings or other development projects. Rooftops are essentially areas that are not being utilized and solar installations provide a good opportunity to change that. Also, they are less visible on rooftops, therefore, barriers due to aesthetics could be avoided.

**Table 1. Details about available square footage and structural integrity at potential sites**

| Potential Solar Array Sites at The Ohio State University | | |
|---|---|---|
| **Rooftop Installations** | | |
| **Site Name** | **Potential Available Area (sq. ft.)** | **Design Live Load (lbs. / sq. ft.)** |
| 4-H Building | 4,700 | 20 |
| 600-680 Ackerman Road | 46,000 | 20 |
| Agricultural Engineering Building | 47,000 | 25 |
| Blackburn House | 5,500 | 20 |
| Bowen House | 3,500 | 20 |
| Busch House | 5,000 | 20 |
| Center for Automotive Research (CAR) | 8,000 | N/A |
| Chemical & Biomolecular Engineering & Chemistry (CBEC) | 7,300 | N/A |
| Curl Market | 3,000 | 20 |
| Drinko Hall | 23,000 | 25 |
| Houston House | 7,000 | 20 |
| Jameson Crane Sports Medicine Institute | 7,500 | 25 |
| Kottman Hall | 10,500 | 25 |
| Library Book Depository/Archives | 17,000 | 25 |
| North Recreation Center | 4,800 | 20 |
| Nosker House | 7,200 | 20 |
| Physical Activity and Educational Services (PAES) | 14,000 | N/A |
| Physics Research Building | 22,300 | 25 |
| Raney House | 5,500 | 20 |
| Recreation and Physical Activity Center (RPAC) | 18,500 | 25 |
| Schottenstein Center | 45,600 | 20 |
| Schumaker Student-Athlete Development Complex | 30,000 | 20 |
| Scott House | 5,000 | 20 |
| Student Academic Services | 10,000 | 20 |
| Torres House | 5,000 | 20 |
| UniPrint on Kenny Rd. | 19,700 | N/A |
| Veterinary Hospital | 8,400 | N/A |
| **Rooftop Area Total** | **391,000** | |
| **Ground Installations** | | |
| **Site Name** | **Potential Available Area (sq. ft.)** | |
| Ackerman Road Parking Lot | 41,000 | |
| Schottenstein South Lawn | 50,000 | |
| Wastewater Drainage Site | 90,000 | |
| **Ground Area Total** | **181,000** | |
| **Final Total** | **572,000** | |

Acceptable ground locations on the main campus are quite rare, so we decided to choose them only if we felt it was necessary in order to reach the total square footage goal. Sites such as the Oval, South Oval, Waterman Farms, and Carmack parking lots were all large portions of land that were excluded as options due to historical reasons or current/future development plans. These disqualified sites are visible on our GIS map (See Figure 2 below).

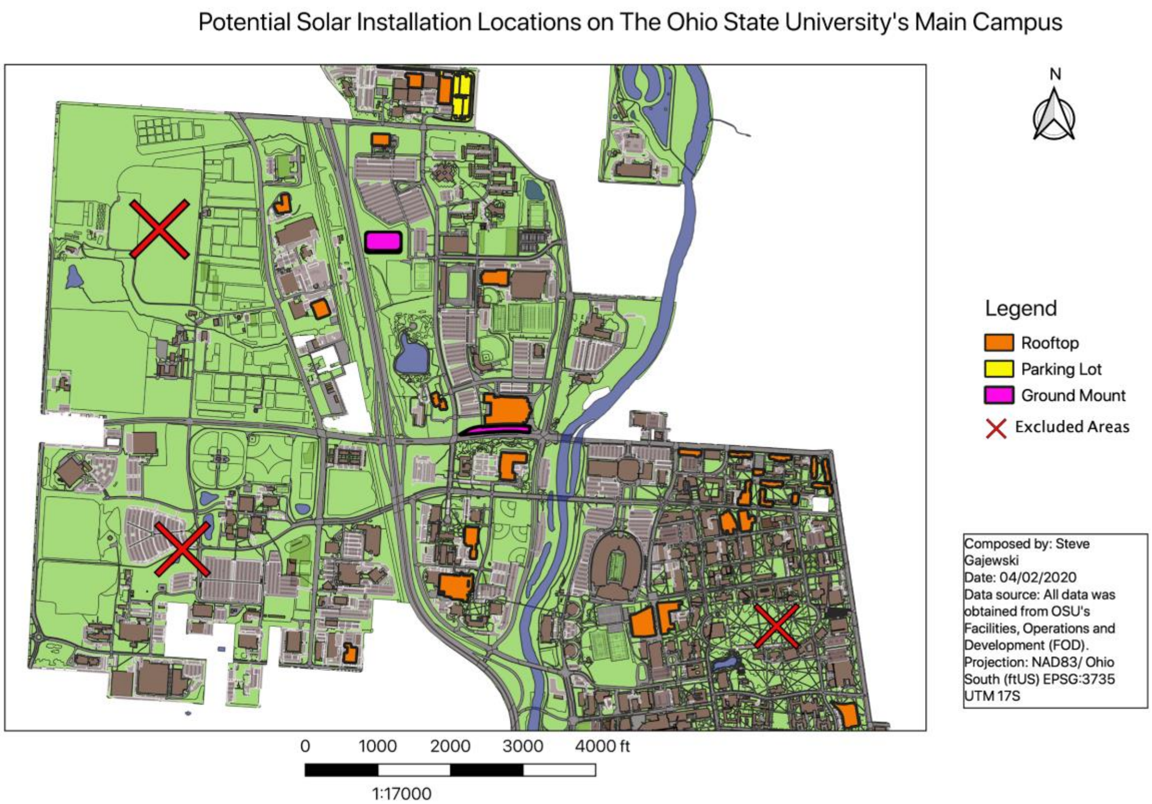


*Figure 2: GIS map indicating chosen and excluded site locations*

The three priority ground locations include the Ackerman Road parking lot, the south lawn of the Schottenstein Center, and a wastewater drainage site. Only one parking lot was chosen due to the fact that these can often be the most expensive installations and are highly visible. This parking lot was one of the last locations we decided to include. Examples of the differences between rooftop, parking lot, and ground mounted installations can be viewed in Figures 3-5 in the Appendix.

Ohio State has an excellent GIS tool on its website which allowed us to view satellite images of the campus and draw shapes on the map to find out the square footages of particular areas (GIS Maps, n.d.). This was a very important step due to the fact that rooftops often have infrastructure on them that would restrict installations from being distributed throughout the entire space. Ground installations must also take nearby trees and buildings into account. Impediments such as these can cast shadows on the surfaces of the panels, and although they would still produce electricity, their output could be reduced significantly. Our priority sites account for this factor, and the proposed location at the wastewater drainage site also maintains an appropriate distance away from the waterline (See Figure 6 below). We believe that the square footages we attributed to every location give a realistic and fair approximation of the total viable area available.

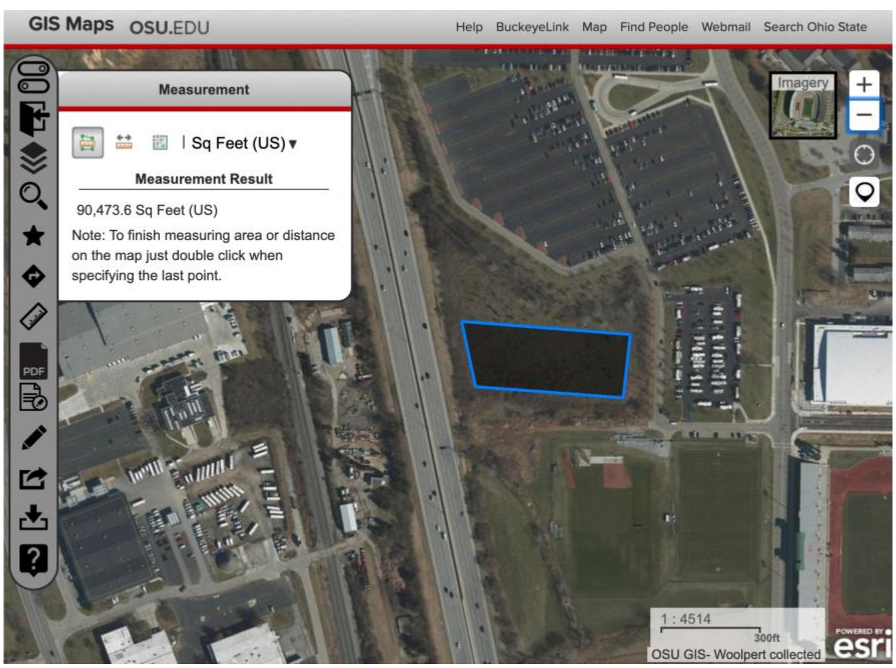


*Figure 6: Screenshot illustrating the optimal location for ground mounted PV panels within the wastewater drainage site (GIS Maps, n.d.)*

One of the main objectives we consistently held throughout the duration of this research was to find locations that offered the largest amounts of square footage. We strongly believe that solar energy is much more likely to be adopted at Ohio State if it is able to reach 10 MW using as few individual sites as possible. Some of the first sites we deemed viable were the Agricultural Engineering Building (47,000 sq. ft.), the Ackerman Road Buildings 600-680 (46,000 sq. ft.), the Schottenstein Center (45,600 sq. ft.), the Schumaker Student-Athlete Development Complex (30,000 sq. ft.), Drinko Hall (23,000 sq. ft.), the Physics Research Building (22,300 sq. ft.), as well as a few other large buildings.

We then found that looking toward the North Residential buildings could provide significant space. Though these buildings are not nearly as large as others, there is a significant number of them. A dozen or so buildings, each with approximately 5,000 sq. ft., provides an attractive installation opportunity. The North Residential district can be thought of as one large solar development itself.

We reviewed this list with Caitlin Holley (Project Manager at ENGIE), Tony Gillund, and Mike Shelton. After discussions with these representatives it was concluded that these are all currently acceptable locations until otherwise proven to be disqualified for some reason in the future. Our next step was to obtain all of the building blueprints and determine if the rooftops had the structural integrity to support the load of the equipment. Every building that listed a Design Live Load for its rooftop was rated 20-25 pounds per sq. ft., which far exceeds the load that the equipment would have (FOD, The Ohio State University, 2016). Each panel weighs 57.3 pounds and has the dimensions of 20.908 sq. ft., which produces a result of 2.74 lbs./sq. ft. (Trina Solar, 2016). The mounting infrastructure is documented to be another 2-3 lbs./sq. ft., meaning that an overall 4-5 lbs./sq. ft. can be expected for each installation (Simone, 2013).

After several discussions with Mike Shelton and Caitlin Holley, we also determined which sites would face immediate disqualification. Roofs that are old, slated, expected to be torn down or replaced within the next 25 years, or ones that have historical value all fit the criteria for why a site was disqualified. These locations are displayed in Table 2 below.

**Table 2. List of disqualified sites and the reasoning behind the decisions**

| Disqualified Sites for Solar Arrays | |
|---|---|
| **Rooftop Installations** | |
| **Site Name** | **Reason for Disqualification** |
| Orton Hall | Historical Purposes |
| Hayes Hall | Historical Purposes |
| University Hall | Historical Purposes |
| Thompson Library | Historical Purposes |
| Hale Hall | Historical Purposes / Roof Angle Too Steep |
| Townshend Hall | Slated Roof |
| Lazenby Hall | Slated Roof |
| John Glenn College of Public Affairs | Slated Roof |
| St. John Arena | Potential Future Development |
| McCorkle Aquatic Pavilion | Roofing Material Possibly Undesirable |
| **Ground Installations** | |
| Waterman Farms | Land Already Being Used / Crops Can't Be Covered by Panels |
| The Oval & South Oval | Historical Purposes |
| Carmack Parking Lots | Potential Future Development |
| Ohio Stadium Parking Lots | Potential Issues with Tailgating |

The proposed solar arrays will benefit the university by reducing Ohio State's scope 2 carbon emissions (The Ohio State University, 2020). For every megawatt hour of solar energy generated, approximately 920 lbs. of $CO_2$ emissions will be avoided compared to the same amount of energy created from natural gas (U.S. Energy Information Administration, n.d.). The amount of emissions reduced is even higher when compared to electricity generated from coal, with 2,210 lbs. of $CO_2$ avoided (U.S. Energy Information Administration, n.d.). The exact amount of annual reductions will take time to discover. Once an installation has been fully operational for at least a year, data would become available to base future projections on.

Several additional sites beyond our list of 30 priority sites may also be considered in the future, should Ohio State wish to develop additional solar capacity. While these sites are probably costlier and more time consuming to develop per kilowatt than the 30 priority sites, they may represent important opportunities to develop in the future. There is a significant amount of parking real estate that could be utilized, and regional campuses have a lot of land where installations could be constructed. Also, Ohio State's Framework 2.0 outlines very clearly where newly constructed developments are planned to be located (Planning, Architecture and Real Estate, 2017). This documentation provided us with sufficient data to base forecasts on. We created a list of these sites and have provided the information in Table 3 below.

**Table 3. List of sites where Ohio State could expand its solar footprint beyond 10MW**

| Future Sites for Ohio State to Consider for Additional Capacity |
|---|
| Dodd Rehabilitation Hospital |
| McCampbell Hall |
| Atwell Hall |
| Knowlton Hall |
| 9th Ave. East & West Garages |
| Neil Ave. Garage |
| SAFEAUTO Garage |
| Tuttle Garage |
| Northwest Garage |
| Lane Ave. Garage |
| Ohio Union North & South Garages |
| 11th Ave. Garage |
| Scarlett Parking Lots 1-5, Gray Parking Lots 1-7 |
| Fawcett Event Center Parking Lot |
| The Ohio State University Airport Parking Lots |
| Ohio State East Hospital |
| Regional campuses (Lima, Mansfield, Marion, Newark, ATI in Wooster) |
| New buildings planned to be constructed in the future |
| - Ambulatory Facilities on West Campus |
| - Research and Innovation Corridor on West Campus |
| - The Sustainability Institute |
| - Future Ice Arena |
| - Future Indoor Track |
| - New College of Medicine Building |

# Recommendations

Through this analysis, several key recommendations are being made for Ohio State regarding solar energy. First, we recommend that the university strives for a goal of 545,455 sq. ft. of space in various locations around the main campus to install solar arrays. This can be accomplished using the highly efficient model, Trina Solar TSM-345DD14A(II) 345W, which a monocrystalline silicon panel design. Installing anything but the highest efficiency or quality would only force the university to use more space in order to achieve 10 MW.

Second, we recommend the University pursues construction on a specific set of priority sites. In terms of size, our recommended ground sites offer almost a third of the total area required. The wastewater drainage site has 90,000 sq. ft. of adequate space available, followed by the Schottenstein South Lawn with 50,000 sq. ft., and the Ackerman Road Parking Lot with 41,000 sq. ft. Regarding rooftop installations, we suggest considering the Agricultural Engineering building first. It has the largest rooftop area with 47,000 sq. ft., which is then followed by the Ackerman Road Buildings 600-680 (46,000 sq. ft.), the Schottenstein Center (45,600 sq. ft.), the Schumaker Student-Athlete Development Complex (30,000 sq. ft.), Drinko Hall (23,000 sq. ft.), and the Physics Research Building (22,300 sq. ft.). We believe starting with the largest sites is the most efficient strategy in terms of time and costs.

Our final recommendation is to use these installations as an educational tool as much as possible during their 25-year lifespan. Having hands-on, structural examples of solar panels on campus can inspire innovative ideas from various university departments. Lessons and projects surrounding the arrays can help advance all solar technology and the way we use it in the future.

## Conclusion

The Ohio State University has enormous potential to expand its capacity of solar energy generation on its main campus. We have identified 30 prime locations for such installations to take place. The square footage of each array varies from 3,000 sq. ft. to 90,000 sq. ft., which is evidence that we have considered all available options. Installing 10 MW of capacity ultimately requires all options to be considered. Utilizing GIS software to approximate available square footages, our team was able to take into consideration any infrastructure or impediments that would decrease the amount of productive and available space. We have presented a list of sites which provides 572,000 sq. ft. of potential space, which exceeds the amount of square footage (545,455 sq. ft.) required to achieve an additional 9 MW of capacity. Every site that we have selected has the structural integrity to accommodate the installation of a solar array. We have also developed a list of potential sites which could be considered in the future if Ohio State were to expand its capacity beyond 10 MW, as well as a list of sites that have been disqualified immediately due to present/future development plans.

As stated previously, it is our strong belief that the most efficient PV models be utilized. Ohio State is ambitious both for striving for 10 MW of solar energy, and also for considering the option that the capacity could be installed across the main campus of a large university. This would separate Ohio State from other universities because developing large-scale solar generation capacities is often achieved by constructing arrays in rural settings. Land-use values are very much a part of the conversation when it comes to renewable energy, and Ohio State's example could set a trend for how solar energy is developed. We believe this research provides strong momentum for these developments to take place. We look forward to seeing this project maintain progress and hope to see solar being installed on our 30 selected locations in the future.

# Appendix

*Figure 3: Example of rooftop solar array installation on Ohio State's RPAC building (AEP Energy, 2015)*


*Figure 4: Example of a typical parking lot solar installation (Knowridge Science Report, 2018)*

*Figure 5: Example of a typical ground mount solar installation (Oregon State University, 2014)*

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