UNIVERSITY OF TOLEDO PVIC SOLAR ARRAY MODIFICATIONS

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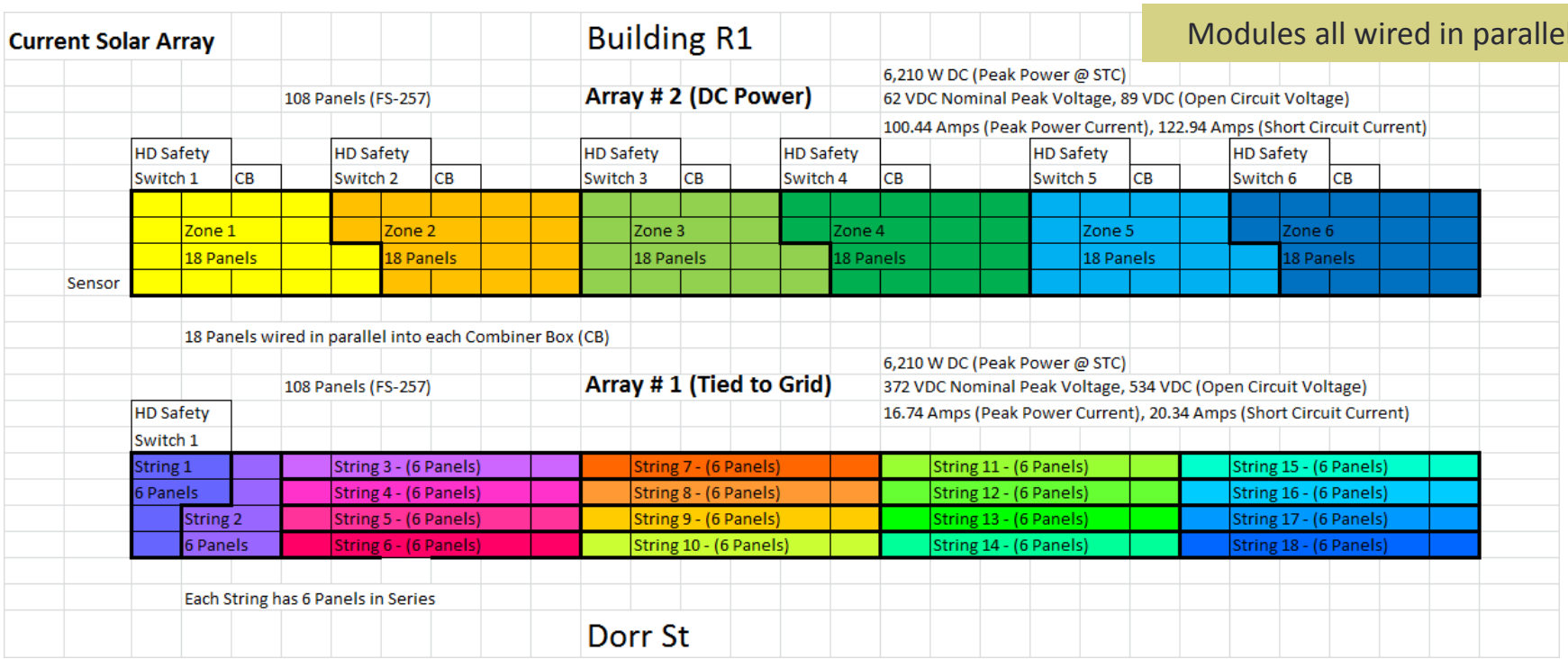
Current Configuration

Array #2 wired for the electrolyzer as follows: All 108 panels are wired in parallel resulting in an mpp at STC of Vmpp = 62 V and Impp = 100.5 A. There are six zones, each of which can be turned off or on presumably affecting the total current delivered.



Array #1 wired for connection to the SunnyBoy inverter (grid-tied) such that sets of six modules are wired together in series into a “string”, and then 18 “string” of 6 modules are wired in parallel resulting in an mpp at STC of Vmpp = 372 V and Impp = 16.7 A.

Assumptions:

- Electricity Cost: $0.05/kWh
- No upgrade to existing electrical service
- Electrician labor: $100/hr
- Time to rewire a module: one electrician, 5 minutes
- Replace a First Solar module (Scenarios B and C): 2 electricians working for 10 minutes
- Install power inverter: 2 men, 2 hours
- Solar module cost = $1.00/watt
- Resale of used First Solar modules = $0.30/Watt

Scenario A
Tie Array #2 to Grid (add inverter)

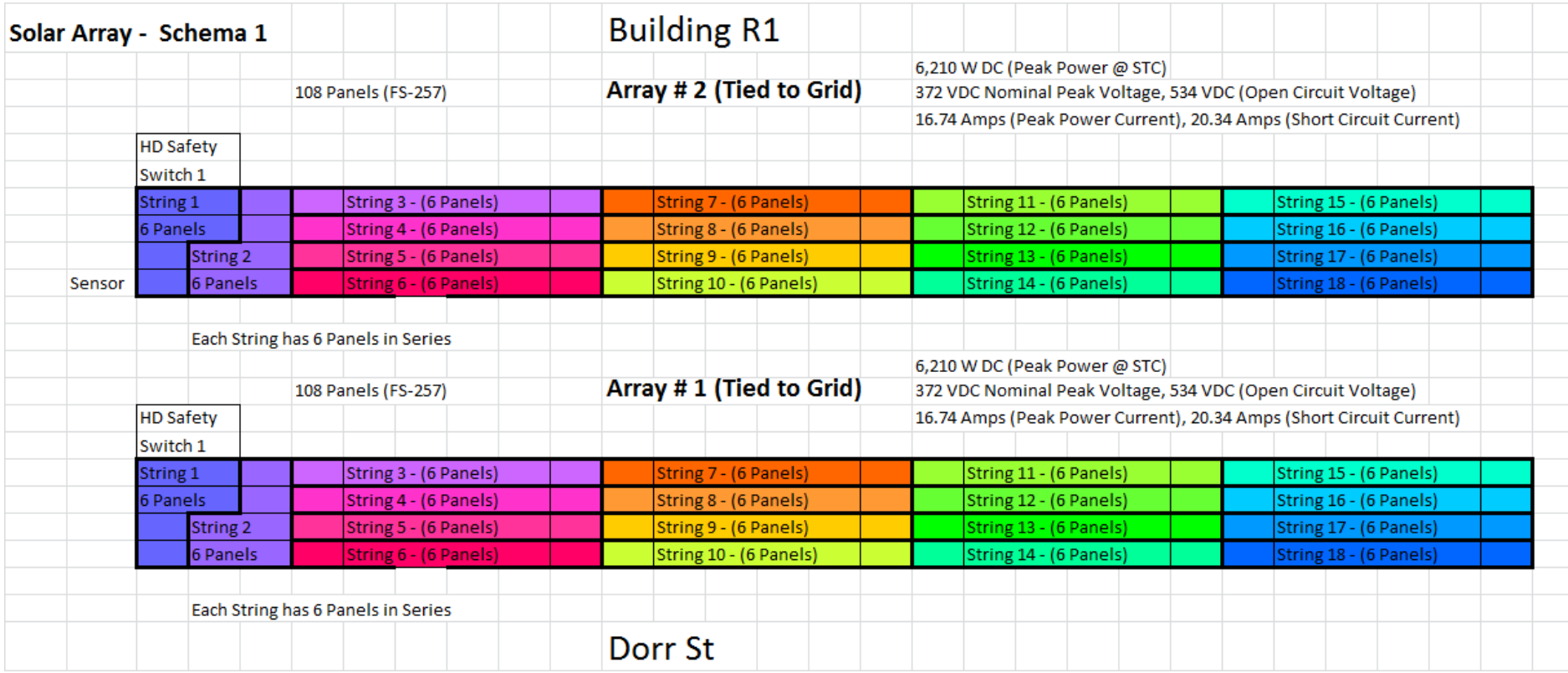
Scenario A: Current Solar Modules

- Manufacturer: First Solar
- Model #: FS-257 CdTe

- Electrical Specs @ STC
  - Power: 58 Watts
  - Voltage: 61.5 Volts
  - Current: .94 Amps
  - Efficiency: 8%

- Mechanical Spec.
  - Width: 600 mm
  - Length: 1200 mm
  - Area: 0.72 m
  - Weight: 25.1 lbs.

Scenario A: Configuration



Scenario A: DC Output Expected from Array #2

- 6 Panels/String
- 18 Strings
- 108 Panels
- 6,210 W DC (peak power @ Standard Test Conditions (STC))
- 372 VDC nominal peak voltage
- 534 VDC open circuit voltage
- 16.74 Amps at maximum power point (mpp)
- 20.34 short circuit current

Scenario A: AC Output Expected from Array #2 = 7,533 kW-hr/yr

PVWatts

AC Energy & Cost Savings

Cautions for Interpreting the Results

(Type comments here to appear on printout; maximum 1 row of 90 characters.)

Station Identification	
Cell ID:	0249368
State:	Ohio
Latitude:	41.8 ° N
Longitude:	83.8 ° W
PV System Specifications	
DC Rating:	6.21 kW
DC to AC Derate Factor:	0.770
AC Rating:	4.78 kW
Array Type:	Fixed Tilt
Array Tilt:	41.8 °
Array Azimuth:	180.0 °
Energy Specifications	
Cost of Electricity:	5.0 ¢/kWh

Results

Month	Solar Radiation (kWh/m²/day)	AC Energy (kWh)	Energy Value ($)
1	3.06	471	23.55
2	3.85	538	26.90
3	4.63	689	34.45
4	5.49	765	38.25
5	5.66	778	38.90
6	5.88	756	37.80
7	5.74	751	37.55
8	5.64	746	37.30
9	5.43	713	35.65
10	4.17	585	29.25
11	2.73	383	19.15
12	2.40	358	17.90
Year	4.56	7533	376.65

Scenario A: Cost

- Inverter: SunnyBoy SB6000US 1 Phase - $2,735
- Rewire 108 modules from parallel to 18 groups of 6 modules per string - $900
- Install inverter, attach to electrical panel, and connect to grid - $400
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- Total $4,035

Scenario B: Upgrade Array #2 and Tie to Grid (new inverter)

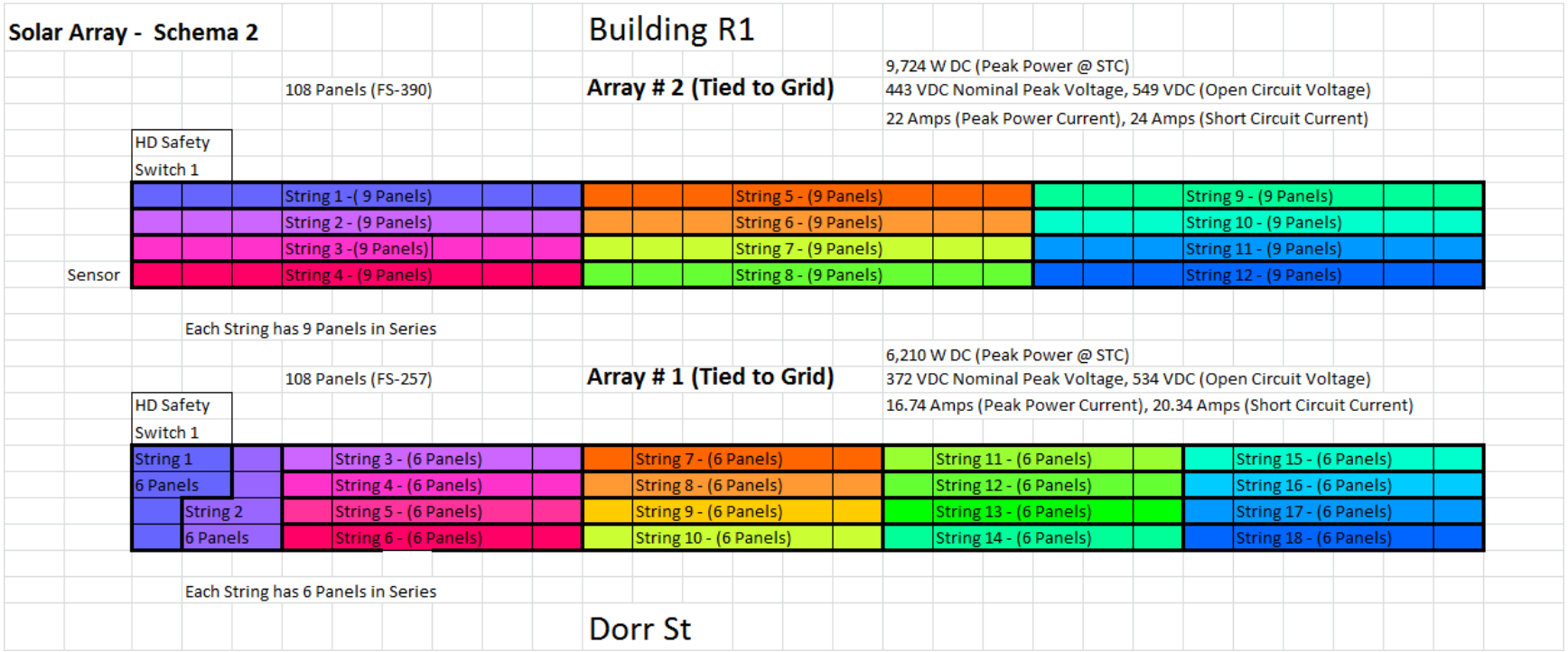
Scenario #2
Upgrade First Solar Panels

- Manufacturer: First Solar
- Model: FS-390 CdTe

- Electrical Specs @ STC
  - Power: 90 Watts
  - Voltage: 49.2 Volts
  - Current: 1.83 Amps
  - Efficiency: 13%

- Mechanical Spec.
  - Width: 600 mm
  - Length: 1200 mm
  - Area: 0.72 meters
  - Weight: 12 lbs.

Scenario #2- Configuration



Scenario B: DC Output

- 9 Panels/String
- 12 Strings
- 108 Panels
- 9,700 W DC (Peak Power @ STC)
- 443 VDC Nominal Peak Voltage
- 549 VDC (Open Circuit Voltage
- 21.96 Amps (Peak Power Current)
- 24.48 Amps (Short Circuit Current)

Scenario B: AC Output = 11,791 kW-hr / year

PVWatts

AC Energy & Cost Savings

(Type comments here to appear on printout; maximum 1 row of 90 characters.)

Station Identification	
Cell ID:	0249368
State:	Ohio
Latitude:	41.8 ° N
Longitude:	83.8 ° W
PV System Specifications	
DC Rating:	9.72 kW
DC to AC Derate Factor:	0.770
AC Rating:	7.48 kW
Array Type:	Fixed Tilt
Array Tilt:	41.8 °
Array Azimuth:	180.0 °
Energy Specifications	
Cost of Electricity:	5.0 ¢/kWh

Results

Month	Solar Radiation (kWh/m²/day)	AC Energy (kWh)	Energy Value ($)
1	3.06	738	36.90
2	3.85	842	42.10
3	4.63	1078	53.90
4	5.49	1198	59.90
5	5.66	1218	60.90
6	5.88	1183	59.15
7	5.74	1176	58.80
8	5.64	1168	58.40
9	5.43	1115	55.75
10	4.17	915	45.75
11	2.73	599	29.95
12	2.40	560	28.00
Year	4.56	11791	589.55

Scenario B: Cost

- Buy 108 - FS-390 First Solar Panels - $9,724
- Remove old Panels and Install new ones – $3,600
- Rewire Solar panels with 9 panels in series per string - $900
- Buy inverter 10000TL-US - $5,600
- Install inverter, attach to electrical panel, and connect to grid - $400
- Sell Used Panels – ($1,880)
- ----------
- Total - $ 18,344

Scenario C

Tie Array #2 to Grid; Upgrade Modules for Both Arrays; Requires new inverter(s)

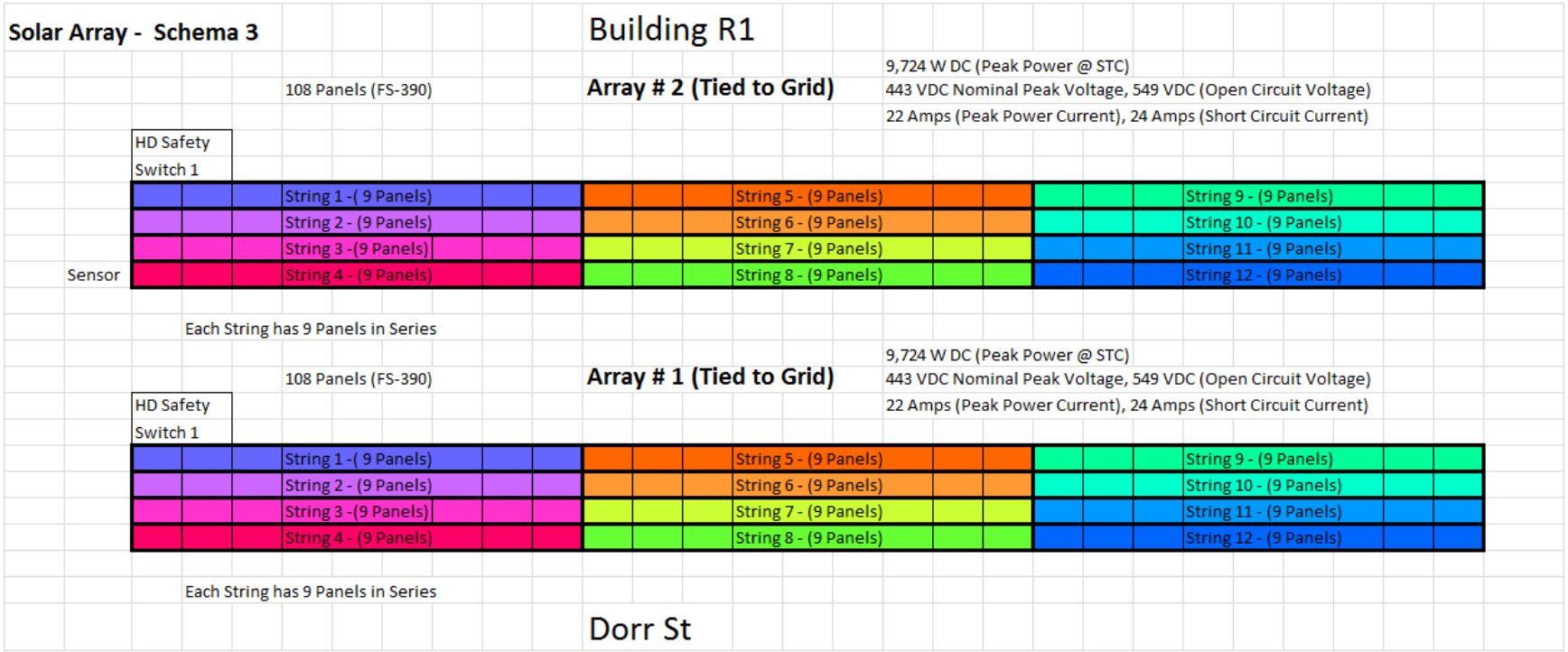
Scenario C: Upgrade Both Arrays to First Solar FS-390 Modules

- Manufacturer: First Solar
- Model: FS-390 CdTe

- Electrical Specs @ STC
  - Power: 90 Watts
  - Voltage: 49.2 Volts
  - Current: 1.83 Amps
  - Efficiency: 13%

- Mechanical Spec.
  - Width: 600 mm
  - Length: 1200 mm
  - Area: 0.72 meters
  - Weight: 26.4 lbs.

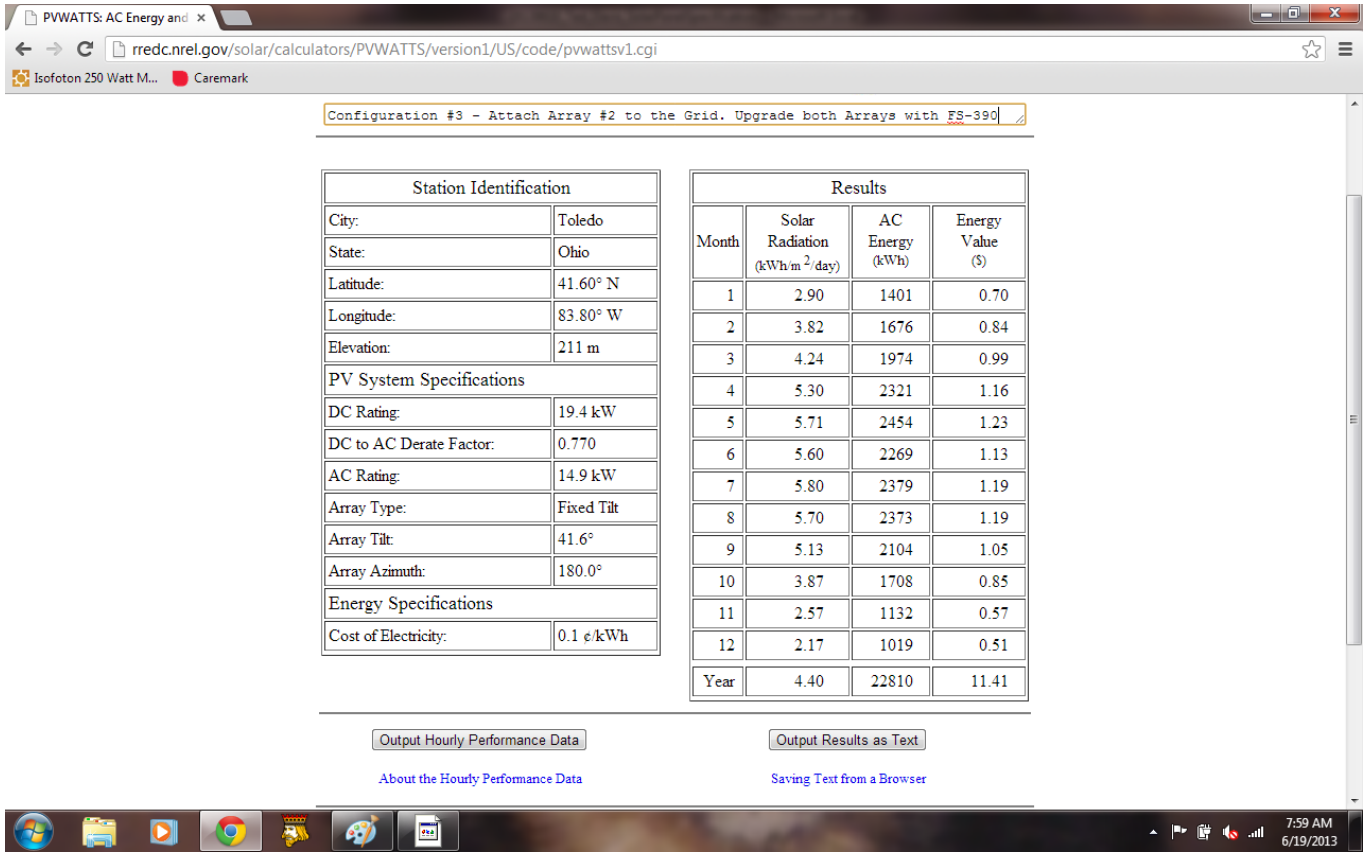
Scenario C: Configuration



Scenario C: DC Output / Array

- 9 Panels/String
- 12 Strings
- 108 Panels
- 9,700 W DC (Peak Power @ STC)
- 443 VDC Nominal Peak Voltage
- 549 VDC (Open Circuit Voltage
- 21.96 Amps (Peak Power Current)
- 24.48 Amps (Short Circuit Current)

Scenario C: Total AC Output = 23,582 kW-hr/yr



Station Identification	
City:	Toledo
State:	Ohio
Latitude:	41.60° N
Longitude:	83.80° W
Elevation:	211 m
PV System Specifications	
DC Rating:	19.4 kW
DC to AC Derate Factor:	0.770
AC Rating:	14.9 kW
Array Type:	Fixed Tilt
Array Tilt:	41.6°
Array Azimuth:	180.0°
Energy Specifications	
Cost of Electricity:	0.1 ¢/kWh

Results			
Month	Solar Radiation (kWh/m^2/day)	AC Energy (kWh)	Energy Value ($)
1	2.90	1401	0.70
2	3.82	1676	0.84
3	4.24	1974	0.99
4	5.30	2321	1.16
5	5.71	2454	1.23
6	5.60	2269	1.13
7	5.80	2379	1.19
8	5.70	2373	1.19
9	5.13	2104	1.05
10	3.87	1708	0.85
11	2.57	1132	0.57
12	2.17	1019	0.51
Year	4.40	22810	11.41

Scenario C: Cost*

- Buy 216 - FS-390 First Solar Panels - $19,448
- Remove old Panels and Install new ones – $7,200
- Rewire Solar panels with 12 panels in series per string - $1,800
- Buy 2 inverters 10000TL-US - $11,200
- Install 2 inverter, attach to electrical panel, and connect to grid - $800
- Sell Used Panels – ($3,760)
- ----------
- Total - $ 36,688

LEC Assumptions

- $0.05 / kWh
- 1% increase in Electric Price/Year
- 0.5% yearly decrease in power output due to module aging
- 3.5% Discount Rate

Comparison

	Scenario A	Scenario B	Scenario C
	Attach to Grid	Attach to Grid, Upgrade to new Panels FS-390	Attach to Grid, Upgrade both Arrays to new Panels FS-390
Cost	$4,035	$18,344	$36,688
Annual kWh	7,355	11,791	23,582
LEC Break Even	10 Years	Never	Never
LEC @ 10 Years	$0.053/kWh	$0.133/kWh	$0.191/kWh
LEC @ 15 Years	$0.040/kWh	$0.099/kWh	$0.140/kWh
LEC @ 20 Years	$0.034/kWh	$0.082/kWh	$0.115/kWh
LEC @ 25 Years	$0.031/kWh	$0.072/kWh	$0.101/kWh

Energy Cost Increase

	Grid Energy Cost	Scenario A	Scenario B	Scenario C
	Cost @ 25 Years	Attach to Grid	Attach to Grid, Upgrade to new Panels FS-390	Attach to Grid, Upgrade both Arrays Panels FS-390
Starting Cost	$0.05/kWh	Break Even	Break Even	Break Even
1% Increase/Yr	$0.063/kWh	10 Years	> 25 Years	> 25 Years
3% Increase/Yr	$0.102/kWh	9 Years	19 Years	25 Years
5% Increase/Yr	$0.154/kWh	8 Years	15 Years	19 Years