



# Aria Health | Torresdale Campus Emergency Department | Expansion

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**Senior Thesis Presentation | April 16<sup>th</sup>, 2014**

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Robert M. Stano | AE | Construction Option  
Adviser | Dr. Chimay Anumba

**Project Summary**

Analysis 1: Rainwater Collection

- Analysis Goals
- Data Collection
- Description & Design
- Cost Estimation
- Economic Analysis

Analysis 2: Photovoltaic Array

- Analysis Goals
- Data Collection
- Description & Design
  - Electrical Breadth
- System Layout & Cost Estimation
- Economic Analysis

Analysis 3: Operable Solar Shading

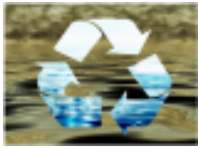
- Analysis Goals
- Colt Shadoglass
- Cost Estimation
- Sequencing, Schedule, Logistics
- Energy Model
  - Mechanical Breadth

Thesis Recap

Acknowledgements

**Bob Stano | Construction**

*Analysis 1 - Rainwater Collection*



*Analysis 2 - Photovoltaic Array*



**Project Summary**

**Overall Theme**

***Sustainable  
Construction***

**Aria Health | Torresdale Campus | ED Expansion**

*Analysis 3 - Operable Solar Shading*



*Analysis 4 - Modularization of Patient Treatment Rooms (not presented)*



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## Project Summary

**Location:** Philadelphia, PA

**Building Information:**

- 2 Stories Above Grade, 1 Below
- Structural Steel
- 80,000 SF
- Emergency Department Addition and Renovation

**Construction:**

- \$35 MM
- 2/25/13 - 6/27/14
- CM at Risk
- GMP Contract

## Aria Health | Torresdale Campus | ED Expansion

**Owner:** Aria Health Systems

**Owner's Representative:** Stantec

**Architect:** Francis Cauffman

**MEP Design:** PWI

**Structural Design:** O'Donnell & Naccarato

**Civil Design:** Barry Isett & Associates

**Construction Manager:** Turner Construction Company



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## Analysis 1 - Rainwater Collection

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### Analysis Goals

Primary: To show how sustainable construction techniques can be used for the purpose of *resource conservation*.

### Data Collection

Rainwater Conductors		
Tag	Size (in)	Service (SF of Roof Area)
RWC 1.1	5	1745
RWC 1.2	5	1960
RWC 1.3	6	7740
RWC 1.4	6	3385
RWC 1.5	6	4755
RWC 2.1	5	2855
RWC 2.2	5	4490
RWC 2.3	6	3385
RWC 2.4	6	6205
RWC 3.1	5	3020
RWC 3.2	5	1795
[E] RWC	5	1525
Misc. System No. 3		615
<b>Total SF</b>		<b>43475</b>

Conversions		
Average Annual Rainfall	41.53	Inches
1 Acre	43560	SF
1 Inch/1 Acre	27154	Gal

$$\text{Roof Area (Acres)} = \frac{\text{Roof Area (SF)}}{\# \text{ SF per Acre}}$$

$$\text{Rainfall} \left( \frac{\text{Gal}}{\text{Inch}} \right) = (\text{Inches per Acre}) \times (\text{Roof Area (Acres)})$$

$$\text{Annual Rainfall (Gal)} = (\text{Average Annual Rainfall}) \times (\text{Rainfall} \left( \frac{\text{Gal}}{\text{Inch}} \right))$$

$$\text{Monthly Rainfall (Gal)} = \frac{\text{Annual Rainfall (Gal)}}{12 \text{ Months}}$$

Rainfall Calculations				
Roof Area (SF)	Roof Area (Acres)	Rainfall (Gal/Inch)	Annual Rainfall (Gal)	Monthly Rainfall (Gal)
43475	0.998	27101.01	1125505.09	93792.09

### Data Collection



Water Use Calculations						
Fixture	Flushes/Day/Fixture	QTY	GPF	Gal/Day	Days/Mo	Gal/Mo
Water Closets	50	34	1.6	2720	30	81600
Urinals	50	3	0.125	18.75	30	562.5

**Total Water Usage 82162.5**

$$\frac{\text{Gal}}{\text{Moth}} = (\text{Flushes per day per fixture}) \times (\text{QTY}) \times \left( \frac{\text{Gal}}{\text{Day}} \right) \times (30 \text{ days per mont})$$

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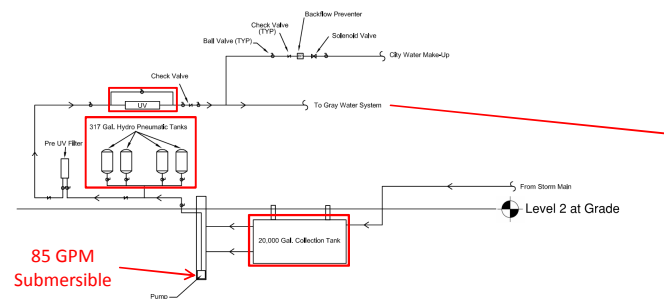
**Analysis 1 - Rainwater Collection**

**Aria Health | Torresdale Campus | ED Expansion**

Description



Design



Design



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### Cost Estimate

Total Rainwater Collection Estimate			
Item	Copper/Steel	PVC/Fiberglass	
Gray Water Piping	\$74,849.30		\$41,979.70
Fittings	\$13,141.45		\$4,255.92
Tanks	\$56,300.00		\$47,810.00
Harvesting Components	\$32,403.00		\$32,403.00
<b>Sub-Total</b>	<b>\$176,693.75</b>		<b>\$126,448.62</b>
Overhead & Profit (10%)			\$12,644.86
Tax (6%)			\$7,586.92
<b>Grand Total Cost</b>	<b>\$204,964.75</b>		<b>\$146,680.40</b>

Fittings Estimate			
Item	Copper Tubing	PVC Pipe	
Couplings	QTY UOM Material Labor Total Unit Cost	Material Labor Total Unit Cost	Total Cost
2 1/2"	10 EA \$22.00 \$30.50 \$52.50	\$52.50	\$105.00
2"	13 EA \$16.50 \$35.50 \$52.00	\$52.00	\$104.00
1 1/2"	27 EA \$18.00 \$55.50 \$73.50	\$73.50	\$147.00
<b>Total</b>			<b>\$356.00</b>
2 1/2", 2"	1 EA \$0.00 \$14.40 \$14.40	\$14.40	\$14.40
2 1/2"	15 EA \$0.00 \$13.15 \$13.15	\$13.15	\$13.15
<b>90 Degree Elbows</b>			<b>\$41.55</b>
2 1/2"	3 EA \$146.00 \$65.00 \$211.00	\$65.00	\$276.00
2"	19 EA \$29.00 \$44.50 \$73.50	\$44.50	\$142.50
1 1/2"	28 EA \$60.00 \$56.00 \$116.00	\$56.00	\$144.00
<b>Total Copper</b>	<b>\$13,141.45</b>		<b>\$4,255.92</b>

## Analysis 1 - Rainwater Collection

Piping Estimate									
Horizontal Piping									
Copper Tubing/Sch. 40 Steel, Flanged					PVC Pipe				
Item	QTY	UOM	Material	Labor	Total Unit Cost	Material	Labor	Total Unit Cost	Total Cost
Level 2 West									
12" Storm Main	181	LF	\$163.00	\$92.00	\$255.00	\$46,155.00	\$103.00	\$30.50	\$133.50
2 1/2" Gray Supply	70	LF	\$35.00	\$13.35	\$48.35	\$3,384.50	\$9.15	\$14.80	\$23.95
2" Gray Supply	366	LF	\$22.00	\$10.95	\$32.95	\$12,659.70	\$5.95	\$14.05	\$20.00
1 1/2" Gray Supply	70	LF	\$14.35	\$8.85	\$23.20	\$1,624.00	\$4.76	\$12.80	\$17.56
Level 2 East									
2" Gray Supply	23	LF	\$22.00	\$10.95	\$32.95	\$757.85	\$5.95	\$14.05	\$20.00
1 1/2" Gray Supply	5	LF	\$14.35	\$8.85	\$23.20	\$116.00	\$4.76	\$12.80	\$17.56
Level 1									
2 1/2" Gray Supply	5	LF	\$35.00	\$13.35	\$48.35	\$241.75	\$9.15	\$14.80	\$23.95
2" Gray Supply	145	LF	\$22.00	\$10.95	\$32.95	\$4,777.75	\$5.95	\$14.05	\$29.00
1 1/2" Gray Supply	15	LF	\$14.35	\$8.85	\$23.20	\$348.00	\$4.76	\$12.80	\$17.56
<b>Total Horiz Copper</b>	<b>\$69,464.55</b>					<b>Total Horiz PVC</b>	<b>\$38,220.15</b>		

Vertical Piping									
Copper Tubing/Sch. 40 Steel, Flanged					PVC Pipe				
Item	QTY	UOM	Material	Labor	Total Unit Cost	Material	Labor	Total Unit Cost	Total Cost
2 1/2" Gray Supply	25	LF	\$35.00	\$13.35	\$48.35	\$1,208.75	\$9.15	\$14.80	\$23.95
1 1/2" Gray Supply	180	LF	\$14.35	\$8.85	\$23.20	\$4,176.00	\$4.76	\$12.80	\$17.56
<b>Total Vert Copper</b>	<b>\$5,384.75</b>					<b>Total Vert PVC</b>	<b>\$3,759.55</b>		
<b>Total Copper</b>	<b>\$74,849.30</b>					<b>Total PVC</b>	<b>\$41,979.70</b>		

## Aria Health | Torresdale Campus | ED Expansion

Harvesting Components Estimate						
Pumps						
Item	QTY	UOM	Material	Labor	Total Unit Cost	Total Cost
Domestic Booster Pump	1	EA	\$7,550.00	\$860.00	\$8,410.00	\$8,410.00
Valves						
Item	QTY	UOM	Material	Labor	Total Unit Cost	Total Cost
Check Valve	4	EA	\$760.00	\$55.50	\$815.50	\$3,262.00
Ball Valve	13	EA	\$295.00	\$51.00	\$346.00	\$4,498.00
Backflow Preventer	1	EA	\$1,923.00	\$60.00	\$1,983.00	\$1,983.00
Solenoid Valve	1	EA	\$300.00	\$50.00	\$350.00	\$350.00
<b>Total Valves</b>					<b>\$10,093.00</b>	
Filters						
Item	QTY	UOM	Material	Labor	Total Unit Cost	Total Cost
Pre-UV Filter	1	EA	\$3,200.00	\$800.00	\$4,000.00	\$4,000.00
UV Filter	1	EA	\$8,700.00	\$9,900.00	\$18,600.00	\$18,600.00
<b>Total Filters</b>					<b>\$13,900.00</b>	
<b>Total Components</b>					<b>\$32,403.00</b>	

Tanks Estimate									
Steel					Fiberglass				
Item	QTY	UOM	Material	Labor	Total Unit Cost	Material	Labor	Total Unit Cost	Total Cost
20,000 Gal. Storage Tank	1	EA	\$16,300.00	\$1,200.00	\$17,500.00	\$26,000.00	\$1,000.00	\$27,000.00	\$44,500.00
4000 Pneumatic Tank	1	EA	\$3,900.00	\$1,500.00	\$5,400.00	\$4,700.00	\$1,800.00	\$6,500.00	\$11,900.00
<b>Total Steel</b>					<b>\$22,900.00</b>			<b>\$33,500.00</b>	
<b>Total Fiberglass</b>								<b>\$47,810.00</b>	

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**Analysis 1 - Rainwater Collection**

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**Water Cost Calculations**

Amount of Reclaimed Water (Gal)	Amount of Reclaimed Water (kCF)	Utility Water (Cost/kCF)	Wastewater (Cost/kCF)	Total (Cost/1,000CF)	Total Annual Cost
1125505.09	150.07	\$37.12	\$26.19	\$63.31	\$9,500.76

**References and Assumptions:**

Philadelphia water cost data is from www.phila.gov/water  
 Information based on average annual rainfall in Philadelphia, PA  
 Conversion: 1 Gal = 7.5 CF  
 Conversion: 1kCF = 1,000 CF

**Cost Payback After: 12.18 Years**

**Cumulative Income After 25 Years: \$281,105.50**

**References and Assumptions**

Maintenance based on 16 Hours/Year after 5 maintenance-free years for a Union Plumber Rate of \$59.68/Hour  
<http://www.plumbers690.org/library/document-library/20120719095713.Apprent%20Phila%2012-13%20wages.pdf>  
 General Inflation Rate Assumed to be 3% for 25 Years  
 Water Inflation Rate Assumed to be of 5% per Year for 25 Years  
 Philadelphia Water Utility Cost/kCF is Assumed to be \$37.12/kCF for Water and \$26.19/kCF for Wastewater

**Economic Analysis for Rainwater Collection System**

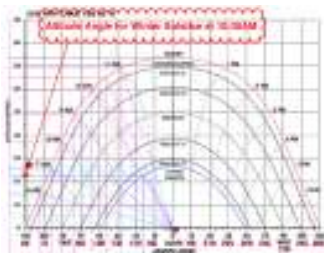
	After 25 Years	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	
<b>Total Upfront Costs:</b>																											
Cost of Rainwater Collection System	\$146,680.40	\$146,680.40	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
Maintenance	\$25,657.95	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$954.83	\$968.98	\$983.13	\$997.28	\$1,011.43	\$1,025.58	\$1,039.73	\$1,053.88	\$1,068.03	\$1,082.18	\$1,096.33	\$1,110.48	\$1,124.63	\$1,138.78	\$1,152.93	\$1,167.08	\$1,181.23	\$1,195.38	\$1,209.53	\$1,223.68	\$1,237.83
<b>Total Costs</b>	<b>\$172,338.35</b>	<b>\$146,680.40</b>	<b>\$0.00</b>	<b>\$0.00</b>	<b>\$0.00</b>	<b>\$0.00</b>	<b>\$954.83</b>	<b>\$968.98</b>	<b>\$983.13</b>	<b>\$997.28</b>	<b>\$1,011.43</b>	<b>\$1,025.58</b>	<b>\$1,039.73</b>	<b>\$1,053.88</b>	<b>\$1,068.03</b>	<b>\$1,082.18</b>	<b>\$1,096.33</b>	<b>\$1,110.48</b>	<b>\$1,124.63</b>	<b>\$1,138.78</b>	<b>\$1,152.93</b>	<b>\$1,167.08</b>	<b>\$1,181.23</b>	<b>\$1,195.38</b>	<b>\$1,209.53</b>	<b>\$1,223.68</b>	<b>\$1,237.83</b>
<b>Total Cost Savings:</b>																											
Water Production Savings	\$453,443.84	\$9,500.76	\$9,975.80	\$10,474.59	\$10,998.32	\$11,548.24	\$12,125.05	\$12,731.96	\$13,368.95	\$14,036.92	\$14,736.88	\$15,475.74	\$16,249.59	\$17,062.01	\$17,915.11	\$18,810.81	\$19,751.14	\$20,738.98	\$21,775.90	\$22,864.71	\$24,007.98	\$25,208.15	\$26,466.77	\$27,792.21	\$29,185.92	\$30,648.91	
<b>Total Income</b>	<b>\$453,443.84</b>	<b>\$9,500.76</b>	<b>\$9,975.80</b>	<b>\$10,474.59</b>	<b>\$10,998.32</b>	<b>\$11,548.24</b>	<b>\$12,125.05</b>	<b>\$12,731.96</b>	<b>\$13,368.95</b>	<b>\$14,036.92</b>	<b>\$14,736.88</b>	<b>\$15,475.74</b>	<b>\$16,249.59</b>	<b>\$17,062.01</b>	<b>\$17,915.11</b>	<b>\$18,810.81</b>	<b>\$19,751.14</b>	<b>\$20,738.98</b>	<b>\$21,775.90</b>	<b>\$22,864.71</b>	<b>\$24,007.98</b>	<b>\$25,208.15</b>	<b>\$26,466.77</b>	<b>\$27,792.21</b>	<b>\$29,185.92</b>	<b>\$30,648.91</b>	
<b>Annual Cash Flow</b>																											
Annual Cash Flow	-\$137,179.64	\$9,975.80	\$10,474.59	\$10,998.32	\$11,548.24	\$11,170.77	\$11,748.41	\$12,355.50	\$12,993.53	\$13,664.08	\$14,368.78	\$15,109.33	\$15,887.62	\$16,705.49	\$17,564.96	\$18,468.13	\$19,417.20	\$20,414.49	\$21,462.48	\$22,563.61	\$23,720.68	\$24,936.47	\$26,213.94	\$27,556.20	\$28,966.52		
<b>Cumulative Cash Flow</b>	<b>\$281,105.50</b>	<b>-\$137,179.64</b>	<b>-\$127,203.83</b>	<b>-\$116,729.24</b>	<b>-\$105,730.92</b>	<b>-\$94,182.68</b>	<b>-\$83,011.91</b>	<b>-\$71,263.51</b>	<b>-\$58,908.01</b>	<b>-\$45,914.48</b>	<b>-\$32,250.40</b>	<b>-\$17,881.63</b>	<b>-\$2,772.27</b>	<b>\$13,115.33</b>	<b>\$29,820.84</b>	<b>\$47,385.80</b>	<b>\$65,853.93</b>	<b>\$85,271.13</b>	<b>\$105,685.62</b>	<b>\$127,148.07</b>	<b>\$149,711.68</b>	<b>\$173,432.37</b>	<b>\$198,368.84</b>	<b>\$224,582.76</b>	<b>\$252,138.98</b>	<b>\$281,105.50</b>	

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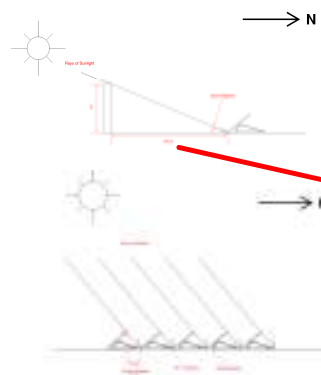
### Analysis Goals

Primary: To show how sustainable construction techniques can be used for the *self-production of electricity*.



## Analysis 2 - Photovoltaic Array

### Data Collection



## Aria Health | Torresdale Campus | ED Expansion

### Data Collection





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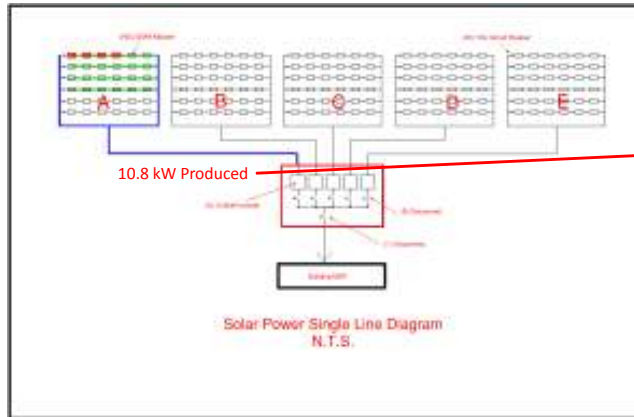
### Description & Design



ELECTRICAL CHARACTERISTICS	
Maximum Power (Pmax)	300 W
Tolerance of Pmax	0%/5%
Type of Cell	Polycrystalline silicon
Cell Configuration	72 in series
Open Circuit Voltage (Voc)	45.1 V
Maximum Power Voltage (Vmp)	35.2 V
Short Circuit Current (Isc)	8.94 A
Maximum Power Current (Imp)	8.53 A
Module Efficiency (%)	15.3%
Maximum System (DC) Voltage	3000 V
Series Fuse Rating	15 A
NOCT	46.2 °C
Temperature Coefficient (Pmax)	-0.439%/°C
Temperature Coefficient (Voc)	-0.32%/°C
Temperature Coefficient (Isc)	0.052%/°C
<small>*Sumation of 1 kW/m<sup>2</sup> (1 sun) at spectral distribution of AM 1.5 (ASTM E892) global spectral irradiance at a cell temperature of 25°C.</small>	
MECHANICAL CHARACTERISTICS	
Dimensions (in x h x c (mm))	39" x 71.6" x 1.5" (994 x 1811 x 46 mm)
Cable Length (ft)	43.7 (13.3)
Output Interconnect Cable	12 AWG with SMA Locking Connector
Weight	50 lbs / 22.7 kg
Max Load	30 psf (1440 Pascals)
Operating Temperature (min)	-40 to 134°F / -40 to 50°C

Sharp ND-F4Q300

## Analysis 2 - Photovoltaic Array



## Aria Health | Torresdale Campus | ED Expansion



Schletter VarioTop Racking System



Aurora PVI-12.0-I Inverter

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## Bob Stano | Construction

### Direct Current

$$W = VA$$

### Series Branch

$$V = (6 \text{ Modules}) \times (35.2V \text{ per Module})$$

$$V = 211.2 \text{ Volts}$$

$$A = \frac{(6 \text{ Modules}) \times (300W \text{ per Modules})}{211.2V}$$

$$A = 8.52 \text{ Amps}$$

### Parallel Feeder

$$A = (8.52 \text{ Amps}) \times (6 \text{ Series Branches})$$

$$A = 51.14 \text{ Amps}$$

## Analysis 2 - Photovoltaic Array

Conductor Schedule							
Item	# Modules	Watts/Module	Tot W	VDC/Module	Tot VDC	Amps	Wire Size Type
Series Connection	6	300	1800	35.2	211.2	8.52	#12 AWG
Parallel Connection	36	300	10800	35.2	211.2	51.14	#4 AWG
To Building Grid (A/C)	180	300	44300	35.2	480	53.28	#4 AWG

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### Alternating Current

$$\text{Tot AC Pwr} = 44,300 \text{ Watts}$$

$$A = \frac{W}{V\sqrt{3}}$$

$$A = \frac{44,300 \text{ W}}{480\sqrt{3}}$$

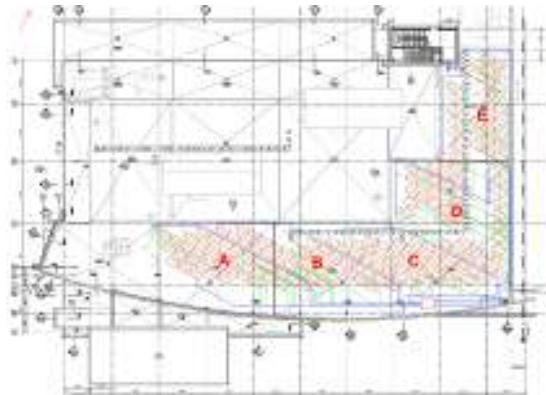
$$A = 53.28 \text{ Amps}$$

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Total Photovoltaic System Estimate	
Item	Total Cost
300W Module	\$83,430.00
10A Circuit Breaker	\$14,670.00
13.6 kW Inverter	\$24,065.00
30A Disconnect	\$1,095.00
100A Disconnect	\$475.00
Paralleling Switchboard	\$2,075.00
Racking System	\$33,390.00
1/2" EMT Conduit	\$13,054.00
1" EMT Conduit	\$10,664.88
#12 Wire	\$2,722.08
#4 Wire	\$6,878.85
#8 Wire	\$170.17
<b>Sub Total</b>	<b>\$192,689.98</b>
Overhead & Profit (10%)	\$19,269.00
Tax (Exempt)	\$0.00
<b>Grand Total Cost</b>	<b>\$211,958.98</b>
Cost/Watt (AC)	\$4.78

## Analysis 2 - Photovoltaic Array



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Copper Conductor Estimate											
Item	Wire Size	No. Wires	LF	QTY	UOM	Material Cost	Labor Cost	Unit Cost	Total Cost	Daily Output	No. Days
Series Branch	#12	3	2140	64.2	CLF	\$9.40	\$53.00	\$42.40	\$2,722.08	13.00	5
Parallel Feeder	#4	3	1014	30.42	CLF	\$101.00	\$80.50	\$181.50	\$5,521.23	10.60	3
A/C Feeder	#4	4	187	7.48	CLF	\$101.00	\$80.50	\$181.50	\$1,357.62	10.60	1
A/C Ground	#8	1	187	1.87	CLF	\$37.50	\$53.50	\$91.00	\$170.17	8.00	1
									<b>Total Wire \$9,771.10</b>	<b>Total Days 10</b>	

EMT Conduit Estimate											
Item	Conduit Size	QTY	UOM	Material Cost	Labor Cost	Unit Cost	Total Cost	Daily Output	No. Days	Crew Size	
Series Branch	1/2"	2140	LF	\$1.83	\$4.27	\$6.10	\$13,054.00	100.00	5	4 Elec	
Parallel Feeder	1"	1014	LF	\$3.53	\$5.35	\$8.88	\$9,004.32	80.00	3	4 Elec	
A/C Feeder	1"	187	LF	\$3.53	\$5.35	\$8.88	\$1,660.56	80.00	1	2 Elec	
									<b>Total Conduit \$23,718.88</b>	<b>Total Days 10</b>	

PV Components Estimate											
Item	Qty	UOM	Material Cost	Labor Cost	Equipment Cost	Total Unit Cost	Total Cost	Daily Output	No. Days	Crew Size	
300W Module	180	EA	\$410.00	\$53.50	\$0.00	\$463.50	\$83,430.00	8.00	6	4 Elec	
10A Circuit Breaker	30	EA	\$356.00	\$133.00	\$0.00	\$489.00	\$14,670.00	3.20	3	3 Elec	
13.6 kW Inverter	5	EA	\$4,600.00	\$233.00	\$0.00	\$4,833.00	\$24,065.00	3.20	1	1 Elec	
30A Disconnect	5	EA	\$86.00	\$133.00	\$0.00	\$219.00	\$1,095.00	3.20	1	2 Elec	
100A Disconnect	1	EA	\$250.00	\$225.00	\$0.00	\$475.00	\$475.00	1.90	1	1 Elec	
Paralleling Switchboard	1	EA	\$1,300.00	\$775.00	\$0.00	\$2,075.00	\$2,075.00	1.10	1	1 Elec	
Racking System	180	EA	\$48.50	\$137.00	\$0.00	\$185.50	\$33,390.00	5.13	5	7 Elec	
									<b>Total Components \$159,200.00</b>	<b>Total Days 17</b>	

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### Analysis 2 - Photovoltaic Array

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PV Watts AC Energy & Cost Savings					
Station Identification		Month	Solar Radiation (kWh/m <sup>2</sup> /day)	AC Energy (kWh)	Energy Value (\$)
City:	Philadelphia	1	3.30	4669.00	\$466.90
State:	Pennsylvania	2	4.16	5306.00	\$530.60
Latitude:	39.88 Degrees N	3	4.74	6395.00	\$639.50
Longitude:	75.25 Degrees W	4	5.06	6411.00	\$641.10
Elevation:	9m	5	5.20	6565.00	\$656.50
PV System Specifications		6	5.43	6439.00	\$643.90
DC Rating:	54.0 kW	7	5.51	6663.00	\$666.30
DC to AC Derate Factor:	0.82	8	5.67	6904.00	\$690.40
AC Rating:	44.3 kW	9	5.07	6115.00	\$611.50
Array Type:	Fixed Tilt	10	4.59	5976.00	\$597.60
Array Tilt:	39.9 Degrees	11	3.37	4308.00	\$430.80
Array Azimuth:	180 Degrees	12	2.67	3495.00	\$349.50
Energy Specifications		Year	4.57	69496.00	\$6,949.60
Cost of Electricity:	\$0.10/kWh				



SREC Credit Value Calculations					
kWh Produced/Year	Mwh Produced/Year	No. SREC	Income/SREC	Annual SREC Income	SREC Income/kWh
69496	69.496	69	\$40.01	\$2,760.69	\$0.04

**Cost Payback After: 19.52 Years**

**Cumulative Income After 25 Years: \$94,467.20**

Economic Analysis for Photovoltaic System																												
	After 25 Years	No. of Years																										
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25		
<b>Total Upfront Costs:</b>	\$211,958.00	\$211,958.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	
Cost of Photovoltaic System	\$47,567.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
Maintenance	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
<b>Total Tax-Exempt Cost</b>	\$211,958.00	\$211,958.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
<b>Total Cost Savings:</b>	\$313,684.20	\$6,646.60	\$13,293.20	\$19,939.80	\$26,586.40	\$33,233.00	\$39,879.60	\$46,526.20	\$53,172.80	\$59,819.40	\$66,466.00	\$73,112.60	\$79,759.20	\$86,405.80	\$93,052.40	\$99,699.00	\$106,345.60	\$112,992.20	\$119,638.80	\$126,285.40	\$132,932.00	\$139,578.60	\$146,225.20	\$152,871.80	\$159,518.40	\$166,165.00	\$172,811.60	\$179,458.20
Solar Power Production	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96
SREC Credit Value (\$0.04/kWh)	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96	\$22,308.96
<b>Total Tax-Exempt Income</b>	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16	\$333,993.16
<b>Annual Cash Flow</b>	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20	\$102,025.20
<b>Cumulative Cash Flow</b>	\$94,467.20	\$202,229.54	\$309,991.88	\$417,754.22	\$525,516.56	\$633,278.90	\$741,041.24	\$848,803.58	\$956,565.92	\$1,064,328.26	\$1,172,090.60	\$1,279,852.94	\$1,387,615.28	\$1,495,377.62	\$1,603,140.00	\$1,710,902.34	\$1,818,664.68	\$1,926,427.02	\$2,034,189.36	\$2,141,951.70	\$2,249,714.04	\$2,357,476.38	\$2,465,238.72	\$2,573,001.06	\$2,680,763.40	\$2,788,525.74	\$2,896,288.08	\$2,994,050.42

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**Analysis 3 - Operable Solar Shading**

**Aria Health | Torresdale Campus | ED Expansion**

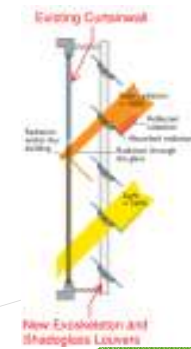
Analysis Goals

**Primary:**  
 To show how sustainable construction techniques can be used for the purpose of annual *energy savings*.

Description

- Design and Prefabrication
  - Mestek's Linel Fabrication
- Automation
  - Preprogrammed Weather Data
- Contractual Agreements
  - Lump Sum Quote
- Procurement and Logistics
  - 16-20 Week Lead

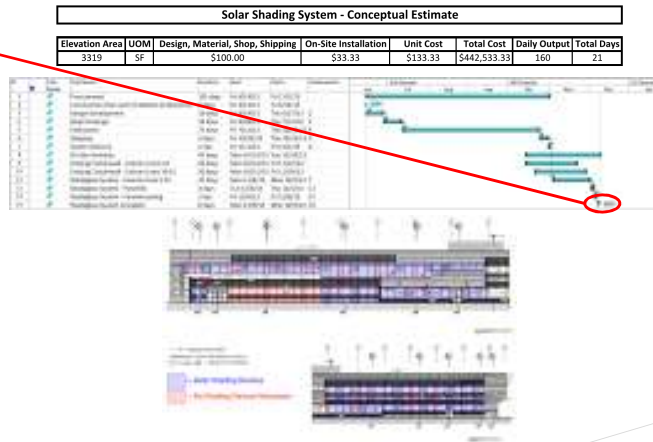
Description



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### Analysis 3 - Operable Solar Shading

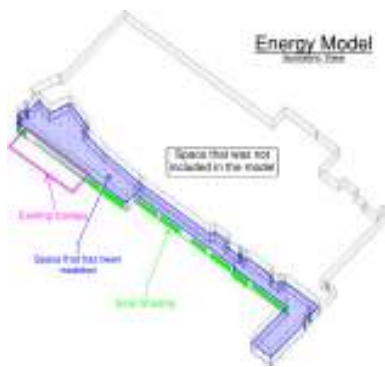


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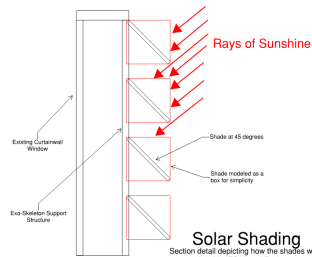


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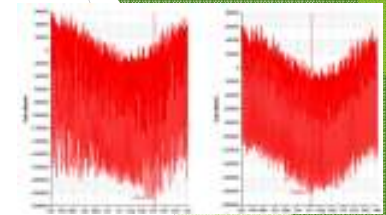
## Analysis 3 - Operable Solar Shading



Simulation Results

Simulation Results	
Energy Savings (BTU/h)	45220.70
Equivalent Load (kWh/yr)	2700.00
Energy Savings/Yr (BTU)	124795890.00
Energy Savings/Yr (Tons)	10399.66

## Aria Health | Torresdale Campus | ED Expansion



Energy Savings due to Solar Shading					
Baseline (BTU/h)	w/ Solar Shading (BTU/h)	Energy Savings (BTU/h)	Equivalent Load (kWh/yr)	Energy Savings/Yr (BTU)	Energy Savings/Yr (Tons)
231471.80	185251.10	46220.70	2700.00	124795890.00	10399.66

Cost Savings due to Solar Shading				
Energy Savings/Yr (Tons)	kWh/Ton	Electricity Savings (kWh/Yr)	Cost of Electricity (\$)	Cost Savings/Year
10399.66	0.90	9359.69	\$0.10	\$935.97

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Supply Air Calculations - Baseline

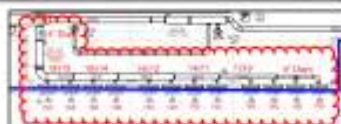
BTU/h	Delta T	Constant Value	CFM	Area of Space (SF)	CFM/SF
231471.80	20.00	11573.59	10716.29	7200.00	1.49

Supply Air Calculations - Proposed

BTU/h	Delta T	Constant Value	CFM	Area of Space (SF)	CFM/SF
185251.10	20.00	9262.56	8576.44	7200.00	1.19

$$\dot{q} = 1.08 \times CFM \times (\Delta T)$$

## Analysis 3 - Operable Solar Shading



## Aria Health | Torresdale Campus | ED Expansion

Baseline Ductwork			Proposed Ductwork		
Air Volume (CFM)	Velocity (FPM)	Duct Size (Inches)	Air Volume (CFM)	Velocity (FPM)	Duct Size (Inches)
400	750	10	320	750	9
800	925	12x12	640	925	12x9
1200	1000	14x14	960	1000	14x11
1600	1200	16x14	1280	1200	14x12
2000	1100	18x16	1600	1100	16x14
2400	1175	20x16	1920	1175	18x15
2400	1750	16	1920	1750	14



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**Thesis Recap and Recommendations**

**Aria Health | Torresdale Campus | ED Expansion**

**Analysis 1 - Rainwater Collection**



**Initial Cost:** \$146,680.40  
**Payback:** 12.18 Years  
**Cumulative Income:** \$281,105.50

**Recommended**

**Analysis 2 - Photovoltaic Array**



**Initial Cost:** \$211,958.98  
**Payback:** 19.52 Years  
**Cumulative Income:** \$94.467.20

**NOT Recommended**

**Analysis 3 - Operable Solar Shading**



**Initial Cost:** \$442,533.33  
**Energy Savings:** 20% Reduction in cooling load  
**Cost Savings:** \$935.97 savings per year

**NOT Recommended**

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**Bob Stano | Construction**

**Adviser:**  
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 D.Sc., Dr.h.c., P.E.

*The Pennsylvania State University*  
 Architectural Engineering  
 Faculty and Staff

**Project Team:**  
 Patrick F. Kershner, Project Manager  
 Michael Zarzycki, Superintendent  
 Tolulope A. Adenubi, Project Engineer

**Acknowledgements**



**Aria Health | Torresdale Campus | ED Expansion**

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 Francis O'Neill  
 Ted Border  
 Nicholas M. Rekstad  
 Kevin A. Martyn  
 Friends and Family

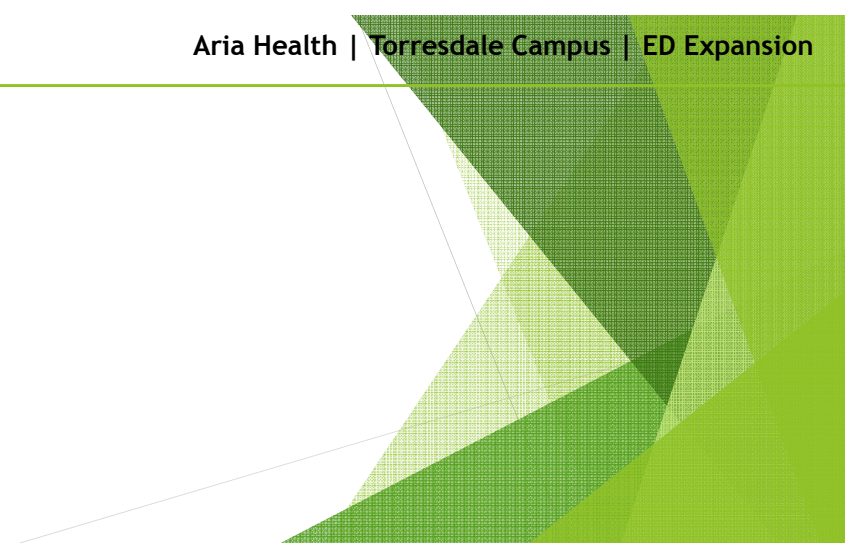
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Thank You

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Questions?



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### Pump Sizing – Fixture Units

- 10 fixture units per water closet
- 5 fixture units per urinal

$$\begin{aligned}
 &(34 \text{ Water Closets})(10 \text{ Fixture Units}) \\
 &+ (3 \text{ Urinals})(5 \text{ Fixture Units}) \\
 &= 355 \text{ Fixture Units}
 \end{aligned}$$

**Cross referenced with the hunter curve to find 85 GPM**

**Pipe Wheel used for pipe sizing**

## Appendix - Rainwater Collection

### Hydro Pneumatic Tank Sizing

Worked backwards....

Assume 850 Gal, or 2/3 capacity is available before booster pump kicks on.

$$\frac{93,792.09 \frac{\text{gal}}{\text{mo}}}{\frac{30 \text{ days}}{850 \text{ gal}}} = 4 \text{ times/day}$$

for

$$\frac{850 \text{ gal}}{85 \text{ GPM}} = 10 \text{ mins}$$

## Aria Health | Torresdale Campus | ED Expansion

### Rainwater Economic Analysis

- Maintenance: 16 hours/day at union plumber wage of \$59.68/hour
- General Inflation = 3% per year
- Utility Inflation = 5% per year

Category	Value
Monthly Maintenance Charge	1,355.04
Monthly Utility Charge	1,355.04
Monthly Total Charge	2,710.08
Annual Total Charge	32,520.96
Annual Total Charge (with inflation)	33,496.98

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  - Energy Model
    - Mechanical Breadth
- Thesis Recap
- Acknowledgements

## Bob Stano | Construction

### Photovoltaic Economic Analysis

- Maintenance: 16 hours/day at union electrician wage of \$110.64/hour
- General Inflation = 3% per year
- Utility Inflation = 5% per year

Item	Price in 2012	Price in 2013	Price in 2014	Price in 2015
1000 kWh	0.11	0.113	0.116	0.119
1000 kWh	0.11	0.113	0.116	0.119
1000 kWh	0.11	0.113	0.116	0.119

## Appendix - Photovoltaic Array

### Solar Renewable Energy Credits

$$No. SRECs = \frac{kWh \text{ Produced per year}}{1000} \times \frac{1 SREC}{1 Mwh}$$

$$Annual SREC Income = No. SRECs \times \frac{Income}{SREC}$$

It is assumed that SREC's will DEFLATE by 5% per year for ten years, after which SREC's will no longer exist.

## Aria Health | Torresdale Campus | ED Expansion

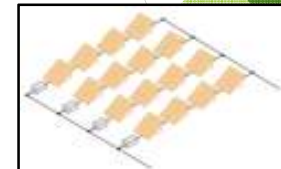
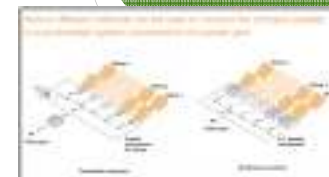


ABB: Protecting and Isolating PV Systems

- Project Summary
- Analysis 1: Rainwater Collection
  - Analysis Goals
  - Data Collection
  - Description & Design
  - Cost Estimation
  - Economic Analysis
- Analysis 2: Photovoltaic Array
  - Analysis Goals
  - Data Collection
  - Description & Design
    - Electrical Breadth
    - System Layout & Cost Estimation
    - Economic Analysis
- Analysis 3: Operable Solar Shading
  - Analysis Goals
  - Colt Shadoglass
  - Cost Estimation
  - Sequencing, Schedule, Logistics
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Cost Savings due to Solar Shading				
Energy Savings/Yr (Tons)	kWh/Ton	Electricity Savings (kWh/Yr)	Cost of Electricity (\$)	Cost Savings/Year
10399.66	0.90	9359.69	\$0.10	\$935.97

References and Assumptions:
kWh/Ton value is assumed to be the amount of electricity required to produce 1 ton of cooling
Cost of Electricity value based on PECO data from February 2013

**Industry Standard Value**

$$\frac{\text{Energy Savings}}{\text{year}} \text{ (in tons)} = \frac{\text{Energy Savings} \left( \text{in } \frac{\text{BTU}}{\text{h}} \right) \times (\text{Equivalent Load Hrs per year})}{12,000 \text{ BTUs per Ton}}$$

$$\text{Electricity Savings} \left( \text{in } \frac{\text{kWh}}{\text{year}} \right) = \frac{(\text{Energy Savings})}{\text{year}} \text{ (in tons)} \times \left( \frac{\text{kWh}}{\text{ton}} \right)$$

