ngVLA Electronics Memo No. 2

ngVLA Solar Power Trade Study

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I. Executive Summary

The use of solar power at the ngVLA site has been proposed by a number of sources. This paper seeks to consider the value of utilizing solar power at the main ngVLA site in three different capacitates: full site power, central processor power, and limited distributed systems.

Overall, this paper concludes that implementing solar power at the ngVLA site is not worth additional pursuit. At best, it offers a limited cost savings, and, at worst, a significant increase in site expenses.

II. Background

In May of 2013, the National Renewable Energy Laboratory (NREL) provided a report on the potential cost of a 1 megawatt solar array owned and operated by a contracted entity under a purchased power agreement (PPA). (Savage, 2013)

A. Utility Power Cost

As a point of reference, the VLA currently holds a standard commercial billing agreement with Socorro Electric Cooperative, that charges both a kWH rate and a demand factor. The demand factor is calculated from the greater of actual demand and 1MW. (Socorro Electric Cooperative, Inc., 2011). For the purposes of this paper, it is assumed that any connection to the local utility grid will operate under similar terms. Additionally, this paper will consider power costs in respect to 2019 rates. This provides us with an estimated fee schedule of ~$0.085/kWH and $15/kW demand (where demand is greater than or equal to 80% of nominal power draw) (Socorro Electric Cooperative, Inc., 2011).

Optimistic expectations of the ngVLA place estimated site loads at about 4.5 MW. Approximately one third of that total estimated load, 1.5MW, is attributed to the new central Processor. The remaining 3 MW is assumed to be distributed amongst the 214 core, plains, and mid-baseline antennas for approximate loads of 16.7kW each.

The 16.7 kW antenna load is further expected to be divided between 208VAC and 48VDC loads. For the purposes of this paper, it is assumed that at least half of the 16.7kW antenna loads will operate at 48VDC. This is consistent with the 48VDC power supply requirements presented in 2018 (Lopez, 2018).

Electrical loads for other onsite facilities are considered negligible and excluded from consideration in this document.

B. Available Daylight

Based on Albuquerque sunrise and sunset times, the ngVLA site can expect at least 10 hours of daylight even at the winter solstice (Albuquerque, New Mexico, USA — Sunrise, Sunset, and Daylength, June 2019, 2019).

III. Battery Sizing

In order to maximize lifespan, it is typically recommended that a lead acid battery system remain charged above 80%. As such, in order to supply a load at the ngVLA overnight, the battery system must be sized greater than Sustained load (watts) * 14 hours of darkness / Battery Voltage / 0.2 (discharge) = Amp-hours. As an example, a 48 volt battery bank must contain at least 1.46 Amp-hours per watt of load. This is an optimistic value, as it assumes no energy losses, aging affects, or cloudy weather.

As a point of reference, the jVLA has recently purchased a pair of 48v battery strings capable of supplying the WIDAR Correlator for approximately 15 minutes. These batteries provide 2000 amp-hours with a lifespan of 1200 cycles at 20% usage. These battery strings each occupy a volume of approximately 64 cubic inches and cost $21 per amp-hour.

Carrying these values through provides the following space and cost requirements to supply different portions of the proposed array.

Table 1: Battery Sizing

Array Section	Cost	Cubic Feet	Lifecycle	Annual Cost
Non-descript 1kW	$30.7k	54	3 1/3 Years	$9.2k
16.7kW Antenna	$513k	907	3 1/3 Years	$153.9k
Processor 1.5MW	$46M	81,428	3 1/3 Years	$13.8M
Total Site 4.5MW	$138M	244,284	3 1/3 Years	$41.4M

IV. Potential Cost Savings

Based on the fee schedule discussed in Section II.A Utility Power Cost, above, onsite power generation would reduce the annual power costs as follows (based on winter solstice daylight hours):

Table 2: Power Savings vs Battery Cost

Array Section	Annual Savings (kWH)	Annual Savings (Demand)	Solar Array Size	Annual Battery Cost	Annual Savings

Daylight Hours Only					
Non-descript 1kW	$310	0	1kW	0	**$310**
Antenna 16.7kW	$5.25k	0	16.7kW	0	**$5.2k**
Processor 1.5MW	$465k	0	1.5MW	0	**$465k**
Total Site 4.5MW	$1395k	0	4.5MW	0	**$1.395M**
24 Hours					
Non-descript 1kW	$755	$180	2.4kW	$9.2k	**$8.3k Loss**
16.7kW Antenna	$124k	$1.26k	16.8kW	$153.9k	**$28.6k Loss**
Processor 1.5MW	$1.1M	$270k	3.6MW	$13.8M	**$12.4k Loss**
Total Site 4.5MW	$3.3M	$810k	10.8MW	$41.4M	**$37.3k Loss**

From Table 2, it is clear that any attempt to power the ngVLA overnight without a secondary source of power is cost prohibitive. Even if these numbers were to improve, Table 2 does not take into consideration any additional expenses associated with constructing and operating a solar plant. Any benefit to be derived provided by solar power would need to be developed by reducing overall power draw and/or peak shaving.

Since the expected utility power agreement imposes a minimum demand cost, an attempt to fully power the site with solar power would best be served by either accepting full site load or serving in a peak shaving capacity. As site loads are largely consistent at all hours of the day and night, this would necessitate the use of large battery banks and/or onsite diesel generation.

V. PPA

As an alternative to any NRAO owned solar power system, it may be possible to enter into a power purchase agreement with a third party. Under such a contract, the ngVLA would agree to purchase power for a predetermined number of years with a set pricing plan. Such an agreement allows the buyer to support the development of solar power in the region without incurring any of the direct costs. This paper will not discuss details of such a plan, as they are functionally identical to a normal utility provider.

VI. Impact

A. Cost

1. Construction

Typical solar installations are comprised of four major elements. These are the panels themselves, a battery charger, a battery bank, and a converter/inverter stage.

A rough estimate for the installation cost of a solar array without battery backup is $3 per Watt. Federal incentives may reduce this by as much as one third. (Aggarwal, 2019) This estimate is consistent with the average installation cost discussed in the NREL report. (Savage, 2013)

Once construction is completed, maintenance costs become the driving force. Solar array maintenance includes a number of tasks from the specialized to the mundane. Some of the most basic task would include panel cleaning and adjustment to maintain efficiency. Electrical enclosures and buswork must be cleaned and checked. Additional land usage requires increased grounds keeping services to maintain the site.

2. Shielding

Regardless of their implantation at the ngVLA, it is necessary to utilize switching converters with solar panels. Even if paired with a load that requires the rated voltage provided by a solar bank, commercially available solar panels produce as much as 50% higher voltage than their nominal rating due to varying exposure to sunlight.

The two most common approaches to RFI mitigation applied to power infrastructure at the VLA are shielded enclosures and geographical distancing. Due to the highly variable cost of either approach, this cost is excluded from the overall discussion in this document. Should further discussion into specific implementations of solar power be desired, a deeper investigation into shielding costs will be included.

3. Labor

Based on man power required for similar work at the VLA, it is assumed that a solar array would require approximately two full time electricians and a few hundred hours each year from supporting groups. To arrive at a usable cost, the following equation was used.

Labor estimate = 2.2 (3.3 for full site array) MYE at median electrician pay + 50% for raises, engineering design work etc.

This is doubled to account for benefits

(50k * 2)*1.5*2*25 years

4. Summary

The lifetime savings identified in Table 3 are based on the annual savings provided in Table 2 multiplied by 25 years.

Table 3: Solar System Cost Savings Over 25 Years

Array Section	**Lifetime Savings**	**Solar Array Size**	**Construction Cost ROM**	**Labor Estimate**	**Net Savings Over 25 Years**
Processor 1.5MW	$11.6M	1.5MW	$4.5M	$8.25M	**$1.15M Loss**
Total Site 4.5MW	$34.95M	4.5MW	$13.5M	$12.38M	**$9.08M**

VII. Conclusions

The best case scenario presented by this paper is to install a solar array capable of running the entire site during daylight hours, as batteries were shown to be a cost prohibitive option. This scenario allows for a $9M savings over 25 years, or $360k annually.

As stated earlier in this document, this savings does not factor in increased construction costs required for RFI reduction. This number is also dependent on the relatively optimistic assumption that no power distribution equipment will fail during the proposed 25 year lifecycle. While neither of these factor should be significant enough to eliminate the overall savings they would reduce it significantly. If further consideration for an NRAO operated solar array is desired, the discussion should include a reliability analysis and RFI costing for a more refined cost analysis.

VIII. Works Cited

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