University of North Carolina Asheville
Journal of Undergraduate Research
Asheville, North Carolina
May 2022

A Feasibility Study of Solar Energy Production and a Microgrid on the University of North Carolina Asheville Campus

Lief vanSliedrecht and Corey McVay
Department of Engineering
The University of North Carolina Asheville
One University Heights
Asheville, North Carolina, 28804 USA

Faculty Advisor: Dr. N Moorthy Muthukrishnan

Abstract

Climate studies have shown an imminent and disastrous change in global temperature directly related to the extraction and electricity generation from fossil fuels. The University of North Carolina Asheville campus energy profile is split 53% electrical and 47% natural gas. This study explores the possibility of a solar based solution for electrical energy generation. Using a software aided process, a feasibility study was produced to evaluate power output and specific designs for self contained production and distribution of solar energy. A whole-campus approach was taken, including designs for rooftop mounted and parking lot canopy sites in order to find a clean method of powering the University's operations. Solar designs were modeled for a total of 18 buildings and 7 parking lots. From these simulated solar capture designs, it is estimated that roughly 8,039,794 kWh of energy could be produced yearly, accounting for 42.16% of the total campus electrical consumption. This research examines options for integration into the existing electrical grid with a self contained solar based microgrid, all in the pursuit of remaining consistent with commitments set by the University, regional, and global communities to minimize environmental impact.

1. Introduction

This research aimed to provide a solar feasibility study of the University of North Carolina Asheville campus. The campus is made up of approximately 38 different buildings, ranging from large facilities such as the Sherrill Center, which houses Kimmel Arena, to small residential facilities like Governors Village. Aurora Pro Solar[1] software was used to help develop a computer-aided design (CAD) model of photovoltaic solar (PV) panel arrays placed on campus buildings, parking lots, and other potential sites.

The solar arrays were designed to maximize potential energy capture, with the goal of replacing the entire campus energy consumption with renewable sources. In total, 17 buildings and 7 parking lot sites were determined to be fit for solar and had systems modeled. One other focus of the study is to examine the integration into a campus microgrid. A microgrid is a system of sources, storage, and distribution components interfacing with the larger outside grid in order to maximize efficiency and modularity of the system. This study suggests future actions for fulfilling the campus energy demands with solar capture sources, reducing its carbon emissions while striving towards a resilient and independent energy infrastructure. Solar capture becomes more effective when acting in tandem with microgrid infrastructure.

This study has been motivated by major climate agreements and reports in both local and global communities. Nearly all organizations focused on studying the impact human development has had on the natural environment are in agreement about disastrous events increasing exponentially without immediate and drastic changes in energy generation. The first is the University's decision to sign the Second Nature Carbon Commitment, an agreement to achieve carbon neutrality by 2050[2,9]. This goal for carbon neutrality also aligns environmental interests with the UNC System goals[3]. The second is the Buncombe County renewable energy plan to reach 100% renewable sources for county operations by 2030, and in the community by 2042[4]. The Glasgow Climate Pact from the United Nations' 26th

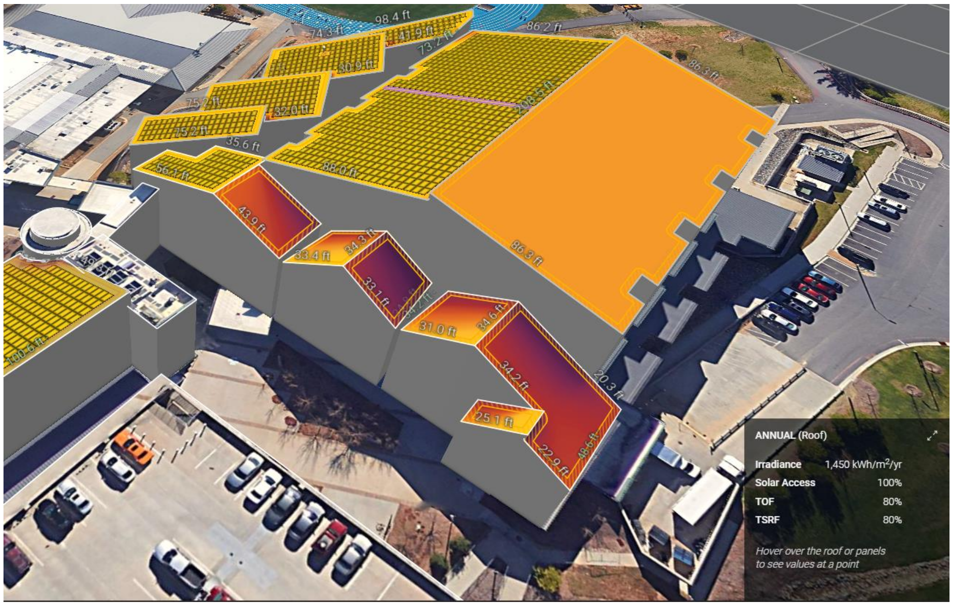
Conference of the Parties (COP 26), which maintains the goal of limiting the rise in global temperatures to 1.5° Celsius[5], along with the Intergovernmental Panel on Climate Change (IPCC) report[14] outlining the likely impacts of climate change have added urgency to conducting this study as a step towards implementing decarbonization.

Several other universities in the United States and worldwide have led initiatives to become less reliant on fossil fuel energy sources, and base their consumption on solar capture or other renewables. Stanford University has made the change to 100% renewable energy sources including rooftop solar and large scale PV generation sites[16], marking a new era of sustainable campus operation. The University of North Carolina Asheville's carbon neutrality goals are a great starting point for taking similar actions, and must be supported by a wide variety of initiatives, including renewable energy such as solar PV.

2. Methods

2.1 Modeling and Simulation

Aurora Solar provides an arsenal of computationally assisted modeling tools, from virtual placement and solar access calculations, to the cost analysis. As shown in figure 1, the program is equipped with satellite imagery and Light Detection and Ranging (LiDAR) depth mapping to make accurate preliminary designs possible when physical access to a roof is not. This study utilized irradiance calculations in order to determine if a site is feasible, as shown in figure 2. The process started by defining buildings using their roof type, roof size, and azimuth (roof face direction in degrees from North). Aurora employs the National Renewable Energy Laboratory (NREL) PVWatts[6] calculators, as well as its own algorithms for evaluating the yearly energy output of a system. Parking lots were later identified as candidates for carport solar based upon their solar exposure and layout. Using these specifications, solar system designs were built in Aurora for each of the most viable campus buildings and parking lots. Throughout the process, the goal was to maximize theoretical solar power production.



ANNUAL (Roof)

Irradiance	1,450 kWh/m²/yr
Solar Access	100%
TOF	80%
TSRF	80%

Hover over the roof or panels to see values at a point

Figure 1. Highsmith Student Union LiDAR Imaging

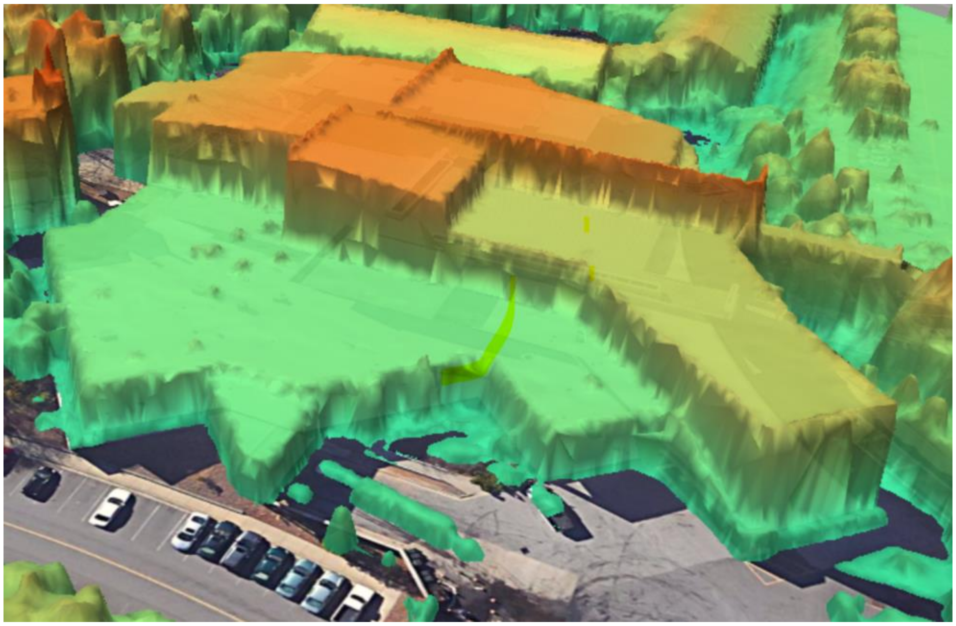


Figure 2. Sherrill Center Irradiance Map

The equipment used in this study was selected based on previous studies done on the campus, market availability, and solar industry professional recommendation. The components were intentionally chosen to be below the highest quality panels. This decision was made with the assumption that unaccounted for losses or unforeseen constraints are present in the system, and provide an underestimated total value. In other words, this is a baseline number that can be upgraded when better technology is more widely available. The panels selected for this study were the QCell Q.MAXX-G2 350 panels and inverters were SMA Sunny TriPower inverters of various sizes depending on the specific array with the most common being the SMA STP 110-60.

Azimuth, or the cardinal direction the array faces, is a major determining factor in a rooftop array's efficiency per unit area. Pure south facing rooftops are the most effective, while skew sites lose some solar capture ability. Most arrays were given a tilt angle between twenty and thirty degrees based upon the Energy Information Administration (EIA) data on utility scale fixed solar arrays at first[7], then maximized productive tilt angle was found for each building by iterating through tilt from 40 degrees down to 5 degrees in increments of 5 degrees while noting the change in simulated energy production at each step. Building sites were more efficient with the same amount of panels with a low angle, between 5 degrees and 10 degrees, when the azimuth was skewed off of direct south. However, rooftops facing due south were found to have a higher energy production output with a higher tilt angle between 20 degrees and 30 degrees.

2.2 Site Selection

Determination of site viability for supporting PV generation was based on criteria of site direction, size, roof geometry, shade cover from nearby obstructions, and in the case of building rooftop sites, the roofing material[8]. Sites were examined using satellite imagery and irradiance maps in Aurora. Rooftop geometries were usually the deciding factor of a site's feasibility for a PV system. Geometries that were closer to rectangles, the shape of the panels, were able to fit more panels. Unusual or complex angles decreased the amount of panels that could be placed on a roof, while also increasing the need for a high-cost racking system.

Most rooftops on campus are either metal standing seam or some form of flat membrane roof. The metal roofs are best for installing solar panels, as no complex racking system is needed to secure the array. This can be seen on the roof of Mills Hall shown in Figure 3, as there are brackets built into the roof to which solar panels can be fixed. In the case of flat roof types, a racking system must be installed, which adds a significant cost to the project. For this reason, changing to metal standing seam should be considered if a roof is in poor condition and/or is made from a different material. An example of a system design on a flat roof is shown below on the right of Figure 3. Racking systems account for a large portion of the cost of both material and labor for parking lot canopy installations, however these costs are offset by the portion of energy they are able to supply.

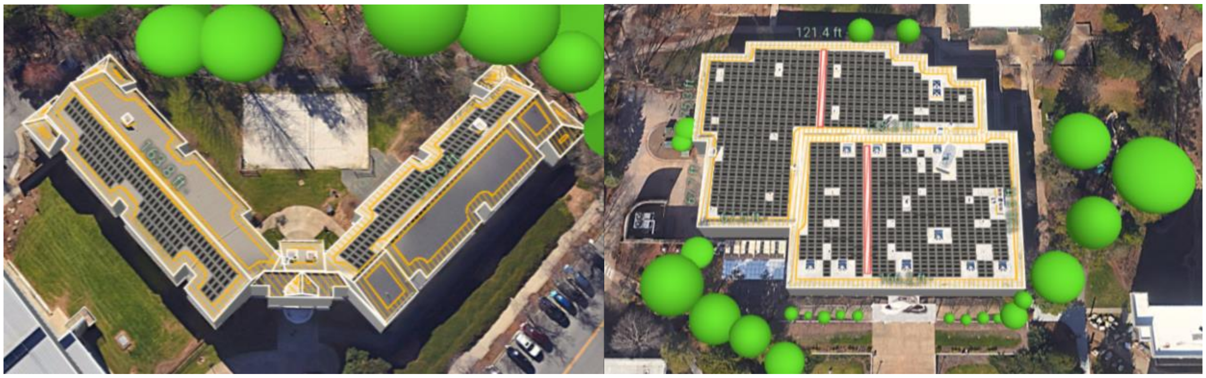


Figure 3. Mills Hall (left) and Ramsey Library (right) PV designs

2.3 Campus Energy Data

Campus energy consumption data was collected through the main campus substation meter and individual building meters. 2019 data was used in order to provide a realistic representation of the campus at full capacity, as COVID-19 remote education temporarily reduced the energy needs of the campus. The campus energy consumption data was provided through an internal document with data from the substation and individual building meters that measure natural gas and electricity usage. This data provided a baseline to calculate the estimated energy offset by each solar PV system.

3. Results

University energy consumption data was collected from the substation level, allowing a value for total yearly consumption to be calculated. Table 1 below shows this value, along with the estimated total energy offset and total percentage offset from the simulated PV systems.

Table 1. Total Campus Energy Consumption

Total Annual Energy Consumption (kWh/year)	**Total Potential Campus Energy Offset by Solar PV (kWh/year)**	**Total Potential Campus Energy Offset by Solar PV (%)**
19,068,000	8,039,794	42.16

Specific building rooftop PV designs were generated using Aurora, then recorded along with the roof type. Buildings with too small of an area, an incompatible roof type, or geometry to create a notable impact on campus production when compared with the cost of installing a PV system were not considered. Other buildings could theoretically house small systems in order to completely maximize the campus solar capture potential, but should not be prioritized until the major sites have been exhausted. Major sites are sites that could contribute towards offsetting a significant percentage of the campus consumption. Table 2 summarizes the individual building energy and power output, percentage offset, and roof type.

Table 2. Estimated Rooftop Mounted Solar Capture Potential

Building	Approximate Annual Energy production (kWh / year)	Maximum Power Output (kW)	Estimated Campus Energy Offset (%)	Roof Type
Sherrill Center / Health and Wellness	766,582	557.7	4.02	Metal standing seam, TPO Membrane
Highsmith Student Union	740,206	634.9	3.88	Metal standing seam, PVC Membrane
Ramsey Library	563,398	516.6	2.95	PVC Membrane
Student Rec. Center / Justice Center	455,816	435.8	2.39	Metal standing seam, Gravel Surface, PVC Membrane
Sam Millar Complex	272,894	206.2	1.43	Metal standing seam, PVC Membrane
Karpen Hall	241,050	190.4	1.26	SBS Membrane
Mills Hall	114,022	84.3	0.60	Metal standing seam
Chestnut Hall (Woods Welcome Center)	31,109	22.4	0.16	Metal Standing Seam
Phillips Hall	116,417	195.3	0.61	PVC Membrane
Owen Hall	227,666	311.5	1.19	Information Not Available
Brown Hall	83,483	183.1	0.44	Metal standing seam, TPO Membrane
Lipinsky Hall	278,435	256.2	1.46	PVC Membrane
Rhoades-Robinson Hall	130,690	297.5	0.69	Metal standing seam, PVC Membrane, BUR
Whitesides Hall	136,281	146.3	0.71	TPO Membrane
Zageir Hall	201,616	196.0	1.06	Metal standing seam
Delany Hall	167,509	158.6	0.88	PVC Membrane
Zeis Hall	96,036	157.8	0.50	Metal standing seam, PVC Membrane
Belk Theater	25,860	40.6	0.14	Metal standing seam, EPDM Membrane
Total	**4,649,070**	**4,591.2**	**24.37**	—

Parking lot canopy solar designs were also modeled using Aurora. These systems help to utilize a larger portion of campus, and do not take away any usable parking space. Smaller, more shaded parking lots were not selected for designs as these would not provide an efficient location for solar installation. However, there is still potential for more parking lot canopy systems, particularly in the Faculty/Staff lots P24 and P25. Table 3 outlines the estimated values for these systems, including the annual energy production, power output, and percentage offset.

Table 3. Estimated Ground Mounted Solar Capture Potential

Site	Approximate Annual Energy production (kWh / year)	Maximum Power Output (kW)	Estimated Campus Energy Offset (%)
Parking Lot P1	633,343	533.4	3.32
Parking Lot P8	483,086	326.3	2.53
Parking Deck P9	588,558	428.4	3.09
Parking Deck P12	202,532	152.9	1.06
Curbside Parking P18/P19	426,641	309.1	2.24
Parking Lot P29	317,609	321.3	1.67
Parking Lot P34	738,955	553.0	3.88
Total	**3,390,724**	**2624.4**	**17.79**

4. Discussion

4.1 Assumptions

Computer-aided modeling and simulation software, such as Aurora, is able to provide a highly accurate estimation of values depending on several assumptions. Assumptions used in this study were minimized in order to lay usable ground-work for future implementation of solar installations. However, certain understandings were not realistic to obtain without licensed engineers conducting studies that were outside of the scope of this project. It was assumed that roof and ground obstructions (HVAC components, trees, etc.) were accurate. Roof and ground obstructions were included using satellite imagery combined with LiDAR datasets. These datasets may have been outdated considering the updates and physical changes the campus goes through on a regular basis.

Roof structure was assumed to be sound and capable of safely supporting a maximum amount of PV panels and racking systems. Information regarding roof structure and load capacity was unavailable. Due to the safety concerts related to loading a rooftop, an in-depth structural analysis conducted by a licensed structural engineer would be needed to verify that a roof can support the PV arrays. These analyses should be done before each respective installation in order to ensure a safe campus is maintained.

4.2 Component Selection

Panels, inverters, and wiring were selected primarily on basic market availability. It can be safely assumed that within the market solar capture components, cost will decrease and availability will increase. This is a significant trend that is expected to continue.

The 350 watt QCell panels used in these simulations have a power output on the low end of panels available on the market today. Using high efficiency panels would increase the production potential per unit area and these panels will become increasingly more available over time. Inverter choice was far more complex, and made little difference in the yearly energy output as long as a similar specification unit was chosen. SMA Sunny TriPower inverters were selected based on recommendation from industry professionals, a prior campus solar proposal, and its stringing capabilities.

4.3 Modeling and Simulation Limitations

Aurora[1] provides a powerful toolset that is mostly complete and allows for a wide variety of realistic systems to be modeled. While the majority of sites are within the capability of the software, there are some limitations that may hinder the accuracy of the models. Aurora lacks the ability to accurately simulate curved surfaces or angled ground, including arched rooftops and hillsides. These both appear in numerous places on the University's campus, and may result in some inconsistencies in the actual potential output compared with these simulated studies.

4.4 Adding a Microgrid to On-Campus Solar

A microgrid is a self-contained system for producing, storing, and distributing energy. These are highly beneficial in several facets while providing a scalable solution to problems that were previously detrimental to solar energy generation.

Peak demand is a large factor in the cost of buying energy from an outside grid, making up to a third of the total campus electricity bill. Peak demand charges are based on criteria set by the utility provider and the University consumption profile, generally. A microgrid system remediates this by storing energy whenever possible and supplying the system during peak hours. Maintaining a microgrid also provides a level of resilience to natural and economic disasters. Even a system that is only able to supply a small amount of the maximum normal load can be critical in emergency situations. Each component to the microgrid is important, but most are already present in a system. An automated, programmable control system integrating all pieces of a campus energy profile allows for the system to work at its full potential. This technique is called "peak-shaving"[11], and drastically reduces energy costs both directly and through demand charges. It is important to note that for the university, demand charges are not simply based on the demand at a given time, but are calculated by the electric utility with a specific formula[12].

Energy storage capabilities are another important component to a reliable, renewable energy utility solution. In most cases, large batteries are used to store produced energy to be used at a later time. Pumped-storage hydropower, mechanical flywheels, and compressed air are other examples of energy storage solutions. One of the most relevant benefits of energy storage is the ability to produce energy from a renewable source, store, and then use that energy later when it is needed without being dependent on an outside grid. This is known as "islanding"[11]. In a solar PV with storage system, energy produced during peak solar production hours is stored in batteries and can then be used at any time, even when the external grid is without power and global energy production is unreliable.

The implementation of a microgrid on the UNC Asheville campus would provide additional benefits as the campus moves away from fossil fuels for heating and vehicle fuel. Currently, the campus is heated primarily with natural gas. In the coming years, the University plans to move towards electrified heating sources[12]. As this occurs, an additional electrical peak may occur during the winter months, as there will be added electrical loads. Most campus vehicles are also currently fueled with fossil fuels. As the University electrifies its vehicle fleet, there will also be increased electrical demands from charging these vehicles. The energy storage capabilities of a microgrid can help reduce the electrical peaks from these additional loads, as energy can be drawn from batteries and other modes of energy storage.

Although all components of a microgrid are important, it is arguable that the definitive piece is the smart distribution and control system that connects everything. Without an effective distribution controller, the benefits of energy storage and renewable generation are greatly reduced. Solar capture in particular varies based on time of day, season, and weather conditions. Utilizing a microgrid ecosystem to store and redistribute energy as needed mitigates these negative effects of variable source availability.

The cost of a microgrid installation is trending lower in the coming years, but for now the price per watt of capacity ranges between two and four dollars, slightly higher than the average for PV installations alone[13]. Since this system is reliant on a renewable solar generation source, the infrastructure cost would lie on the top end of that range, including the cost of solar capture arrays. The benefits in system independence, disaster resilience, and efficacy boosts in solar generation are significant and merit serious consideration.

4.5 Solutions to Reduce Campus Energy Costs

The University's campus has an active building automation system and management crew that has been able to achieve some of the highest building efficiencies in the UNC system[12], however some of the equipment and usage habits lead to an increased cost of purchased energy.

Converting the source of consumed energy is crucial in achieving carbon neutrality, but needs to be accompanied by other technological and behavioral changes. Updating fixtures and equipment to higher efficiency models and changing the load profile in order to align with renewable sources is necessary for utilizing the full potential of a PV generation source. For example, replacing campus vehicle fleets with electric vehicles so they can utilize solar energy and act as a dynamic battery bank benefits decarbonization in multiple ways.

Most equipment operations on campus draw a large quantity of reactive power. Reactive power, measured in volts-amperes reactive, is a type of power draw occurring when a load is overly inductive or capacitive[10]. Generally, the former is the case as inductive loads include motors, transformers, and other equipment that includes an inductive coil. A large reactive power results in a higher utility rate due to unneeded power being pulled from the utility provider. This can be remedied through adding capacitive storage systems to the load, proportional to the inductive "lag" that is present due to motors and other coils. These capacitors can either be placed on the equipment level, or as a large bank in a separate facility before the utility connection.

4.6 Cost and Value of PV

Assigning a quantitative value to the production of solar energy can be a complex and subjective task. Conducting a financial analysis alongside efficacy and feasibility studies is also important in order to compare and evaluate feasibility. Careful action is necessary when addressing the response to climate change, and a sound financial analysis should be included in that process. The scope of this research did not include an in-depth financial analysis, but is still valuable to include a brief discussion on in order to give financially quantified reference. Cost analysis can be easily done through many softwares, including Aurora[1]. The cost of PV installations varies greatly depending on vendor, contractual agreements, and size of purchase with an average for North Carolina at $2.49 per watt[17]. An analysis should include payback period calculation as well as net return on investment while taking into account federal and local incentives.

Value analysis is much more difficult and needs to include facets that are challenging to estimate monetarily. This has been estimated by several studies and included both grid factors such as capacity, risk reliability, and policy compliance, along with societal factors in an environmental and economic sense. Environment America's 2019 study produced values averaging around $0.229 per kilowatt-hour produced when including societal values[14]. This is nearly double the average cost per kilowatt-hour in North Carolina, which sits at $0.115 per kilowatt-hour[15].

5. Conclusion

This study was able to determine a total of 24 feasible sites for solar PV installations on the UNC Asheville campus. Feasible sites were chosen primarily based on their size, the geometry of the space, and potential shading. The solar PV system designs for these sites have been virtually modeled and could be translated into physical systems for installation if the University moves forward with any of these sites with minor modification and further necessary safety studies. If installed, these simulations suggest it is feasible to produce an estimated 42.16 % of the total campus electricity consumption, based on 2019 data, with purely rooftop and parking lot canopy PV arrays. This is a sizable portion of the campus electricity usage and would make a significant impact on converting the current campus energy profile into renewable solar capture. While this is a large portion of the University's energy profile, in order to power the campus with 100% renewable resources and become truly carbon neutral, a variety of solutions would be necessary. These could include off-campus solar farms, changes in energy consumption behavior, and other renewable resources that all work together in a sustainable ecosystem providing the University with clean energy. These changes, both behavioral and equipment/sourcing, are not likely to decarbonize the University's consumption on their own, but together are able to create a multi-faceted, renewable solution for the University's energy needs.

The scope of this study was only able to cover some of the factors related to the design and installation of solar PV systems on campus, and their incorporation into a microgrid. To build upon this work, a full rooftop structural analysis should be completed for each roof included in the study. An in-depth financial analysis should also be done to determine the broad range of economic benefits that can be realized with this kind of project. Additional research into the specific electrical components used in the designs should be conducted to determine the most efficient and cost-effective options. Although the components and benefits of a solar-based microgrid have been discussed, a detailed simulation has not been conducted. This should be done to demonstrate the specifications and benefits to our buildings and campus energy ecosystem at large. Powering the University with solar PV systems integrated into a microgrid promotes sustainable, equitable action with cutting edge technological advancements empowering the University of North Carolina Asheville as a local and global leader in clean energy.

6. Acknowledgements

This research was made possible largely through the support of Dr. Alison Ormsby, lecturer of Environmental Studies and Co-Director of Sustainability, Dan Croisant I, PE, UNC Asheville campus Energy Manager and Mechanical Engineer, the entire Critical Services Microgrid (CSM) / Applied Microgrid Institute (AMI) team, including Keith Thomson, Kelly Gloger, Michael Totten, Bill Fleming, Michael Benson, and Walt Bussells. Dr. N. Moorthy Muthukrishnan, Teaching Professor, served as our faculty advisor, providing structure, support, and sound guidance for the entire duration of the project. We would like to extend our gratitude to these individuals, the Engineering department faculty and students, Environmental Studies department faculty and students, and the University of North Carolina Asheville for facilitating this study.

7. References

1. Aurora Solar Technologies. Aurora. Aurora Solar Technologies. Cloud-Based. 2013.
2. “Stories from UNC Asheville.” UNC Asheville Stories. UNC Asheville, April 12, 2021. [online] Available at: https://stories.unca.edu/a-carbonless-commitment.
3. “The University of North Carolina Sustainability Policy”, UNC Policy Manual and Code, last modified June 14, 2013, [online] Available at: https://www.northcarolina.edu/apps/policy/doc.php?id=776.
4. Buncombecounty.org. 2022. 100% Renewable Energy Plan - Buncombe County Sustainability Office | Asheville. [online] Available at: https://www.buncombecounty.org/governing/depts/sustainability-office/clean-energy-resources/100-percent-renewable-plan.aspx.
5. “COP26 The Glasgow Climate Pact - Ukcop26.Org.” COP26.com. COP26, November 12, 2021. [online] Available at: https://ukcop26.org/wp-content/uploads/2021/11/COP26-Presidency-Outcomes-The-Climate-Pact.pdf.
6. Dobos, A. P. 2014. "PVWatts Version 5 Manual". United States. https://doi.org/10.2172/1158421.[online] Available at: https://www.osti.gov/servlets/purl/1158421.
7. Eia.gov. 2022. Most utility-scale fixed-tilt solar photovoltaic systems are tilted 20 degrees-30 degrees. [online] Available at: <https://www.eia.gov/todayinenergy/detail.php?id=37372>.
8. Stack, Victoria, and Lana L. Narine. 2022. "Sustainability at Auburn University: Assessing Rooftop Solar Energy Potential for Electricity Generation with Remote Sensing and GIS in a Southern US Campus" Sustainability 14, no. 2: 626. [online] Available at: https://doi.org/10.3390/su14020626.
9. “Carbon Commitment.” secondnature.org. Second Nature, n.d. [online] Available at: https://secondnature.org/wp-content/uploads/Carbon-Commitment-2017-Second-Nature.pdf.
10. U.S. Department of Energy, “Reducing Power Factor Cost”, Fact Sheet. [online] Available at: https://www.energy.gov/sites/prod/files/2014/04/f15/mc60405.pdf
11. L. Hadjidemetriou et al., "Design factors for developing a university campus microgrid," 2018 IEEE International Energy Conference (ENERGYCON), 2018, pp. 1-6, doi: 10.1109/ENERGYCON.2018.8398791.
12. Croissant, Dan. UNCA Facilities Mechanical Engineer, Campus Energy Manager. Interview. April 19, 2022.
13. Howland, Ethan. “Microgrid Costs and How to Lower Them: Microgrid 2021.” MicrogridKnowledge.com. Microgrid Knowledge, May 28, 2021. [online] Available at:https://microgridknowledge.com/microgrid-costs-microgrid-2021
14. Weissman, Gideon, Emma Searson, and Rob Sargent. “The True Value of Solar.” Environment America. Frontier Group, July 2019. [online] Available at: https://environmentamerica.org/sites/environment/files/resources/AME%20Rooftop%20Solar%20Jul19%20web.pdf
15. Hope, Matt. “North Carolina Electricity in Facts, Statistics, Companies.” Find Energy. Find Energy, April 20, 2022. [online] Available at:

https://findenergy.com/nc/#:~:text=North%20Carolina's%20Electricity%20Prices%20and,based%20on%20average%20electricity%20rate

16. Adami, Chelcey. “Stanford Transitions to 100 Percent Renewable Electricity with Second Solar Plant.” Stanford Report, March 28, 2022. [online] Available at: https://news.stanford.edu/report/2022/03/24/stanford-transitions-100-percent-renewable-electricity-second-solar-plant-goes-online/

17. Parkman, Kathryn. “How Much Do Solar Panels Cost?” ConsumerAffairs. ConsumerAffairs, January 17, 2022. [online] Available at: https://www.consumeraffairs.com/solar-energy/how-much-do-solar-panels-cost.html.