

# *Milwaukee Public Museum*

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800 West Wells Street, Milwaukee, Wisconsin

## **Photovoltaic Feasibility Study**



Architecture | Engineering | Planning

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HGA Commission Number  
1215-011-00

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**Final Report**

**June 14, 2012**

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## SUMMARY

This study was commissioned by the MPM, Inc. to determine the feasibility and evaluate the benefits and implications of replacing the existing marble on the south façade of the Museum with a photovoltaic array. The study includes an analysis of the PV system installation and cost estimates for construction. A cost benefit analysis is not included in the scope of this study. This pre-design study will potentially allow Milwaukee County and MPM, Inc. to move forward with design and construction bidding documents if funding is available.



Milwaukee Public Museum viewed from the south.

The Milwaukee Public Museum is located on the north side of Wells Street between James Lovell Street and 9<sup>th</sup> Street. The building is clad predominantly in limestone panels with the exception of the eight-story center tower, where the north and south ends are clad in marble. The existing white marble façade presents the Museum to the community. Over the years, the existing marble has deteriorated to the point that replacement is required. Hammel, Green and Abrahamson, Inc. has been commissioned by Milwaukee County to design a replacement façade for the marble. The Architect analyzed and presented several options for a new façade to replace the marble. MPM, Inc. requested this photovoltaic feasibility study to determine whether installing a photovoltaic array on the south wall is a practical solution. The Architect has been directed by the responsible

representatives of Milwaukee County and the MPM, Inc. to proceed with design development work on the north wall pending a decision on the south wall.

### **Existing Conditions**

The Museum is constructed with a poured-in-place concrete frame. Concrete masonry walls infill the space between the concrete columns and beams. The masonry walls are flush with the concrete frame and provide a backup wall for the 4-inch marble veneer that also conceals the concrete frame. The original wall construction does not include insulation or specific provisions for control of moisture or water vapor. This type of exterior wall construction was not uncommon for the time the building was constructed.

### **Proposed Façade Replacement**

The proposed marble veneer replacement system will use state-of-the-art rain screen principles to greatly improve the thermal and moisture performance of the wall. After removal of the marble veneer, the conditions of the concrete masonry walls and relief angles which remain will be verified. Any required repairs will be made. The proposed replacement wall system will consist of an insulated metal panel back-up wall system installed on the exterior face of the exposed concrete masonry wall. The metal panel will provide thermal, moisture and vapor protection and support the frame for the new façade. The new veneer will be supported on an independent frame braced by the metal panel back-up wall system.

### **Photovoltaic System**

The marble on the south face of the Museum could be replaced with photovoltaic panels in lieu of another veneer selection. In a photovoltaic panel system the metal panel backup wall system would remain the same as the proposed veneer back-up system providing thermal, moisture and vapor protection and support for the frame that would carry the solar panels.

The south façade of the Museum is approximately 80 feet wide by 95 feet high. The south façade is set back from the street a sufficient distance that it remains exposed to the sun throughout the year.

The basis of the photovoltaic design for this study is the Helios 9T6 400 watt panel constructed by a Milwaukee photovoltaic panel manufacturer, Helios Solar Works. The Helios panel is 51 ½" wide by 77 ¾" tall.

The PV panel array would consist of 234 PV panels arranged uniformly in 13 vertical rows with 18 panels in each row. The framing system proposed to support the all-glass façade in the marble replacement project could be modified slightly to support the framing system for the PV panels.

The balance of system would be as follows:

- BOD: Utility Interactive, Power-One String Inverter (Aurora PVI-CENTRAL-100-480-US) 100kW Central String Inverter; one (1) PVI-VSN-AU-RG-PACK Universal Commercial energy

## Milwaukee Public Museum Photovoltaic Feasibility Study

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meter-display-data logger; three (3) Aurora Smart Combiners for Grounded Arrays – 12 string inputs with integrated DC disconnect; Factory Commissioning/Monitoring.

- DC Grounding Electrode System.
- 250A - 480Y/277V, 3P, 4W +G Feeder (4#250kcmil, plus 1#4 Gnd. in 2-1/2" EMT) from indoor inverter to existing suitable unit substation.
- 800A/3P Frame, (250A trip set) 600V Feeder Breaker suitable for existing unit substation.



Milwaukee Public Museum with PV Array installed.

The rendering above shows that the PV wall would present a new, aesthetically pleasing image to the public and respect the iconic character and mission of the Museum.

The ideal angle for a solar panel array in this latitude is 43 degrees. The wall of the Museum is 90 degrees, which reduces the average amount of energy that can be produced by a solar array approximately 25%. This comparison can be reviewed in Appendix 2. Even with this reduction, it is estimated that PV panels on the south wall could produce over \$7,000 in electrical energy every year at today's prices. The PV panels carry a 30 year warranty. Over that time frame, this represents a savings of \$210,000 or more if the price of energy goes up.

### Photovoltaic Cost Estimate

The budget analysis for this study assumes that the photovoltaic system will be installed on the south face of the Museum as part of, or in conjunction with, the current marble replacement project.

The installation cost for the system was developed using a combination of historical cost data, cost information provided by equipment manufacturers and installation costs from contractors and other sources. The following PV specific costs are included in the estimate.

• PV Panels (\$520 + \$30 SH each)	\$128,700
• BOD	\$75,000
• DC Grounding Electrode System	\$5,000
• 250A - 480Y/277V, 3P, 4W +G Feeder	\$20,000
• 800A/3P Frame, 600V Feeder Breaker	\$7,500
• Back-up frame, panel clips, labor and other miscellaneous costs	<u>\$149,760</u>
PV Specific Total Budget	\$385,960

### Project Estimate

The Project Budget Options Summary and Preliminary Construction Cost Estimates can be found in Appendix 3. The Budget Options Summary outlines on a single page the probable cost of options investigated for the Exterior Façade Restoration Project and the PV option. This information is derived from the more detailed cost estimate information found in the Preliminary Construction Cost Estimates. Each estimate shows an estimated cost for each side of the building.

Four façade design options were reviewed for the marble replacement and are outlined below.

1. Glass Façade Option – Install an all-glass façade on the North and South face of the Museum. The probable construction cost for this Option is \$1,190,798.
2. Glass Façade Option with Photovoltaic Panels – Install an all-glass façade on the North face and PV Panels on the South face of the Museum. The probable construction cost for this Option is \$1,315,852.
3. Phenolic Panel Option – Install a phenolic panel façade on the North and South face of the Museum. The probable construction cost for this Option is \$1,000,877.
4. Phenolic Panel Option with Photovoltaic Panels – Install a phenolic panel façade on the North face and PV Panels on the South face of the Museum. The probable construction cost for this Option is \$1,211,324.

The probable Construction Budget for the PV panel option with an all-glass façade on the North wall is \$1,315,852, 10% over the Project budget.

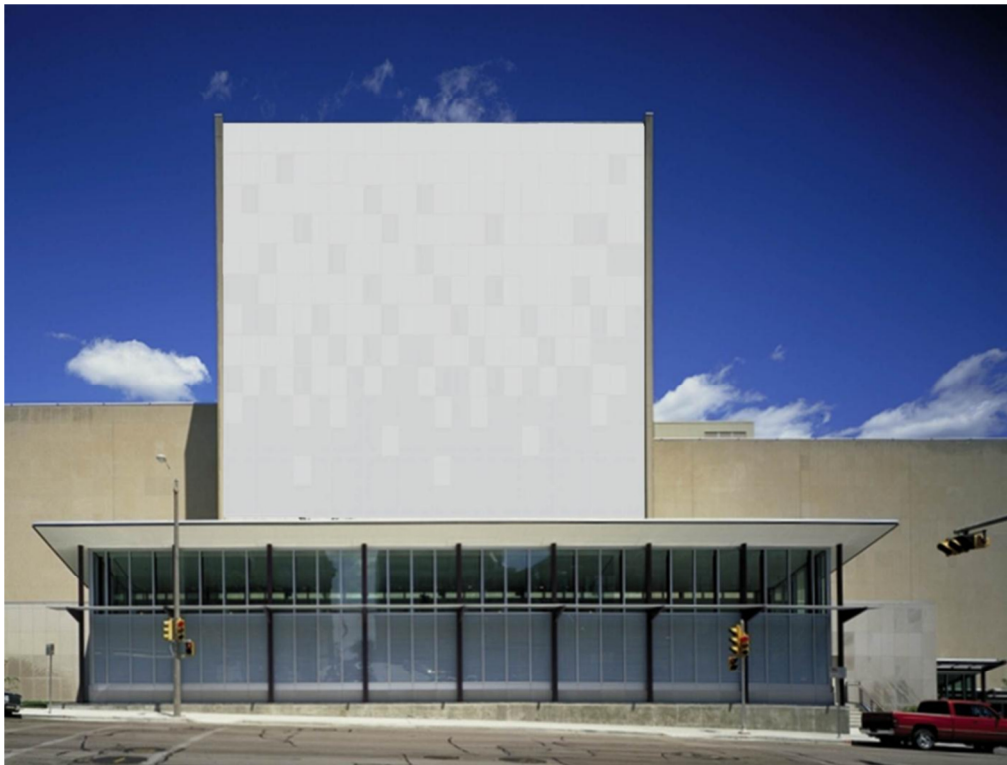
The probable Construction Budget for the PV panel option with a phenolic panel façade on the North wall is \$1,211,324, less than 1% over the Project budget.

### Conclusion

The photovoltaic array installed in a prominent location on the South wall of the Milwaukee Public Museum would present a positive image of the Museum to the public. The PV would allow the Museum to add educational programs on renewable energy that would dovetail with other education programs on sustainability, such as the recently installed green roof.

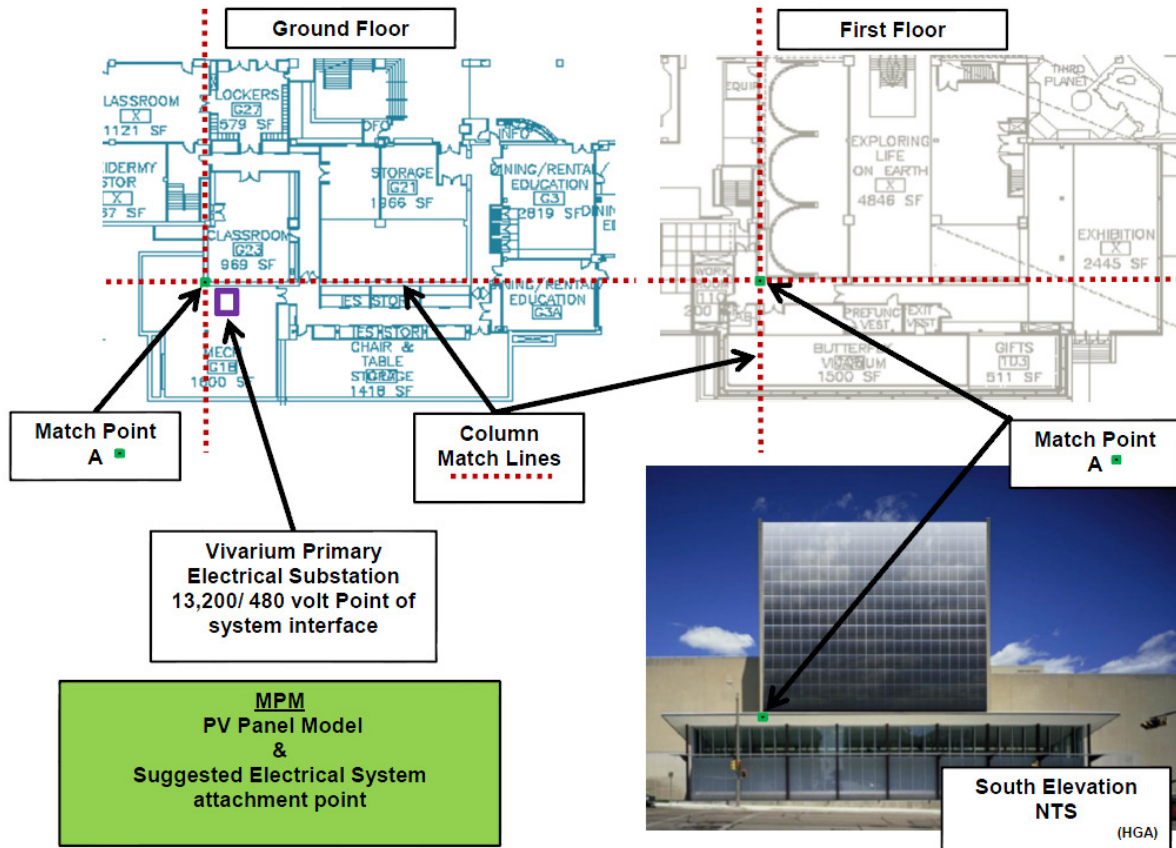
The PV installation in conjunction with the all-glass façade on the North face is the more expensive option and is over the Project budget. Changing the marble replacement on the north wall from all glass to a phenolic panel system creates a Project within one percent of the budget. A life cycle cost benefit analysis was not included in the scope of this study, but a significant electrical energy savings will be realized with a PV system.

A rendering of the north façade of the Milwaukee Public Museum was not in the scope of this study but a rendering of Phenolic Panels installed on the South façade was created in the Schematic Phase of the MPM Exterior Façade Restoration Project. The rendering is reproduced below. This is an attractive and durable solution. This design which looks similar to marble can be readily adapted to the North face.



## Appendix 1

### Schematic Plan of PV System



## Appendix 2

### AC Energy and Cost Savings Calculations

**Optimum Installation for Milwaukee  
 (Array installed at 43 degrees)  
 Provided for comparison purposes**

Station Identification	
City:	Milwaukee
State:	Wisconsin
Latitude:	42.95° N
Longitude:	87.90° W
Elevation:	211 m
PV System Specifications	
DC Rating:	93.6 kW
DC to AC Derate Factor:	0.770
AC Rating:	72.1 kW
Array Type:	Fixed Tilt
Array Tilt:	43.0°
Array Azimuth:	180.0°
Energy Specifications	
Cost of Electricity:	9.1 ¢/kWh

Results			
Month	Solar Radiation (kWh/m <sup>2</sup> /day)	AC Energy (kWh)	Energy Value (\$)
1	3.32	8035	731.19
2	3.96	8399	764.31
3	4.28	9697	882.43
4	5.11	10747	977.98
5	5.58	11819	1075.53
6	5.88	11603	1055.87
7	5.66	11320	1030.12
8	5.60	11336	1031.58
9	5.19	10431	949.22
10	4.34	9286	845.03
11	2.96	6376	580.22
12	2.49	5836	531.08
Year	4.53	114883	10454.35



## Appendix 2

### AC Energy and Cost Savings Calculations

#### Milwaukee Public Museum Installation on Vertical Wall

Station Identification	
City:	Milwaukee
State:	Wisconsin
Latitude:	42.95° N
Longitude:	87.90° W
Elevation:	211 m
PV System Specifications	
DC Rating:	93.6 kW
DC to AC Derate Factor:	0.770
AC Rating:	72.1 kW
Array Type:	Fixed Tilt
Array Tilt:	90.0°
Array Azimuth:	180.0°
Energy Specifications	
Cost of Electricity:	9.1 ¢/kWh

Results			
Month	Solar Radiation (kWh/m <sup>2</sup> /day)	AC Energy (kWh)	Energy Value (\$)
1	3.44	8308	756.03
2	3.70	7813	710.98
3	3.43	7631	694.42
4	3.12	6140	558.74
5	2.89	5408	492.13
6	2.78	4689	426.70
7	2.80	4844	440.80
8	3.21	5978	544.00
9	3.65	7131	648.92
10	3.67	7755	705.71
11	2.75	5869	534.08
12	2.56	5966	542.91
Year	3.16	77533	7055.50

### Appendix 3 – Preliminary Construction Cost Estimates

#### Project Budget Options Summary

##### Project Budget

Total Budget	\$1,400,000	
AE and County Fees	\$200,000	
Construction Budget	<u>\$1,200,000</u>	<u>\$1,200,000</u>

##### Glass Façade Option

	Glass Façade	Photovoltaic Option
North Wall	\$484,967	\$484,967
South Wall	\$597,577	\$711,262
Subtotal	<u>\$1,082,544</u>	<u>\$1,196,229</u>
Construction Contingency 10%	\$108,254	\$119,623
Construction Budget	<u>\$1,190,798</u>	<u>\$1,315,852</u>
Percent of Construction Budget	99.23%	109.65%

##### Phenolic Panel Façade Option

	Phenolic Panel Façade	Photovoltaic Option
North Wall	\$379,853	\$379,853
South Wall	\$530,035	\$721,351
Subtotal	<u>\$909,888</u>	<u>\$1,101,204</u>
Construction Contingency 10%	\$90,989	\$110,120
Construction Budget	<u>\$1,000,877</u>	<u>\$1,211,324</u>
Percent of Construction Budget	83.41%	100.94%

##### Potential Alternates

###### Add Parapet Guardrails

Parapet Guardrails	\$17,388
Construction Contingency 10%	\$1,739
Total Add for Parapet Guardrails	<u>\$19,127</u>

###### Add North Window Replacement

North Window Replacement	\$130,390
Construction Contingency 10%	\$13,039
Total Add for Window Replacement	<u>\$143,429</u>

## Appendix 3 – Preliminary Construction Cost Estimates

### North Wall – Glass Facade Option

#### MPM Building Re-Cladding



#### *Preliminary Construction Cost Estimate*

Rev Date : 6-11-12

<b>North Wall - Glass Façade</b>		5860 sqft	(wo/windows)	
Item		Quantity	Unit Price	Total\$
Remove existing stone		5,860 sqft	\$7.77	\$45,532
Reinstall salvaged stone & back-up		220 sqft	\$42.35	\$9,318
Aluminum flashing on base soffit & parapet		160 Inft	\$35.00	\$5,600
Window flashing @ new or existing windows		448 Inft	\$20.00	\$8,960
Moisture barrier & insulated back-up panel	<i>material</i>	5,860 sqft	\$12.00	\$70,320
Install moisture barrier & insulated back-up panel	<i>material</i>	5,640 sqft	\$3.00	\$16,920
1/2" laminated tempered glass cladding w/ film	<i>material</i>	5,640 sqft	\$18.00	\$101,520
Stainless steel glass support framing system	<i>material</i>	2,080 Inft	\$10.75	\$22,360
Stainless steel glass fasteners	<i>material</i>	1,368 each	\$28.00	\$38,304
Install glass cladding system & support framing system	<i>labor &amp; equipment</i>	5,640 sqft	\$14.68	\$82,795
<b>Mobilization/General Conditions</b>		<b>15%</b>		<b>\$60,244.34</b>
<b>Estimating Contingency Factor</b>		<b>5%</b>		<b>\$23,093.66</b>
<b>Total Construction Cost (North Wall)</b>				<b>\$484,967</b>
<b>Cost per Square foot</b>				<b>\$82.76</b>
<b>Potential Add Alternate - Replace Windows</b>		1,534 sqft	\$85.00	\$130,390
<b>Total Construction Cost w/ windows (North Wall)</b>				<b>\$615,357</b>
				<b>\$83.22</b>
<b>Guardrail Alternate</b>				
Item		Quantity	Unit Price	Total\$
New cable guardrail & support @ parapet		160 Inft	\$90.00	\$14,400
<b>General Conditions</b>		<b>15%</b>		<b>\$2,160.00</b>
<b>Estimating Contingency Factor</b>		<b>5%</b>		<b>\$828.00</b>
<b>Total Guardrail Alternate Cost</b>				<b>\$17,388.00</b>

## Appendix 3 – Preliminary Construction Cost Estimates

### South Wall – Glass Facade Option

#### MPM Building Re-Cladding



#### *Preliminary Construction Cost Estimate*

Rev Date : 6-11-12

<b>South Wall - Glass Façade</b>		<b>7600 sqft</b>	
<b>Item</b>	<b>Quantity</b>	<b>Unit Price</b>	<b>Total\$</b>
Remove existing stone	7,600 sqft	\$7.77	\$59,052
Remove & salvage bronze artwork	1 lsum	\$3,500.00	\$3,500
Reinstall salvaged bronze artwork	1 lsum	\$4,000.00	\$4,000
Aluminum flashing on base soffit & parapet	160 lft	\$35.00	\$5,600
Base flashing & roof repair/replace	160 lft	\$60.00	\$9,600
Moisture barrier & insulated back-up panel	<i>material</i> 7,600 sqft	\$12.00	\$91,200
Install moisture barrier & insulated back-up panel	<i>material</i> 7,600 sqft	\$3.00	\$22,800
1/2" laminated tempered glass cladding w/ film	<i>material</i> 7,600 sqft	\$18.00	\$136,800
Stainless steel glass support framing system	<i>material</i> 2,560 lft	\$10.75	\$27,520
Stainless steel glass fasteners	<i>material</i> 1,536 each	\$28.00	\$43,008
Install glass cladding system & support framing system	<i>labor &amp; equipment</i> 7,600 sqft	\$12.08	\$91,808
<b>Mobilization/General Conditions</b>	<b>15%</b>		<b>\$74,233.20</b>
<b>Estimating Contingency Factor</b>	<b>5%</b>		<b>\$28,456.06</b>
<b>Total Construction Cost</b>			<b>\$597,577</b>
<b>Cost per Square foot</b>			<b>\$78.63</b>

## Appendix 3 – Preliminary Construction Cost Estimates

### South Wall – Photovoltaic Panel Option (Use with North Glass Façade)

#### MPM Building Re-Cladding

##### *Preliminary Construction Cost Estimate*



Rev Date : 6-11-12

South Wall - Photovoltaic Panels Option		7600 sqft		
Item		Quantity	Unit Price	Total\$
Remove existing stone		7,600 sqft	\$7.77	\$59,052
Remove & salvage bronze artwork		1 lsum	\$3,500.00	\$3,500
Reinstall salvaged bronze artwork		1 lsum	\$4,000.00	\$4,000
Aluminum flashing on base soffit & parapet		160 lft	\$35.00	\$5,600
Base flashing & roof repair/replace		160 lft	\$60.00	\$9,600
Moisture barrier & insulated back-up panel	<i>material</i>	7,600 sqft	\$12.00	\$91,200
Install moisture barrier & insulated back-up panel	<i>material</i>	7,600 sqft	\$3.00	\$22,800
Metal panel cladding	<i>material</i>	560 sqft	\$8.00	\$4,480
Install metal cladding system & back-up walls	<i>labor &amp; equipment</i>	560 sqft	\$5.08	\$2,845
<b>Subtotal</b>				<b>\$203,077</b>
<b>PV Panels - South Side</b>				
PV Panels	<i>material</i>	234 ea	\$550.00	\$128,700
Panel backup frame and installation	<i>material</i>	4,720 lft	\$8.00	\$37,760
Panel Clips	<i>material</i>	1,440 ea	\$12.00	\$17,280
Panel Installation	<i>labor &amp; equipment</i>	234 ea	\$211.41	\$49,470
Wire, Inverter and Misc Materials w/design & installation		234 ea	\$652.78	\$152,751
<b>Subtotal</b>				<b>\$385,960</b>
<b>Mobilization/General Conditions</b>		<b>15%</b>		<b>\$88,355.59</b>
<b>Estimating Contingency Factor</b>		<b>5%</b>		<b>\$33,869.64</b>
<b>Total Construction Cost</b>				<b>\$711,262</b>
<b>Cost per Square foot</b>				<b>\$93.59</b>

## Appendix 3 – Preliminary Construction Cost Estimates

### North Wall – Phenolic Panel Option

#### MPM Building Re-Cladding



#### *Preliminary Construction Cost Estimate*

<b>North Wall - Phenolic Panels</b>		5860 sqft	(wo/windows)	
Item		Quantity	Unit Price	Total\$
Remove existing stone		5,860 sqft	\$7.77	\$45,532
Reinstall salvaged stone & back-up		220 sqft	\$42.35	\$9,318
Aluminum flashing on base soffit & parapet		160 lft	\$35.00	\$5,600
Window flashing @ new or existing windows		448 lft	\$20.00	\$8,960
Moisture barrier & insulated back-up panel	<i>material</i>	5,860 sqft	\$12.00	\$70,320
Install moisture barrier & insulated back-up panel	<i>material</i>	5,640 sqft	\$3.00	\$16,920
Install phenolic panel cladding system w/suppost frame	<i>labor &amp; material</i>	5,640 sqft	\$28.00	\$157,920
<b>Mobilization/General Conditions</b>		<b>15%</b>		<b>\$47,185.46</b>
<b>Estimating Contingency Factor</b>		<b>5%</b>		<b>\$18,087.76</b>
<b>Total Construction Cost (North Wall)</b>				<b>\$379,843</b>
<b>Cost per Square foot</b>				<b>\$64.82</b>
<b>Potential Add Alternate - Replace Windows</b>		1,534 sqft	\$85.00	\$130,390
<b>Total Construction Cost w/ windows (North Wall)</b>				<b>\$510,233</b>
				<b>\$69.01</b>
<b>Guardrail Alternate</b>				
Item		Quantity	Unit Price	Total\$
New cable guardrail & support @ parapet		160 lft	\$90.00	\$14,400
<b>General Conditions</b>		<b>15%</b>		<b>\$2,160.00</b>
<b>Estimating Contingency Factor</b>		<b>5%</b>		<b>\$828.00</b>
<b>Total Guardrail Alternate Cost</b>				<b>\$17,388.00</b>

## Appendix 3 – Preliminary Construction Cost Estimates

### South Wall – Phenolic Panel Option

#### MPM Building Re-Cladding



#### *Preliminary Construction Cost Estimate*

<b>South Wall - Glass Façade</b>		7600 sqft		
Item		Quantity	Unit Price	Total\$
Remove existing stone		7,600 sqft	\$7.77	\$59,052
Remove & salvage bronze artwork		1 lsum	\$3,500.00	\$3,500
Reinstall salvaged bronze artwork		1 lsum	\$4,000.00	\$4,000
Aluminum flashing on base soffit & parapet		160 lnft	\$35.00	\$5,600
Base flashing & roof repair/replace		160 lnft	\$60.00	\$9,600
Moisture barrier & insulated back-up panel	<i>material</i>	7,600 sqft	\$12.00	\$91,200
Install moisture barrier & insulated back-up panel	<i>material</i>	7,600 sqft	\$3.00	\$22,800
Install phenolic panel cladding system w/suppost frame	<i>labor &amp; material</i>	7,600 sqft	\$32.00	\$243,200
<b>Mobilization/General Conditions</b>		<b>15%</b>		<b>\$65,842.80</b>
<b>Estimating Contingency Factor</b>		<b>5%</b>		<b>\$25,239.74</b>
<b>Total Construction Cost</b>				<b>\$530,035</b>
<b>Cost per Square foot</b>				<b>\$69.74</b>

### Appendix 3 – Preliminary Construction Cost Estimates

#### South Wall – Photovoltaic Panel Option (Use with North Phenolic Panel Façade)

##### MPM Building Re-Cladding



##### *Preliminary Construction Cost Estimate*

<b>South Wall - Photovoltaic Panels Option</b>		7600 sqft		
Item		Quantity	Unit Price	Total\$
Remove existing stone		7,600 sqft	\$7.77	\$59,052
Remove & salvage bronze artwork		1 lsum	\$3,500.00	\$3,500
Reinstall salvaged bronze artwork		1 lsum	\$4,000.00	\$4,000
Aluminum flashing on base soffit & parapet		160 lft	\$35.00	\$5,600
Base flashing & roof repair/replace		160 lft	\$60.00	\$9,600
Moisture barrier & insulated back-up panel	<i>material</i>	7,600 sqft	\$12.00	\$91,200
Install moisture barrier & insulated back-up panel	<i>material labor &amp;</i>	7,600 sqft	\$3.00	\$22,800
Install phenolic panel cladding system w/suppost frame	<i>material</i>	560 sqft	\$28.00	\$15,680
<b>Subtotal</b>				\$211,432
<b>PV Panels - South Side</b>				
PV Panels	<i>material</i>	234 ea	\$550.00	\$128,700
Panel backup frame and installation	<i>material</i>	4,720 lft	\$8.00	\$37,760
Panel Clips	<i>material labor &amp;</i>	1,440 ea	\$12.00	\$17,280
Panel Installation	<i>equipment</i>	234 ea	\$211.41	\$49,470
Wire, Inverter and Misc Materials w/design & installation		234 ea	\$652.78	\$152,751
<b>Subtotal</b>				\$385,960
<b>Mobilization/General Conditions</b>		<b>15%</b>		<b>\$89,608.87</b>
<b>Estimating Contingency Factor</b>		<b>5%</b>		<b>\$34,350.07</b>
<b>Total Construction Cost</b>				<b>\$721,351</b>
<b>Cost per Square foot</b>				<b>\$94.91</b>

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