2A. CONCEPTUAL SYSTEM DESIGN—LAYOUT AND SPECIFICATIONS

INSTITUTION: NORTHEASTERN UNIVERSITY

TEAM: NUESS HUSKY POWER

USE CASE: NORTH CAROLINA STATE UNIVERSITY

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Introduction

North Carolina State University, a land-grant university established in 1887, is the use case that we were given. About halfway down the East Coast of the United States, Raleigh, North Carolina, is where this university is situated. As part of the American College and University Presidents' Climate Commitment, setting a goal of reaching climate neutrality by 2050 [4]. NC State's goal in this project is to Reduce peak demand on Centennial Campus to save utility costs and Reduce energy use to lower overall utility costs and contribute toward the university's energy and climate goals. This concept note evaluated Multiple sources of energy generation.

Site Information	
Name of the Use Case	North Carolina State University
Co-ordinates	35.7847° N, 78.6821° W

Figure:1

System Design Summary

To maximize energy output and reduce utility costs, we have explored options for designing the project: rooftop, ground mount, floating solar and Battery storage for the critical load support. The goal is to minimize peak demand utility costs and overall utility costs. Based on the 15-minute load data provided, it has been determined that the minimum load between 10 am to 5 pm is 6.5MW. It is important to note that all of this load is metered at the substation. This proposal conveys the solar sizing of the roof-top, Ground mount, Floating solar and Battery Storage and their system layout. We have chosen the buildings for the rooftop design based on various factors, including the availability of load data, the minimal impact of shadows on the buildings, and the amount of space available on the roof. The following buildings have been selected for the rooftop design.

1. College of Textiles Complex
2. James B. Hunt Jr. Library
3. Engineering Building-I
4. Engineering Building-II
5. Engineering Building-III
6. Research I
7. Toxicology Building
8. Partners II
9. Partners III

Building Name	Building Estimated Consumption	Solar Estimated annual Production	Energy offset	DC Capacity
	MWh	MWh	%	KWp
College of Textiles Complex	4750	409	9%	345
James B. Hunt Jr. Library	1808	614	34%	455
Engineering Building-I	5490	370	7%	284
Engineering Building-II	3767	775	21%	584
Engineering Building-III	3735	499	13%	385
Research I	2446	37	2%	26
Toxicology Building	2577	102	4%	89
Partners II	2550	219	9%	166
Partners III	3953	92	2%	77
Total	**31076**	**3117**	**10%**	**2411**

Table-1

In the above table energy offset is based on Solar estimated annual production on building estimated consumption. Floating Solar is considered Ciel et Terra floats and module-to-module spacing of 0.5 Inches with afixed tilt towards the south direction. The solar-generated capacity obtained is 2MWp, with a 2795MWhyearly production estimate. A single-a axis tracker is taken into consideration for ground mount and has an estimated annual production of 3823 MWh with combined total of 4.19 MWp DC.

Project	Solar Estimated annual Production	DC
	MWh	MWp
Floating solar	2795	2
Ground Mount	3823	2.19
Total	6618	4.19

Table-2

The Combined Capacity of Nine Rooftops, Ground Mount and Floating Solar is 6.6MW

System Design Solution and Approach

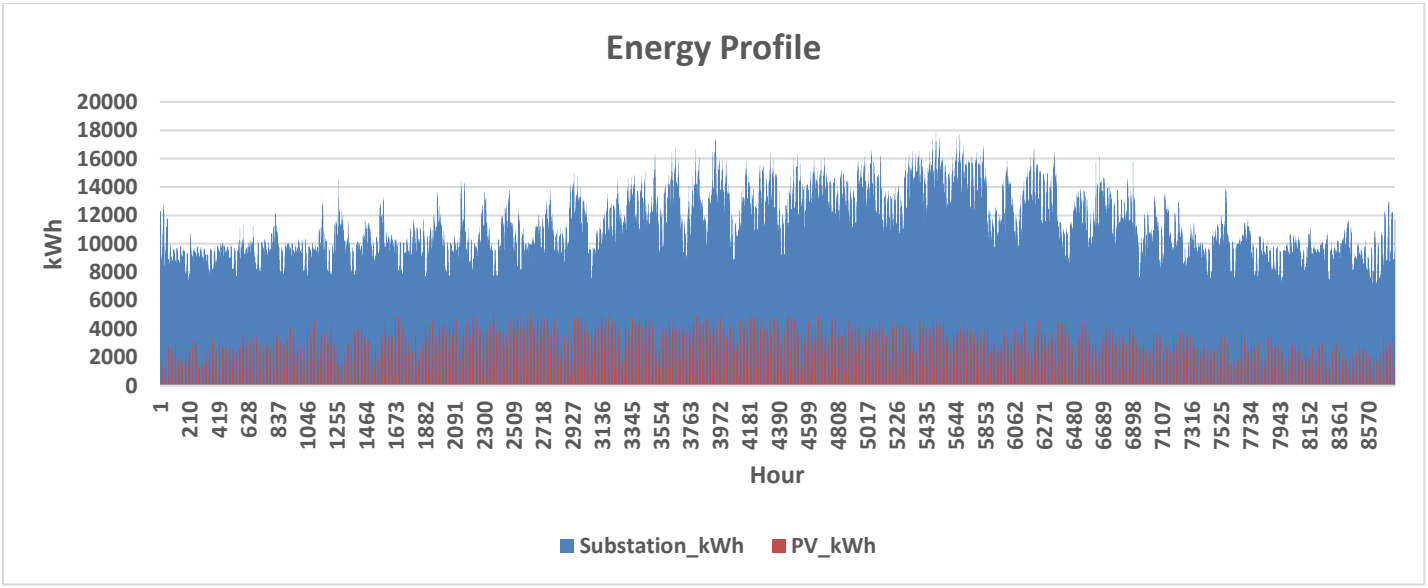
This project is intended to offset peak demand rates by catering Peak loads with solar and critical loads supported by battery storage. In this project, it is proposed to install PV panels on nine rooftops, ground Mount and Floating Solar in that six rooftop's are connected to the building's AC panel (College of Textiles Complex, Engineering Building I, Research I, Toxicology Building, Partners 2 & 3), and the remaining three rooftop's, Ground mount, and floating solar are connected to the distribution circuits (James B. Hunt Jr. Library, Engineering Building 2 & 3, Ground mount, and floating solar). In this proposal, For the electrical system and equipment design installation, and operation all required NEC, NFPA, and IECC Codes are considered.

During a grid outage, the batteries mentioned below for resilience will provide ride through for the building's critical loads.

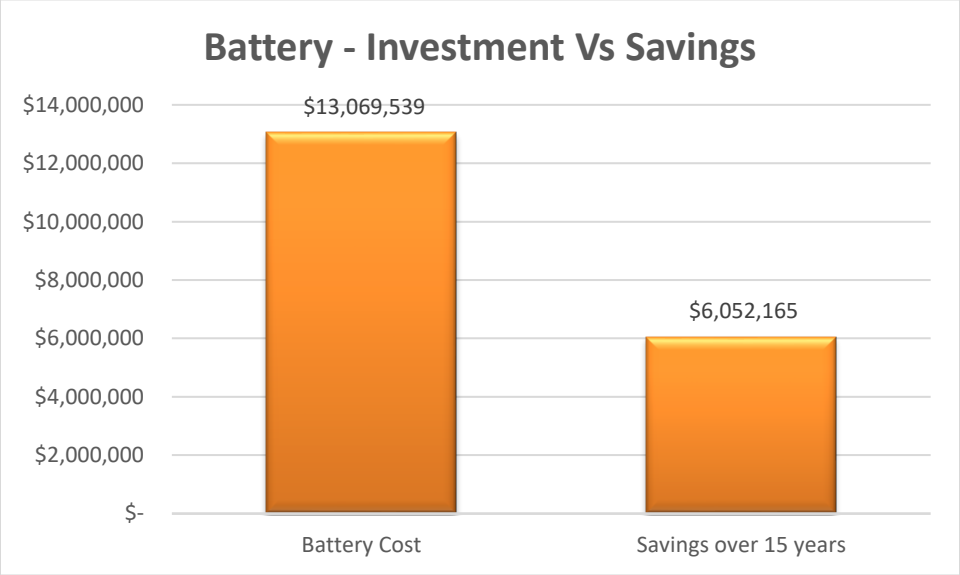
Roof top Buildings	Peak Load of the Building KW	Required Battery Capacity KWh
Engineering Building II	682	341
Toxicology Building	457	548
Partners III	573	344
Research I	440	220

Table-3

The distance between Engineering Building 2 and Partners 3 is 0.1 mile, and the distance between Partners 3 and Toxicology is 0.03 mile. As a result, it is decided that a single battery with a capacity of 1223 kWh will be installed near Partner 3's building. Since the distance between Partners 3 and Research 1 is 0.4 miles, it has been decided that a second battery with a capacity of 220KWh will be installed near the Research 1 building.



In this proposal, peak shaving analysis is performed to determine the feasibility of battery installation. While the analysis shows that the cost of installing a battery for peak shaving is higher than the expected savings for the next 15 years and obtained payback period is approximately 32 years. Therefore, it is concluded that installing a battery for peak shaving is not feasible. [1]



Battery Investment Analysis		
Battery Cost	$	13,069,539.00
Energy Saving each year	$	403,478.00
Energy Saving for 15 years	$	6,052,165.00
Payback period (yrs)		32.00

Table :4

Solar PV Specifications

1. Solar PV Module- JK Solar- 540Wp [2]

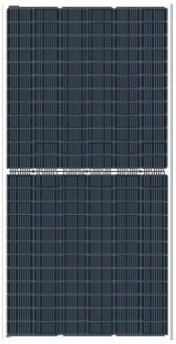


Figure:2

Strategy to select Jinko Solar Module:

Monocrystalline Silicon, Half-cell modules are selected for this project as they have the followingadvantages:

1. Highly efficient modules
2. High power density
3. Reduce internal resistance.
4. Reduced shadow impact

And Jinko Solar provides a 25-year Linear Power Warranty.

The PV module converts the sunlight into DC electricity and is certified for use up to a system voltage of1500 VDC. The Salient features of the PV module are as follows:

PV Module Salient Features		
Description of parameter	**Unit**	**Module**
Nominal Power (+ve tolerance)	PMPP (W)	540Wp
Voltage at Pmax	VMPP (V)	40.7V
Current at Pmax	IMPP (A)	13.27A
Open Circuit Voltage	VOC (V)	49.42V
Short Circuit Current	ISC (A)	13.85A
Maximum System Voltage	VSYS (V)	1500V
Maximum Series Fuse rating	ICF (A)	25A
Operating Range	(°C)	-40 to +85°C
Temperature Coefficient of PMPP	TK (PMPP)	-0.35%/°C
Temperature Coefficient of VOC	TK (VOC)	-0.28%/°C
Temperature Coefficient of ISC	TK (ISC)	0.05%/°C
Standard	IEC	61215, 61730

Table :5

Inverter Specifications

Figure:3

The SolarEdge [3] SE100KUS Multi-MPPT String Inverter, 1000 Vdc System is proposed to provide higher generation (Multiple MPPT) and reliability (Worst case scenario) [3]

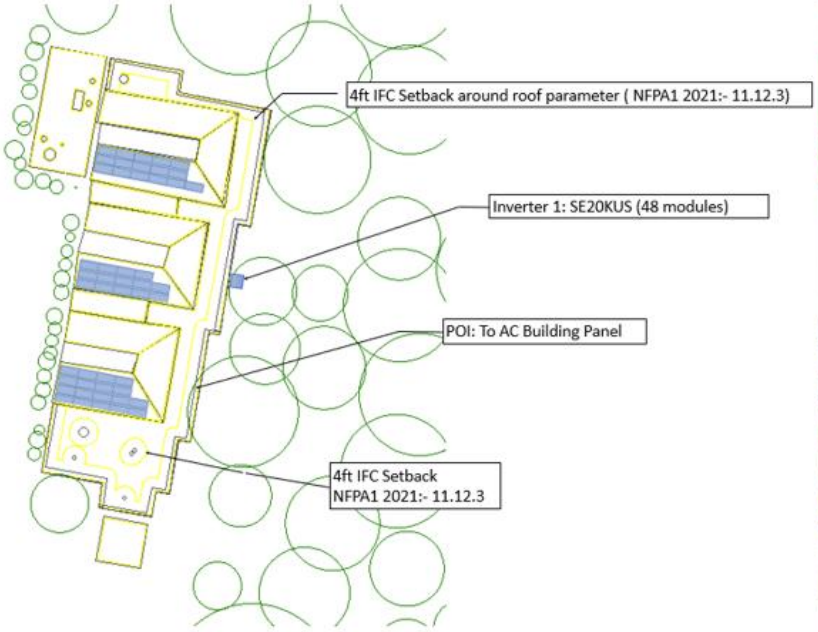
Reason to select SolarEdge Inverter:

The Advantage Program by SolarEdge provides extensive coverage for any possible loss of production due to power optimizer downtime. The program also generates a comprehensive report containing all relevant power optimizer data, which is available for download via the SolarEdge monitoring platform at any time. SolarEdge sends the Advantage Report to the EPC every six months, fully detailing the relevant coverage.

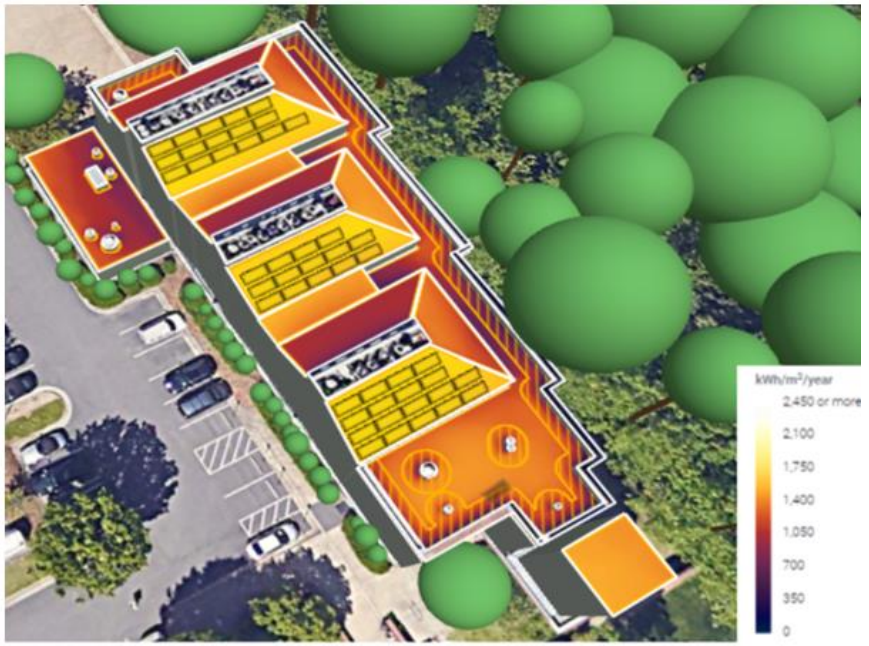
Salient feature of the inverter	
100KVA	
MPP voltage range VDC	850– 1000 V
Max. input voltage VDC, max	1000 V
Max. Current per MPPT	40 A
Number of DC inputs	12
Number of MPP Trackers	4
AC output power	100kVA
Nominal AC voltage	480 V
Maximum Efficiency	98.50%
Safety	UL1699B, UL1741, UL1741 SA, UL1741 SB, UL1998, CSA C22.2#107.1
Degree of protection	NEMA 3R
Grid Connection Standards	EEE 1547-2018, Rule 21, Rule 14 (HI)

Table :6

Layout and Specifications: Research 1 – Building

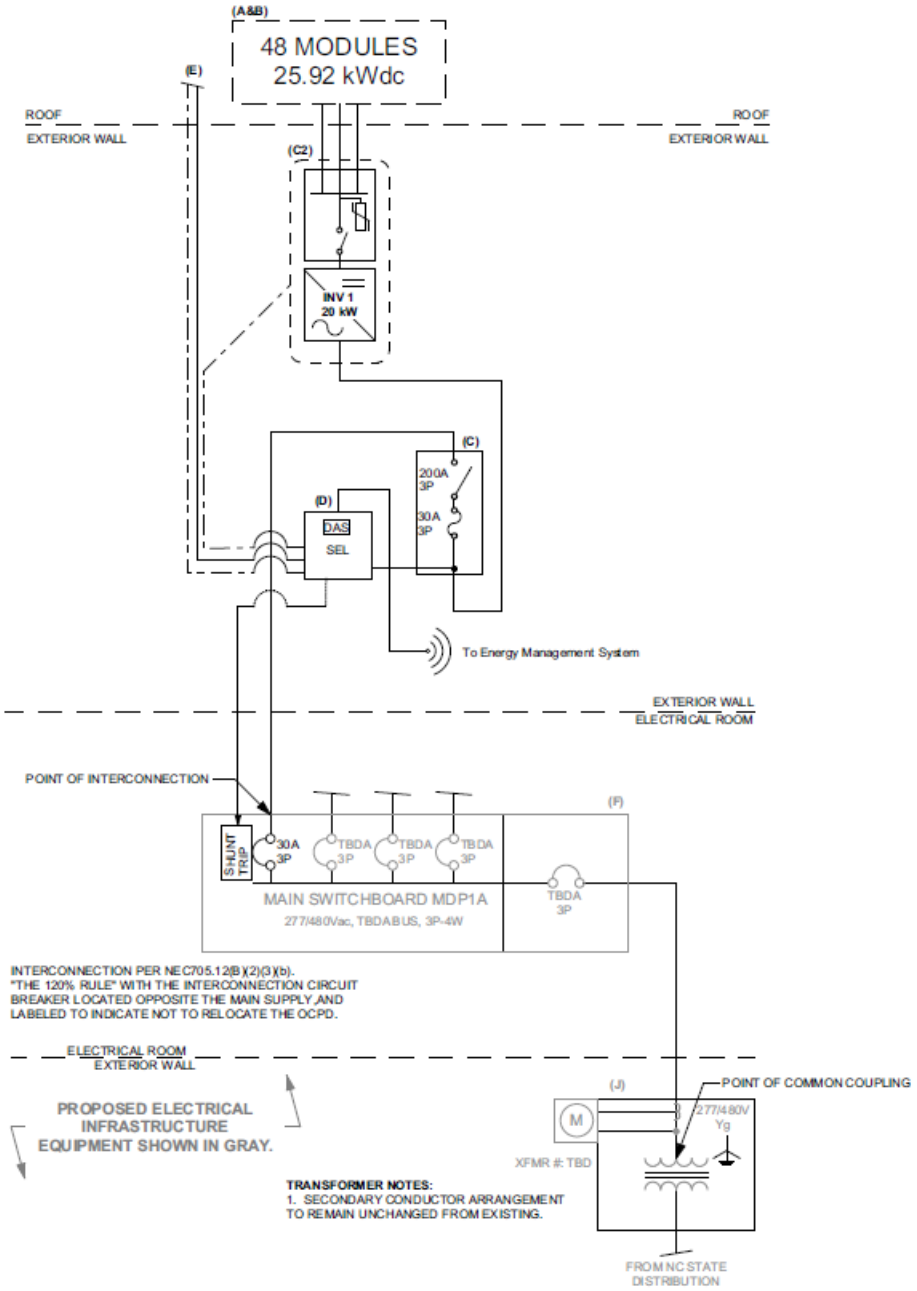


1 26KWdc (20KWac) PV LAYOUT 48 MODULES

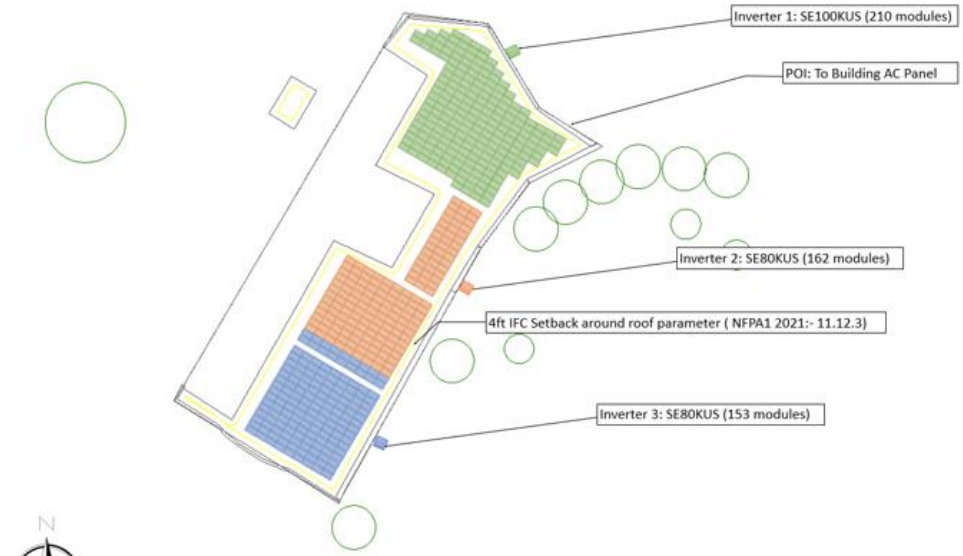


2 ANNUAL IRRADIANCE / SHADDING ANNALYSIS

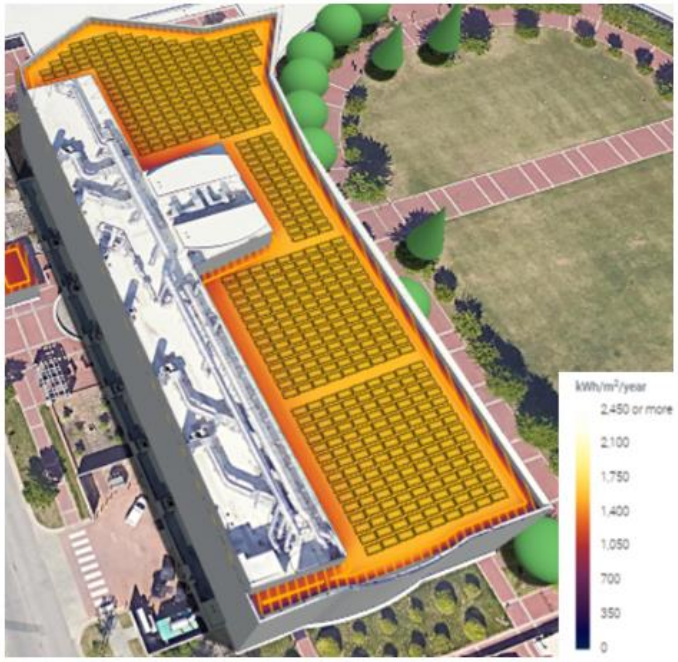
Module Make - Rating (Wp)	**JK Solar- 540Wp**
Module Model	**JKM540M-72HL4-V**
No of Inverters	**(1) SE20KUS (277/480V)**
Tilt	**5° - Fixed Tilt**
Module Orientation	**Landscape**
Type of Mounting	**Roof Top**
DC Capacity	**26 KWp**
Estimated Annual Production	**37 MWh**
Off-Set energy	**2%**
Parapet Set-back	**4 feet**
Obstacle Set-Back	**4 feet**
Racking Type	**Roof Ballast Mount**


(A&B)
48 MODULES
25.92 kWdc
(E)
ROOF
EXTERIOR WALL
ROOF
EXTERIOR WALL
(C2)
INV 1
20 kW
(C)
200A
3P
30A
3P
(D)
DAS
SEL
To Energy Management System
EXTERIOR WALL
ELECTRICAL ROOM
POINT OF INTERCONNECTION
(F)
SHUNT TRIP
30A
3P
TBDA
3P
TBDA
3P
TBDA
3P
MAIN SWITCHBOARD MDP1A
277/480Vac, TBDABUS, 3P-4W
TBDA
3P
INTERCONNECTION PER NEC705.12(B)(2)(3)(b).
"THE 120% RULE" WITH THE INTERCONNECTION CIRCUIT
BREAKER LOCATED OPPOSITE THE MAIN SUPPLY AND
LABELED TO INDICATE NOT TO RELOCATE THE OCPD.
ELECTRICAL ROOM
EXTERIOR WALL
PROPOSED ELECTRICAL
INFRASTRUCTURE
EQUIPMENT SHOWN IN GRAY.
(J)
POINT OF COMMON COUPLING
M
277/480V
Yg
XFMR #: TBD
TRANSFORMER NOTES:
1. SECONDARY CONDUCTOR ARRANGEMENT
TO REMAIN UNCHANGED FROM EXISTING.
FROM NC STATE
DISTRIBUTION

Layout and Specifications: Engineering Building I

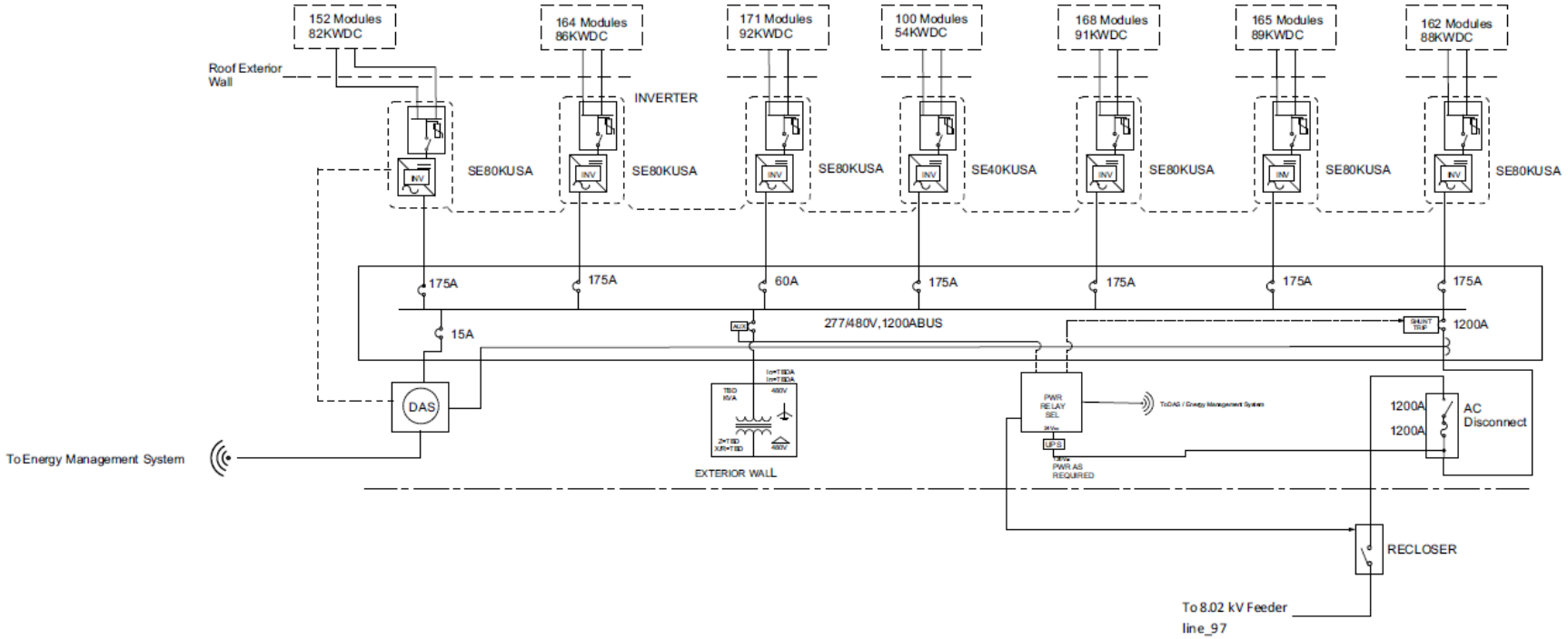


1 284KWdc (260KWac) PV LAYOUT 525 MODULES



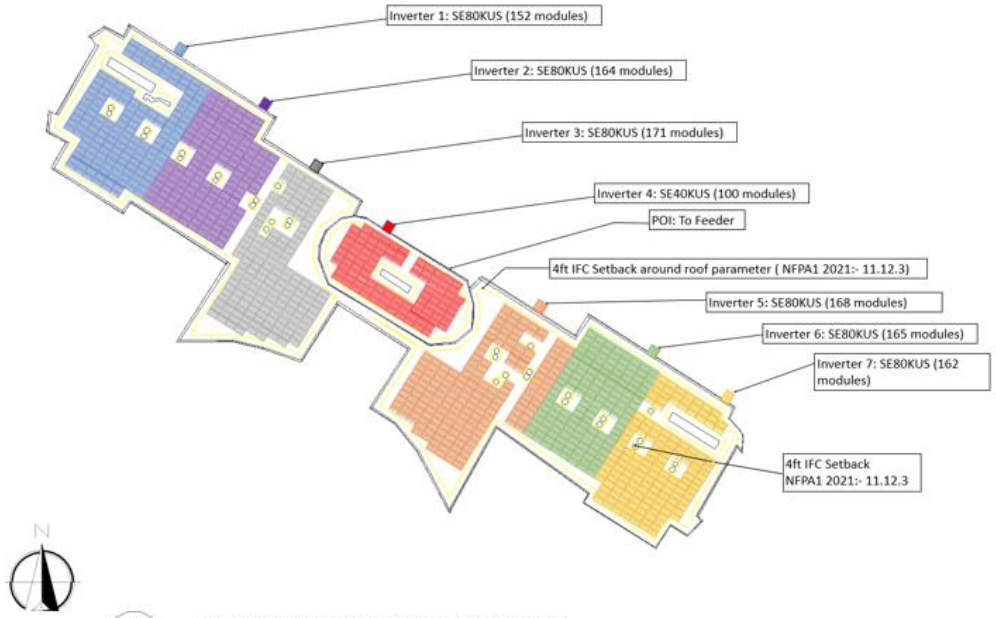
2 ANNUAL IRRADIANCE / SHADDING ANNALYSIS

Module Make - Rating (Wp)	**JK Solar- 540Wp**
Module Model	**JKM540M-72HL4-V**
Inverter	**(1) SE100KUS (277/480V)** **(2) SE80KUS (277/480V)**
Tilt	**5° - Fixed Tilt**
Module Orientation	**Landscape**
Type of Mounting	**Roof Top**
DC Capacity	**284 KWp**
Estimated Annual Production	**370 MWh**
Off-Set energy	**7%**
Parapet Set-back	**4 feet**
Obstacle Set-Back	**4 feet**
Racking Type	**Roof Ballast Mount**

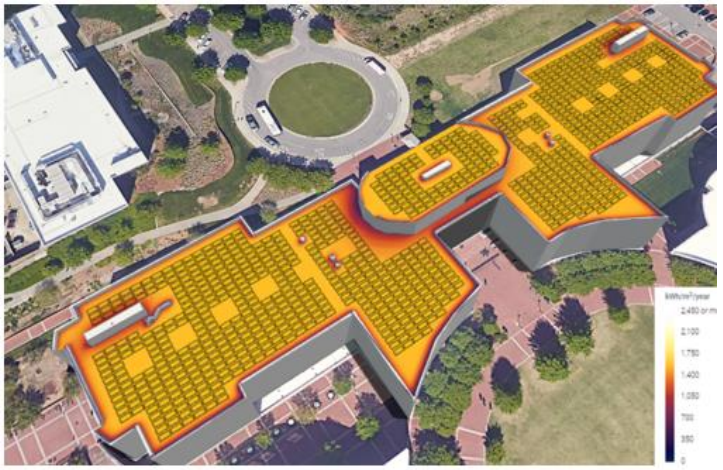


3 **284KWdc (260KWac) Engineering Building-1, SLD**

Layout and Specifications: Engineering Building II

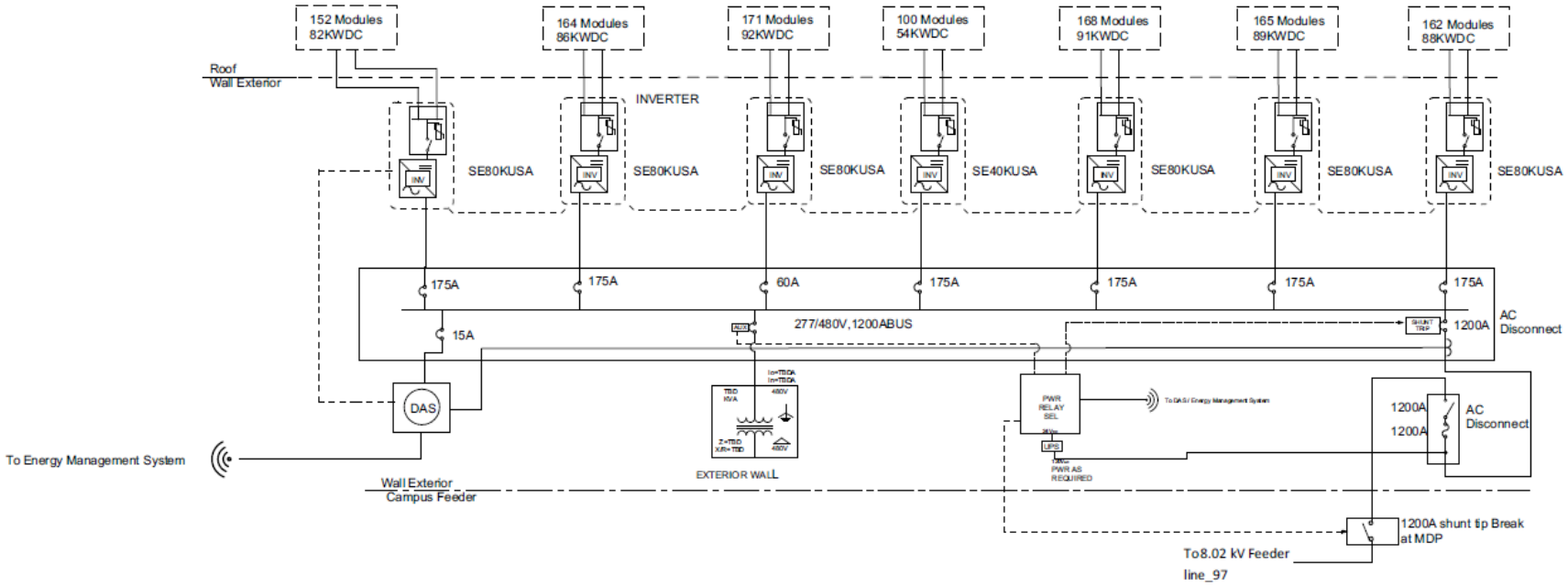


1 584KWdc (440KWac) PV LAYOUT 1082 MODULES



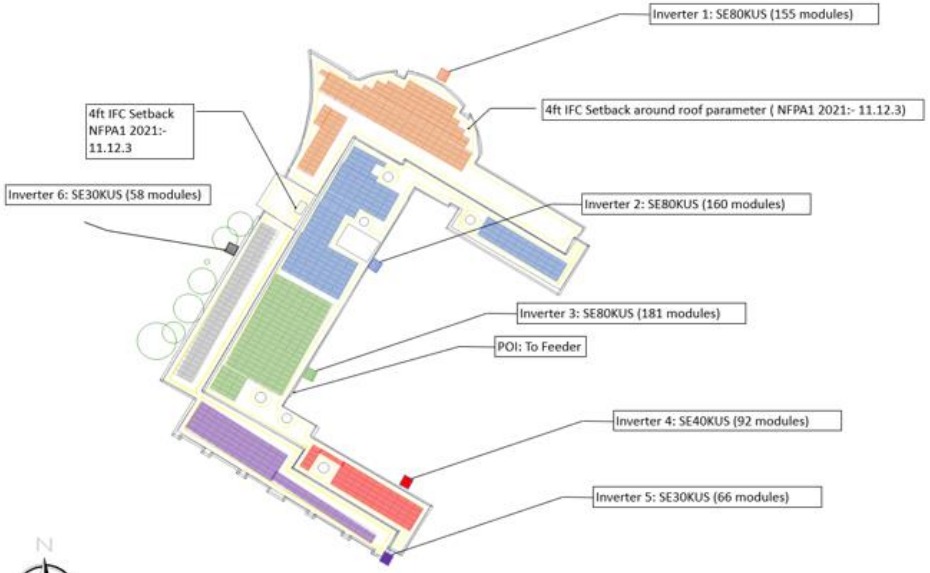
2 ANNUAL IRRADIANCE / SHADDING ANNALYSIS

Module Make - Rating (Wp)	**JK Solar- 540Wp**
Module Model	**JKM540M-72HL4-V**
Inverter	**(6) SE80KUS (277/480V) (1) SE40KUS (277/480V)**
Tilt	**5° - Fixed Tilt**
Module Orientation	**Landscape**
Type of Mounting	**Roof Top**
DC Capacity	**584 KWp**
Estimated Annual Production	**775 MWh**
Off-Set energy	**21%**
Parapet Set-back	**4 feet**
Obstacle Set-Back	**4 feet**
Racking Type	**Roof Ballast Mount**



3 **584KWdc (440KWac) Engineering Building II, SLD**

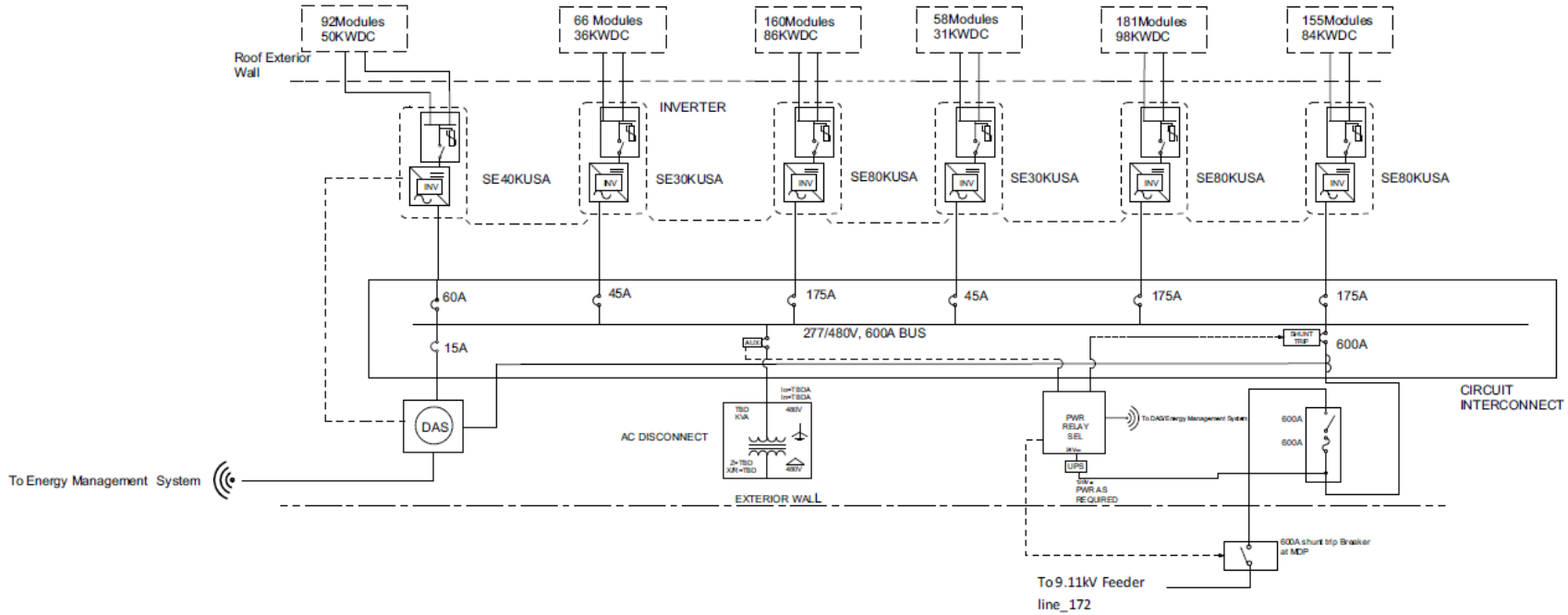
Layout and Specifications: Engineering Building III



1 385KWdc (340KWac) PV LAYOUT 712 MODULES

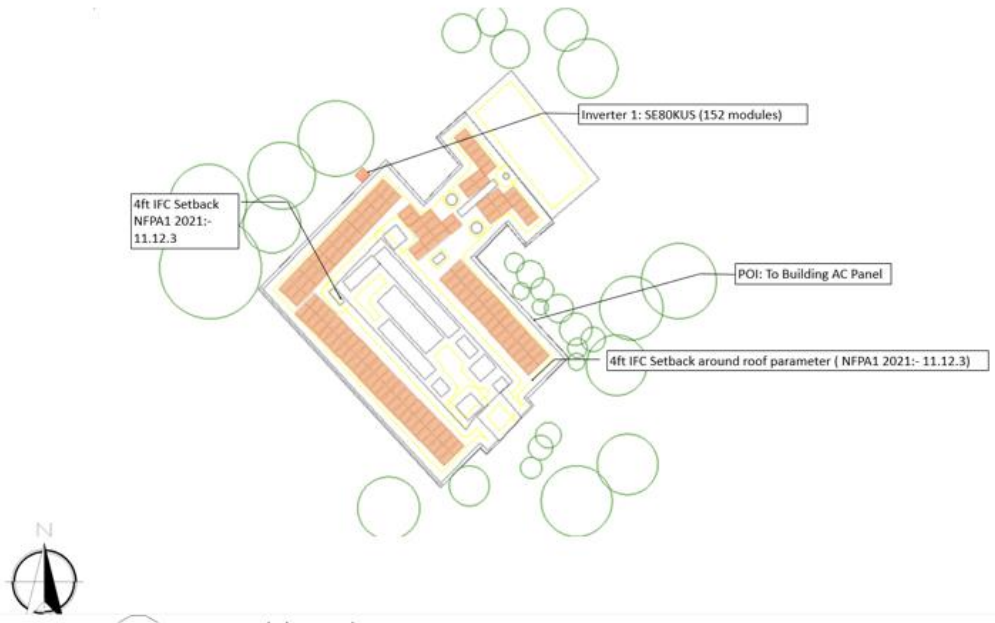
2 ANNUAL IRRADIANCE / SHADDING ANNALYSIS

Module Make - Rating (Wp)	**JK Solar- 540Wp**
Module Model	**JKM540M-72HL4-V**
Inverter	**(3) SE80KUS (277/480V) (1) SE40KUS (277/480V) (2) SE30KUS (277/480V)**
Tilt	**5° - Fixed Tilt**
Module Orientation	**Landscape**
Type of Mounting	**Roof Top**
DC Capacity	**385 KWp**
Estimated Annual Production	**499 MWh**
Off-Set energy	**14%**
Parapet Set-back	**4 feet**
Obstacle Set-Back	**4 feet**
Racking Type	**Roof Ballast Mount**

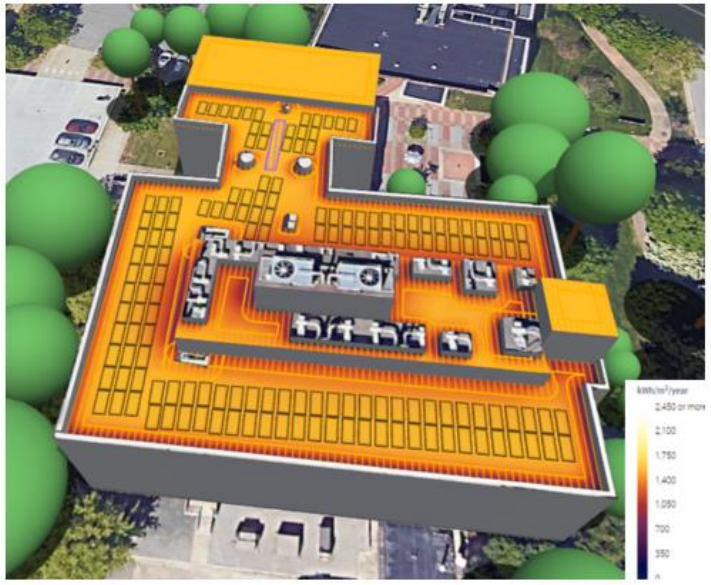


3 **385KWdc (340KWac) Engineering Building III, SLD**

Layout and Specifications: Toxicology Building

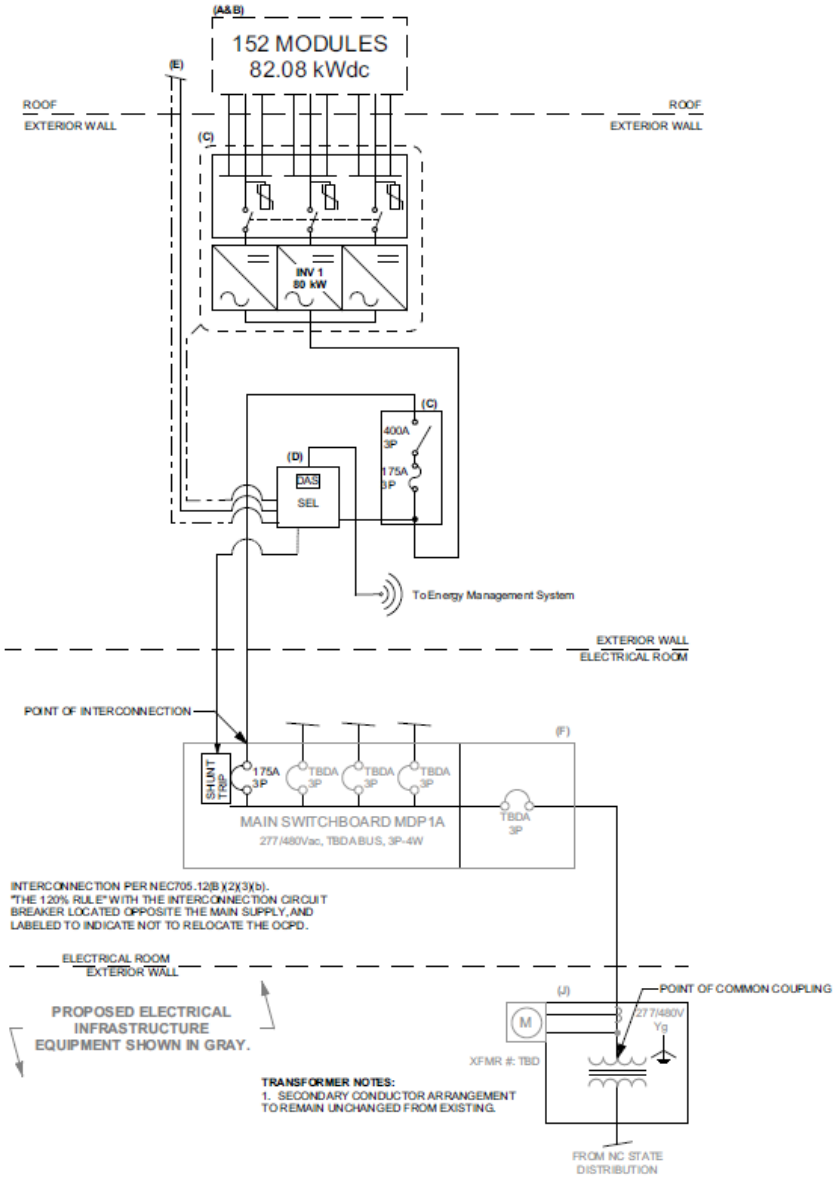


1 82KWdc (80KWac) PV LAYOUT 152 MODULES



2 ANNUAL IRRADIANCE / SHADDING ANNALYSIS

Module Make - Rating (Wp)	**JK Solar- 540Wp**
Module Model	**JKM540M-72HL4-V**
Inverter	**(1) SE80KUS (277/480V)**
Tilt	**5° - Fixed Tilt**
Module Orientation	**Landscape**
Type of Mounting	**Roof Top**
DC Capacity	**82 KWp**
Estimated Annual Production	**102 MWh**
Off-Set energy	**4%**
Parapet Set-back	**4 feet**
Obstacle Set-Back	**4 feet**
Racking Type	**Roof Ballast Mount**


(A&B)
152 MODULES
82.08 kWdc
(E)
ROOF
EXTERIOR WALL
ROOF
EXTERIOR WALL
(C)
INV 1
80 kW
(C)
400A
3P
(D)
DAS
SEL
175A
3P
To Energy Management System
EXTERIOR WALL
ELECTRICAL ROOM
POINT OF INTERCONNECTION
(F)
SHUNT TRIP
175A
3P
TBDA
3P
TBDA
3P
TBDA
3P
MAIN SWITCHBOARD MDP1A
277/480Vac, TBDA BUS, 3P-4W
TBDA
3P
INTERCONNECTION PER NEC705.12(B)(2)(3)(b).
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BREAKER LOCATED OPPOSITE THE MAIN SUPPLY, AND
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PROPOSED ELECTRICAL
INFRASTRUCTURE
EQUIPMENT SHOWN IN GRAY.
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TRANSFORMER NOTES:
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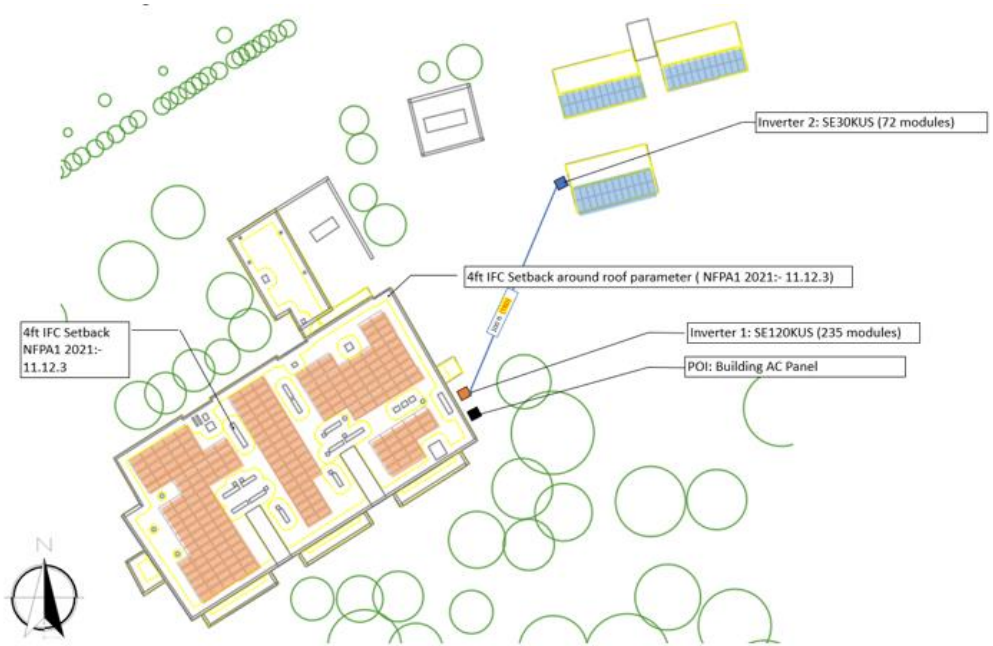
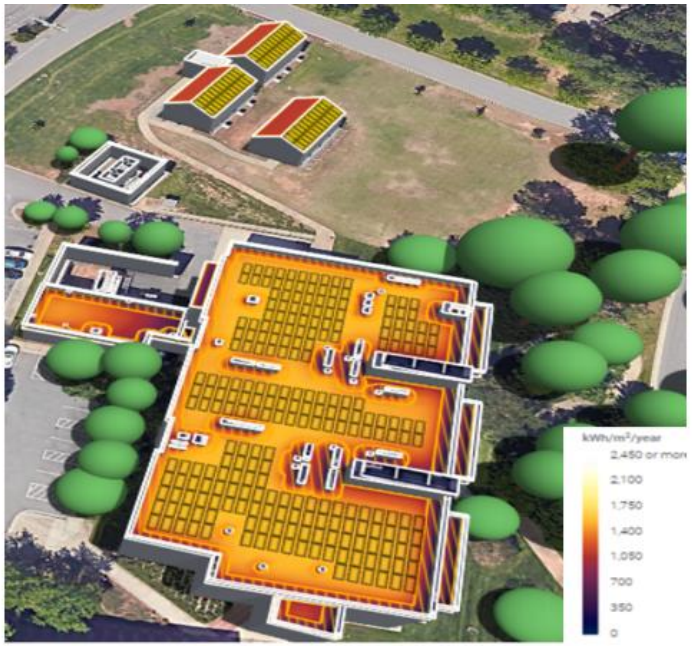
Layout and Specifications: Partners II – Building

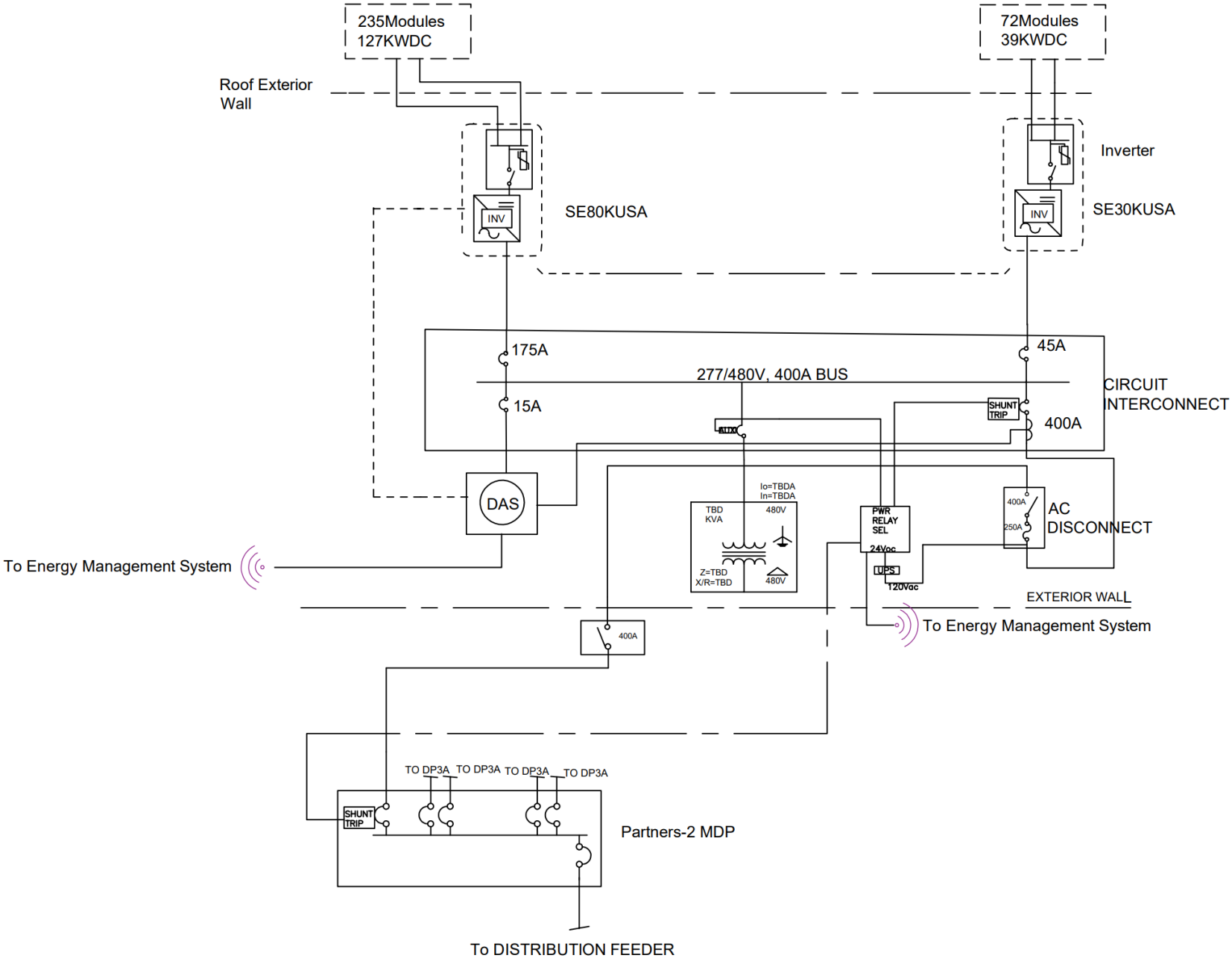


1 166KWdc (130KWac) PV LAYOUT 307 MODULES



2 ANNUAL IRRADIANCE / SHADDING ANNALYSIS

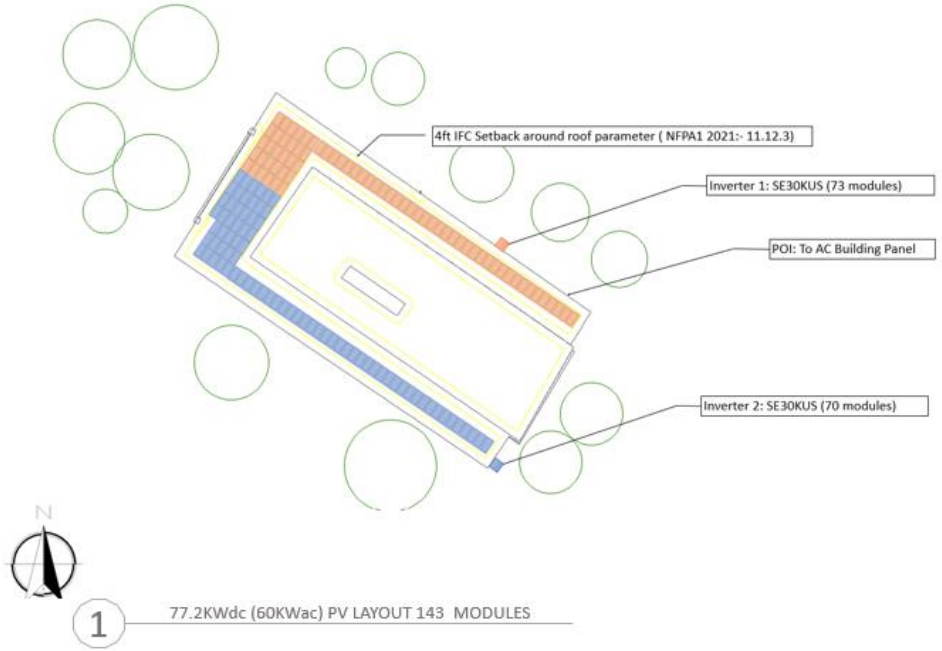
Module Make - Rating (Wp)	**JK Solar- 540Wp**
Module Model	**JKM540M-72HL4-V**
Inverter	**(1) SE100KUS (277/480V)** **(1) SE30KUS (277/480V)**
Tilt	**5° - Fixed Tilt**
Module Orientation	**Landscape**
Type of Mounting	**Roof Top**
DC Capacity	**166 KWp**
Estimated Annual Production	**219 MWh**
Off-Set energy	**9%**
Parapet Set-back	**4 feet**
Obstacle Set-Back	**4 feet**
Racking Type	**Roof Ballast Mount**



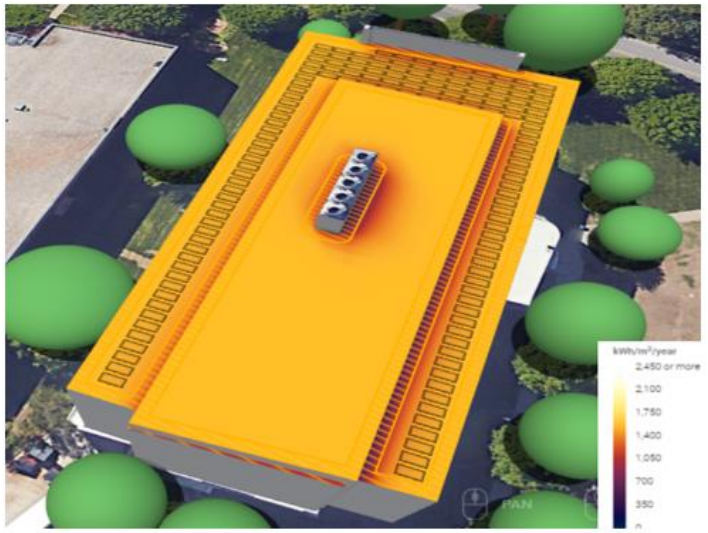
3

166KWdc (130KWac) Partners II, SLD

Layout and Specifications: Partners III – Building

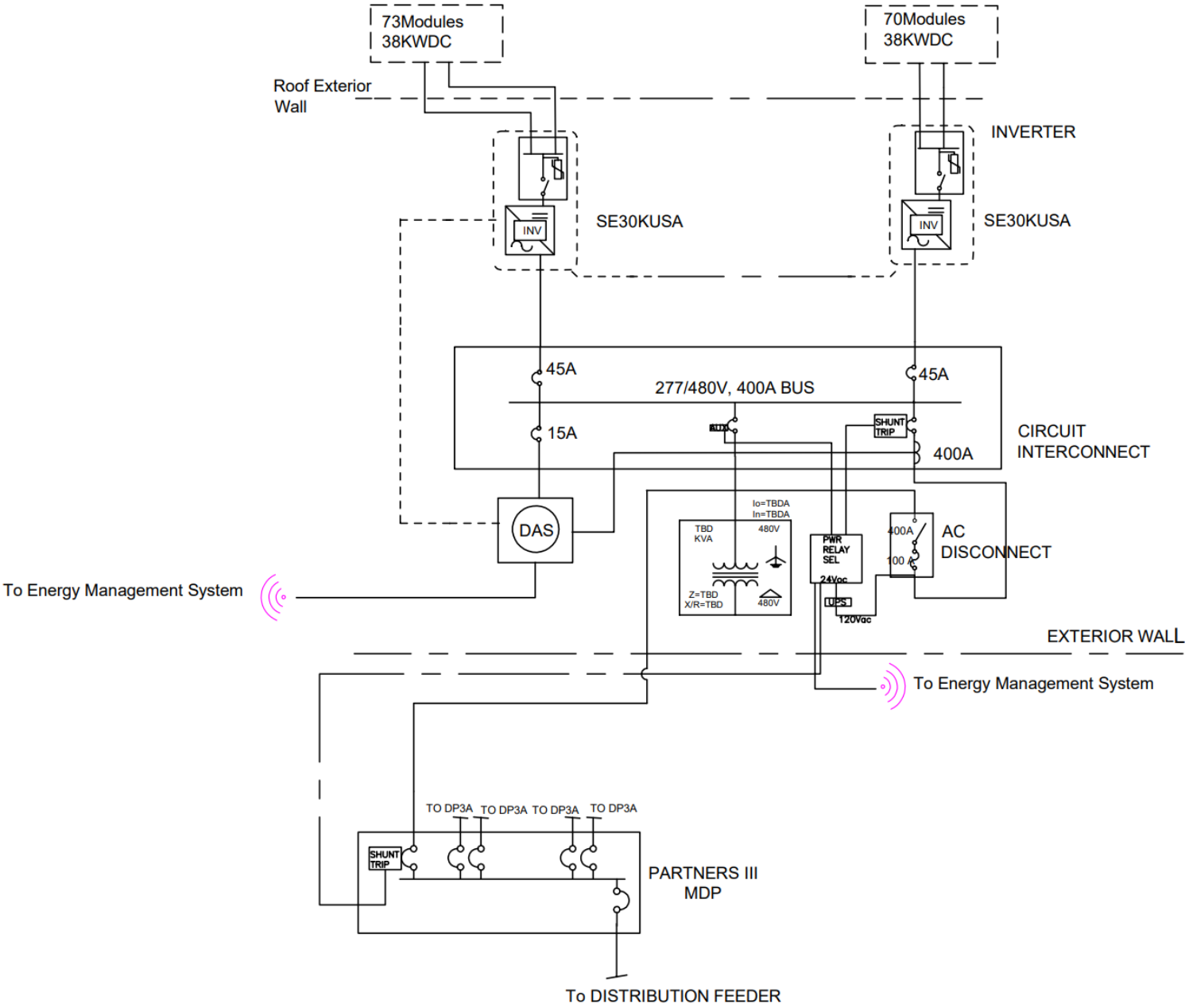


1 77.2KWdc (60KWac) PV LAYOUT 143 MODULES

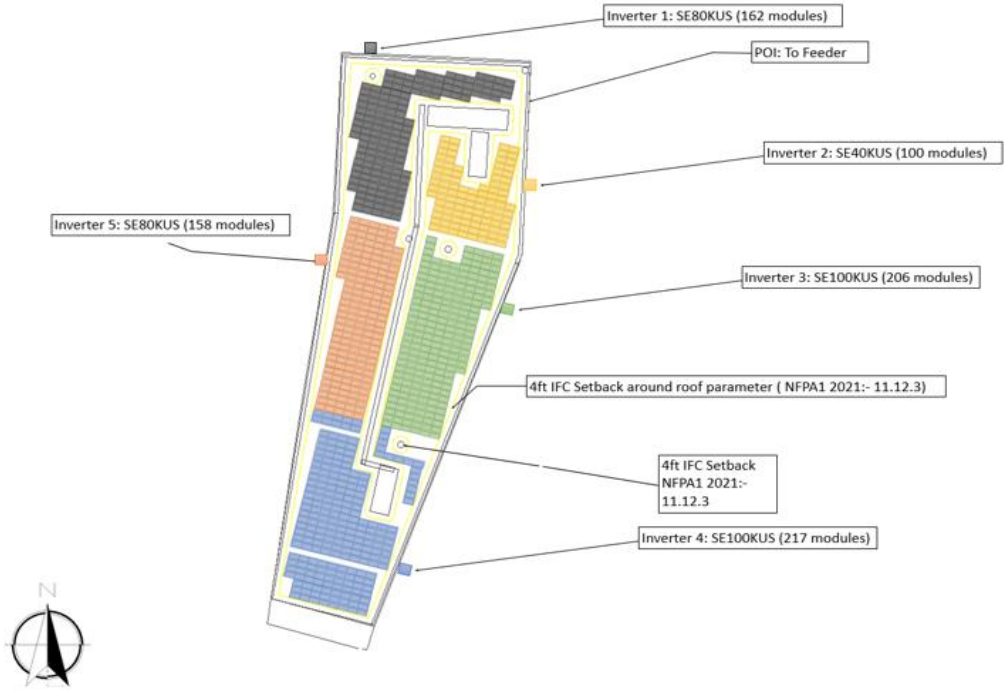


2 ANNUAL IRRADIANCE / SHADDING ANNALYSIS

Module Make - Rating (Wp)	**JK Solar- 540Wp**
Module Model	**JKM540M-72HL4-V**
Inverter	**(1) SE30KUS (277/480V)**
Tilt	**5° - Fixed Tilt**
Module Orientation	**Landscape**
Type of Mounting	**Roof Top**
DC Capacity	**77 KWp**
Estimated Annual Production	**92 MWh**
Off-Set energy	**2%**
Parapet Set-back	**4 feet**
Obstacle Set-Back	**4 feet**
Racking Type	**Roof Ballast Mount**


73Modules
38KWDC
70Modules
38KWDC
Roof Exterior
Wall
INVERTER
SE30KUSA
INV
SE30KUSA
INV
45A
277/480V, 400A BUS
45A
15A
SHUNT
TRIP
400A
CIRCUIT
INTERCONNECT
DAS
Io=TBDA
In=TBDA
TBD
KVA
480V
Z=TBD
X/R=TBD
480V
PWR
RELAY
SEL
24Vac
UPS
120Vac
400A
100 A
AC
DISCONNECT
To Energy Management System
EXTERIOR WALL
To Energy Management System
TO DP3A
TO DP3A
TO DP3A
TO DP3A
SHUNT
TRIP
PARTNERS III
MDP
To DISTRIBUTION FEEDER

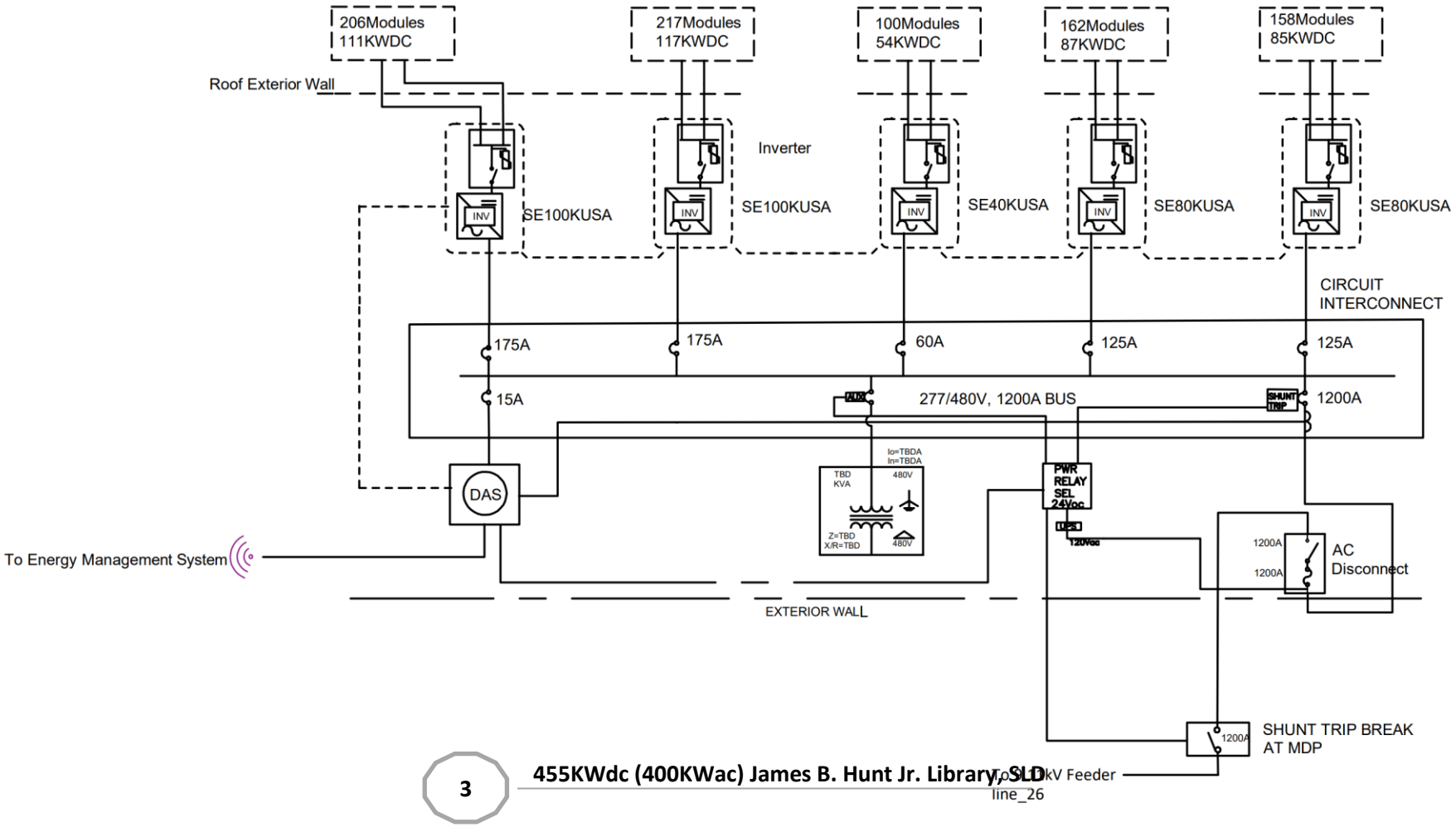
Layout and Specifications: James B. Hunt Jr. Library – Building



1 455KWdc (400KWac) PV LAYOUT 843 MODULES

2 ANNUAL IRRADIANCE / SHADDING ANNALYSIS

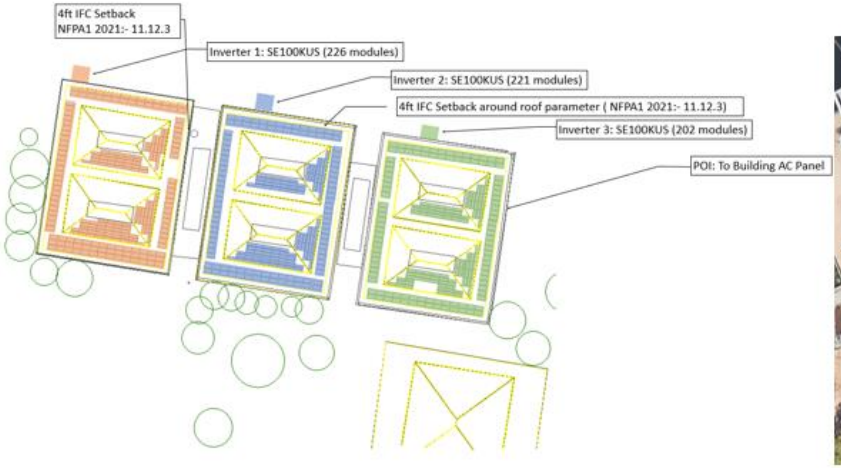
Module Make - Rating (Wp)	**JK Solar- 540Wp**
Module Model	**JKM540M-72HL4-V**
Inverter	**(2) SE100KUS (277/480V)** **(2) SE80K(277/480V)** **(1) SE40K(277/480V)**
Tilt	**5° - NCSU-Hunt Library**
Module Orientation	**Landscape**
Type of Mounting	**Roof Top**
DC Capacity	**455 KWp**
Estimated Annual Production	**614 MWh**
Off-Set energy	**34%**
Parapet Set-back	**4 feet**
Obstacle Set-Back	**4 feet**
Racking Type	**Roof Ballast Mount**

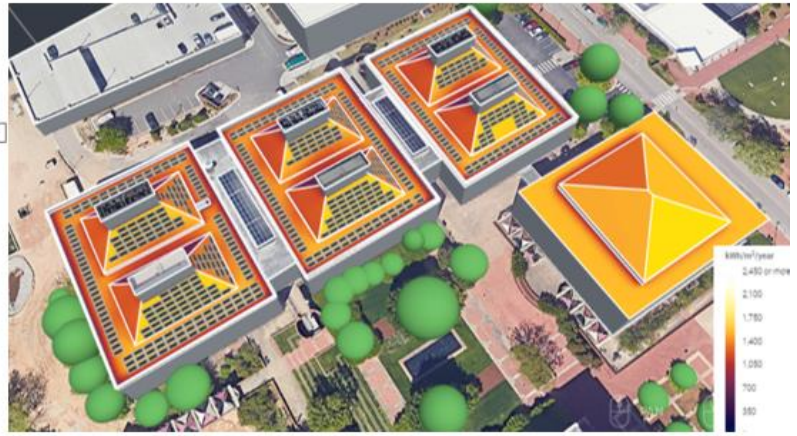


3

455KWdc (400KWac) James B. Hunt Jr. Library SLD

Layout and Specifications: College of Textiles Complex– Building

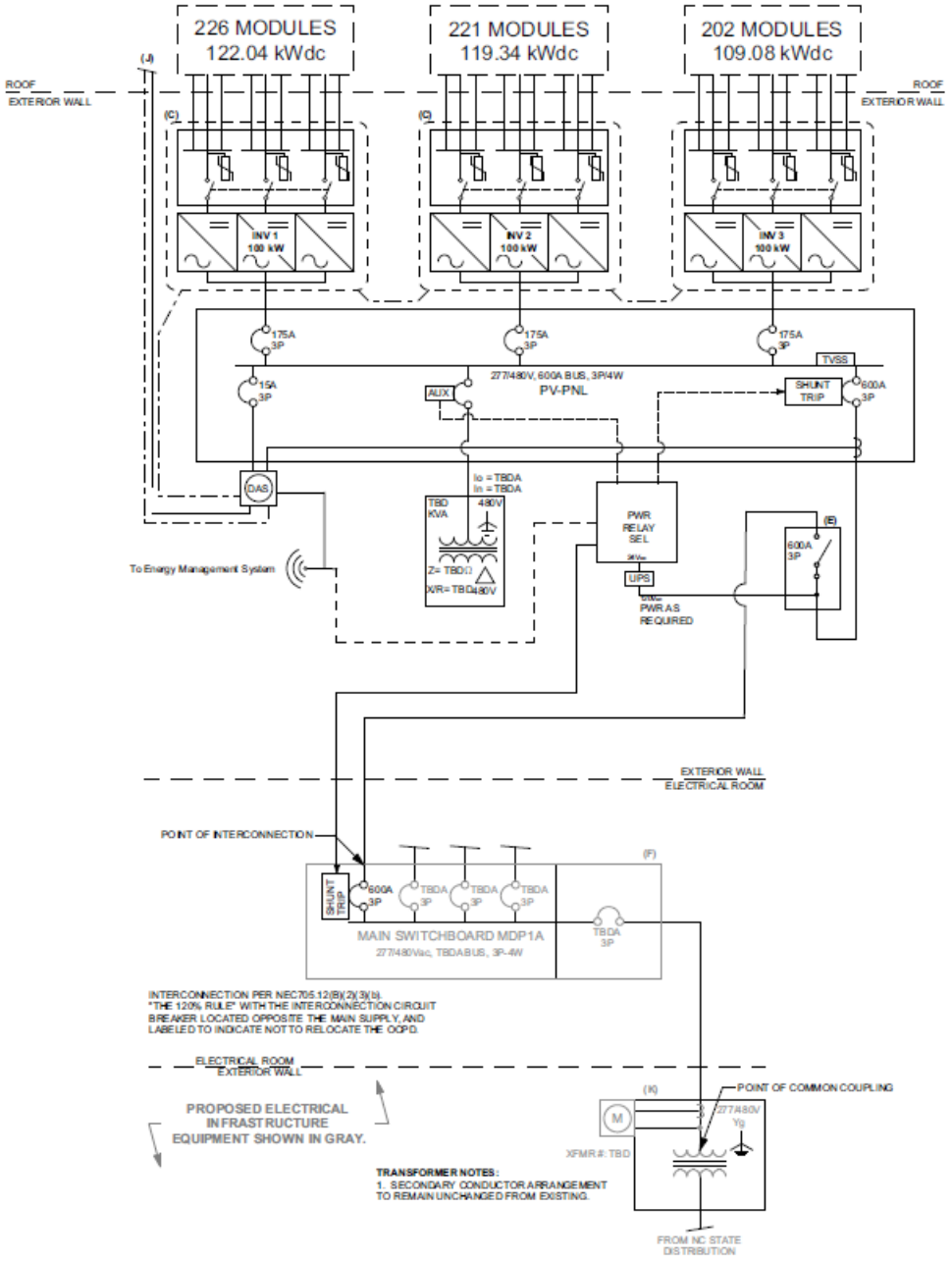




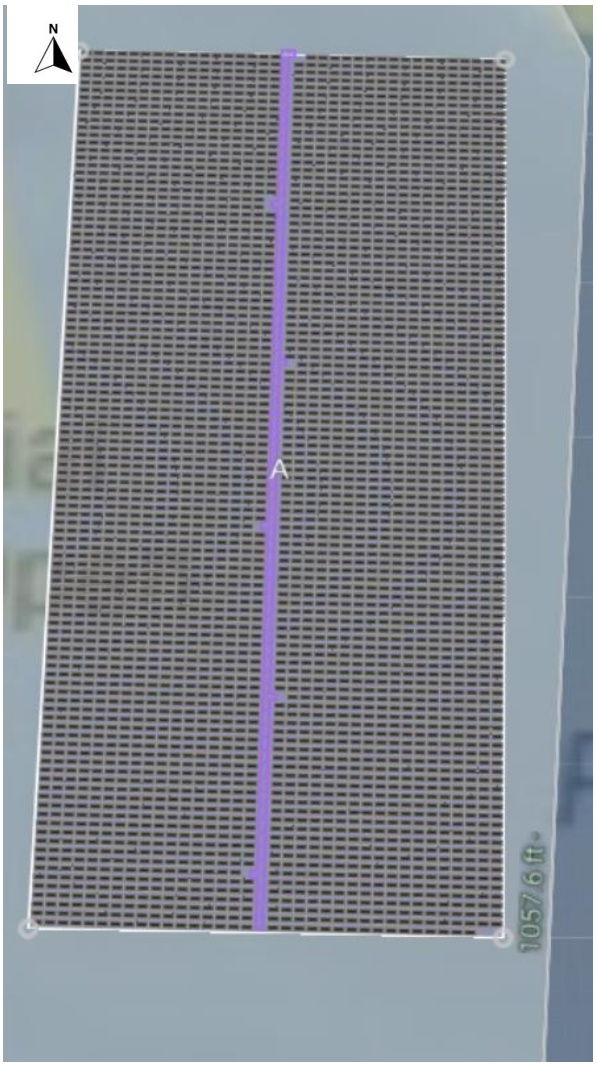
1 345kW dc(300Ac) PV layout 639 Modules

2 ANNUAL IRRADIANCE/ SHADING ANALYSIS

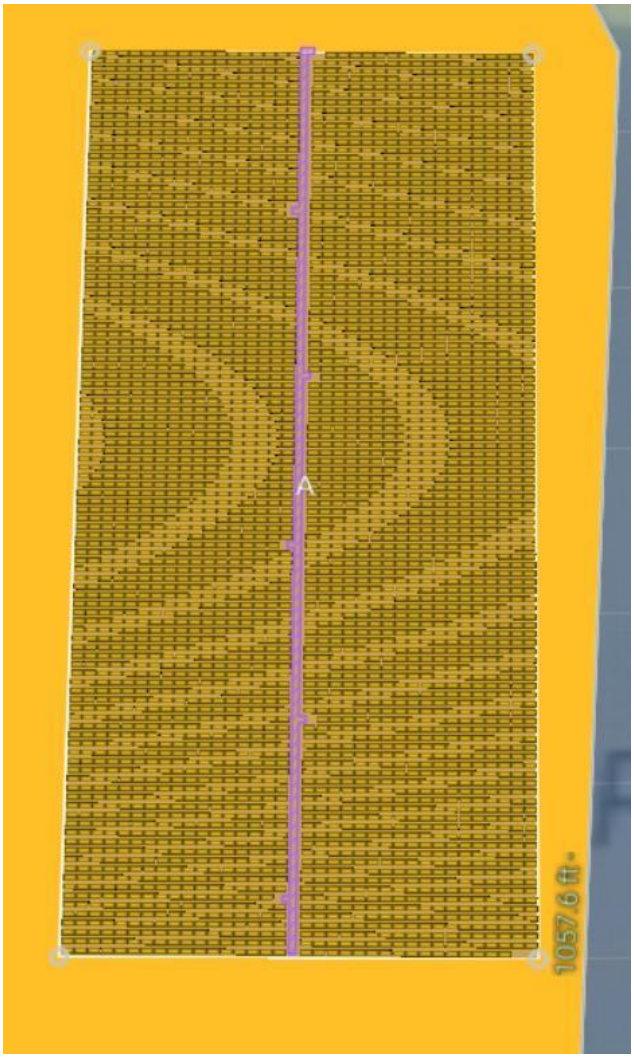
Module Make - Rating (Wp)	**JK Solar- 540Wp**
Module Model	**JKM540M-72HL4-V**
Inverter	**(2) SE100KUS (277/480V)**
Tilt	**5° - College of Textiles Complex**
Module Orientation	**Landscape**
Type of Mounting	**Roof Top**
DC Capacity	**345 KWp**
Estimated Annual Production	**409 MWh**
Off-Set energy	**9%**
Parapet Set-back	**4 feet**
Obstacle Set-Back	**4 feet**
Racking Type	**Roof Ballast Mount**


226 MODULES
122.04 kWdc
221 MODULES
119.34 kWdc
202 MODULES
109.08 kWdc
ROOF
EXTERIOR WALL
INV 1
100 kW
INV 2
100 kW
INV 3
100 kW
175A
3P
15A
3P
277/480V, 600A BUS, 3P/4W
PV-PNL
AUX
TVSS
SHUNT
TRIP
600A
3P
DAS
To Energy Management System
Io = TBDA
In = TBDA
TBD
kVA
480V
Z= TBDΩ
X/R= TBD
480V
PWR
RELAY
SEL
UPS
PWR AS
REQUIRED
600A
3P
EXTERIOR WALL
ELECTRICAL ROOM
POINT OF INTERCONNECTION
SHUNT
TRIP
600A
3P
TBDA
3P
MAIN SWITCHBOARD MDP1A
277/480Vac, TBDA BUS, 3P-4W
INTERCONNECTION PER NEC705.12(B)(2)(3)(b).
"THE 120% RULE" WITH THE INTERCONNECTION CIRCUIT
BREAKER LOCATED OPPOSITE THE MAIN SUPPLY, AND
LABELED TO INDICATE NOT TO RELOCATE THE OCPD.
ELECTRICAL ROOM
EXTERIOR WALL
PROPOSED ELECTRICAL
INFRASTRUCTURE
EQUIPMENT SHOWN IN GRAY.
POINT OF COMMON COUPLING
277/480V
Yg
XFMR #: TBD
TRANSFORMER NOTES:
1. SECONDARY CONDUCTOR ARRANGEMENT
TO REMAIN UNCHANGED FROM EXISTING.
FROM NC STATE
DISTRIBUTION

Layout and Specifications: Floating

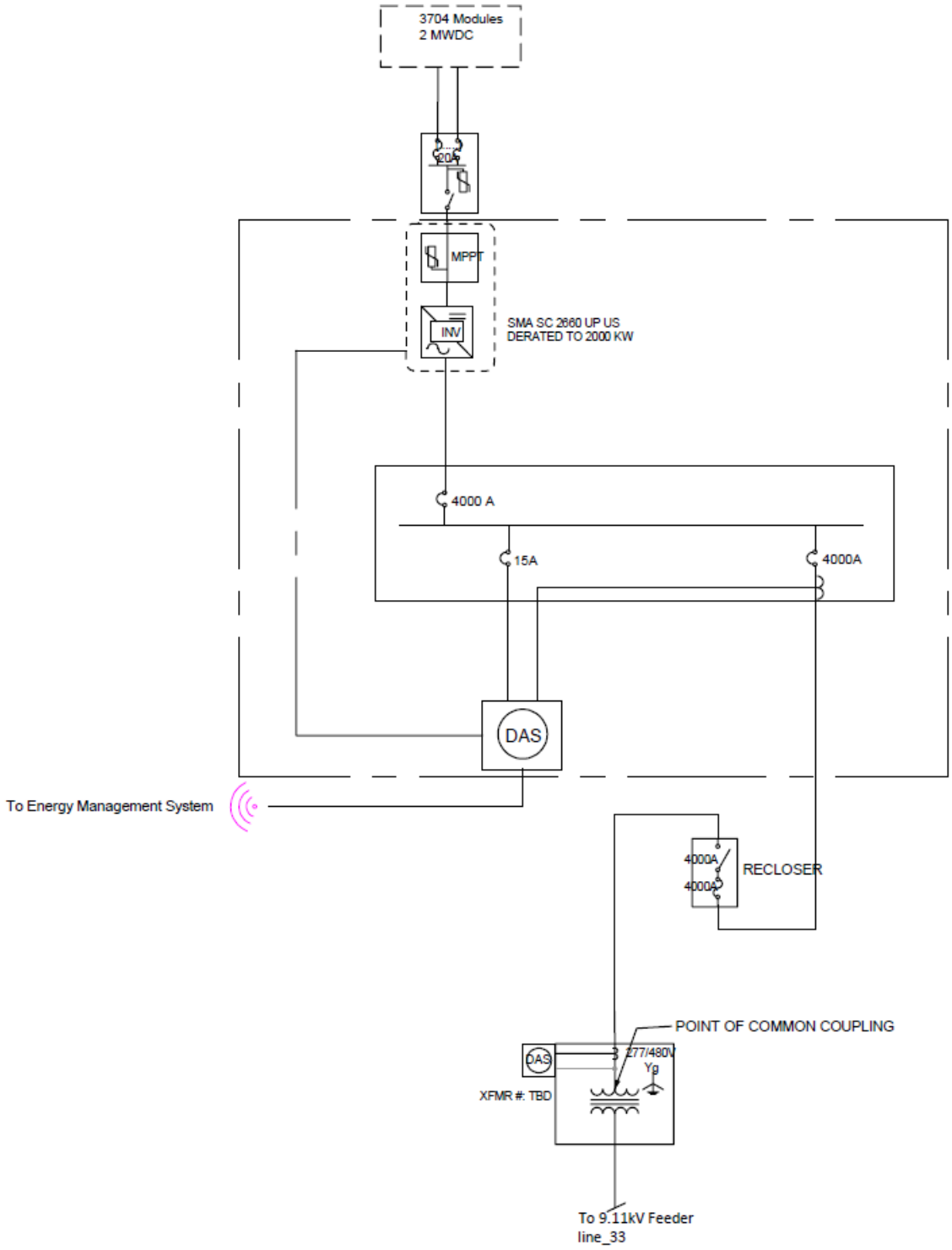


1. 2MW dc PV layout



2. Annual Irradiance/Shadow Analysis

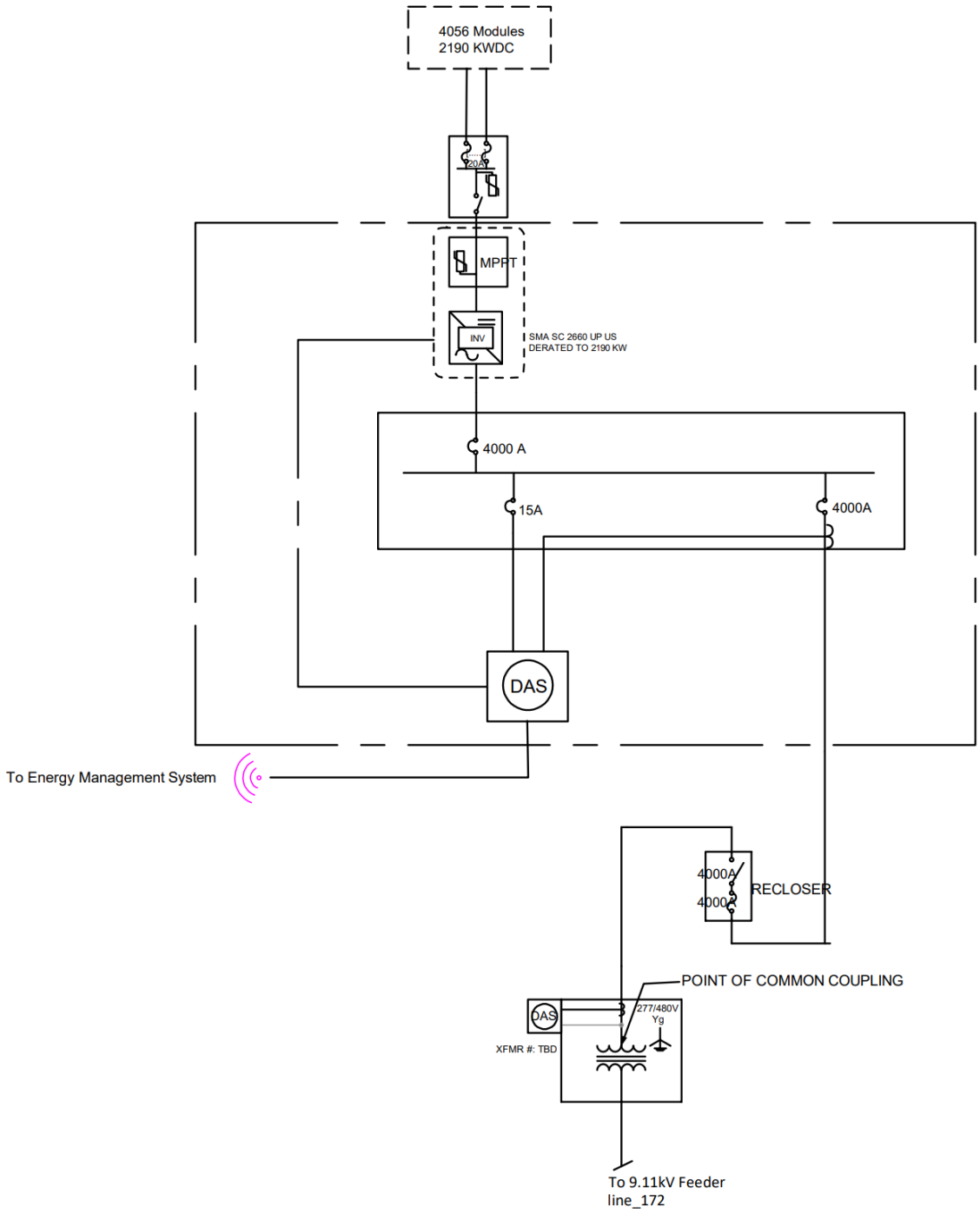
Module Make - Rating (Wp)	**JK Solar- 540Wp**
Module Model	**JKM540M-72HL4-V**
Location	**NCSU-Lake Raleigh**
Tilt	**10° - Fixed Tilt**
Module Orientation	**Landscape**
Type of Mounting	**Floating solarRoof Top**
DC Capacity	**2 MWp**
Estimated Annual Production	**2795 MWh**
Float	**Ciel et Terra floats**



3 **2 MW dc Floating Solar, SLD**

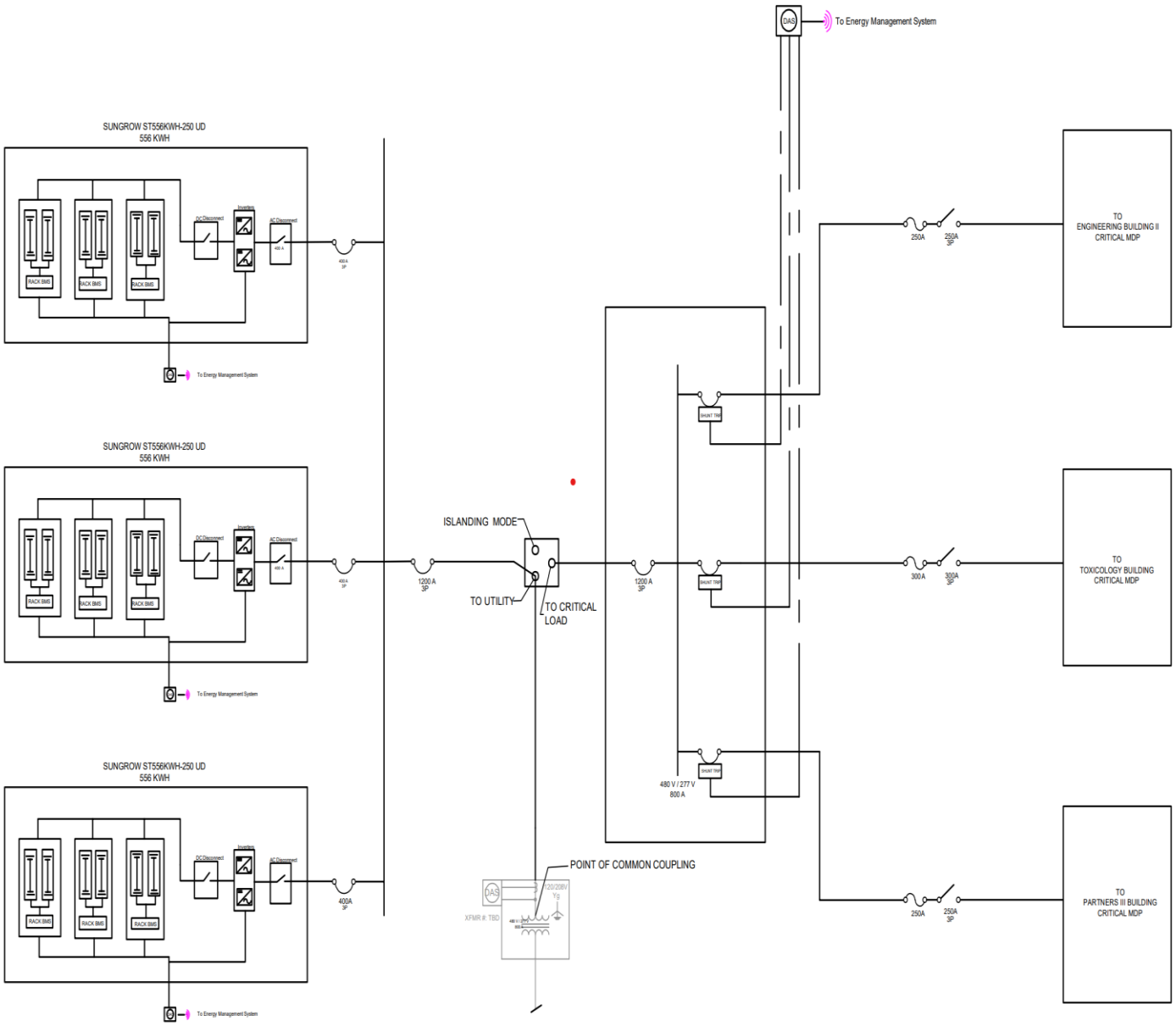
Layout and Specifications: Ground Mount

Module Make - Rating (Wp)	JK Solar- 540Wp
Module Model	JKM540M-72HL4-V
Location	NCSU
Tilt	Single Axis tracker
Module Orientation	Landscape
Type of Mounting	Ground Mount
DC Capacity	2.19 MWp
Estimated Annual Production	3823 MWh



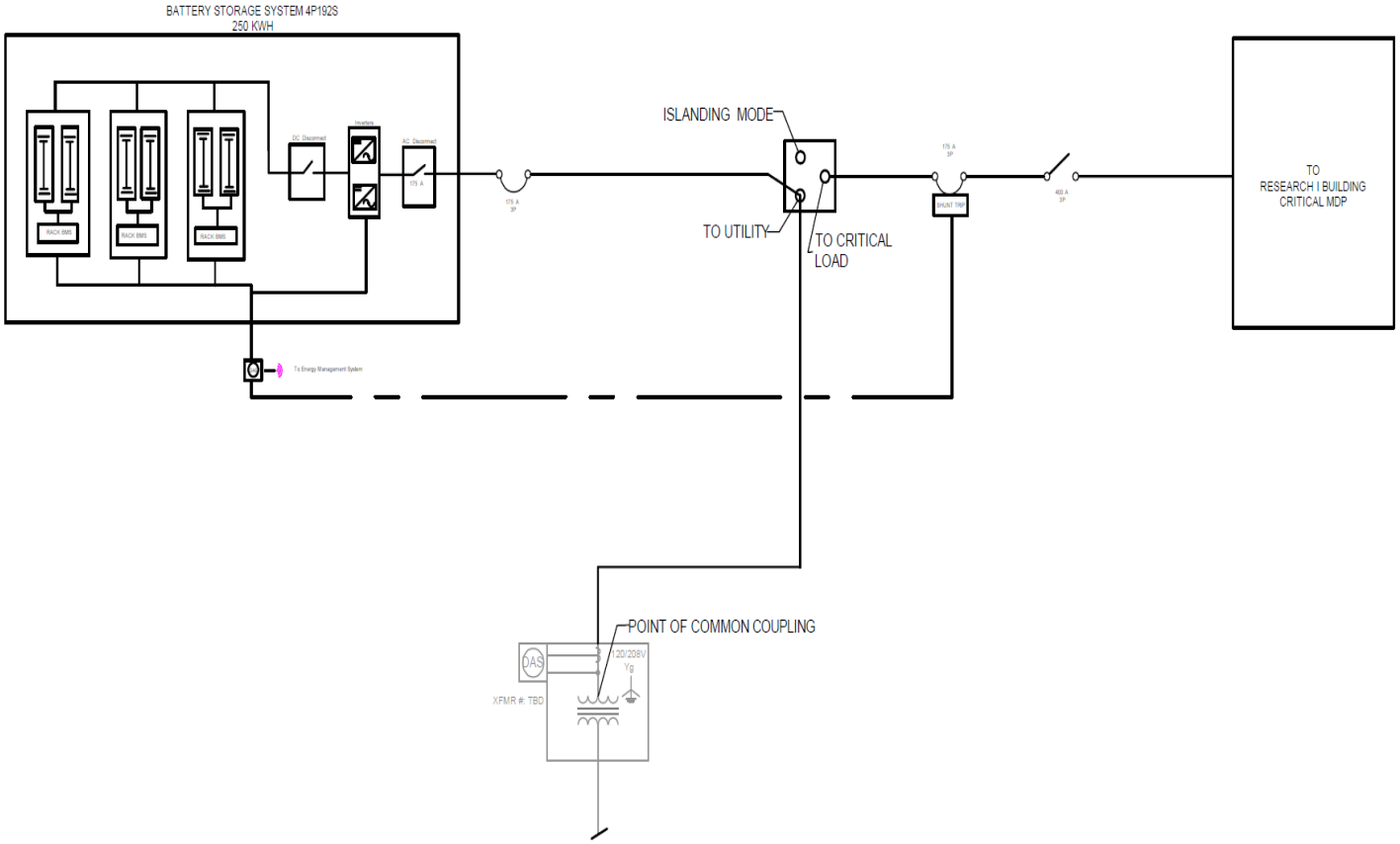
1 **2.19MWWdc Ground Mount, SLD**

Resiliency Battery - 1



Size of battery	1668 kWh
Manufacturer	Sungrow ST 556KWH-250UD
Location	NCSU

Resiliency Battery - 2



Size of battery	250 kWh
Manufacturer	CATL 4P192S
Location	NCSU

Site plan(s) summary showing the layout of all proposed installations

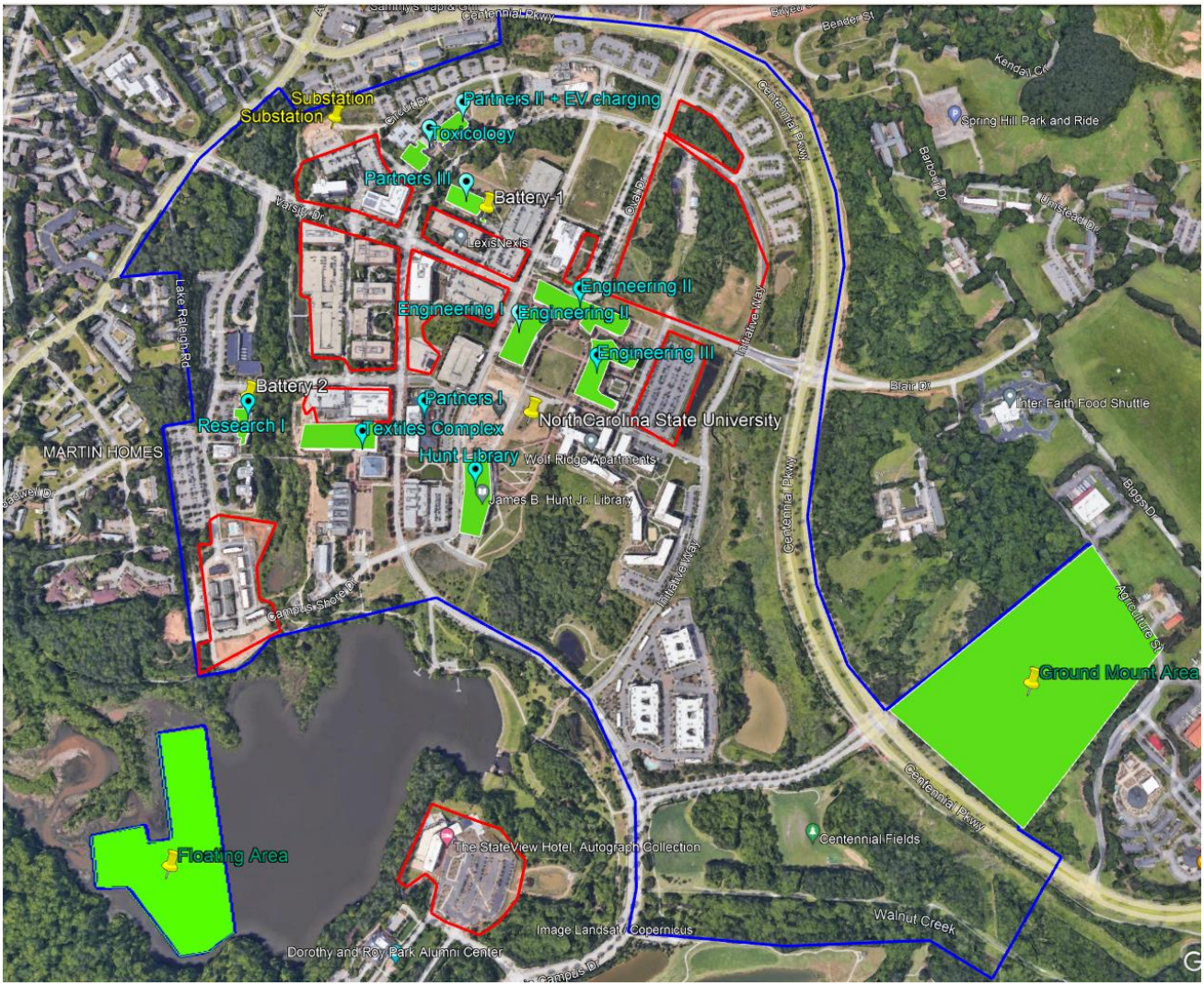


Figure:3

In Figure 3

- Green Colored area Indicates the working area for Roof-top+ Ground Mount + Floating Solar
- Red Colored boundary indicates the Endorsement parcels which we are not allowed any type ofinstallation.
- Finally, after carefully examining each work location, we decided to use rooftop, ground-mount and floating solar on this deliverable. In order to lower campus power costs overall and during peak hours bytaking into account buildings that cast less shade, larger roof sizes with fewer obstructions, and load data availability.

Assumptions

Preliminary design assumptions:

- Considered Module level rapid shutdown.

System Types:

- For Flat roofs considered Default 4 feet set-back.
- For the Mechanical equipment and skylights considered 4 feet set-back and have access to the outside perimeter.

Pitched Roof System:

- Considered 0.5 set-back for the hips, valleys, ridges and vents or any other obstacle.
- Allowing 1-foot space for the ridges and valleys as per IFC standards.

Racking:

We are using a 5Degree Tilt for the flat roof, with an inter-row spacing of 10 inches and module-to-module spacing of 0.3 inches. For the initial analysis, the Roof ballast system is used to meet the uplift wind requirements and it is assumed that every roof has the same structural capacity.

Pitched roof systems:

- Considered 0.3 inches module-to-module spacing.
- Assumed that structural capacity for each system is below 3 lbs/sqft.

Floating solar:

- Considered module fixed tilt angle 10-degree.
- Considered 72 cells module form the make of Ciel et Terra floats.
- Considered module-to-module spacing is 0.5 inches.

Ground mount:

- Tilt angle: 35 degrees (+/- 15 degrees) - Calculated using PVWatts calculator.
- Calculations for min and max inter-row spacing of the module is

$$Module\ Spacing = \frac{Height\ Difference}{\tan(\emptyset)}$$

- Spacing between adjacent panels: 0.25 ft
- Spacing between panel rows: 18.7 ft
- Setback from transmission line: 50 ft
- Panel used: JK 540 W
- Setback from the industrial building: 100 ft
- Setback from wetland stream: 100 ft
- Setback from parcel boundary: 50 ft
- Setback from steep area (greater than 20% slope): 25 ft

References

[1] D. Energy. [Online]. Available: Large General Service (T-O-U) [9/15/93] (duke-energy.com).

[2] Jinko, "Jinko Solar," [Online]. Available: https://www.jinkosolar.com/uploads/5ff587a0/JKM530-550M-72HL4-(V)-F1-EN.pdf.

[3] S. Edge, "Solar Edge," [Online]. Available: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.solaredge.com/sites/default/files/se_commercial_three_phase_inverters_for_medium_voltage_grid.pdf.

[4] NCSU, "NorthCarolina State University," [Online]. Available: https://www.ncsu.edu/