

34.5/115 kV Solar Power Plant & Substation Senior Design Project

Senior Design Team 18 - May 2024

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BLACK & VEATCH



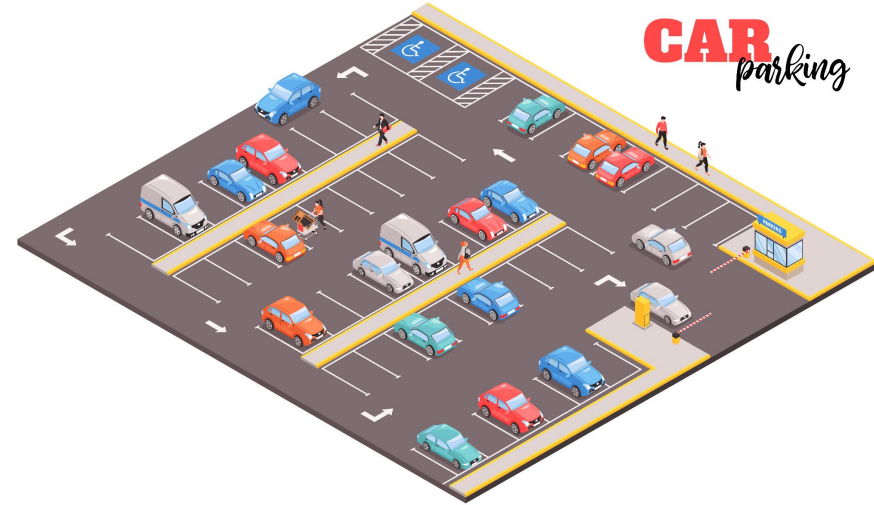
Agenda

- Safety Moment
- Array Tool
- Sizing - Solar Farm
- Outputs - Solar Farm
- Equipment - Solar Farm
- Cost - Solar Farm Progress
- Location - Solar Farm



Safety Moment - Parking lot safety

- Concentrate
- Lock Car
- Look Both way
- Stay in the line
- Walk around car before leaving
- Pull Through when possible
- Keep Valuable out of sight
- Slow Down
- Follow Direction



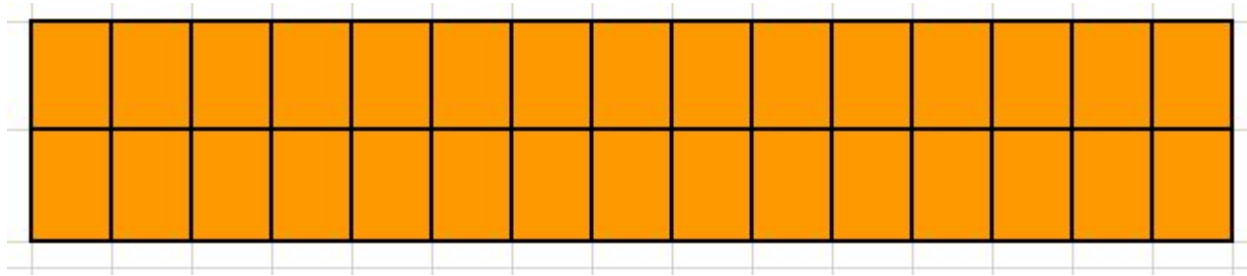
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Array Tool

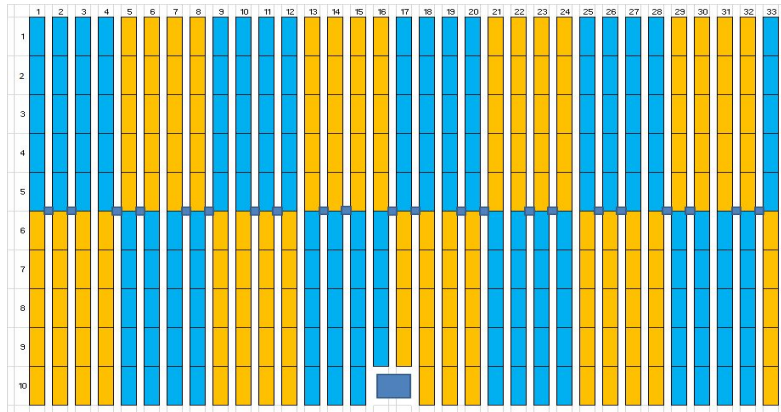
Solar Plant Size				Total Components	
Access Road w/ Space for CB	30 ft			Panels	179,310
Height	2790 ft			CBs	401
Width	3601.2 ft			Inverters	19
Area of Plant	10,047,348.00 ft ² 230.66 acres				
Solar Plant Cost					
Panels		??	million \$		
CBs		??	million \$		
Inverters		??	million \$		
Solar Plant					
Arrays in Plant	18.22				
Panels in Plant	179,310				
Inverters in Plant	19				
CBs in Plant	401				
DC Plant Output	78 MW				
AC Plant Output	60 MW				



Array Tool



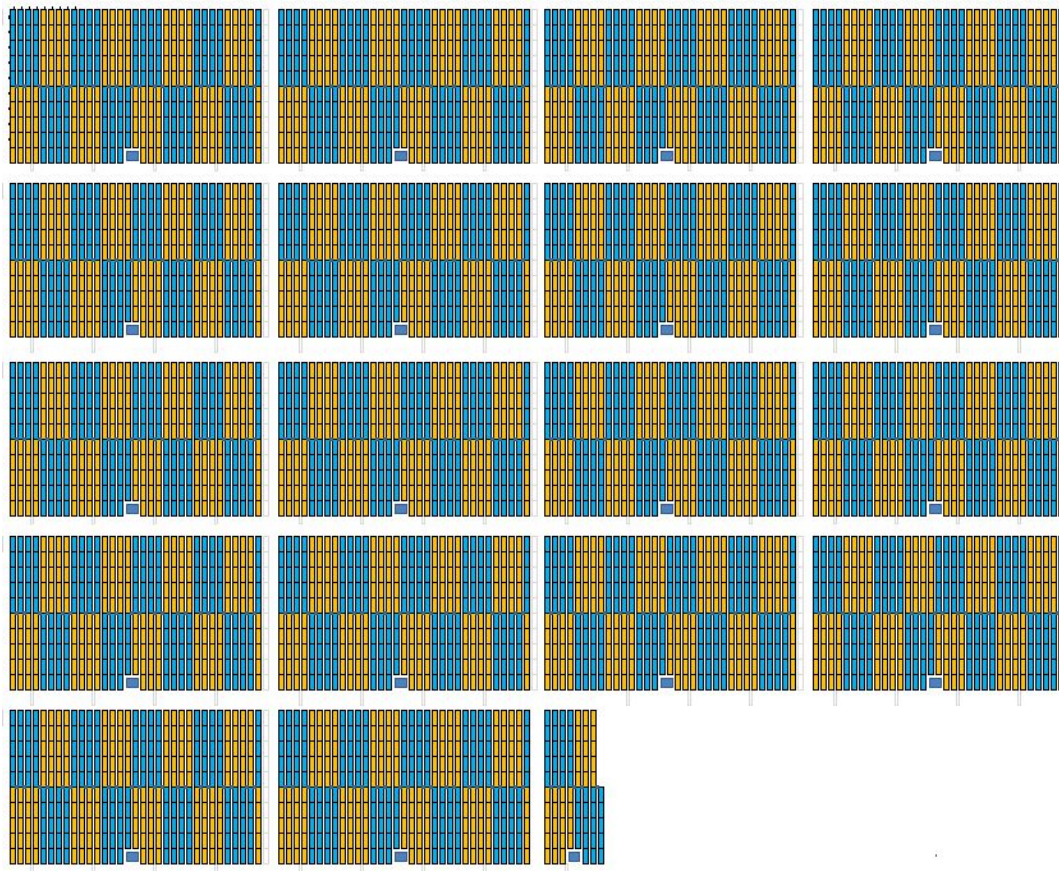
Design for 1 rack



Design for 1 array:
22 Combiner boxes per array
18.22 arrays total



Array Tool



Outputs

Option 1

- DC combiner box to the inverter
- Each AC circuit output connects to a transformer connecting to grid

Option 2

- DC combiner box to inverter
- Multiple AC circuits combine to an AC combiner box
- AC combiner box to transformer connecting to grid

[Option 1&2 Picture Link](#)

FIGURE 1: CENTRAL INVERTER ARCHITECTURE

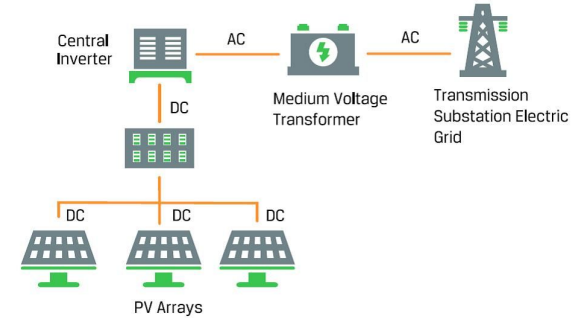
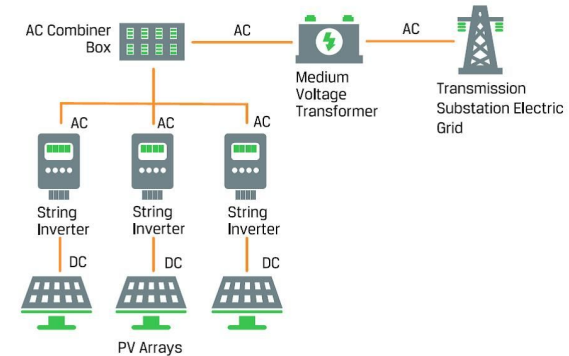


FIGURE 2: STRING INVERTER ARCHITECTURE



Sizing

PV Cells: Sunpower E Series Commercial Solar Panel

- Nominal Power of 435 W
 - Rated Voltage of 72.9 V (DC)
 - Rated Current of 5.97 A (DC)
- Array Parameter Tool:
 - 15 modules per string
 - 6525 W per string
- #10 AWG for each PV Cell
- Land Area Needed:
 - 1 kW of solar panels requires 100 sq ft for installation
 - Still configuring total number of racks and land areas need

Electrical Data	
SPR-E20-435-COM	
Nominal Power (P _{nom}) ⁶	435 W
Power Tolerance	+5/-3%
Avg. Panel Efficiency ⁷	20.3%
Rated Voltage (V _{mpp})	72.9 V
Rated Current (I _{mpp})	5.97 A
Open-Circuit Voltage (V _{oc})	85.6 V
Short-Circuit Current (I _{sc})	6.43 A
Max. System Voltage	1500 V UL & 1000 V IEC
Maximum Series Fuse	15 A
Power Temp Coef.	-0.35% / °C
Voltage Temp Coef.	-235.5 mV / °C
Current Temp Coef.	2.6 mA / °C



Sizing

Combiner Box: SolarBOS Disconnect Combiners

- Conductor Sizes (AWG)
 - #10 for input conductor size
 - 400 MCM for output conductor size
 - 1 output conductor
- Combiner Box to Transformer
 - #10 rated for 2 kV

Specifications

Disconnect Ampacity	200 Amps	250 Amps
Number of Input Circuits	8 to 20	12 to 24
Input Conductor Size (AWG)	#14 - 8	#14 - 8
Max Fuse Size (Amps)	30	30
Max Rated Current (ADC Continuous)	200	250
Number of Output Conductors	1 or 2	1 or 2
Output Conductor Size Range (AWG) *	#6 to 350	#6 to 350
Steel Enclosure Dimensions (Inches) *	20x20x6 / 24x24x8	24x24x8
Approx. Weight - Powder Coated or Stainless Steel (Pounds) *	50	55
Fiberglass Enclosure Internal Dimensions (Inches) *	24x20x8 / 24x24x8	24x24x8
Approx. Weight - Fiberglass (Pounds) *	33	38
Enclosure NEMA Ratings	3R / 4 / 4X	3R / 4 / 4X



Equipment

Solar Panel:

- SunPower E-Series Commercial Solar Panel:
https://us.sunpower.com/sites/default/files/media-library/data-sheets/sunpower-e-series-commercial-solar-panels-e20-435-com-datasheet-521912-revb_1.pdf
 - Output: 435W, 72.9V(DC) 5.97A(DC)
 - Quantity: 180000

Combiner Box:

- SolarBOS Disconnect Combiners:
<https://www.terrasmart.com/wp-content/uploads/2021/10/SS03-SolarBOS-1000VDC-Disconnect-Combiners.pdf>
 - Output: 1000V(DC), 250A(DC)
 - Quantity: 4500

Inverter:

- HEMK-690V-FS3670K:
<https://www.power-electronics.co.nz/assets/brochures/20190606-SolarBrochure-v11.pdf>
 - Output: 3670kW, 690V±10%(AC), 50Hz/60Hz
 - Quantity: 125

Other Equipment might be need:

- Freemaq DC/DC
- BESS (Battery Energy Storage System)
- Wires
- AC combiner box



Solar Field/Farm Cost

Solar Cells

- Couldn't find the one we picked out, but asked for a quote
- \$450/cell
 - 50 V vs 73 V
 - 40 mm vs 46mm
 - 430W vs 435W

Combiner Boxes

- Couldn't find the one we picked out, but asked for a quote
- \$1,000/box
 - 16 Inputs vs 24
 - 1000 VDC

Skids

- Couldn't find the one we picked out, but asked for a quote
- Couldn't find one similar to what we had picked out
- Guessing \$15-20k

[Solar Cells](#)

[Combiner Boxes](#)



Solar Field/Farm Cost

Land

- 250 Acres
- In NM so \$2,000/acre
 - \$500,000

Cables

- #10 for Solar cells to combiner boxes
 - \$390/1000'
- 400 MCM for everywhere else
 - \$6.10/ft

Labor & O-M

- 6hrs/person/week
- 15 weeks
- \$20–25/hr

#10 AWG

400 MCM Wire



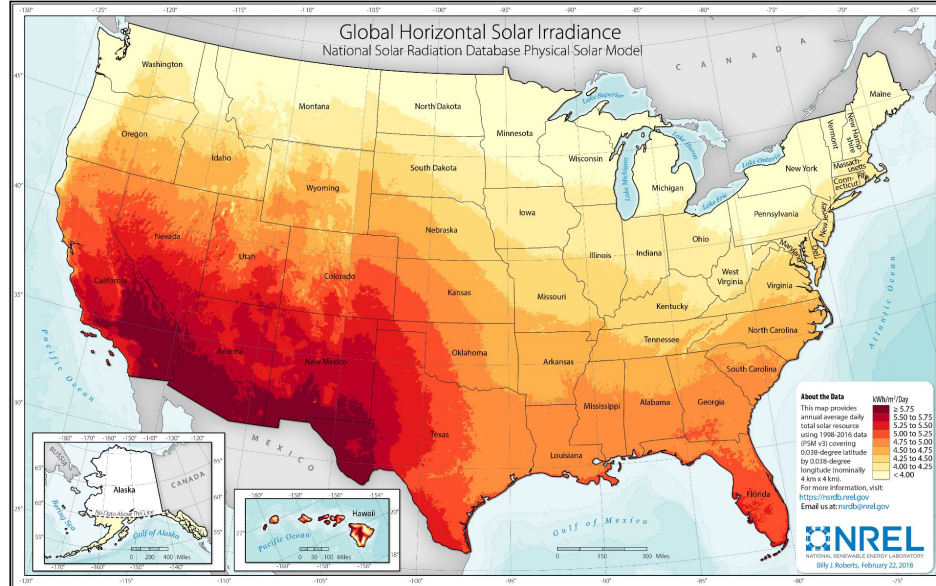
Location - New Mexico (South New Mexico)



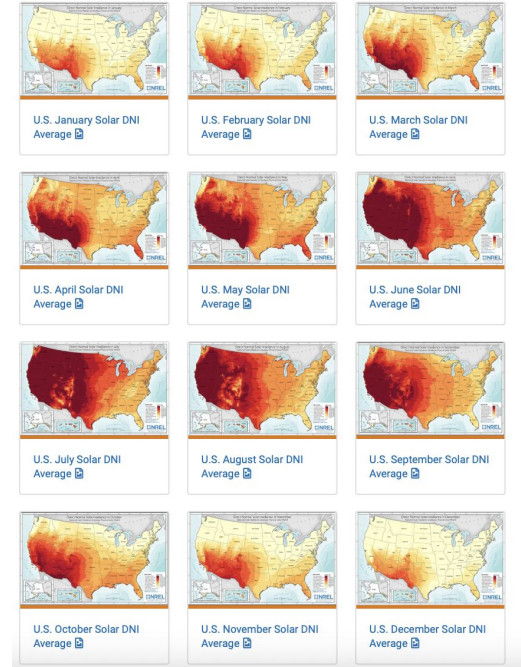
Location - New Mexico

1. Solar Irradiation

- New Mexico generally has a superior solar resource with higher solar irradiance and more sunny days throughout the year. This results in higher energy production and potentially better ROI.
- Solar resource of: 5.00 - above 5.75 kwh/m2 per day among the highest with Arizona, California, Texas.



Solar radiation in each month



STATE

Location - New Mexico

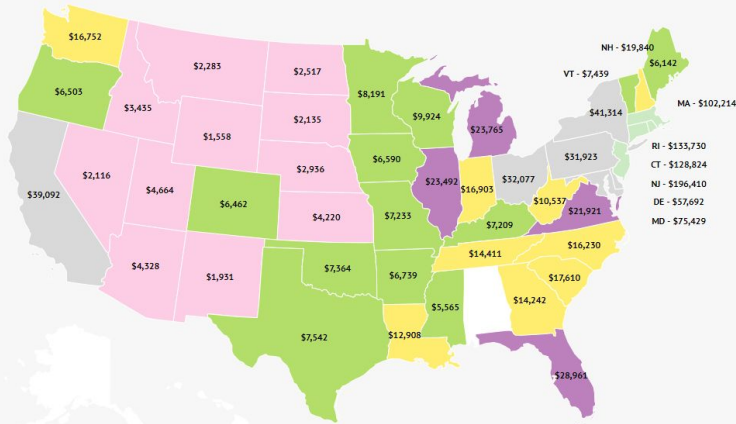
2. Land Availability, Cost and Ownership:

- Land costs can vary significantly in New Mexico, but in many areas, land may be more affordable compared to regions with high agricultural demand.
- Land in southern New Mexico, particularly in rural areas, is often more affordable compared to some other regions with high population density. Lower land costs can significantly reduce the overall project expenses, making it economically attractive for solar developers.
- One of the cheapest in the US, which is approximately \$1931 per acre

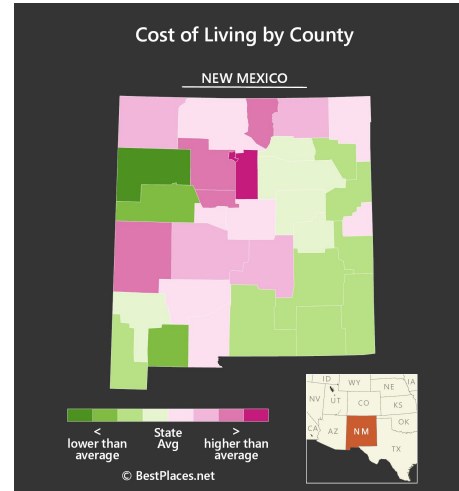
SOLAR PER-ACRE RENTAL RATE BY STATE

STATE	2017 NASS Census Statewide Average Non-Irrigated Per Acre Land & Building Value	Percent of non-irrigated lands with improvements	Equation variable: A Reduced for percentage of improved land	Equation variable: B Multiply by Encumbrance Factor (100%) and round to nearest cent	Equation variable: C Multiply by (2%) Rate of Return and round to nearest cent	Equation variable: D Increase by Annual adjustment (2.1%) and round to nearest cent	Equation variable: E 2021 BLM Statewide Solar Development Per-Acre Rent Rate
ALASKA	\$577.00	1.90%	\$566.04	100%	2%	102.1%	\$11.56
ARIZONA	\$441.00	7.50%	\$407.93	100%	2%	102.1%	\$8.33
CALIFORNIA	\$3,914.00	6.00%	\$3,679.16	100%	2%	102.1%	\$75.13
COLORADO	\$1,290.00	2.10%	\$1,262.91	100%	2%	102.1%	\$25.79
IDAHO	\$1,931.00	3.40%	\$1,865.35	100%	2%	102.1%	\$38.09
MONTANA	\$785.00	1.20%	\$775.58	100%	2%	102.1%	\$15.84
NEW MEXICO	\$399.00	0.70%	\$396.21	100%	2%	102.1%	\$8.09
NEVADA	\$689.00	7.10%	\$640.08	100%	2%	102.1%	\$13.07
OREGON	\$2,470.00	3.00%	\$2,395.90	100%	2%	102.1%	\$48.93
UTAH	\$952.00	2.40%	\$929.15	100%	2%	102.1%	\$18.97
WASHINGTON	\$2,261.00	3.50%	\$2,181.87	100%	2%	102.1%	\$44.56
WYOMING	\$660.00	0.80%	\$654.72	100%	2%	102.1%	\$13.36

How Much An Acre Of Land Costs In Each State



Cost of Living by County



Location - New Mexico

3. Electricity Costs And Return of Investment (ROI)

- 60MW solar farm would need approximately 230 acres (estimate 1kWh per sq ft) + 20 acres (for substation) = 250 acres
- Estimated Cost = \$2000 X 250 acres = \$500,000

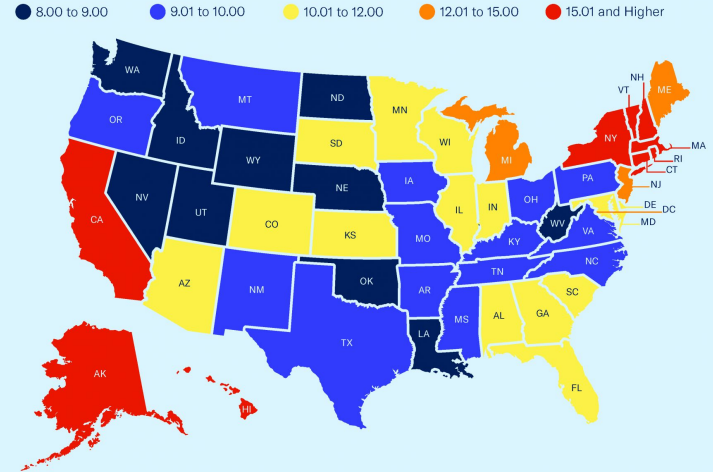
State	Rate of Return (With Tax Credits)	Rate of Return (No Tax Credit)
1. New Mexico	51.4%	7.2%
2. Hawaii	48.3%	23.3%
3. Rhode Island	37.3%	10.1%
4. Texas	33.7%	7.4%
5. Iowa	32.2%	6.4%
6. New York	31.9%	7.9%
7. Arizona	26.6%	13.8%
8. Idaho	23.7%	4.8%
9. California	22.8%	15.1%
10. Connecticut	22.4%	9.2%
11. Colorado	22.3%	8.1%
12. South Carolina	19.7%	6.7%
13. Nevada	18.6%	12.1%
14. Massachusetts	17.4%	8.5%
15. Delaware	16.5%	6.5%

Land required for different substation

Type of Substation	Area Required
132 kV Substation	10 acres
220 kV Substation	25 acres
400 kV Substation	50 acres

2021 Average U.S. Electricity Retail Prices (cents per kWh)

The national average is 11.18 cents per kilowatt hour.



Source: U.S. Energy Information Administration; Electric Power Monthly; February 2022



Feedback and Updates

Price references

Documentation for design work

Possible initial layout - 1 array

IP documentation and sign other docs first and send back

Location: find one if possible, look for ones that are currently for sale

- Noted for soil testing and stuff

