P480 Milestone 4

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System Calculations

Annual Energy Consumption

For this section, we used PVWatts in SAM. By adding up the monthly load data for each month in the Electric Load section, we were able to get an annual energy consumption rate of 17,631kWh and an average peak of 6.05kW (see Figure 1).

	Energy (kWh)	Peak (kW)
Jan	1,693.00	4.17
Feb	1,407.00	3.86
Mar	1,354.00	3.80
Apr	1,280.00	4.56
May	1,099.00	3.80
Jun	1,371.00	4.82
Jul	1,991.00	5.37
Aug	2,009.00	6.05
Sep	1,334.00	4.81
Oct	967.00	2.94
Nov	1,235.00	3.31
Dec	1,891.00	4.84
Annual	17,631.00	6.05

Figure 1. PVWatts Load Details

Solar Fraction

For now, we will be pursuing a 100% solar energy setup. We were able to achieve a 100% solar energy setup however it is expensive so we may have to tweak the system a little bit to lower the cost while maintaining a 100% or close to it. You will find the system's simulation output further in the report.

Inverters

In figures 1 and 2 below, see the two inverters we chose and their specifications. As you can see, each of the inverters have a maximum DC power just higher than our desired array size. We chose to use the inverter seen in Figure 2.

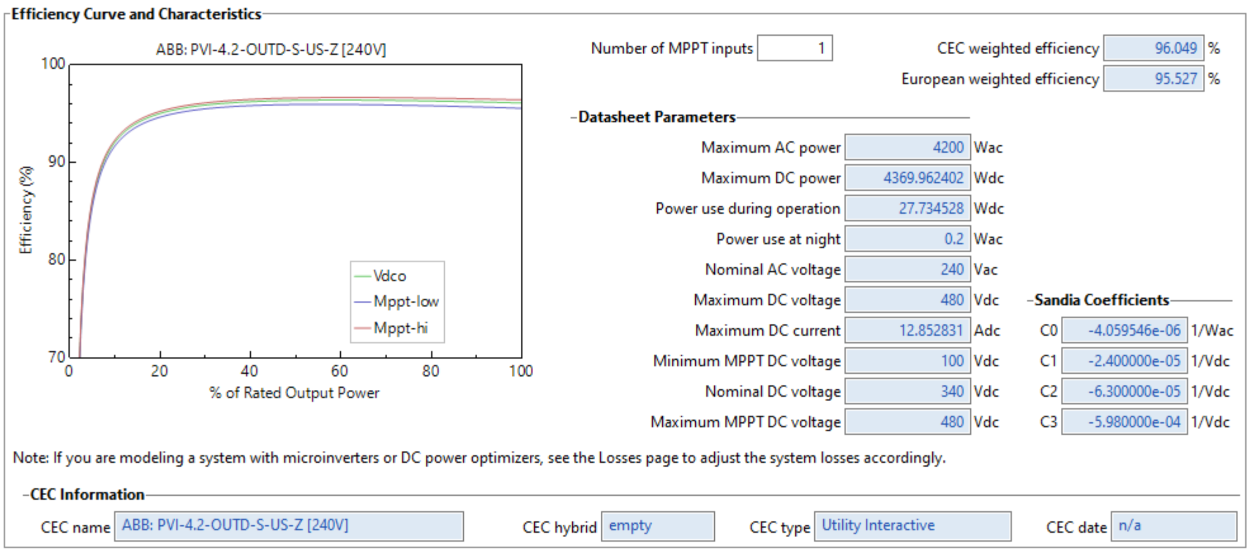


Figure 2. ABB: PVI-4.2-OUTD-S-US-A [240V]

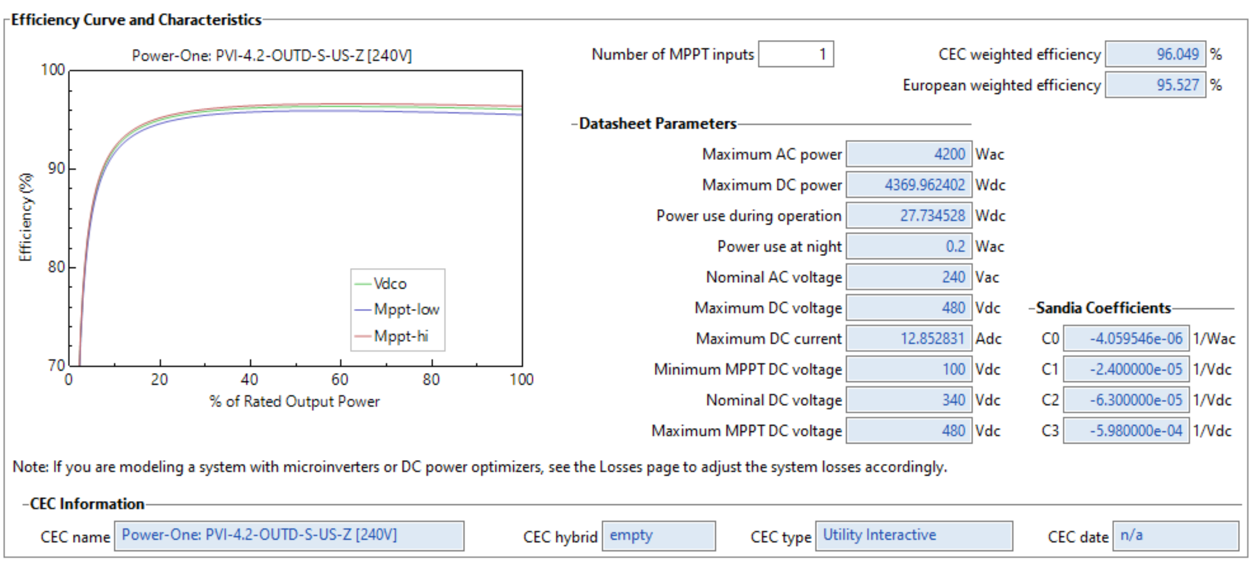


Figure 3. Power-One: PVI-4.2-OUTD-S-US-Z [240V]

Modules

See table 1 for a list of modules which fit the size requirements for our active surfaces. These modules are also between 300 and 450Wdc. For our system, we used only 2 of the active surfaces. We used the roofs marked in figure 4 below. For our system design, we used the last module in table 1.

Figure 4. Active Surfaces Used In System

Table 1. Electrical Characteristics of Six Different PV Modules

Module	**Voc(V)**	**Isc(A)**	**Vm(V)**	**Im(A)**	**ΔVoc/ΔT**	**ΔVm/ΔT**	**NOCT(C°)**
SunPower SPR-343J-WHT-D	68.1	6.4	57.3	6.0	0.013	-0.390	44.5
SunPower SPR-X22-370-D-AC	70.1	6.6	59.6	6.2	0.035	-0.351	46.84
SunPower SPR-P17-355-COM	51.9	8.7	43.4	8.2	0.017	-0.415	48.9
SunPower SPR-X21-350-BLk	68.7	6.4	58.4	6.0	0.035	-0.331	45.3
SunPower SPR-343J-WHT-D	68.1	6.4	57.3	6.0	0.013	-0.390	44.5
SunPower SPR-P17-330-COM	50.9	8.5	41.9	7.9	0.017	-0.415	48.9
SunPower SPR-A410-COM-MLSD	53.4	10.9	44.4	10.1	0.033	-0.329	48.0

Philadelphia temperature extremes range from -14C° to 36C°. Using the equations provided in Figure 5 below allowed us to determine the amount of modules for one and two circuit systems. Using data from Table 1, Voc(max) and Vm(min) were calculated. The mathematical calculations are shown below for module 1 as an example.

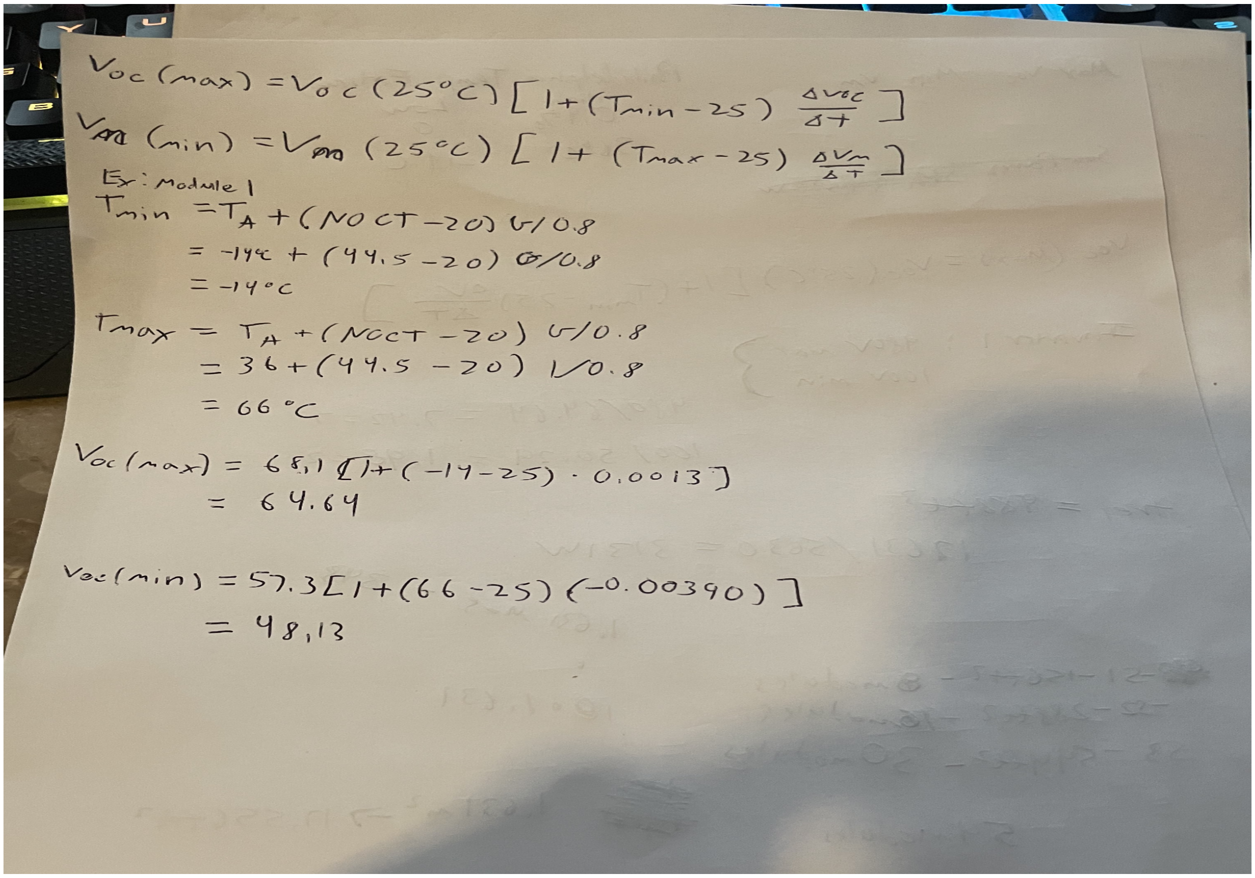


Figure 5. Hand calculations of Voc(max) and Vm(min)

Below is a table provided with the calculations of Voc(Max) and Vm(Min) at their respective temperatures.

Table 2. Tabulation of Voc(max) and Vm(min) for the Modules of Table 1

Module #	**Voc (Max)**	**Vm(Min)**
SunPower SPR-343J-WHT-D	64.64	48.13
SunPower SPR-X22-370-D-AC	60.53	50.29
SunPower SPR-P17-355-COM	48.45	39.09
SunPower SPR-X21-350-BLk	59.32	50.16
SunPower SPR-343J-WHT-D	64.64	48.00
SunPower SPR-P17-330-COM	48.31	33.71

In table 3 below, see the total number of modules permitted for each converter with multiple panel configurations. The allowed modules were determined using the maximum input voltage and minimum MPPT voltage of each respective inverter.

Table 3. Summary of Allowed Numbers of Modules That Fall within Inverter Input Voltage Limits

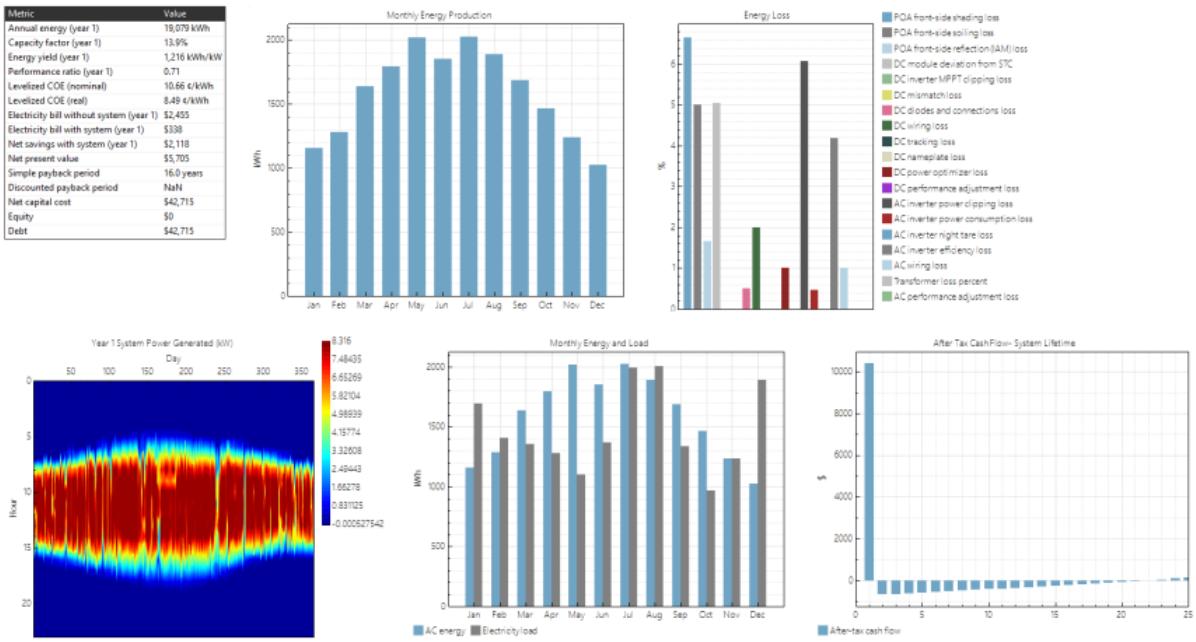
Inverter	**Allowed Module 1**	**Allowed Module 2**	**Allowed Module 3**	**Allowed Module 4**	**Allowed Module 5**	**Allowed Module 6**
Power-One: PVI-4.2-OUTD-S-US-Z[240v]						
One Source Circuit	2,3,4,5,6,7	2,3,4,5,6,7	3,4,5,6,7,8,9	2,3,4,5,6,7 8	2,3,4,5,6,7	3,4,5,6,7,8, 9
Two Source Circuit	4,6,8,10,12, 14,16	4,6,8,10,12, 14,16	6,8,10,12,14, 16,18,20	4,6,8,10,12 ,14,16	4,6,8,10,12, 14,16	6,8,10,12,1 4,16,18,20
ABB: PVI-4.2-OUTD-S-US-a[240v]						
One Source Circuit	2,3,4,5,6,7	2,3,4,5,6,7	3,4,5,6,7,8,9	2,3,4,5,6,7 8	2,3,4,5,6,7	3,4,5,6,7,8, 9
Two Source Circuit	4,6,8,10,12, 14,16	4,6,8,10,12, 14,16	6,8,10,12,14, 16,18,20	4,6,8,10,12 ,14,16	4,6,8,10,12, 14,16	6,8,10,12,1 4,16,18,20

From SAM, the area of each module is $1.631m^2$, which is $17.556ft^2$. Dividing the area of each surface by this value yields the number of modules that fit on that surface.

Table 4. Number of Modules On Each Surface Area

Surface #	1	2	3
# of modules	8	16	30

From Table 4, it can be seen that a total of 54 modules across the three surface areas are needed to produce sufficient array power.



Metric	Value
Annual energy (year 1)	19,079 kWh
Capacity factor (year 1)	13.9%
Energy yield (year 1)	1,216 kWh/kW
Performance ratio (year 1)	0.71
Levelized COE (nominal)	10.66 ¢/kWh
Levelized COE (real)	8.49 ¢/kWh
Electricity bill without system (year 1)	$2,455
Electricity bill with system (year 1)	$338
Net savings with system (year 1)	$2,118
Net present value	$5,705
Simple payback period	16.0 years
Discounted payback period	NaN
Net capital cost	$42,715
Equity	$0
Debt	$42,715

Figure 6. Percentage of the Annual Energy

Figure 6 indicates that the active areas in use produce 19,079kWh compared to 17,631kWh of annual energy, i.e. 108%.