NORTHERN ARIZONA UNIVERSITY

To: Dr. David Willy

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Date: *11/21/25*

Re: *HW04 - Individual Analysis*

1. Introduction

This capstone project retrofits the John C. Stennis Lock and Dam on the Tennessee-Tombigbee Waterway with a low head streamdiver configuration and a co-power solar PV array. The goal is to create a hybrid renewable system that can deliver at least 1MW of power under low flow conditions while remaining in the U.S. Army Corps of Engineers(USACE) property.

This individual analysis focuses primarily on the design decision to install a 1.5MWdc ground mounted photovoltaic plant near the Stennis L&D site. The purpose is as follows:

- Verify using computational modeling, that a realistic sized 1.5MWdc PV system is realistically generating 2.3 GWh/yr.
- Demonstrate that the system fits on existing, disturbed USACE land without new land acquisition.
- Justify choice of system size, hardware, and layout as technically viable for the hydro-solar plant.

2. Problem Definition

Is a 1.5MWdc fixed tilt PV array at John C. Stennis L&D realistically feasible and capable of delivering enough energy to meaningfully supplement the hydro unit, while existing on USACE land. To answer this, I used NREL's System Advisory Model(SAM) to model detailed photovoltaic performance and combined it with a land-use analysis based on array geometry and USACE site information.

3. Necessary Assumptions

3.1 Site and Resource Assumptions

- Location approximated as 33.49° N, −88.43° W, elevation ≈ 57 m.
- Solar resource from NSRDB PSM v3 TMY data (typical meteorological year).
- Climate similar to Columbus, MS; negligible snow losses.
- Site terrain is mostly flat, with no significant horizon shading.

3.2 System Design Assumptions

- DC nameplate capacity: P_{DC}=1.50 MWdc
- AC inverter capacity: P_{AC}=1.20 MWac, 20 × 60 kW Sungrow SG60CX-US
- Inverter loading ratio (DC/AC): ILR=PDC/PAC=1.25
- Mounting: fixed-tilt open rack, tilt = 25°, azimuth = 180° (south).
- Ground coverage ratio (GCR): 0.45 (moderate row spacing).
- Land-use intensity: 3.0 acres/MWac
- PV module: JA Solar JAM72S30-545/MR, 545 W mono-PERC bifacial.
- Electrical configuration: 16 modules per string, 172 parallel strings.

3.3 Loss and Availability Assumptions

- Soiling loss: 5% annual average.
- DC losses: module mismatch (2%), diodes & connections (0.5%), DC wiring (1%).
- AC wiring loss: 1%.
- Transformer & transmission losses: 0% (assumed near-bus interconnection).
- Plant downtime: 2% (AC-side).
- All modules and inverters are assumed to perform per manufacturer datasheets at standard test conditions.

3.4 Key Variables

- G_h: Global horizontal irradiance [kWh/m^2/yr]
- E_{AC}: Annual AC energy delivered to grid [kWh/yr]
- P_{DC}: DC nameplate capacity [kW]
- P_{AC}: AC inverter capacity [kW]
- CF_{DC}: DC capacity factor [–]
- Y_{spec}: Specific energy yield [kWh/kWdc/yr]
- A_{mod}: Total module area [m^2]
- A_{land}: Land area requirement [acres]
- G_h:Annual in-plane (POA) irradiance [kWh/m^2/yr]

4. Physical / Computational Modeling

Using the SAM model specifically for photovoltaic detailed models, we first started with the following key inputs:
Weather file: NSRDB PSM v3 TMY for Columbus, MS.
Module model: JA Solar JAM72S30-545/MR from the CEC module library.
Inverter model: Sungrow SG60CX-US [480 V] from the CEC inverter library, 20 units.
Array geometry: single subarray, fixed open rack, tilt 25°, azimuth 180°, GCR 0.45.
Bifacial modeling: module marked as bifacial, bifaciality factor 0.70, ground clearance height 1 m, ground albedo ~0.18–0.20.
Losses: as listed in Section 3.3, implemented through SAM's Irradiance Losses, DC Losses, AC Losses, and System Availability sections.

The module was selected because it utilizes similar technology to the new 545 W mono-PERC module and similarly the JA models are commonly used in TVA/SE regions per EPC contracts. The inverter model was similar to the paired inverter for the selected module however is slightly unconservative in this run through.

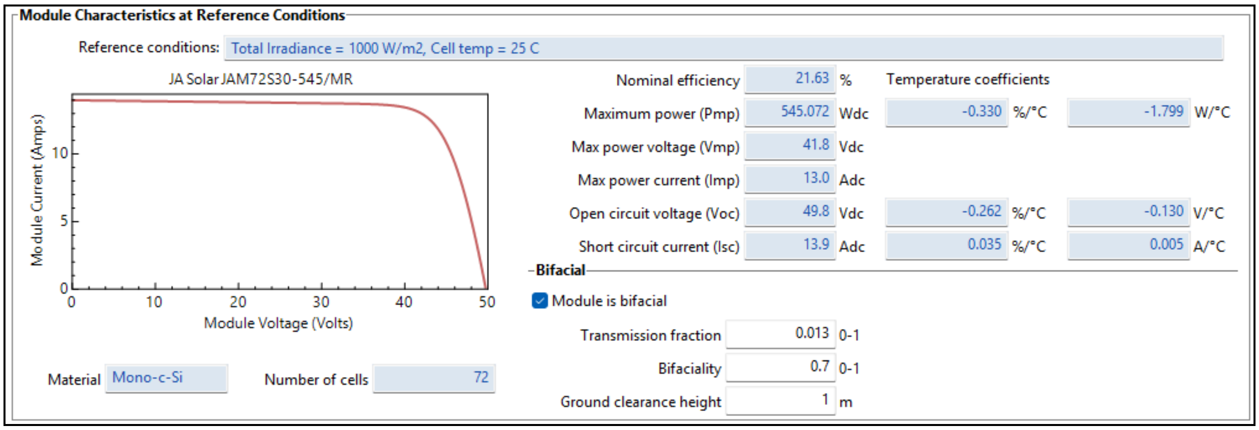

Figure 1. Module Characteristics for JA Solar JAM72S30-545/MR

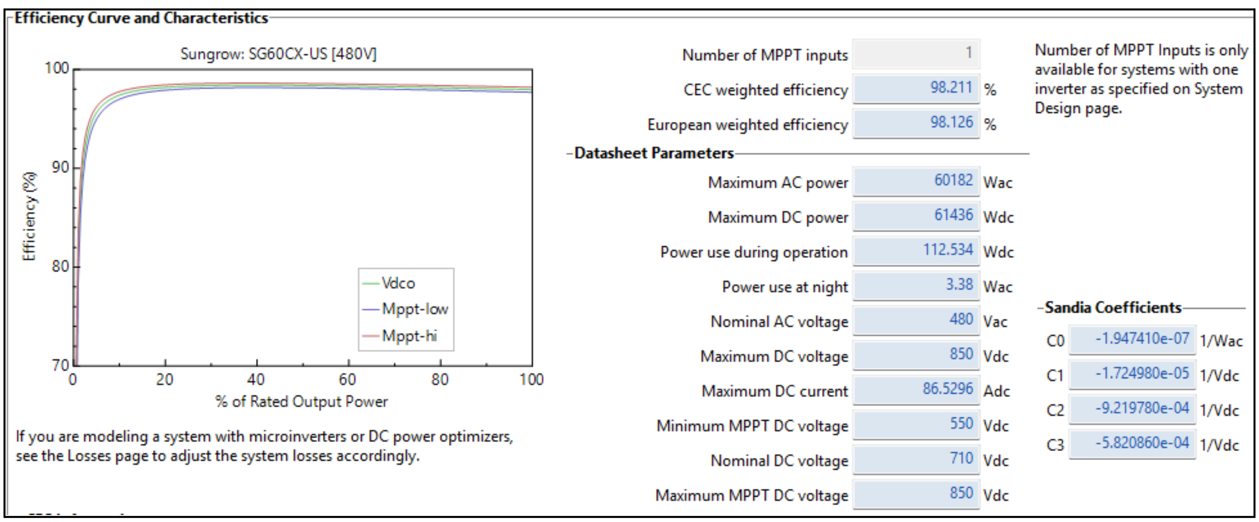

Figure 2. Efficiency Curve of Sungrow SG60CX-US [480 V]

SAM internally solves the PV performance model using:

- Plane-of-array irradiance and cell temperature models based on NSRDB weather.
- The single-diode PV module electrical model.
- Inverter efficiency curves and MPPT voltage windows.
- Hourly simulation over 8,760 hours for a typical meteorological year.

Figure 3 shows the anticipated AC monthly energy production,

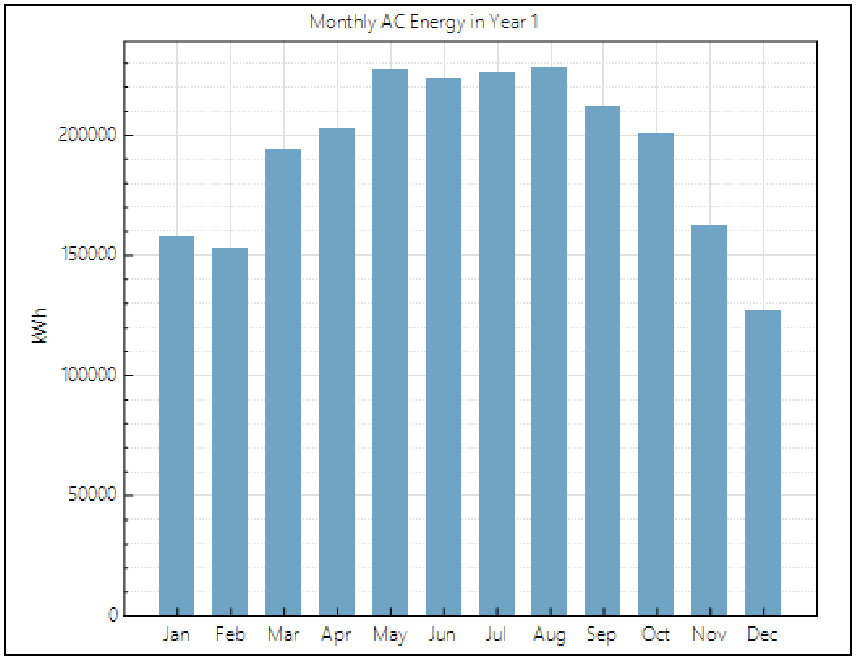

Figure 4. Monthly AC Energy Production

5. Site Selection & Site Justification

John C. Stennis has multiple suitable locations:

- Maintained East Bank recreational area
- Dredged material disposal sites AL16, AL18

These sites were optimal because it is previously disturbed land, leading to low environmental impact. These locations require no forest clearing or new land acquisitions. East Bank Recreational Center offers about 5 acres of land that is regularly cleared and maintained, open field with plenty of sunlight, and easiest for construction and O&M. Dredged material disposal area 16&18 both offer at least 12 acres of usable land, though slightly farther away from the dam site they would provide site utilization of the land on USACE property. Low ecological footprint due to these areas already being disturbed it would be useful in selecting this location. Accessible by the USACE road network so construction and O&M would be slightly higher than the East Bank site.

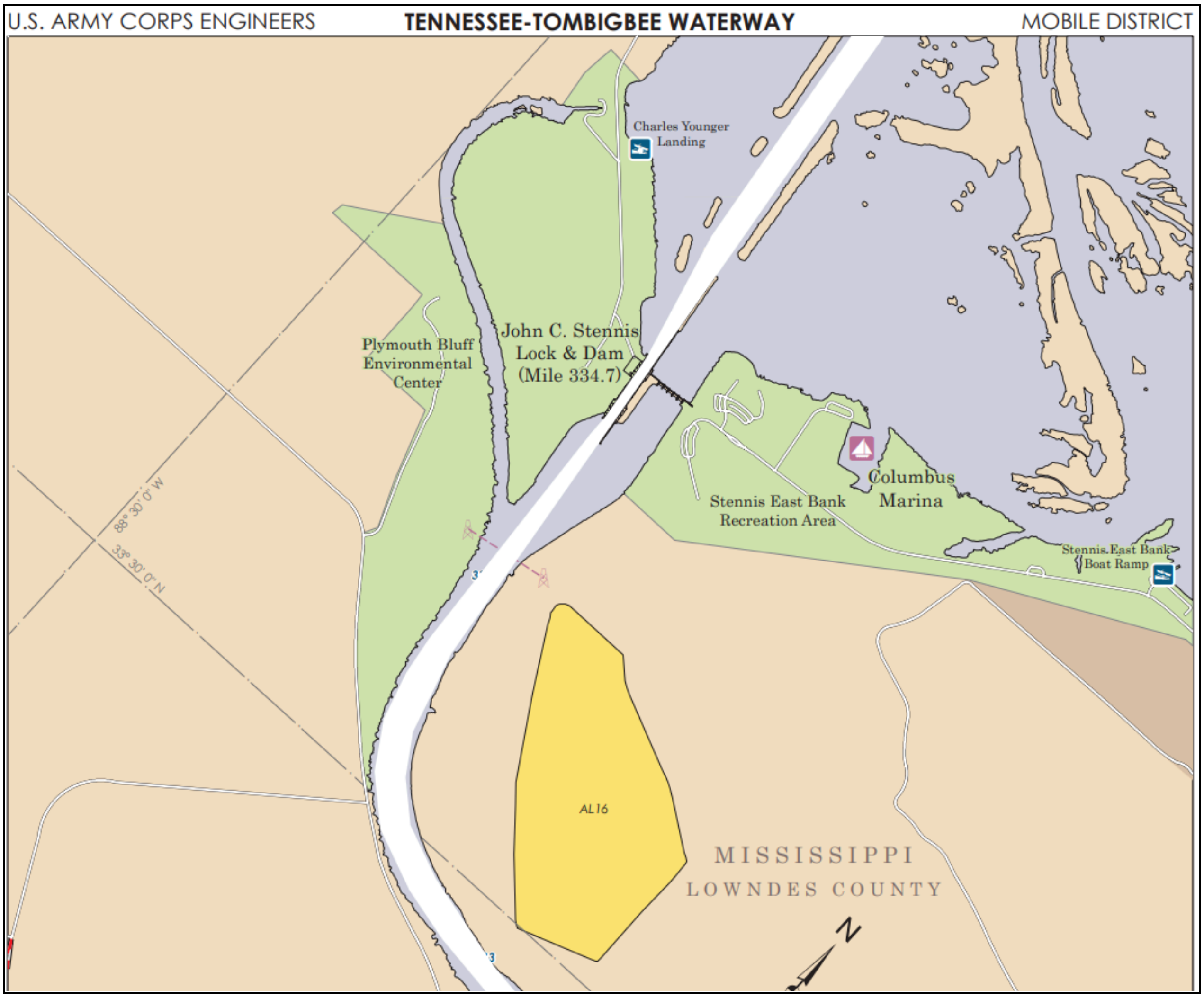

Figure 4. East Bank Recreation Area

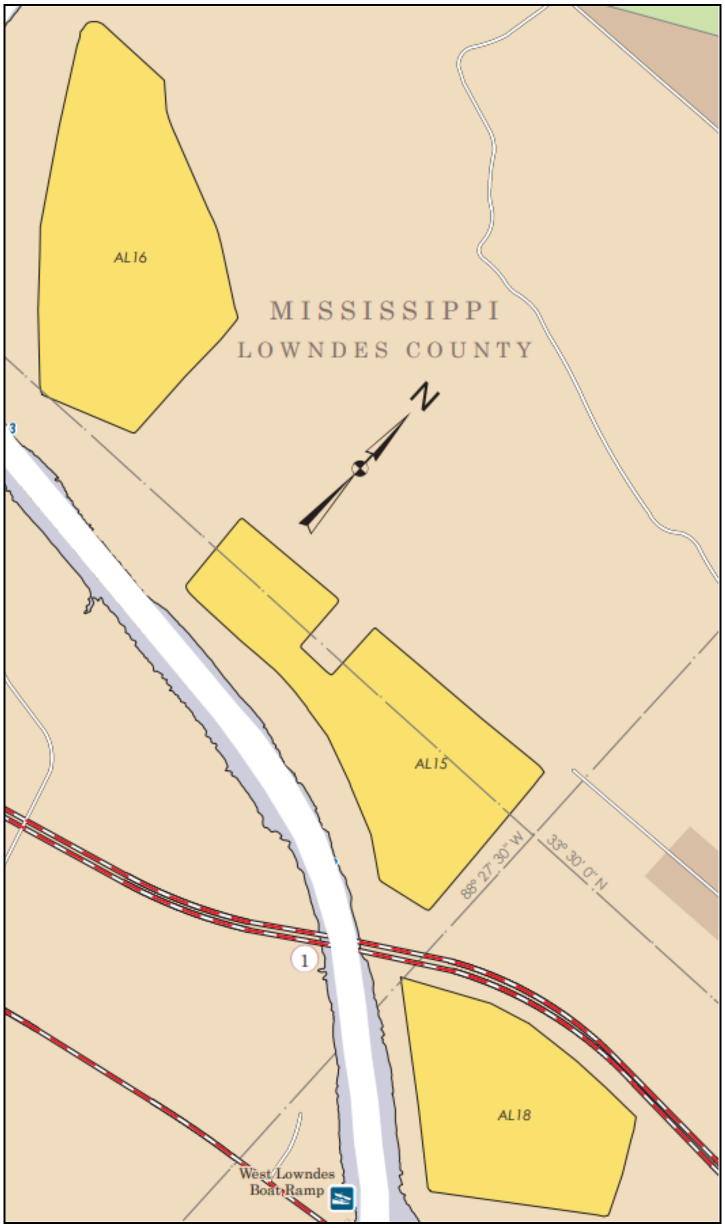

Figure 5. AL16 & AL18

6. Equations Used

Land area is denoted as,

$$A_{Land} = P_{AC} * \frac{acres}{MW_{AC}} \quad (1)$$

Where P_{AC} is the AC rating, and the design rule of thumb 3 acres per MW_{AC}

Specific energy yield

$$Y_{spec} = \frac{E_{AC}}{P_{DC}} \qquad (2)$$

Where E_{AC} is the annual dc energy and P_{DC} is nameplate capacity.
Capacity factor is given by,

$$CF_{DC} = \frac{E_{AC}}{P_{DC}*8760} \qquad (3)$$

Where E_{AC} is the annual AC energy, and P_{DC} is nameplate capacity.
Performance ratio is given by,

$$PR = \frac{E_{AC}}{G_h A_{mod} \eta STC} \qquad (4)$$

Where E_{AC} is the annual AC energy, G_h is the annual in-plane radiance,A_{mod} is the total module area, η_{STC} is the efficiency of the selected module.

7. Results

When comparing the potential space we have to the land use estimation would show us how much space is required out of the potential sites.

$$A_{Land} = 1.203 * 3 \frac{acres}{MW_{AC}} = 3.61\, acres$$

From this calculation we see that in order to generate 1.5MW of power via solar requires 3.61 acres which is comparable to similar projects near Stennis, Similarly we see that both of our potential sites could house this PV plant. Next, looking at the specific energy yield, capacity factor, and performance ratio calculated within SAM, given by Figure 6.

Metric	Value
Annual AC energy in Year 1	2,311,302 kWh
DC capacity factor in Year 1	17.6%
Energy yield in Year 1	1,541 kWh/kW
Performance ratio in Year 1	0.81

Figure 6. Table Of Resulting Values

Then looking at an annual heatmap for any monthly irregularities,

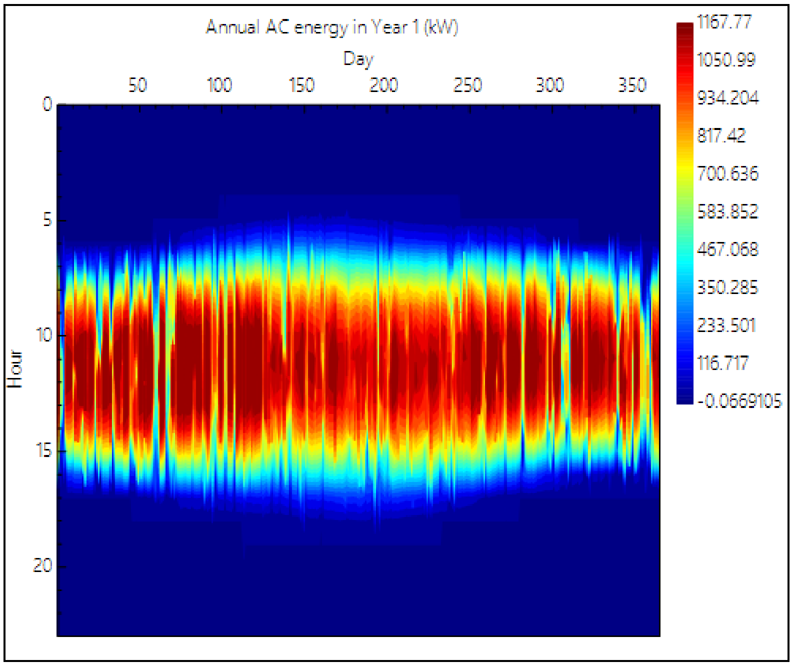

Figure 7. Annual Heat Map Of Stennis Site

8. Loss Breakdown

- Soiling: 5%
- DC losses: ~4.4%
- Inverter efficiency & clipping: ~2.5%
- AC wiring: 1%
- Availability: 2%

The overall losses are visualized in the following figures,

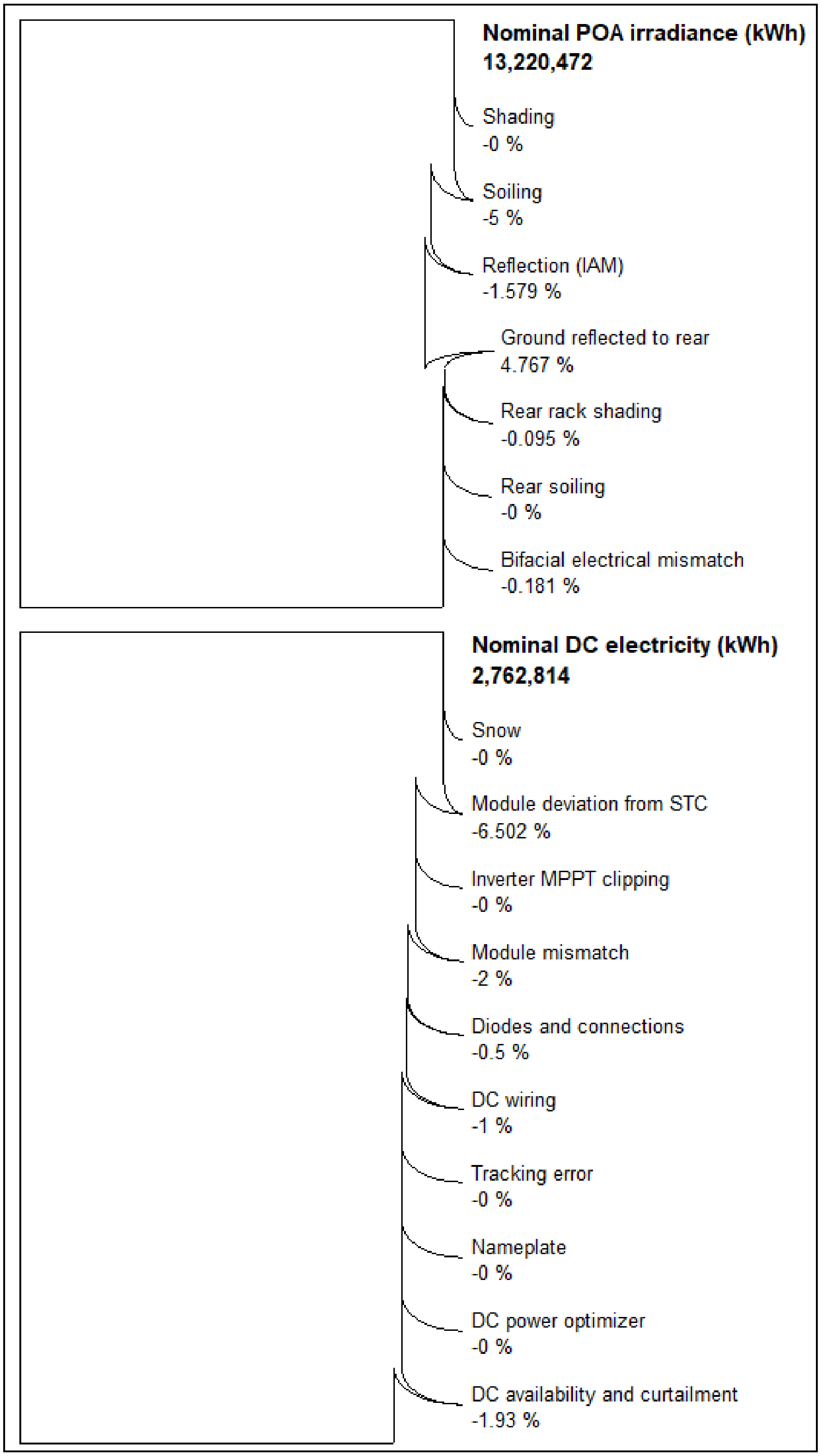

Figure 9. First Segment Of Overall Losses

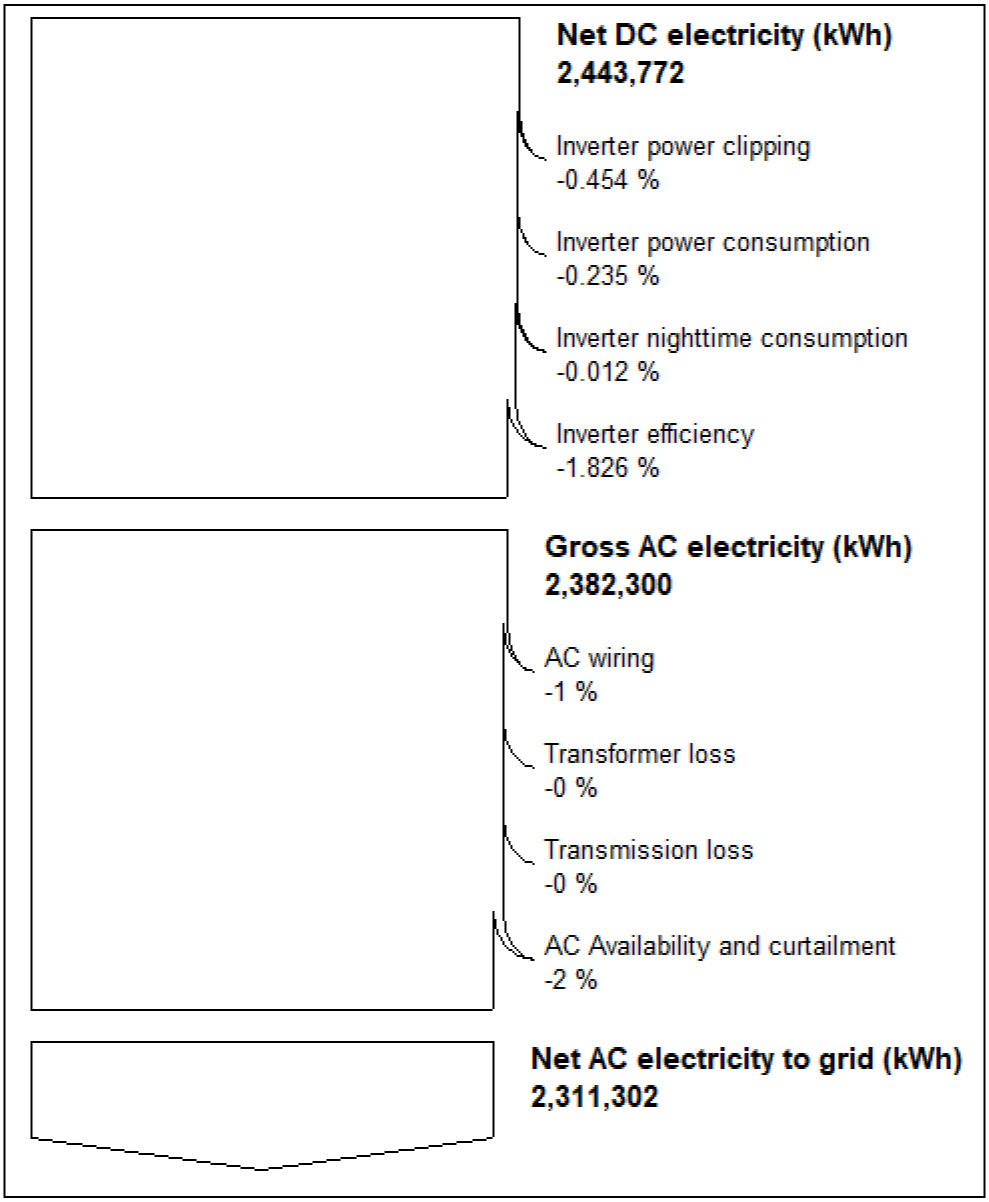

Figure 10. Second Segment Of Overall Losses

9. Impact On Design

After the PV plant and land analysis using the SAM and USACE data it is confirmed that the design achieves the technical feasibility of integrating 1.5 MWdc solar into the Stennis hybrid concept. This design also provides 2.31GWh/yr of clean energy which can be used in tandem with the hydro facility. The land availability is more than enough and the sun profiles are strongly in favor of implementing a PV plant in this area. Using the hardware selections of 545W modules and SG60CX-US inverters validated the electrical modeling and estimated loss performance. This supports the concept of selecting John C. Stennis as the ideal location for our project.

References

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