A Bright Future:

Simulating Southern Oregon University's Solar Energy Potential using 3-D Modeling

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Abstract

This paper presents a model to calculate Southern Oregon University's maximum feasible production capacity for photovoltaic (PV) solar panels installed on building rooftops on the Ashland, Oregon campus. This is done so that the university may fulfill Strategic Direction III and become a more environmentally sustainable campus. Maximum production was calculated by developing realistic parameters for suitable building installations, then capturing those areas using drone-based photogrammetry and three-dimensional model evaluation software to simulate and account for conditions such as shadows and optimal fixed angles. Preliminary analysis of one building was done with Scanifly evaluation software, which was then used to validate average production performance from current installations on campus. Using the average production factor (APF; expressed in kilowatt-hours per square-foot) we extrapolated to the total ideal rooftop area for the university. As the APF varied for each installation, we determined that the production-to-consumption ratio for the university is somewhere between 16.2-27.2%. Using this model and ratio, SOU administration will be able to decide on future development of PV arrays as well as pursue alternate methods of production and conservation in order to raise on-site generation and lower annual consumption. Future work should be done to analyze the return-on-investment and to create a cost-benefit analysis of the models specified herein.

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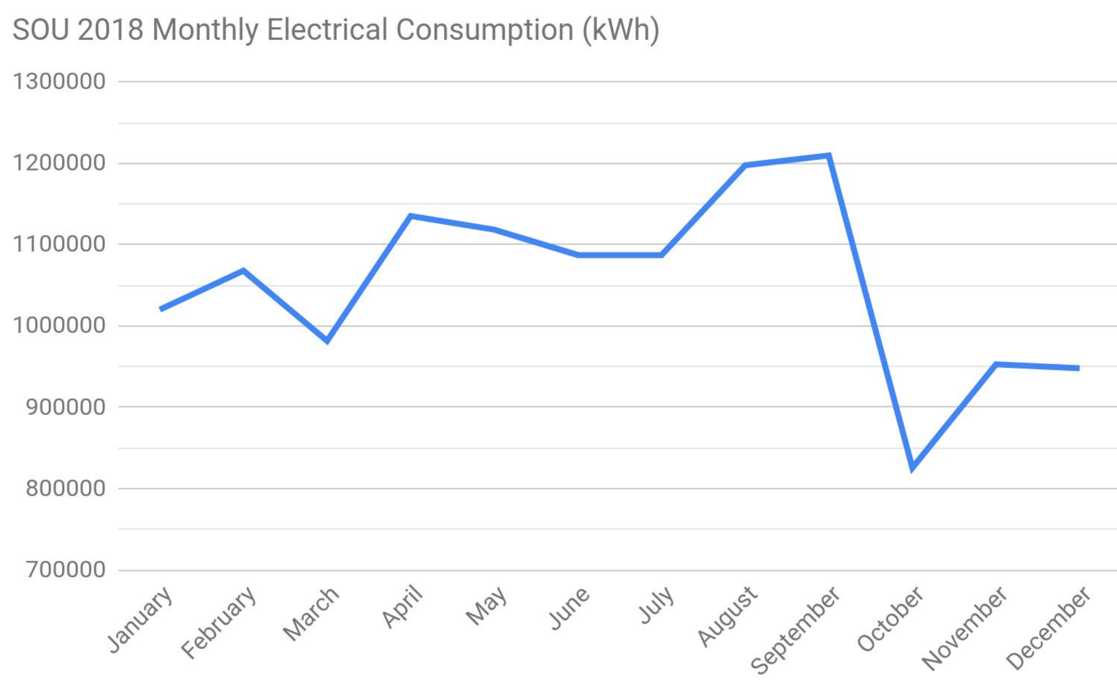
1. Introduction

Southern Oregon University (SOU) is a semi-rural public university located in Ashland, Oregon with 5,985 students enrolled in the Fall 2017 quarter (Office of Institutional Research, 2017). The Strategic Directions & Goals of the university provide an overview of the mission and vision of the university's future. Per Strategic Direction III, SOU "will actively model an environmentally sustainable campus and engage in collaborative research to promote an ecologically-resilient bioregion," (Southern Oregon University, 2018, *The SOU Plan*). In order to become an environmentally sustainable campus, SOU will need to divest from fossil fuel based energy sources and invest in renewable energy sources that do not contribute to global climate change. The purpose of this study is to determine how much of Southern Oregon University's annual electrical energy consumption could be met by installing photovoltaic (PV) solar panels on the rooftops of the buildings on the Ashland, Oregon campus. To meet this purpose, three objectives are stated: first, to estimate SOU's annual electricity consumption; second, to develop parameters for suitable buildings for the installation of photovoltaic panels; and third, to estimate the amount of energy produced by these PV panels annually for comparison to the university's annual consumption.

As a result of Strategic Direction III, SOU has installed seven photovoltaic (PV) solar panel arrays about the Ashland campus. The solar arrays are installed on the roofs of the Hannon Library, Stevenson Union, McLoughlin Hall, Shasta Hall, Student Recreation Center, Recreation Center Storage, and a second array on the Hannon Library installed in 2018 (Southern Oregon University, 2018, *Energy*). The seven arrays at the Ashland campus have a combined annual output of 451,922 kilowatt-hours (kWh) for the 2018 calendar year, whereas the university consumed 12,631,200 kWh at the cost of $1,119,430.54 over that same period (Southern Oregon University, 2018, raw data). In December 2018 these panels produced 3.58% of SOU's annual electrical consumption. However, the production ratio is expected to increase to 5.21% once the newest installations (Student Recreation Center, Recreation Center Storage, and second Hannon Library installation) complete a full calendar year (Roxane Beigel-Coryell, personal communication, October 18, 2018). While these new installations represent a 57% increase from the previous rate of PV generated electricity, the rest of the electricity used at SOU is supplied by the city of Ashland, which sources its electricity from Bonneville Power Administration (Southern Oregon University, 2018, *Energy*).



Graph 1 Line chart of SOU's monthly electrical consumption in kWh for the 2018 calendar year

Graph 1 outlines SOU's electrical consumption for 2018. Consumption peaked in September at 1,209,600 kWh and was lowest in October at 825,600 kWh, with an average of 1,052,600 kWh (Southern Oregon University, 2018, raw data). The sudden drop in consumption is possibly because the installations on the Lithia Motors Pavilion and Recreation Center Storage buildings became operational in October, although that does not explain the sudden increase for the following months. It should also be noted that the second Hannon Library installation (annual rated output of 55,650 kWh) was not in operation until January of 2019, and so it is not reflected in this chart.

1.1 Background

In an effort to estimate the amount of electricity that could be generated by photovoltaics on the Ashland campus, a previous study was done by a former student in completion of the Environmental Science & Policy's capstone graduation requirement. That study found that 59% of SOU's electrical needs could be met through the installation of solar arrays on 17 buildings about campus and above nine parking lots (Ono, 2018). However, significant limitations in the methodology of the study suggest further analysis should be done in order to obtain a more accurate estimate of the amount of energy that could be produced by PV arrays on campus. Primarily, estimates for electrical production were created by finding suitable areas in ArcGIS software and then calculating the amount of electricity that could be generated from those areas by the system efficiencies of a given solar panel combined with the annual insolation levels from National Solar Radiation Database (Ono, 2018). This methodology proves to be limiting in that it does not account for the weight limits of the panels on the buildings, shadows cast by nearby obstacles, or the necessary spatial pathways required by Oregon solar installation codes. As a result, it is believed by the authors of this study that the 59% finding is an overestimation, and so the purpose of this study is to find a more accurate and realistic estimate.

1.2 Literature Review

A study in Michigan's Upper Peninsula analyzed the financial feasibility for homeowners to defect from the utility grid in favor of solar, battery, and small-scale combined heat and power (CHP) technology systems, finding that about 75% of year-round households are projected to be able to defect from the current grid system in favor of these on-site generation and storage technology systems proposed by 2020 (Kantamneni, A., Winkler, R., Gauchia, L., & Pearce, J. M., 2016). For the purposes of this study, this shows that the declining price point of PVs makes it economically realistic to install panels in locations other than ideal areas with high levels of year-round solar insolation.

One case study done at the University of Coimbra, Portugal, found that the holistic combination of energy use reduction, local electricity generation, on-site electricity storage, and smart metering of electrical consumption and generation allowed a retrofitted building to achieve 42.4% reductions on net energy demand (Fonseca, P., Moura, P., Jorge, H., & de Almeida, A., 2018). This case study is also notable for its decision to lessen the slope of optimal angle for one of its three arrays by 20 degrees in order to mitigate the visual impacts of glare or aesthetic taste (Fonseca et al, 2018). While this clearly decreases the amount of power that is able to be generated, it acknowledges that the ambient presence of panels may in some circumstances be given enough consideration to warrant decreases in optimization.

In all of the above studies, estimates for solar energy generation potential were calculated without regard to potential shadows cast by nearby obstacles. To calculate the effect that shadows have on a projected PV panel performance, a study from Israel used a new method of calculating shadows cast onto a surface using a combination of R programming, ArcGIS, SketchUp 3D, and CAD software (Vulkan et al., 2018). Such calculations were performed using a three-dimensional model of the building on which the panels are to be installed and the buildings located nearby which could cast a shadow during a given time interval. This is a primary reason for why the calculations for this study will be done using three-dimensional buildings on Southern Oregon University's campus.

However, manually constructing three-dimensional computer models is a time-consuming process that can push back deadlines depending on the level of detail desired of the project. One method of digital modeling that has become increasingly prominent is drone-based photogrammetry, which combines overlapping photographs taken in flight and reconstructs the building model. In a review of the literature regarding unmanned aerial systems (UAS) such as drones, Rakha and Gorodetsky (2018) concluded that UAS technology is cheaper, safer, faster and more accurate than conventional building audits. In both academic studies and professional work, however, there is a lack of standardization in methodology for pre-, during, and post-flight, as well as numerous variables in post analysis and interpretation. As such, drone-based methodology represents an exciting avenue for research implications and with careful recordkeeping can advance the field of UAS research.

2. Methodology

In order to reflect a realistic scenario for development, parameters for suitable buildings were used to determine which three-dimensional models would be constructed. The parameters for suitable building rooftops are shadow- and structure-free space and no historical significance. Of the 26 buildings included in the study area, the only buildings which did not qualify for installations using these parameters were the Plunkett Center, the Science Building, and the Outreach and Engagement building.

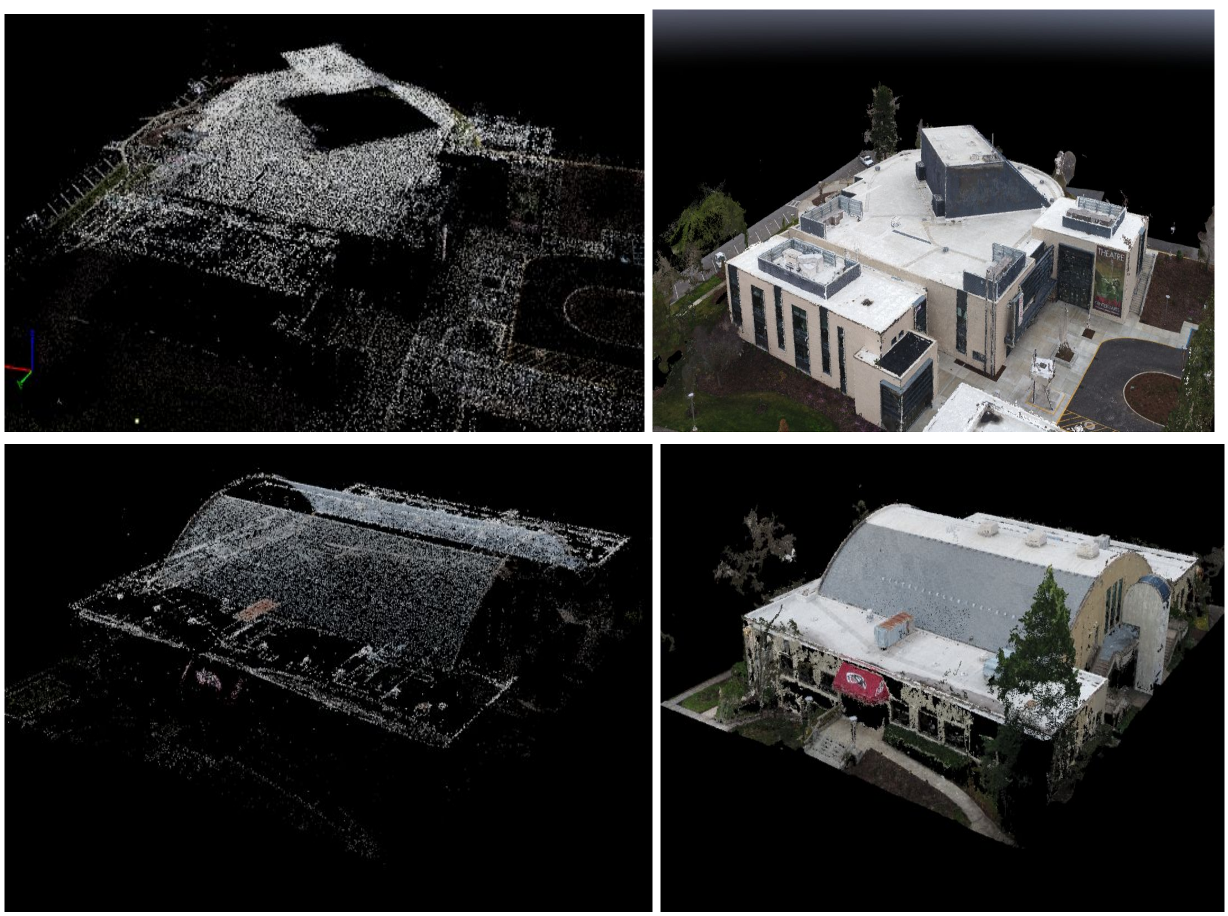


Figure 1 Pointcloud and finished three-dimensional models of Theatre Arts (top) and Britt Hall (bottom)

Once suitable buildings were determined, drone-based photogrammetry acquisition of select buildings and of the entire study area was performed. Select buildings included the Theatre Arts building and Britt Hall, as shown in Figure 1. In addition, photogrammetry of Madrone Hall was completed and building analysis was performed by Scanifly solar evaluation software in order to validate the average production factor that was calculated from current installations. Acquisition flights for specific buildings was done using a oblique-angle flight, while the acquisition flight of the study area was done with a crosshatch method. All flights were done with a DJI Phantom 4 Pro photography drone and imagery was recorded using the standard accompanying camera.

Using the imagery of the entire campus, orthomosaic and digital surface models were built. The digital surface model was then processed using ArcGIS Pro software to produce an aspect map. All south-facing aspects were then measured in accordance with 2010 Oregon Solar Installation Specialty Code to allow for 1-foot ridge pathways and 3-foot egress pathways. Rooftop area with solar installations already in place were not included. Once this total ideal, unoccupied area for all ideal buildings was calculated, the sum total equalled 127,679 ft^2. Chart 1 states the length and width of all buildings on campus and their south facing areas with pathway margins included in the calculations.

Name	Length (ft)	Width (ft)	Area (ft^2)	South Facing Rooftop Area (ft)	Area Rooftop (ft^2)
Art Building	156	73	11,388	L: 114 W: 16	1,824
Britt Hall	110	163	17,930	L: 147 W: 41	6,027
Campbell Center	222	56	12,432	L: 72 W: 16	1,152
Cascade Hall	218	162	35,316	L: 348 W: 120	41,760
Central Hall	202	68	13,736	L: 146 W: 16	2,336
Churchill Hall	236	75	17,700	L: 42 W: 31	1,302

Computing Services	198	89	17,622	L: 154 W: 23	3,542
Cox Hall	252	55	13,860	L: 73 W: 20	1,460
DeBoer Sculpture Studio	102	68	6,936	L: 33 W: 10	330
Education/Psych Building	256	52	13,312	L:89 W: 24	2,136
Hannon Library	330	164	54,120	L: 76 W: 73	5,548
Lithia Motors Pavilion	289	188	54,332	L: 166 W: 166	27,556
Madrone Hall	250	65	16,250	L: 64 W: 55	3,520
Marion ADY	121	106	12,826	L: 114 W: 17	1,938
McLoughlin Hall	428	55	23,540	No Available Rooftop	0
Music Building	151	132	19,932	L: 102 W: 94	9,588
Outreach Engagement	59	26	1,534	No Available Rooftop	0
Plunkett Center				No Available Rooftop	0
Schneider Museum of Art	101	55	5,555	L: 32 W: 31	992
Science Building	400	68	27,200	No Available Rooftop	0
Shasta Hall	428	55	23,540	No Available Rooftop	0
Stevenson Union	196	108	21,168	L: 102 W: 49	4,998
Student Health and Wellness Center	152	39	5,928	L: 56 W: 40	2,240
Susanne Homes Hall	250	38	9,500	L: 135 W: 16	2,160
Taylor Hall	205	58	11,890	L:113 W:62	7,006
Theatre Arts	228	143	32,604	L: 72 W: 29	2,088
Totals	**5,384**	**2,088**	**468,763**		**127,679**

Chart 1 Building area totals for both entire rooftop area and south-facing area

With the total area suited for future solar installations found, the production factor for current installations was calculated. Production analysis for the installations on McLoughlin and Shasta Halls and the Stevenson Union was performed, as they had the most recent data for a complete calendar year (Southern Oregon University, 2018, raw data).

4. Results and Discussion

Measuring the installations' area using the campus orthomosaic was possible due to the sufficient resolution of imagery. Chart 2 presents the total areas, along with each building installation's respective annual kWh output. McLoughlin and Shasta Hall were found to have a similar average production factor (APF) of 24.3 and 22.5 kWh/ft^2, respectively. The Stevenson Union differed greatly, however, producing only 12.4 kWh/ft^2. While numerous factors affect a given installation's APF, part of the difference between the residence halls and the student union is due to the surface area required for flat- versus sloped-rooftop installations. By measuring a three-by-three grid of solar panels on each of the three buildings, it was seen that both McLoughlin and Shasta Halls covered an area of about 150 ft^2, while the Stevenson Union required 250 ft^2 for the same number of panels, an increase of 60%. By comparison, the difference in APF between the two types of building rooftops was 88.7%.

Name	Total area (ft^2)	2018 kWh	APF (kWh/ft^2)	3x3 grid area (ft^2)
McLoughlin	4,556	110,572.47	24.26963784	150
Shasta	4,960	111,508.6	22.48157258	150
Stevenson	3,876	48,212.72	12.43878225	250

Chart 2 Building solar installation area, annual output, average production factor, and area of a three-by-three grid of solar panels

Using the APFs of the three buildings analyzed as upper and lower bounds, we then multiplied each APF by the total amount of unoccupied, ideal space available. The total amount of kWh produced by all current installations on campus for 2018 was then added, and lastly the sum of those values was divided by the total 2018 electrical consumption for the university. The final production-to-consumption ratio was expressed as a percentage. Using the lower APF produced 2,040,093 kWh, or 16.2% of the campus total electrical usage. The upper APF generated 27.2% of total consumption, equal to 3,436,495 kWh.

3. Conclusion

Using Southern Oregon University's total consumption for 2018, the calculations from the model described above state that between 16.2% to 27.2% of the university's electricity is able to be generated on site on Southern Oregon University's Ashland campus. By utilizing the rooftops of its buildings, SOU is able to lower its rate of greenhouse gas contributions while increasing its economic savings over time through the installation of photovoltaic panels. Ultimately, this will allow SOU administration to make informed decisions on future PV installations in order to meet Strategic Direction III. University administration may however decide to alter variables such as number of arrays, type of solar panels, adjust optimum angle in order to lessen visual impact such as glare or aesthetic appeal. Such adjustments are not reflected in this model and could increase or decrease the realized total production on site.

While this study has attempted to address foreseeable limitations in PV performance by accounting for shadows, optimal slope angles, and annual solar insolation levels using projected and historical performance data, some number of limitations still remain. Most notably, this study does not provide an economic analysis in terms of a cost-benefit ratio. Further study will need to be done in order to estimate the return on investment for the model proposed in this study, and to determine initial investment as well as maintenance costs for the university. In addition, considerations for the structural capacity of each building to bear the weight of an installation were not included, and could greatly affect the total amount of surface area available for production. Lastly, the university parking lots were not included in this model, as they had been in the previous study, for the methodology for such installations has not yet been refined to a sufficient degree for calculations. Parking lots do, however, present a significant amount of unobstructed area with direct solar pathways, and could be considered for additional installation if the administration so decides.

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