1A. PROJECT PROPOSAL

INSTITUTION: NORTHEASTERN UNIVERSITY
TEAM: NUESS HUSKY POWER
USE CASE: NORTH CAROLINA STATE UNIVERSITY

EXECUTIVE SUMMARY

North Carolina State University (NCSU or NC State) is a public research university with its main campus in Raleigh, North Carolina. The Raleigh campus has five precincts. One of these precincts is Centennial Campus. Centennial is one of the premier research parks in North America uniting the NC State community with national and international partners and the wider Raleigh community. The campus sits on more than 1100 acres within the Raleigh City limits and includes facilities ranging from academic and research centers to office space, hotel, residence halls, and recreational facilities.

As a leading educational institution, NCSU aims to contribute to sustainable practices by adopting eco-friendly measures. In 2008, the University pledged to achieve climate neutrality by 2050 by signing the American College and University Presidents Climate Commitment. To fulfill this commitment, NCSU has implemented and plans to implement a range of strategies and techniques on campus including energy efficiency measures, water consumption reductions, materials management, transportation improvements, waste reduction, and EUI reductions as outlined in their Climate Action Plan. One of their major objectives is to achieve LEED status for all buildings over 20,000 sqft.

This proposal covers the usage of a PV+ Battery Energy Storage System to assist the University in meeting its energy goals. The project includes 9 rooftop solar systems, 1 ground mount solar system, and 1 floating solar system with a total capacity of 6.6 MWdc. Additionally, the team has proposed 2 backup battery energy storage systems with a capacity of ~1.5 MWh to ensure energy resiliency for critical infrastructure and reduce the University's need for fossil fuel based backup generators during outage scenarios.

Based on the distribution network structure, 6 rooftop PV systems have been designed to connect directly to their respective building's switchgear to offset the building's energy consumption. Other systems (i.e., 3 rooftops, groundmount & floating) will be connected to distribution feeders to offset the entire campus's energy consumption. Table 1 below illustrates the system wise capacity and its point of interconnection.

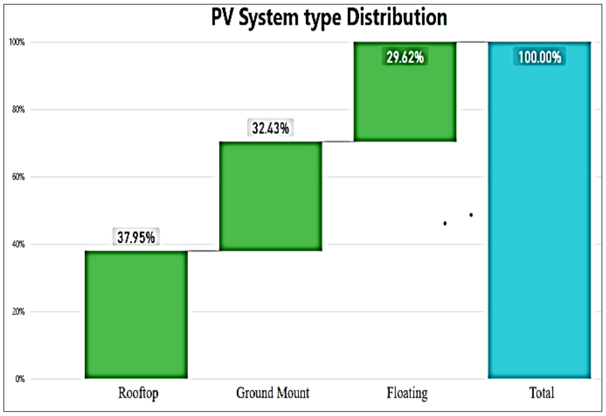


Figure 1. PV Distribution percentage

System Type	Number of systems	Capacity	Interconnection
Rooftop PV	9	2.47 MW	6 rooftops- Connected to building MDP 3 rooftops- Connected to distribution feeders
Floating PV	1	2 MW	Connected to distribution feeders
Groundmount PV	1	2.19 MW	Connected to distribution feeders

Table 1. System Capacity & Interconnection

The total cost of the PV+BESS system would be $11.4 million, and this will be financed through a combination of debt and equity. From the financial analysis, we calculated that the solar + resiliency batteries PPA would be 7.9 cents/kWh for a project IRR of 6.5% with zero NPV for investor, cash & tax equity partners. The PPA rate is almost matched with the utility rate (i.e. 8 cents/kWh) to make this investment profitable or breakeven for the customer. The PV only system yields positive NPV for the customer, but in order to achieve their stated goals, we have also considered the addition of the resiliency batteries which further increases the PPA. This creates additional CapEx with no additional revenues to offset it. Therefore, the NPV for the customer is negative. However, considering the climate benefits, resiliency for critical loads during outage scenarios, and a fixed power price for a substantial portion of their load, a PPA of 7.9 cents is reasonable for them to pursue.

The development of this PV+BESS system is created in accordance with the campus' Master Plan considering the growth of the campus. We chose regions with minimal interruption by eliminating third-party buildings, densely forested areas, and endowment parcel sections to reduce potential delays caused by site ownership, environmental limits, and other undertakings. The development process will take into account all codes and measures, assuring the safety of people and assets, as well as compliance with the City of Raleigh's Unified Development Ordinances (UDO), National Fire Protection Association codes (NFPA), and International Energy Conservation Codes (IECC).

The project's development will be divided into three phases that will begin concurrently, so that delays in permits and approvals in one process do not affect the execution of other systems. Table 2 depicts the three phases of development, as well as their start and the end dates.

Phase	System Type	Start date	End date	Total months
1a	Rooftop PVs + Resiliency BESS	6/1/2023	3/22/2024	9 months
1b	Groundmount PV	6/1/2023	6/3/2024	12 Months
1c	Floating PV	6/1/2023	6/3/2024	12 Months

Table 2. Construction timeline

Overall, this PV+BESS system will assist NCSU in meeting their key goals of lowering grid energy use to reduce utility costs, diversifying energy supplies and improving resiliency through the BESS, offsetting natural gas usage, and accelerating progress toward the Climate Action Plan commitments.

PV+BESS System Design:
11 PV Systems – 6.75 MW
2 BESS – 1. 5 MWh

Annual PV production:
9735 MWh

PV Offset against substation consumption of 96278 MWh:
10.11%

Project Cost / Investment:
$11.4 million

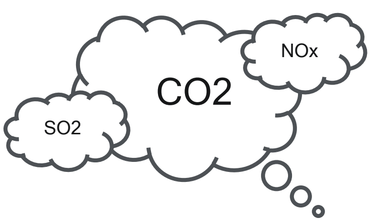
Electricity Cost Savings:
$21,889,369

Federal Benefit:
IRA Incentive benefits: 30% of project cost - $3.4 million

Development Timeline:
12 months

Life of the system:
25 years

Resource diversification:
On-site solar energy production + critical BESS



110,499
tons of GHG offset [3]

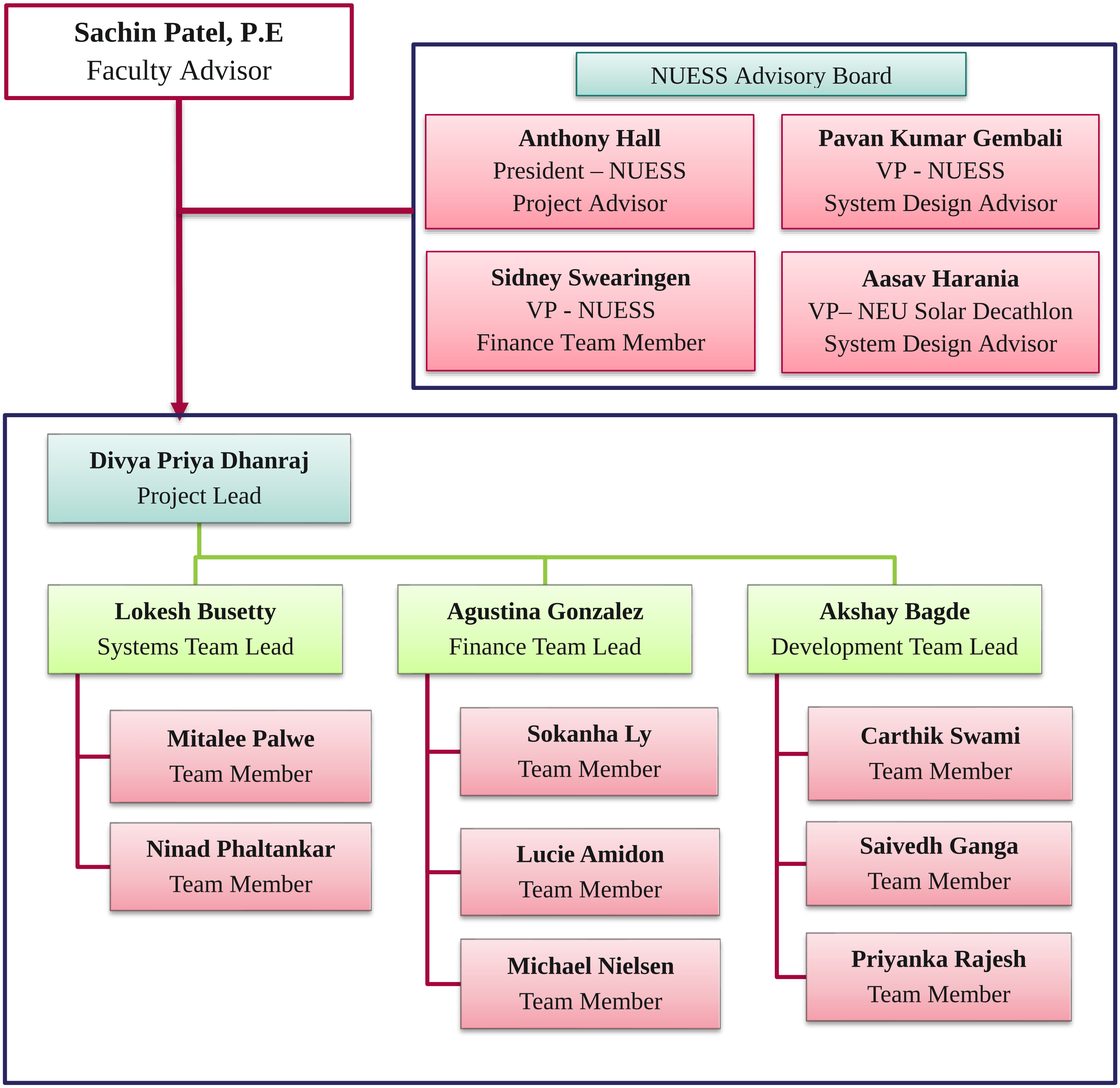
Equivalent to
4,307,738
trees planted [4]

2,729,849
MCF of NG reduction per year [5]

11 LEED points
in 2 category- Energy & innovation [6]

TEAM INTRODUCTION

We are a group of graduate students pursuing an interdisciplinary master's degree in Energy Systems. Our team is comprised of diverse engineering backgrounds such as Mechanical Engineering, Electrical Engineering, Industrial Engineering and Chemical Engineering. Our team structure is divided into three main divisions: system design, finance, and development. A project lead manages and coordinates all three groups, while individual division leads manage each area. The advisory board consists of Northeastern University Professor Sachin Patel and board members of the graduate student group, the Northeastern University Energy System Society (NUESS).



MEET OUR TEAM

Sachin Patel, P.E
Faculty Advisor

Divya Priya Dhanraj
MS Energy Systems
Project Lead
Contribution: Team management & project proposal

Anthony Hall
MS Energy Systems
Project Advisor
Contribution: Project guidance, strategic decisions support & development plan build

Pavan Kumar Gembali
MS Energy Systems
Systems Advisor
Contribution: Distribution study, systems guidance & development plan support

Aasav Harania
MS Energy Systems
Systems Advisor
Contribution: Systems design guidance

Lokesh Busetty
MS Energy Systems
Systems Team Lead
Contribution: System modeling execution & systems report

Mitalee Palwe
MS Energy Systems
Systems Team Member
Contribution: Systems - Single Line Diagram

Ninad Phaltankar
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Agustina Gonzalez
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Contribution: Finance Analysis & Execution

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Contribution: Energy Tool base - customer savings

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Development Team Lead
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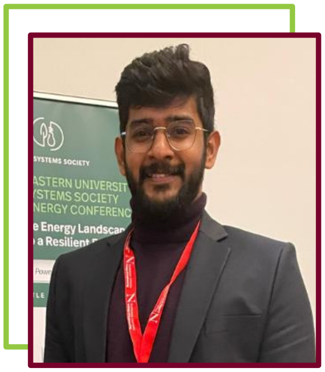

Carthik Swami
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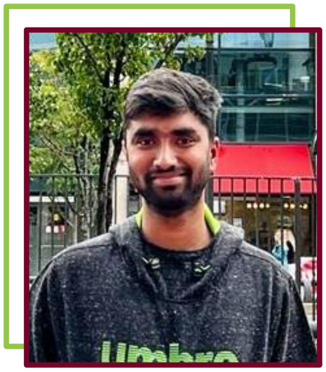
Development Team Member
Contribution: Permits Study



Saivedh Ganga
MS Energy Systems
Development Team Member
Contribution: Codes Study

Priyanka Rajesh
MS Energy Systems
Development Team Member
Contribution: Codes Study

PROJECT OVERVIEW:

SYSTEM DESIGN

Our System design approach started with the aim of utilizing all of the available spaces to offset utility energy consumption and help NCSU go green to achieve their sustainability goals. North Carolina has a strong irradiance profile with averages of 4.0-4.5 kWh/m^2/Day (Figure 2). This provided us with the confidence to develop a relatively large, distributed generation solar project of 6.6 MW.

Our system model consists of 11 photovoltaic systems: 9 rooftops solar, a ground mount single axis tracker system and a floating solar system with total annual production of 9735 MWh which will offset 8.4% of energy use from the grid (96278 MWh). The contribution of production for each system is shown in the below Table 3.

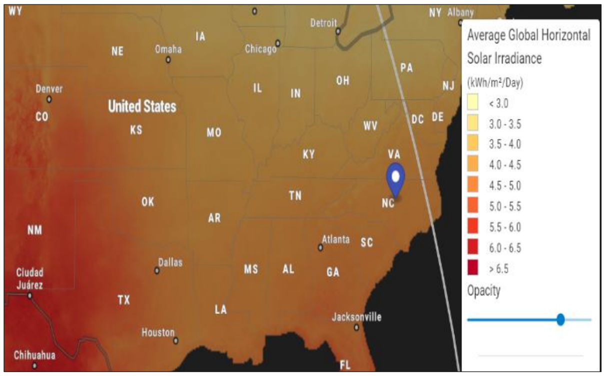


Figure 2. Irradiance Profile

We selected to build our rooftop systems on buildings that have been approved for solar installation based on the use case, and the energy consumption data from those buildings assisted us in determining the size of our system. Our ground mount system was located on the southern portion of campus due to the demand from future buildings planned in that region. Additionally, its naturally south-facing orientation will improve energy production. The floating solar will be built in the area designated by the use case; we see floating as a significant feature of our design considering the difficulty with land acquisition and environmental factors in general. We feel that NCSU and the greater community of North Carolina will benefit from seeing the implementation of this innovative, unique approach.

System Type	Location	PV DC Capacity (MWp)	Annual PV Production (MWh)	Offset against substation consumption of 96278 MWh
Rooftop	College of Textiles Complex	0.345	409.00	0.42%
Rooftop	James B. Hunt Jr. Library	0.455	614.00	0.64%
Rooftop	Engineering Building-I	0.301	370.00	0.38%
Rooftop	Engineering Building-II	0.605	775.00	0.80%
Rooftop	Engineering Building-III	0.406	499.00	0.52%
Rooftop	Research I	0.028	37.00	0.04%
Rooftop	Toxicology Building	0.089	102.00	0.11%
Rooftop	Partners II	0.166	219.00	0.23%
Rooftop	Partners III	0.075	92.00	0.10%
Floating	Raleigh Lake	2.000	2795.00	2.90%
Ground Mount	Campus land	2.190	3823.00	3.97%
Total	**11 Systems**	**6.661**	**9735.00**	**10.11%**

Table 3. PV System Location & Production

Our system design has ensured that the total PV production never exceeds the monthly consumption, as we cannot export any excess energy back to the grid. The graph (Figure 3) illustrates the solar system's monthly production against the energy consumption of the campus. Additionally, the solar production never exceeds the minimum power demand of the campus. This ensures that we can capture all energy produced without the need for any meaningful curtailment.

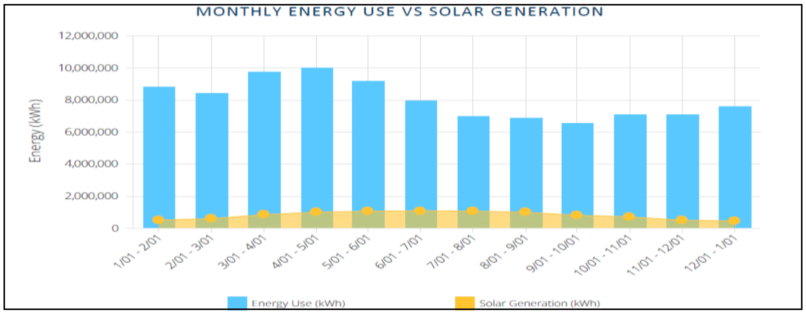


Figure 3. Energy Use vs PV Generation

ROOFTOP SOLAR:

There are a total of 9 rooftop solar systems in our proposal, which will be constructed on the NCSU owned buildings mentioned above in table 1. All our rooftop models are designed to face south along the direction of the building by adjusting the azimuth to capture maximum solar energy during summer days which will is also when the energy consumption of the campus is high. We used fixed tilt of 5° to utilize available roof's space efficiently to have maximum panels installed, thereby maximizing production. Our design also took shading into account, and we decided not to place any panels where the solar access is less than 85% to avoid inefficiencies in the system. The key features of our rooftop design are illustrated in Table 4 below and a model view of a system layout with components is shown in Figure 4.

Rooftop Solar Key Features	
Tilt Type	Fixed Tilt
Tilt Angle	5°
Racking Type	Roof Ballast Mount
Module Orientation	Landscape
Module Peak Efficiency	20.94%

Table 4. Rooftop PV Features

The System layout further describes where the associated components will be placed and the point of interconnection. We have accounted for all codes in our design to avoid any permit denials during the application process and to be compliant with development plan considerations.

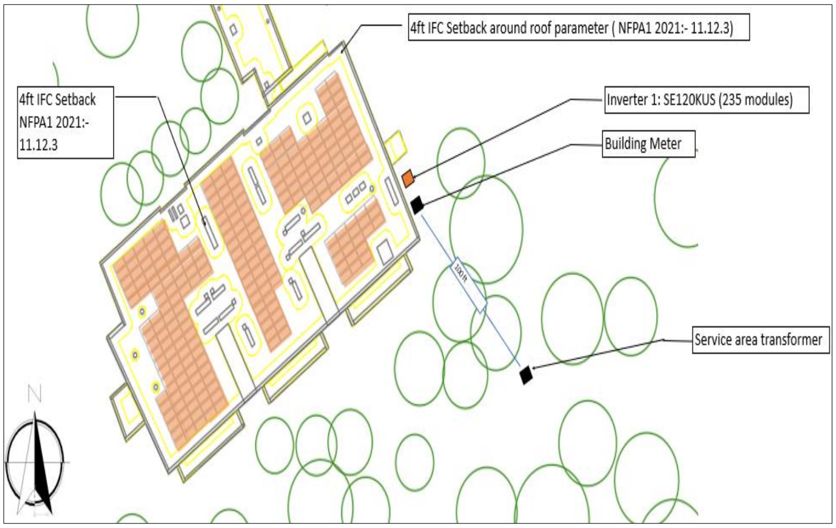


Figure 4. Rooftop Schematic diagram

FLOATING SOLAR:

The floating solar has a system capacity of 2 MW. The floating solar was planned to be built on Lake Raleigh's allowable area for development. Considering the limitation of land availability to build a large solar system, we decided to design a floating solar which will not only be a source for energy, but it will also give us benefits such as reducing water evaporation. Figure 5 below illustrates our floating solar location and its proximity to future developments.

The main advantage of a floating system is that it has high efficiency compared to other solar systems, so it is more energy dense that traditional systems. But there is also consideration of equipment's lifetime considering the exposure to extreme weather conditions such as moisture and mechanical stresses. Our design is considering all aspects of it as part of the development process to ensure the system is with reliability and durability by having right panels, floats, mooring, and anchoring structures.

Floating Solar Key Features	
Tilt Type	Fixed Tilt
Tilt Angle	10°
Anchor	General
Module Orientation	Landscape
Floats	Ciel et Terra floats

Table 5. Floating PV features

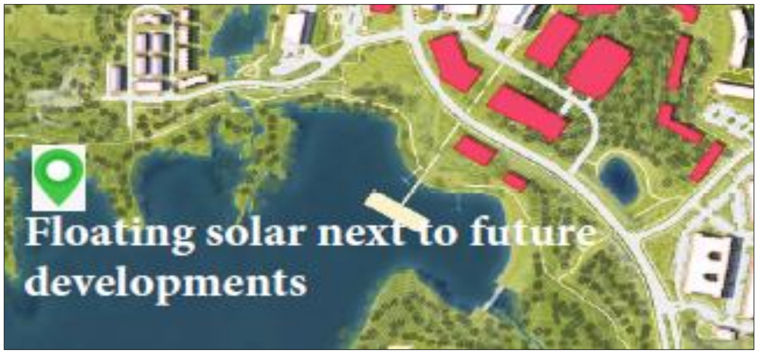


Figure 5. Floating Location

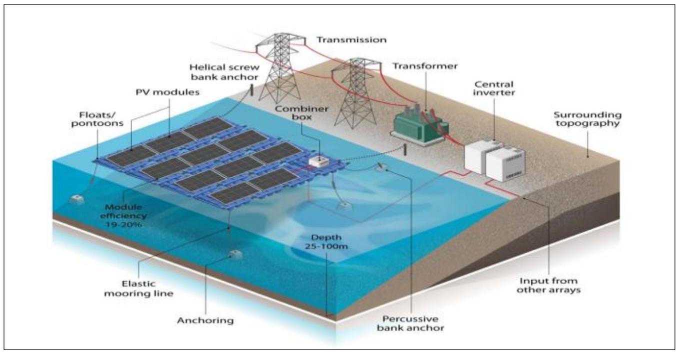


Figure 6. Floating Schematic diagram [1]

GROUNDMOUNT SOLAR:

The groundmount solar is a 2.19 MW single axis tracker system. We have decided to use a Single axis tracker for our design to have maximum production as it's an optimal south facing parcel which can trace the sun path to yield maximum output. The cost of the single axis tracker further increased our cost per watt for the ground-mount design, but looking at the production increase, we decided to use single-axis tracker which will increase our production by 25-30% compared to the usual design of fixed tilt. The following table depicts other salient features of our ground-mount design.

Ground-Mount Solar Key Features	
Tilt Type	Single Axis Tracker
Racking Type	TERRATRAK
Module Orientation	Landscape
Module Peak Efficiency	20.94%

Table 6. Groundmount PV Features

The location of our ground mount is chosen based on the land's grading structure (i.e., south facing slope), which will allow us to maximize production while minimizing harm to the natural eco-system. As the ground is naturally graded, we will cause very less damage to the topsoil. Considering future developments planned near the location, it will also be a great source of energy for the future developments. The picture 7 below illustrates our ground-mount location and future developments around the area as per the master plan of the campus.

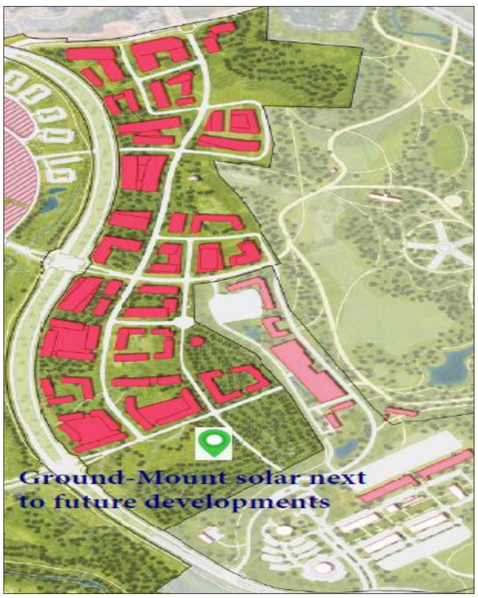


Figure 7. GPV location in the master plan

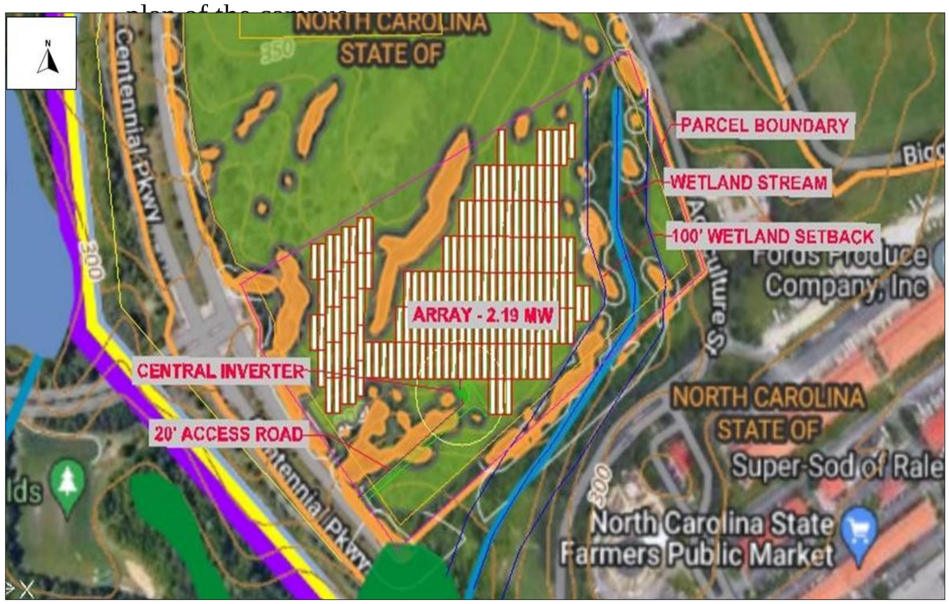


Figure 8. Ground-mount layout

The above layout in Figure 8 for the ground-mount design illustrates our further consideration of setbacks considering wetland and the grading.

DISTRIBUTION IMPACT

CONSTRAINTS

The primary constraint of the electric grid at NCSU is that the excess PV production cannot be exported back to the grid. The secondary limitation is that the existing distribution can take only a maximum of 4.30 MW PV penetration. If we must interconnect a larger PV system, either we must upgrade the system, use a non-wire solution, or curtail the power using smart inverters when the PV production instances exceeds allowable limit.

The analysis of battery revealed that it would make our project less economically viable due to the increased cost of battery. The transmission upgrades cost is substantially higher than the cost of the battery, hence it is not a viable option. We also looked at our PV profile and found out that only for 23 instances, the PV production is greater than kW demand of the campus which is almost less than 1% of chance. But to address those instances as well, we have decided to use smart inverters.

MITIGATION

By exceeding the limit by 1.2 MWac, we are assuring the safety of the systems by using smart inverters with advanced controllers called CERTS [2] (Consortium for Electric Reliability Technology Solutions). The CERTS approach will establish and maintain the electrical requirements for safe, stable operation; this involves controlling both voltage and frequency. These CERTS controllers will monitor energy flow the grid and curtail PV production whenever it senses PV production being higher than the demand, it will curtail the PV production by communicating to the smart inverters. During grid outages, it will disconnect the power supply to the non-critical loads and ensure critical loads are served. These controllers will also act as DAS (Data Acquisition System) to collect solar production and with its energy management capability, we can further adjust and control energy usage of the campus. Further, from our analysis, we have found that only for about 23 instances in a year, the PV system produces more than the campus demand, hence there is not much production loss.

INTERCONNECTION

From the interconnection standpoint, we must decide whether we are going with the Behind the Meter solution or connecting to the nearby feeders. In BTM solution, PVs will be connected directly to the building's AC panel which will not add any constraint for the feeder's PV penetration level because from the analysis we have found that the PV production never exceeds minimum consumption of the building. In the other approach, the PV system will be connected to the grid's feeder/transformer reducing PV penetration level as system size increases. The rooftop PV system's analysis using heatmaps analysis helped us to determine that six buildings which have capacity less than minimum demand of the building can be connected directly to the building's AC panel (show in table 7). The remaining five systems (3 rooftops, ground-mount, floating) will be connected to the nearest feeder/transformer. These systems are connected prioritizing the distance from the substation and the PV penetration limit of the circuit.

Buildings	PV DC Capacity	Building Minimum Load	Distance from substation
	KW	KW	Miles
College of Textiles Complex	345	407	0.981
Engineering Building I	284	474	0.85
Research I	26	171	1.425
Toxicology Building	89	137	1.363
Partners II	166	205	1.254
Partners III	77	294	1.363

Table 7. Behind the Meter Connections

Buildings	DC	Max Energy	Combined Total Energy (Using CERTS)	Distance from substation
	KWp	kWh	kWh	Miles
James B. Hunt Jr. Library	455	272	**4300**	0.851
Engineering Building II	584	305		0.962
Engineering Building III	385	170		1.974
Floating solar	2000	1540		1.958
Ground Mount	2190	2013		1.688

Table 8. Distribution Feeder Connected Systems

BATTERY STORAGE:

BATTERY STORAGE FOR CRITICAL LOADS:

NCSU has four critical loads, and any power outage will have a substantial impact on the labs and other facilities placed in the buildings. To ensure resiliency, we made sure that those facilities are always safeguarded by developing energy storage systems with historical outage and resiliency requirements in the forefront.

These storage systems are charged from the grid and are connected to the grid to detect any grid disruptions and switch to energy storage during outages. Additionally, to reduce interconnection and wiring costs, as well as the design's complexity, we have divided the battery storage into two storage devices: a 1233 kWh battery that will support three critical loads that are close together, and another 220-kWh battery for the building that is located far away from other critical loads. The table illustrates the critical loads, and its battery storage proposal and operation of this battery will be designed to serve only during outages such that we have batteries that are fully charged at any time.

Critical Loads	Battery Demand	Resiliency Hours	Required Capacity	Battery System
Toxicology	182.8 kW	3 Hours	548.4 kWh	Battery 1 – 1233 kWh
Partner III	171.9 kW	2 Hours	343.8 kWh	
Engineering II	170.5 kW	2 Hours	341.0 kWh	
Research I	110.0 kW	2 Hours	220.0 kWh	Battery 2 – 220 kWh

Table 9. Resiliency Batteries

PEAK SHAVING BATTERY ANALYSIS:

Batteries are usually considered as one of the best solutions to reduce demand by buying energy when the price is low (i.e., off-peak hours) and discharging energy during peak hours. But for NCSU case, as per their utility rate structure, they are not paying for any demand charges for use above 10500 kW and they are billed at Real Time Price (RTP) after this threshold. This also conveys that in order to realize any benefit in terms of demand, first we have to reduce the peak demand to 10500 kW and then have additional capacity to offset the peak demand which could give any demand savings. The following graph (figure 9) illustrates the peak demand of each month and its baseline above 10500 kW.

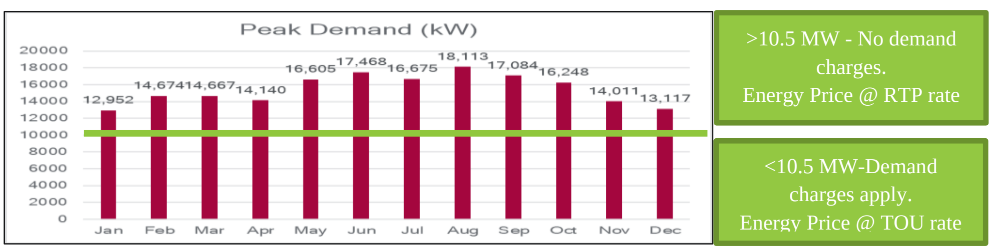


Figure 9. Demand and rate base

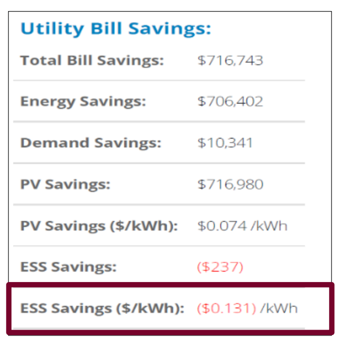


Figure 10. Negative Battery Savings

Additionally, Our Energy Tool base analysis on minimum battery size of 8113kw/16225kWh to realize at least 500 kW demand savings over the baseline reduction revealed that peak shaving battery is not a solution considering the low energy cost during the Real Time Price at average of 7 cents per kWh (Average RTP price referred from the PJM – Duke Energy node located close to NCSU). The figure 10. illustrates how much we will be losing if we have invested in peak shaving battery (-$0.131/kWh) and as we can see in the graph in figure 11, with such a low capacity of battery against campus's base demand (Baseline + 500 kW), there is high chance we might end up not realizing any benefit. If we must increase battery size, the investment will increase, and we will end up with more negative cashflow. Hence, we decided not to design peak shaving battery and do only resiliency batteries.

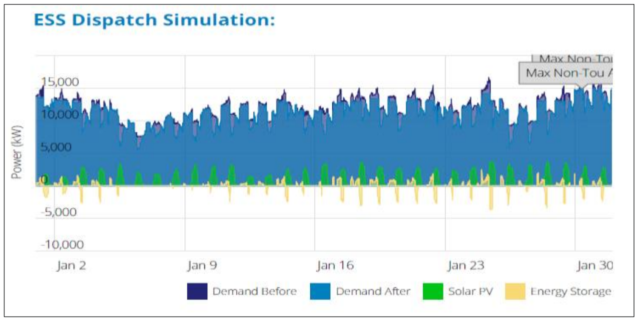


Figure 11. Battery Discharge Profile

FINANCE

SYSTEM COST

All our 11 systems' costs (9 rooftop solar, 1 ground-mount solar, 1 floating solar) were thoroughly assessed against the NREL benchmark to provide greater accuracy in the total cost of the systems and their long-term impact. The table below compares the cost per watt of each system to the standard for 2021. However, the pandemic situation has raised PV costs above what they were previously, but we are seeing a decline in PV costs as economies begin to stabilize. We assumed that our solution will cost roughly the same as mentioned below in Table 11 (the detailed cost/W derivation is showed in the financial model). As per our cost analysis, the total system cost for PV and resiliency battery is $11.4 million.

System	System Size (KW)	Cost/Watt (PV)	Total Cost
Rooftop	2411	$1.43	$3,593,961.00
Groundmount	2190	$1.62	$3,675,121.00
Floating	2000	$1.69	$3,505,476.00
Total	**6601**		**$10,774,558.00**

Table 10. PV System Cost

System	Battery Size (kWh)	Cost/kWh	Total Cost
Battery	1500	$450	**$653,940.00**

Table 11. Battery Cost

INCENTIVE BENEFITS

Incentives provide great financial assistance to solar project developers, making solar energy more economically viable considering the higher initial cost. Tax incentives and other benefits such as depreciation help to lower the cumulative expenses of installing solar panels. In our use case also, these benefits are taken into consideration to further reduce the system cost. The reduced system costs due to tax credits are shown in Table 12. There are currently no other substantive state tax incentives for which this project would be eligible, however, after the system is installed, the University could possibly apply for the Duke Energy NC Solar Rebate program (within 90 days of installing the system). This could provide an additional rebate of $0.75/W, up to $75,000. The batteries will be eligible for a 10% adder to the ITC if we are able to source it from within the country.

Federal Tax Incentives		Benefit
Investment Tax Credit (ITC)	The ITC reduces the federal income tax liability by 30% of the cost of a solar system for the year in which it is installed. For tax exempt organizations (University if Cash Purchase), may receive the ITC as a direct payment option (refund from the IRS) OR they may sell all or a portion of the tax credits to an eligible taxpayer.	Total PV+BESS System cost reduced to: **$7.9 million**

Table 12. Income Tax Credits

PPA VS CASH PURCHASE

The financial analysis sought to maximize customer advantage while also assuring favorable investor benefit. The PV+BESS system has a PPA price of 7.9 cents/kWh. The graph (Figure 12) depicts the PPA price and current utility pricing with a conservative 2.5% escalation over the life of the system. As illustrated in the diagram, the analysis aimed to offer energy at the same price as the utility, with a discount rate of 6.5%. As a non-profit institution, the University's purpose is to promote climate action rather than financial gains, therefore this is a good investment.

The difference between a cash purchase and PPA price is the payment approach. The PPA model allows the customer to pay the cost in installments over the life of the system, and a developer will own and operate the system. On the other hand, the cash purchase model will require the whole system cost to be paid upfront, and the University will be the owner. According to the analysis, the cash purchases model has a negative NPV for the customer at a discount rate of 6.5%. This may be attributed in part to their inability to take depreciation as a non-profit. Another significant obstacle for the cash purchase approach is whether or not the University will be able to obtain financing for this massive investment.

Table 13 below shows the results of the PPA and cash purchase analysis from the energy tool base. The graph (Figure 12) further illustrates the payment options in both methods and how it would compensate the utility bill.

Payment Options	NC (PPA)	Cash Purchase
Investor NPV	$0	-
Utility rate	$0.08/kWh	$0.08/kWh
Customer NPV	($596,069)	($572,050)
Total Payments	($23,475,485)	-
Electricity Bill Savings	$21,889,369	$21,889,369
PPA Escalation Rate	2.50%	-
Starting PPA rate	$0.079	-
Upfront payment	$0	$11,428,498
Term	25 Years	25 Years

Table 13. PPA vs Cash Purchase Analysis

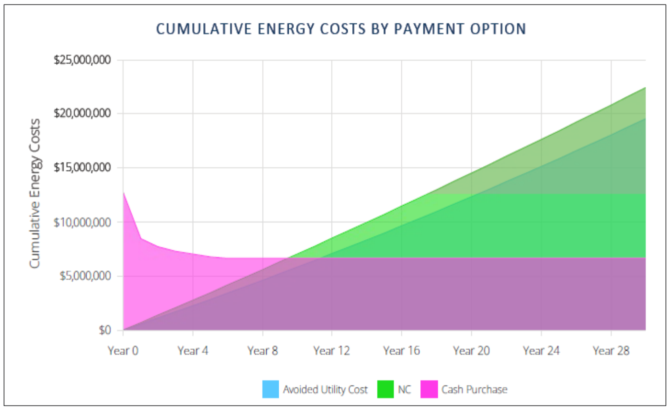


Figure 12. Payment Options

The PV only model yields a positive NPV for the customer, but as previously stated, the inclusion of the BESS yields a negative NPV at the same discount rate for both the cases. However, the battery system provides an added value of resilience, while saving costs from a fuel-dependent generator system (not included in this analysis). Additionally, as opposed to traditional diesel-powered generators, these battery systems provide instant backup power in the case of an outage, which prevents electrical damage to equipment in these buildings. Therefore, despite the negative customer NPV, we believe this system provides an overall customer benefit. Furthermore, from the University's standpoint, the best approach to proceed with this project would be PPA. Following are the reasons why the PPA option might be best for the university.

Challenges with Cash Purchase:

- Financing: Cash purchase requires the system cost to be paid as upfront, sourcing for finance might be difficult.
- Operations: As an education institution, owning and running the system is a non-core investment for them. On the longer run, it might be difficult to operate & run the system.
- Additional System Cost: There will be an additional cost for the developers' margin that has not been included in the cash purchase model. This would further increase the system cost and impair the cash purchase model more.
- Selling Tax Credits: As a non-profit organization, university will not utilize the tax benefit, however they can sell the tax credit to third parties. But there is a chance that they might have to sell the credits at discounts which would further reduce the overall benefit of the system.

Advantages with PPA:

- Fixed Energy Price: The PPA method allows universities to have fixed energy prices over 25 years which is the life of the system. This also gives credibility on energy availability.
- Initial Investment: There is no upfront cost required which would allow the university to not to bear the burden of massive investment on energy.
- Less Complex: From the operations & maintenance standpoint, having the system which is operated by the core developers would be less complex and core developers with their experience will be able to provide assurance on performance.
- Tax Benefit: The developers of the system will be able to realize the tax credits and other advantages such as depreciation. This would allow equity sponsors involvement which would reduce the investment complexities for the university.

DEVELOPMENT PLAN

MASTER PLAN COMPLIANCE

The development of this project aims to reduce energy consumption and promote the use of renewable energy resources to make the campus more sustainable and environmentally friendly, while also adhering to the campus Master Plan and assuring compliance with all authorities and codes. The location for all our systems was chosen based on carefully analyzed pre-installation analysis such as floodplain analysis, topography analysis, site conditions & surrounding land use, soil analysis, and environmental impact. All our systems are designed to be in complete compliance with codes to ensure safety of all people and the assets.

As described earlier, our proposal consists of 11 solar systems which are 9 rooftops solar, 1 groundmount and 1 floating solar with total system size of 6.6 MW and two battery storage systems with capacity of ~1.5 MWh. The rooftop systems will be built on NCSU buildings that have been approved for solar installation (as shown in Figure 13), of which 6 systems will be connected directly to the building's AC panel, as the PV system size is less than the minimum demand of the buildings. The remaining 3 rooftop systems will be connected to the distribution feeders. The groundmount system will be built on the southeast side of the campus, between Agricultural Street and Centennial Parkway, and it will be connected to the distribution feeders. The land for groundmount is chosen based on pre-installation analysis considering minimal disturbance to the natural eco-system. This land is an ideal place to build our groundmount system because it can act as a great energy resource for new buildings that are planned to be built next to it as shown in the preliminary Master Plan. Our floating system will be built on Lake Raleigh's allowable solar installation area, this will also be a great interconnection point of energy for new constructions planned near the lake. The battery storage systems will be placed near the loads. Battery 1 will be placed near Partner III, and it will backup Toxicology & Engineering Buildings II & Partner III. Battery 2 will be placed near Research I for its backup. These batteries will ensure resiliency of the system during grid outages.

The map below illustrates our proposed system's alignment with the Centennial Campus's endowment parcel and preliminary master plan (-PV location; -Battery location).

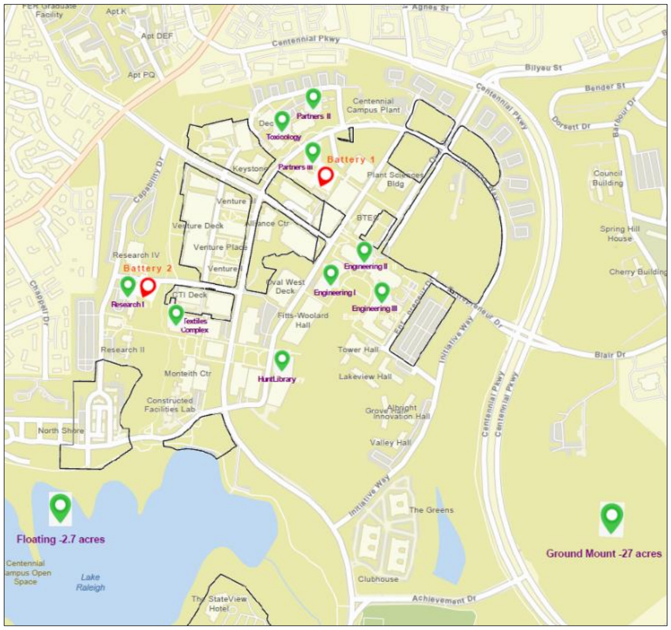


Figure 13. Endowment Parcel

Figure 14. Preliminary Master Plan

The development plan does not only consider the compliance with Master Plan, it also carefully analyzed other benefits of this project to accelerate achieving sustainability goals of the University. In the same sense, this solar project not only reduces energy consumption, but it will help the University to achieve their sustainable goals towards Climate Action Plan by reducing carbon emission, improving source EUI by onsite renewable energy production and gain points for LEED

Silver. As per the certification guidelines, the following are the points that can be scored with this PV+BESS project which will significantly help campus buildings to achieve its sustainability goals such as obtaining LEED Silver (table 14).

LEED Project checklist:

LEED v4 for BD+C: Schools			
Category	**Credit**	**Possible Points**	**Proposal measure**
Energy and Atmosphere	Advanced Energy Metering	1	By its function, the Data Acquisition System of the CERTS Controller will act as an advanced energy metering device. It will capture energy usage from the grid and production from the PV.
	Renewable Energy Production	3	11 solar systems of 6.6 MW onsite PV production
	Green Power and Carbon offsets	2	110,499 tons of GHG offset with PV installation
Innovation	Innovation	5	The development of floating solar to enrich the community knowledge in leveraging use of water bodies for renewable energy.
Total		**11**	

Table 14. Project LEED points summary

CONSTRUCTION PLAN

The development team has decided to split the development into three phases that will begin concurrently. This will consist of the rooftop solar and resiliency batteries in Phase 1a, the ground mount solar in Phase 1b, and the floating solar in Phase 1c such that approval delay in any one project does not affect the other. The rooftop system and resiliency battery installation will take about 9 months to complete, the groundmount and the floating system will be installed in 12 months. Discrepancies in timelines are predominantly due to varied permitting requirements. The following illustrates the construction schedule of each phase.

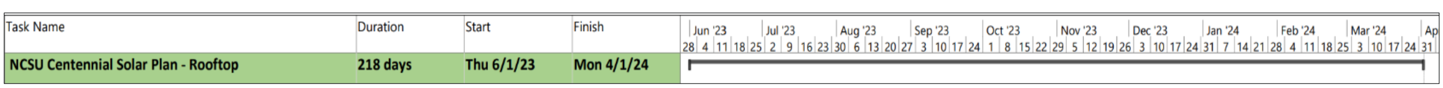


Figure 15. 1a Rooftop Construction Schedule

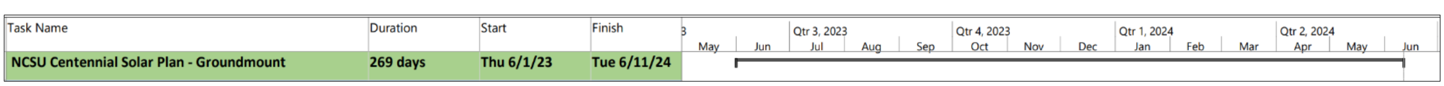


Figure 16. 1b Groundmount Construction Schedule

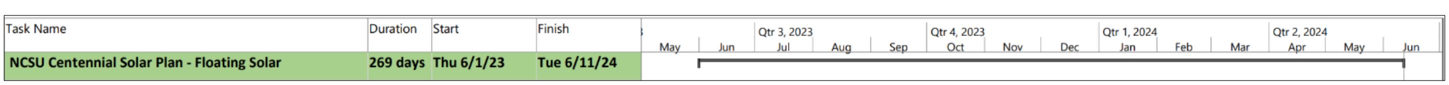


Figure 17. 1c Floating Construction Schedule

All connections are being made behind the University owned substation, and as such, they will be considered behind-the-meter. Seeing as no power will be exported to the grid, no interconnection permit will be required. The system's compliance with all the applicable codes will avoid the risk of denial from the authorities. Also, the project team will ensure to engage the AHJ early in the planning process to create buy-in by highlighting the sustainable development approach and positive impacts the system will have for NCSU's community.

STAGING APPROACH:

The objective of this project is to increase energy resiliency and promote a more sustainable, environmentally friendly campus by reducing dependency on fossil fuel-based generation. In that spirit, the development methodologies and staging approach of physical needs for equipment, vehicles, and temporary storage will also aim to follow the most sustainable and ecologically friendly practices possible. A list and approach for each Phase is as follows:

Phase 1a: Rooftop Solar and Resiliency Batteries

Approach: Equipment will be hoisted onto the rooftops where all connections and racking will be finished in line with standard practices.

Phase 1b: Ground Mount Solar

Approach: The 20 acres previously outlined will need to be logged and cleared. The site will require minimal grading as the system layout was designed along areas of minimal grade, and it is intended to follow the natural south facing slope. This will increase the system output and reduce the ecological impacts of fully grading and disturbing the topsoil. While this will require more diligent vegetation management during operation, maintaining the healthy microbiomes and grasses will improve soil retention and provide structural support for the pilings. Furthermore, the stormwater and wetlands impact reviews may find that the project requires the implementation of water diversion infrastructure or detention ponds. Retaining as much of the natural flora and fauna underneath the panels was possible will help reduce the impacts of runoff as well.

Phase 1c: Floating Solar

Approach: Arrays will be preassembled on the eastern bank of Lake Raleigh and floated into place where final anchoring and float connections will be made.

COMMUNITY ENGAGEMENT:

At North Carolina State University, community involvement for ground-mounted, rooftop, and floating solar panels can take many forms. For example, we can arrange workshops, seminars, and promotional campaigns to educate the community about the advantages of solar power, how they function, and how it can contribute towards the overall sustainability of the community. In addition, the project can provide hands-on training and research opportunities for students, faculty, and staff, promoting innovation and entrepreneurship.

The following communities could be impacted by the solar PV projects at NCSU Centennial campus:

- Campus community: The NCSU campus community includes students, faculty, staff, and visitors who will benefit from the solar PV project.
- Local community: The local community surrounding the campus will also benefit from the solar PV project. The project can create job opportunities and support local businesses, particularly if local suppliers, contractors, and labor are involved in the project.
- Environmental justice communities: Environmental justice communities, particularly communities of color and low-income communities, have historically borne the brunt of environmental pollution. Including these communities in the solar PV project can help address these historical injustices and ensure that the benefits of the project are distributed equitably.

CONCLUSION

In conclusion, the project proposal consists of 11 PV systems and 2 BESS. The 9 rooftop PVs, the combined total capacity of the groundmount PV and the floating PV is 6.6 MW. The annual production is 9735 MWh, and the 2 BESS with capacity of 1.5 MWh will ensure resiliency of the four critical buildings. The total cost of the system would be $11.4 million which NCSU would pay as PPA, starting at $0.079, which results in a project IRR of 6.5% for the developer. The development will take 12 months to fully complete all the three system types.

Overall, the project will bring significant advantages to NC State and the wider community of Raleigh by reducing the grid energy usage, and thereby offsetting greenhouse gas emissions. Additionally, it ensures resiliency with battery storage to meet demand of critical buildings during grid outages. This project will enrich the community by educating the public about sustainable energy by displaying the floating PV and sustainable ground mount PV. Lastly, it will bring clean energy job opportunities to the Raleigh community and engage a new generation of energy pioneers.

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Thank you

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