Chemistry Building

Michael Gallagher | Construction Management
AE Faculty Consultant: Dr. Riley

The Pennsylvania State University AE Senior Thesis Project

Presentation Outline

- Project Background
- Analysis #1: Bringing BIM into the Field
  - Vico Software and Trimble
  - Vela Systems
  - Impacts of Implementing New Technology
- Analysis #2: Alternative Curtain Wall Systems
  - System Design
  - Architectural Impacts
  - Schedule/Cost Impacts
- Analysis #3: Feasibility of PV Curtain Wall
  - Electrical Breadth Design
  - Energy/Electrical Impacts
  - Feasibility Analysis
- Lesson Learned
- Acknowledgments

PROJECT BACKGROUND

Project Data

Occupant:	University
Size:	265,000 SF
Total Height:	4 floors
Function:	Research Labs and Offices
Construction Dates:	9/4/2007 to 11/2/2010

PROJECT BACKGROUND

Project Data

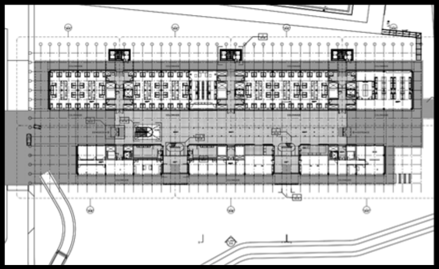
Occupant:	University
Size:	265,000 SF
Total Height:	4 Floors
Function:	Research Labs and Offices
Construction Dates:	9/4/2007 to 11/2/2010

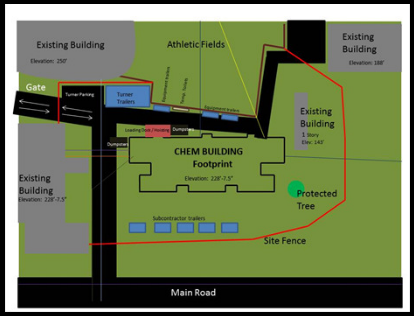
Project Team

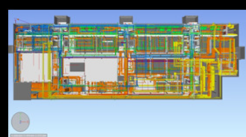
CM Agency:	Turner Construction
Design Architect:	Hopkins Architects
Executive Architect:	Payette Associates
Engineer:	ARUP

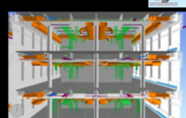
- **Project Background**
- Analysis #1: Bringing BIM Into the Field
- Analysis #2: Alternative Curtain Wall Systems
- Analysis #3 : Feasibility of PV Curtain Wall System
- Lessons Learned
- Acknowledgments & Questions

Building Design / Layout









Bringing BIM Into the Field

Problem Identification

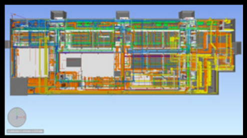
- BIM model only used for 3D MEP Coordination

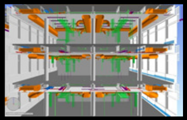
Research Goal

- Show the benefits of BIM and how it can be utilized more on a project

Michael Gallagher
AE Senior Thesis 2011

Construction Management
Advisor: Dr. Riley





Bringing BIM Into the Field

Problem Identification
- BIM model only used for 3D MEP Coordination

Research Goal
- Show the benefits of BIM and how it can be utilized more on a project

Potential Areas to Implement
- Steel, Concrete and MEP Layout
- Commissioning
- Punchlist
- Tracking Progress
- Tracking Materials
- Safety
- QA/QC
- Turnover / Maintenance / Warranty

New Technology

VELA SYSTEMS

VICO SOFTWARE Integrating Construction

Trimble

Bringing BIM Into the Field

Problem Identification

- BIM model only used for 3D MEP Coordination

Research Goal

- Show the benefits of BIM and how it can be utilized more on a project

Potential Areas to Implement

- Commissioning
- Punchlist
- Tracking Progress
- Tracking Materials
- Saftey
- QA/QC
- Turnover / Maintenance / Warranty
- Steel, Concrete, Wall, and MEP Layout

Vico Software and Trimble

- Vico and Trimble have a Partnership
- Allows you to export information from Vico Software and 3D model to Trimble Field Layout Solution
- Can use GPS, Laser, and a Total Station to layout steel, concrete, MEP, and walls all based on coordinates from the 3D Model

Vico Software and Trimble

- Vico and Trimble have a Partnership
- Allows you to export information from Vico Software and 3D model to Trimble Field Layout Solution
- Can use GPS, Laser, and a Total Station to layout steel, concrete, MEP, and walls all based on coordinates from the 3D Model

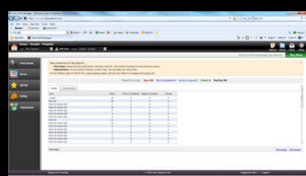
Benefits

- Reduces errors during construction
- Improves QA/QC
- Improved Coordination
- Insures MEP is placed in correct locations

Vela Systems

- Vela's goal is to help better manage construction projects
- Program that contains all the documents pertaining to project such as drawings, ASI's, RFI's, Specs, etc.
- Everyone has access and anyone can upload information to it

VELA SYSTEMS



Vela Systems

- Vela's goal is to help better manage construction projects
- Program that contains all the documents pertaining to project such as drawings, ASI's, RFI's, Specs, etc.
- Everyone has access and anyone can upload information to it

Benefits

- Helps track progress
- Two week look aheads
- Reduces time to complete punchlist, closeout, and commission
- Safety checks
- Improves QA/QC
- Improves Coordination

Impacts of Implementing New Technology

Vela Systems - Case Studies

- Skanska – New Meadowlands Stadium
- Turner Construction – 10 Rittenhouse Square Philadelphia, PA and Hampton Roads Naval Housing Norfolk, VA
- Barton Malow – Maryland General Hospital in Baltimore
- Cianbro – Destiny USA, Syracuse, New York

Michael Gallagher
AE Senior Thesis 2011
Construction Management
Advisor: Dr. Riley

Impacts of Implementing New Technology

Vela Systems - Case Studies

- Skanska – New Meadowlands Stadium
- Turner Construction – 10 Rittenhouse Square Philadelphia, PA and Hampton Roads Naval Housing Norfolk, VA
- Barton Malow – Maryland General Hospital in Baltimore
- Cianbro – Destiny USA, Syracuse, New York

Bob Wunderlich, Quality Control Manager for Turner Construction Company said “We pick up a day of time on schedule every week or so. You continue to pick up a day here and there and pretty soon it adds up.”

VELA SYSTEMS

Impacts of Implementing New Technology

Potential Benefits

- Cost Savings
- Schedule Reduction
- Improved Communication
- Everyone has the newest drawings / information

Vela Systems - Case Studies

- Skanska – New Meadowlands Stadium
- Turner Construction – 10 Rittenhouse Square Philadelphia, PA and Hampton Roads Naval Housing Norfolk, VA
- Barton Malow – Maryland General Hospital in Baltimore
- Cianbro – Destiny USA, Syracuse, New York

Bob Wunderlich, Quality Control Manager for Turner Construction Company said “We pick up a day of time on schedule every week or so. You continue to pick up a day here and there and pretty soon it adds up.”

Alternative Curtain Wall Systems

Problem Identification
- $40+ million dollar curtain wall system
- Size of the glass did not allow to be manufactured in the U.S.
- Egress stair tower glass breaking
- Scope was so large – almost no bidders

Research Goal
- Find another system that costs less and/or is able to incorporate PV into it

System Design

Scenario #1

- Maintain large glass size and implement PV glass where fritted glass is currently located on exterior façade

Scenario #2

- Reduce glass size and implement PV where fritted glass is currently located on exterior façade

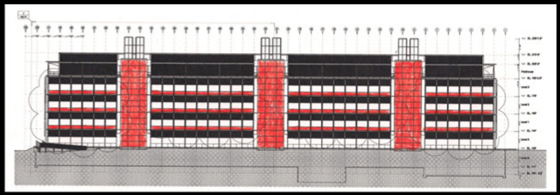
Scenario #3

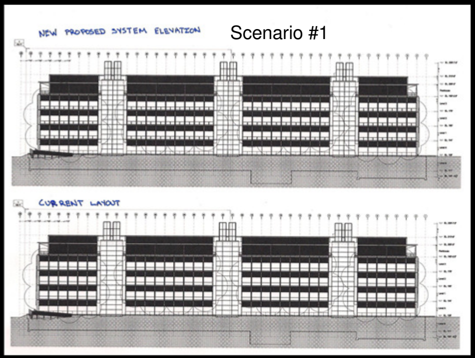
- Reduce glass size and maintain fritted glass where currently located – no PV

System Design

Schuco E² Façade – Scenario #1

- Maintain large glass size and implement PV glass where fritted glass is currently located on exterior façade



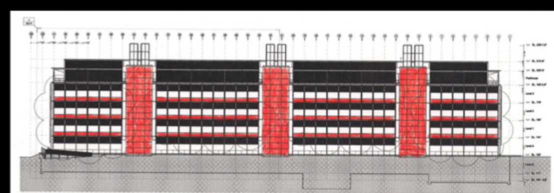


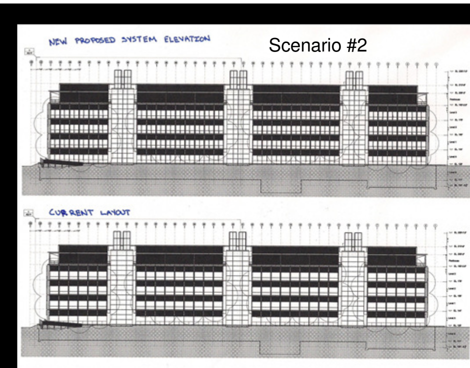
Michael Gallagher
AE Senior Thesis 2011
Construction Management
Advisor: Dr. Riley

System Design

Schuco E² Façade – Scenario #2

- Reduce glass size and implement PV glass where fritted glass is currently located on exterior façade



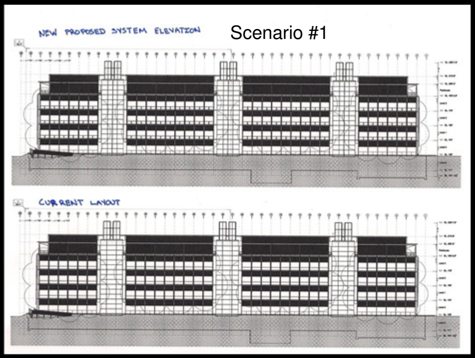


- Project Background
- Analysis #1: Bringing BIM Into the Field
- **Analysis #2: Alternative Curtain Wall Systems**
  - System Design
  - **Architectural Impacts**
  - Schedule/Cost Impacts
- Analysis #3 : Feasibility of PV Curtain Wall System
- Lessons Learned
- Acknowledgments & Questions

Architectural Impacts

Minimal Changes

- Largest PV glass size is 8' x 7'
- Sizes of glass being replaced
  - 5.5' x 5.5'
  - 3' x 10.5'
  - 5.5' x 10.5'
- Proposed New Sizes
  - 5.5' x 5.5'
  - 3' x 5.25'
  - 5.5' x 5.25'
- Non-Stair tower Glass – Interior Mullion is behind Aluminum Panel on the inside



Michael Gallagher
AE Senior Thesis 2011
Construction Management
Advisor: Dr. Riley

Schedule / Cost Impacts

- Current System for the purpose of this analysis is roughly $20 million dollars
- This price only includes the following
  - Price of the glass
  - Aluminum Extrusions
  - Steel Structure supports
  - Gaskets and Silicone
  - Hoisting
  - Installation

$\boxed{\text{Scenario \# 1}}$

cost of PV glass found in the analysis of feasibility of PV curtain wall system

$$(\$280/SF)(79{,}000\,SF) + (\$1{,}593{,}480)$$

$$\boxed{= \$23{,}713{,}480}$$

for LARGE same size glass as current system and PV glass replacing Exterior fritted glass

Schedule / Cost Impacts

- Current System for the purpose of this analysis is roughly $20 million dollars
- This price only includes the following
  - Price of the glass
  - Aluminum Extrusions
  - Steel Structure supports
  - Gaskets and Silicone
  - Hoisting
  - Installation

Scenario #1

cost of PV glass found in the analysis of feasability of PV curtain wall system

$(\$280/SF)(79{,}000\,SF) + (\$1{,}593{,}480)$

$\boxed{= \$23{,}713{,}480}$ for LARGE same size glass as current system and PV glass replacing Exterior fritted glass

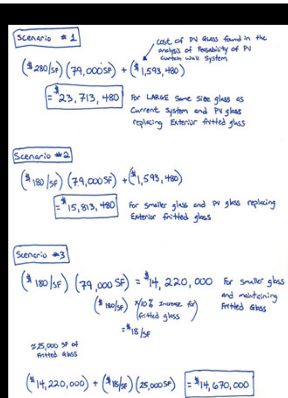
Scenario #2

$(\$180/SF)(79{,}000\,SF) + (\$1{,}593{,}480)$

$\boxed{= \$15{,}813{,}480}$ for smaller glass and PV glass replacing Exterior fritted glass

Schedule / Cost Impacts

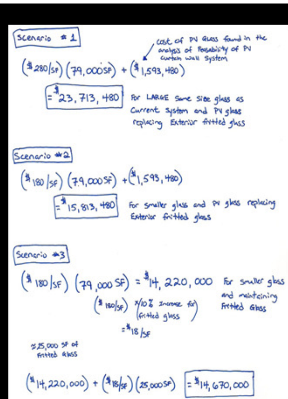
- Current System for the purpose of this analysis is roughly $20 million dollars
- This price only includes the following
  - Price of the glass
  - Aluminum Extrusions
  - Steel Structure supports
  - Gaskets and Silicone
  - Hoisting
  - Installation



Schedule / Cost Impacts

- Current System for the purpose of this analysis is roughly $20 million dollars
- This price only includes the following
  - Price of the glass
  - Aluminum Extrusions
  - Steel Structure supports
  - Gaskets and Silicone
  - Hoisting
  - Installation

- ❑ Project Background
- ❑ Analysis #1: Bringing BIM Into the Field
- ❑ **Analysis #2: Alternative Curtain Wall Systems**
  - ❑ System Design
  - ❑ Architectural Impacts
  - ❑ **Schedule/Cost Impacts**
- ❑ Analysis #3 : Feasibility of PV Curtain Wall System
- ❑ Lessons Learned
- ❑ Acknowledgments & Questions



Scenario #1

cost of PV glass found in the analysis of Feasibility of PV curtain wall system

(\$280/SF)(79,000SF) + (\$1,593,480)

$\boxed{= \$23,713,480}$ for LARGE same size glass as current system and PV glass replacing Exterior fritted glass

Scenario #2

(\$180/SF)(79,000SF) + (\$1,593,480)

$\boxed{= \$15,813,480}$ for smaller glass and PV glass replacing Exterior fritted glass

Scenario #3

(\$180/SF)(79,000 SF) = \$14,220,000 for smaller glass and maintaining fritted glass

(\$180/SF)(w/10% increase for fritted glass)

= \$18/SF

≈25,000 SF of fritted glass

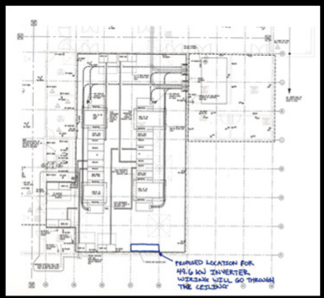
(\$14,220,000) + (\$18/SF)(25,000SF) $\boxed{= \$14,670,000}$

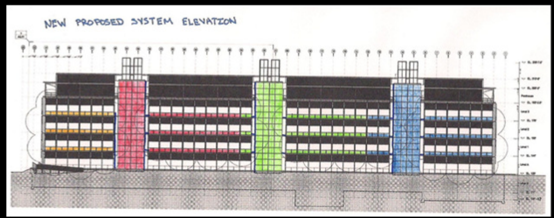
Schedule / Cost Impacts

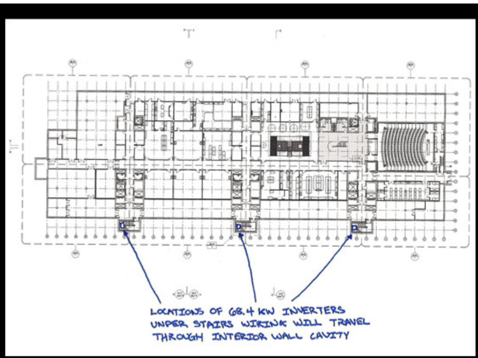
- Current System for the purpose of this analysis is roughly \$20 million dollars
- This price only includes the following
  - Price of the glass
  - Aluminum Extrusions
  - Steel Structure supports
  - Gaskets and Silicone
  - Hoisting
  - Installation

- Scenario #1 is approximately \$3,713,480 more expensive then the current system
- Scenario #1 is Proposed system because it has the least amount of Architectural Impacts
- Smaller glass size should be considered though
  - Reduce Current \$2.65 million dollar cost for packaging and shipping
  - Reduce lead time by about 2 weeks

Feasibility of PV Curtain Wall







Michael Gallagher
AE Senior Thesis 2011
Construction Management
Advisor: Dr. Riley

Feasibility of PV Curtain Wall

SOLAR GLASS

THE GLASS PRODUCES $140\ W/m^2$ of ENERGY

TOTAL SF = 18,970

$= 1,762.4\ m^2$

$(140\ W/m^2)(1,762.4\ m^2) = 246,736$ watts/day

$= 10,280.67$ watts/hr

$= 10.281$ kW/hr

1 year = 8760 hours

$= 90,061.56$ kW's a year

Requires
- (3) – 68.4 kW Inverters
- (1) – 49.6 kW Inverter
- 900’ of DC wire
- 345’ of AC wire

Feasibility of PV Curtain Wall

Year	Energy Cost per kwh	Energy Produced per Hour	Hours per Year	State Tax Credit Per Year	Total Savings Per Year	Total Savings To Date
1	0.1312	10.281	8,760.00	60,791.55	72,607.63	72,607.63
2	0.1325	10.281	8,760.00	60,791.55	72,725.79	145,333.42
3	0.1338	10.281	8,760.00	60,791.55	72,845.13	218,178.55
4	0.1352	10.281	8,760.00	60,791.55	72,965.67	291,144.22
5	0.1365	10.281	8,760.00	60,791.55	73,087.41	364,231.63
6	0.1379	10.281	8,760.00	60,791.55	73,210.37	437,442.00
7	0.1393	10.281	8,760.00	60,791.55	73,334.56	510,776.56
8	0.1407	10.281	8,760.00	60,791.55	73,459.99	584,236.54
9	0.1421	10.281	8,760.00	60,791.55	73,586.67	657,823.21
10	0.1435	10.281	8,760.00	60,791.55	73,714.62	731,537.84
11	0.1449	10.281	8,760.00	60,791.55	73,843.85	805,381.69
13	0.1464	10.281	8,760.00	60,791.55	73,974.38	879,356.06
13	0.1478	10.281	8,760.00	60,791.55	74,106.20	953,462.27
14	0.1493	10.281	8,760.00	60,791.55	74,239.35	1,027,701.62
15	0.1508	10.281	8,760.00	60,791.55	74,373.83	1,102,075.45
16	0.1523	10.281	8,760.00	60,791.55	74,509.65	1,176,585.10
17	0.1538	10.281	8,760.00	60,791.55	74,646.83	1,251,231.93
18	0.1554	10.281	8,760.00	60,791.55	74,785.38	1,326,017.32
19	0.1569	10.281	8,760.00	60,791.55	74,925.32	1,400,942.64
20	0.1585	10.281	8,760.00	60,791.55	75,066.66	1,476,009.30
21	0.1601	10.281	8,760.00	60,791.55	75,209.41	1,551,218.71
22	0.1617	10.281	8,760.00	60,791.55	75,353.59	1,626,572.30
23	0.1633	10.281	8,760.00	60,791.55	75,499.21	1,702,071.51
24	0.1649	10.281	8,760.00	60,791.55	75,646.29	1,777,717.80
25	0.1666	10.281	8,760.00	60,791.55	75,794.83	1,853,512.64

SOLAR GLASS

THE GLASS PRODUCES 140 W/m² OF ENERGY

TOTAL SF = 18,970
= 1,762.4 m²

(140 W/m²)(1,762.4 m²) = 246,736 watts/day
= 10,280.67 watts/hr
= 10.281 kw/hr

1 year = 8760 hours
= 90,061.56 kwh • year

cost = $0.1312/kwh
COST OF ENERGY INCREASES BY 1% PER YEAR

COST OF SYSTEM = ($120/SF)(18,970 SF) = $2,276,400

FEDERAL TAX REBATE OF 30%

($2,276,400)(0.7) = $\boxed{\$1{,}593{,}480 = \text{TOTAL SYSTEM COST}}$

STATE TAX CREDIT/year = $0.675/KWH

($0.675/kwh)(90,061.56 kwh) = $60,791.553 savings per year

year 21 TOTAL SAVINGS TO DATE = $1,551,218.71
year 22 TOTAL SAVINGS TO DATE = $1,626,572.30

FROM INTERPOLATION, THIS SYSTEM WILL BE PAID OFF IN 21.56 years. A LITTLE LESS THAN 21 YEARS and 7 MONTHS.

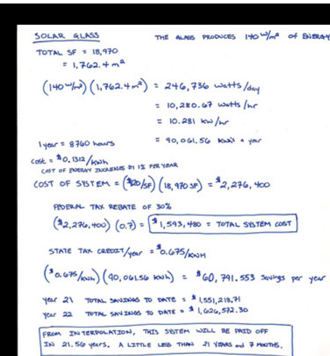
- Project Background
- Analysis #1: Bringing BIM Into the Field
- Analysis #2: Alternative Curtain Wall Systems
- **Analysis #3 : Feasibility of PV Curtain Wall System**
  - Electrical Breadth Design
  - Energy/Electrical Impacts
  - **Feasibility Analysis**
- Lessons Learned
- Acknowledgments & Questions

Justification for Cost

- Current PV Trays above atrium skylight cost about $2 million dollars
  - Produce 85 kV or 68 kWh
- Schuco E^2 system produces just over 3.6 times as much energy
- Schuco system only costs 13.8% more money

Feasibility of PV Curtain Wall

Year	Energy Cost per kwh	Energy Produced per Hour	Hours per Year	State Tax Credit Per Year	Total Savings Per Year	Total Savings To Date
1	0.1312	10.281	8,760.00	60,791.55	72,607.63	72,607.63
2	0.1325	10.281	8,760.00	60,791.55	72,725.79	145,333.42
3	0.1338	10.281	8,760.00	60,791.55	72,845.13	218,178.55
4	0.1352	10.281	8,760.00	60,791.55	72,965.67	291,144.22
5	0.1365	10.281	8,760.00	60,791.55	73,087.41	364,231.63
6	0.1379	10.281	8,760.00	60,791.55	73,210.37	437,442.00
7	0.1393	10.281	8,760.00	60,791.55	73,334.56	510,776.56
8	0.1407	10.281	8,760.00	60,791.55	73,459.99	584,236.54
9	0.1421	10.281	8,760.00	60,791.55	73,586.67	657,823.21
10	0.1435	10.281	8,760.00	60,791.55	73,714.62	731,537.84
11	0.1449	10.281	8,760.00	60,791.55	73,843.85	805,381.69
13	0.1464	10.281	8,760.00	60,791.55	73,974.38	879,356.06
13	0.1478	10.281	8,760.00	60,791.55	74,106.20	953,462.27
14	0.1493	10.281	8,760.00	60,791.55	74,239.35	1,027,701.62
15	0.1508	10.281	8,760.00	60,791.55	74,373.83	1,102,075.45
16	0.1523	10.281	8,760.00	60,791.55	74,509.65	1,176,585.10
17	0.1538	10.281	8,760.00	60,791.55	74,646.83	1,251,231.93
18	0.1554	10.281	8,760.00	60,791.55	74,785.38	1,326,017.32
19	0.1569	10.281	8,760.00	60,791.55	74,925.32	1,400,942.64
20	0.1585	10.281	8,760.00	60,791.55	75,066.66	1,476,009.30
21	0.1601	10.281	8,760.00	60,791.55	75,209.41	1,551,218.71
22	0.1617	10.281	8,760.00	60,791.55	75,353.59	1,626,572.30
23	0.1633	10.281	8,760.00	60,791.55	75,499.21	1,702,071.51
24	0.1649	10.281	8,760.00	60,791.55	75,646.29	1,777,717.80
25	0.1666	10.281	8,760.00	60,791.55	75,794.83	1,853,512.64


SOLAR GLASS
THE GLASS PRODUCES $140\ W/m^2$ OF ENERGY
TOTAL SF = 18,970
$= 1,762.4\ m^2$
$(140\ W/m^2)(1,762.4\ m^2) = 246,736$ watts/day
$= 10,280.67$ watts/hr
$= 10.281$ kw/hr
1 year = 8760 hours
$= 90,061.56$ kwh · year
cost = \$0.1312/kwh
COST OF ENERGY INCREASES BY 1% PER YEAR
COST OF SYSTEM = (\$120/SF)(18,970 SF) = \$2,276,400
FEDERAL TAX REBATE OF 30%
$(\$2,276,400)(0.7) = \boxed{\$1,593,480 = \text{TOTAL SYSTEM COST}}$
STATE TAX CREDIT/year = \$0.675/KWH
(\$0.675/kwh)(90,061.56 kwh) = \$60,791.553 savings per year
year 21 TOTAL SAVINGS TO DATE = \$1,551,218.71
year 22 TOTAL SAVINGS TO DATE = \$1,626,572.30
FROM INTERPOLATION, THIS SYSTEM WILL BE PAID OFF IN 21.56 years. A LITTLE LESS THAN 21 YEARS and 7 MONTHS.

Lesson Learned

Analysis #1:

- Implementing new software and technology can save time, reduce costs, improve communication, and improve the overall construction process

Analysis #2:

- There is a substantial premium for large glass sizes
- Curtain wall systems are becoming more and more efficient and more feasible to implement components like PV into them.

Analysis #3

- Tax rebates and incentives make PV glass affordable

Acknowledgements

Academic Acknowledgements:
Penn State AE Faculty
Dr. Riley – CM Advisor

Industry Acknowledgements:
Turner Construction
Schuco USA
Vela Management Systems
Hopkins Architects

Special Thanks To:
Turner Construction Project Team
Project Architects and Engineers
PACE Industry Members
The Owner