Michael R. Pothering
Construction Management

Science & Technology Center
Chestnut Hill Academy
Philadelphia, PA

Architectural Engineering
Senior Thesis 2009

Science & Technology Center
Chestnut Hill Academy

Presentation Outline

- Project Overview
- Analysis 1: Exterior Façade Redesign
- Analysis 2: Solar Redesign
- BIM Implementation
- Conclusions
- Questions

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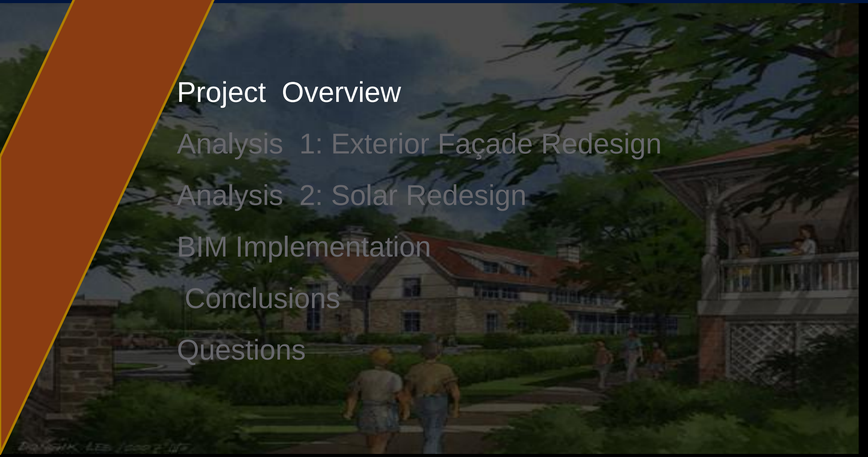

Client Information

- Chestnut Hill Academy was established in 1861
- Located in Philadelphia, PA
- K-12 Boys College Preparatory School
- Enrolls approximately 600 students

Project Team

- GC - Turner Construction
- Architect – Lilley.Dadagian
- Owners Rep. – Aegis Property Group
- Structural Eng. – Roome & Guarracino
- Civil Eng. – Cairone & Kaupp, Inc.
- MEP Eng. – Bruce E. Brooks & Assoc.

LILLEY.DADAGIAN ARCHITECTS

Turner

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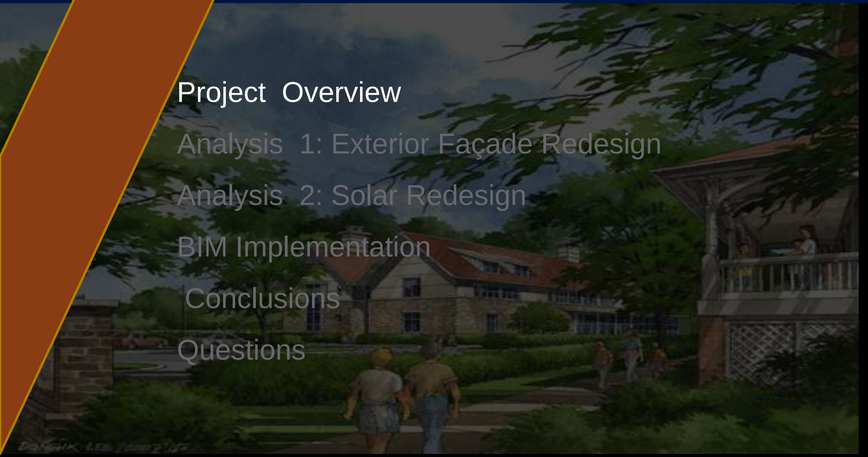
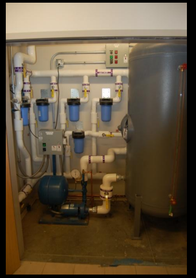


Science & Technology Center:

- 2.5 stories with ½ story mechanical attic
- 26,870 SF
- LEED Silver Certified
- Classrooms
- Science Laboratories
- Faculty Offices

Sustainable Design

- PV panels
- Thermal Heat Conductors
- Wind Turbine
- Greywater System
  - Raingardens
  - Permeable Parking Lot
- Tree Arboretum



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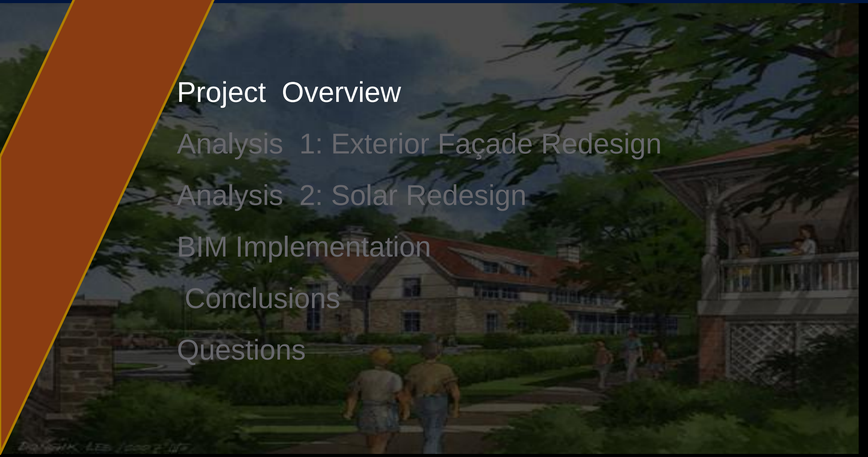

Project Cost:

- $9,600,000

Construction Information:

- Start Date: November 2007
- 12 Month Construction Schedule
- Structural steel frame
- Stucco and Stone veneer

Building System Cost	Total	SF
Concrete	$ 424,600	$ 15.80
Steel	$ 744,600	$ 27.71
Drywall	$ 713,000	$ 26.54
HVAC and Plumbing	$ 1,543,700	$ 57.45
Electrical	$ 866,800	$ 32.26
Fire Protection	$ 109,300	$ 4.07
Roofing	$ 550,700	$ 20.49
Masonry	$ 634,900	$ 23.63
Glass, Glazing, Curtain wall	$ 450,800	$ 16.78

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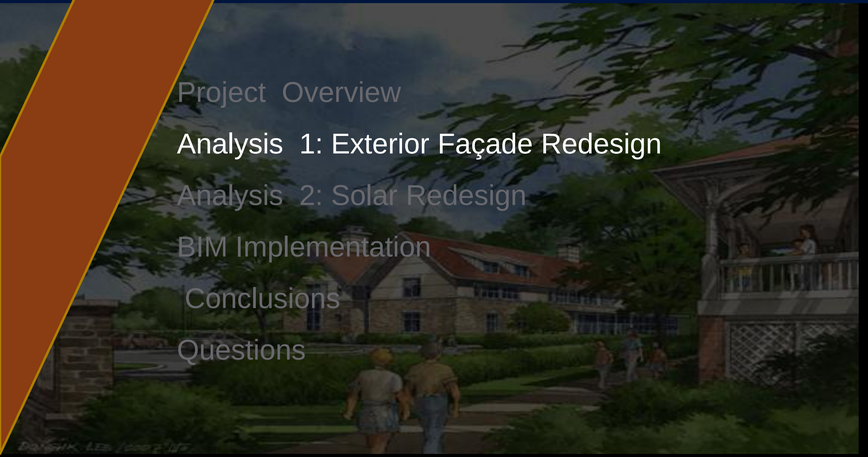

Natural Fieldstone
Masonry Veneer

Problem:

- Long construction time. Material Costs, delay's other schedule activities

Goal:

- Speed up construction schedule and decrease material price
- Maintain envelope requirements

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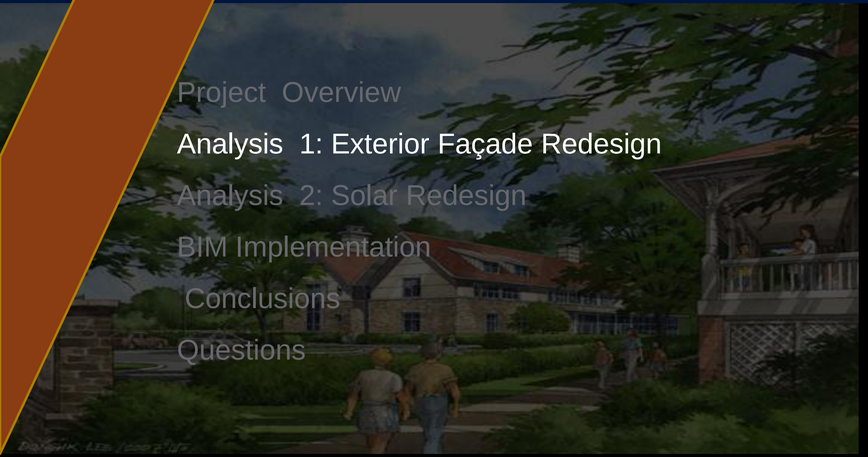
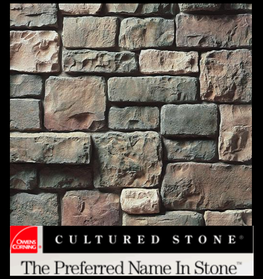


Existing Natural Stone- Material

Natural Field Stone Veneer
- Thickness – 4”-6”
- Weight – 60 lb/ft^2

Precast Stone- Material

Cultured Stone Veneer
Manufactured by Owens Corning
- Thickness – 1” – 2 5/8”
- Weight – 15 lb/ft^2



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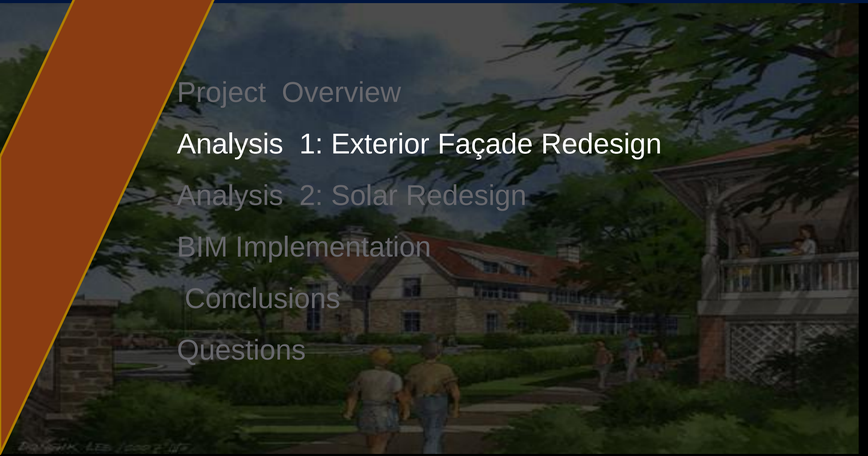
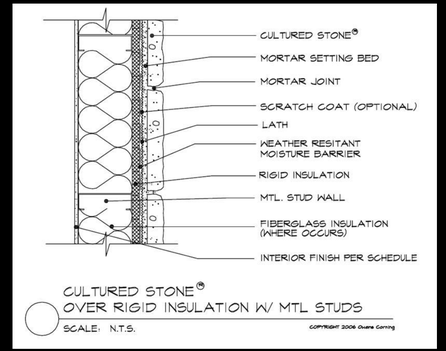
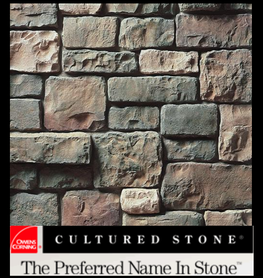


Existing Natural Stone- Material

Precast Stone- Material





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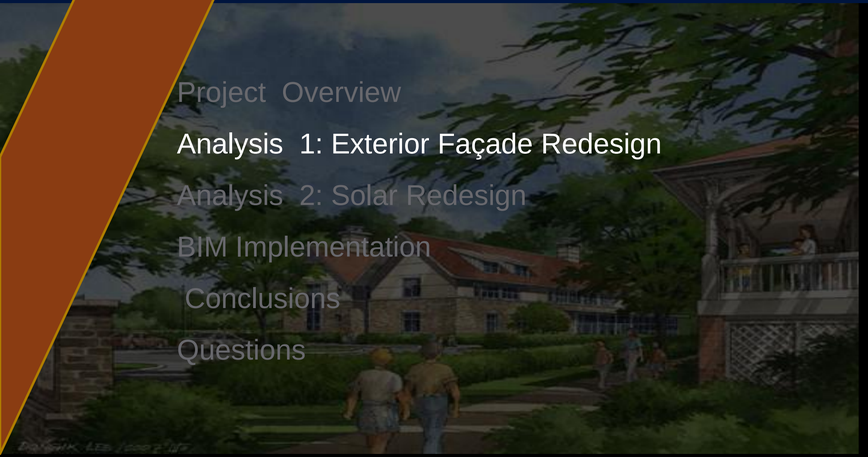


Project Overview

Analysis 1: Exterior Façade Redesign

Analysis 2: Solar Redesign

BIM Implementation

Conclusions

Questions

Natural Stone Cost

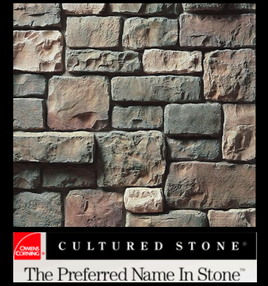
Natural Fieldstone
Masonry Veneer

Exterior Façade Material	Material	Labor
Natural Stone Veneer		
	$126,564	$97,557
	TOTAL	$224,119

Precast Stone Cost

Precast Thin Stone Veneer
Cultured Stone®

Exterior Façade Material	Material	Labor
Cultured Stone®		
	$36,506	$85,165
	TOTAL	$121,670
	Saving's	-$102,450
	% Saving	54.6%



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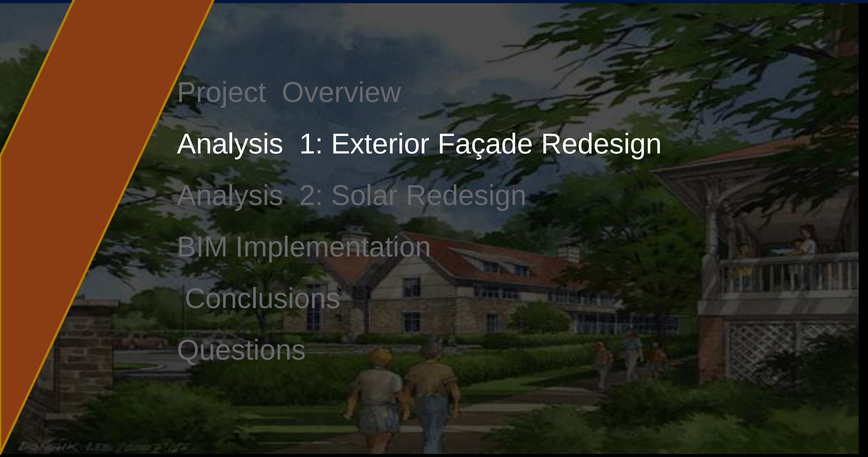

Green Building Design Studio

- Incorporates building location, size, function, and design into calculations
- Utilizes actual wall material thicknesses to calculate energy load
- Considers room volumes and window sizes for heating and cooling loads

Process:

- **Utilize 3D Revit designed model**
- **Export to GBDS**
- **Enter project information (location, type, energy rates)**
- **Add special system considerations**
  I.E. Occupancy/Daylight sensors
- **Adjust specific project equipment (HVAC)**
- **Run analysis program**

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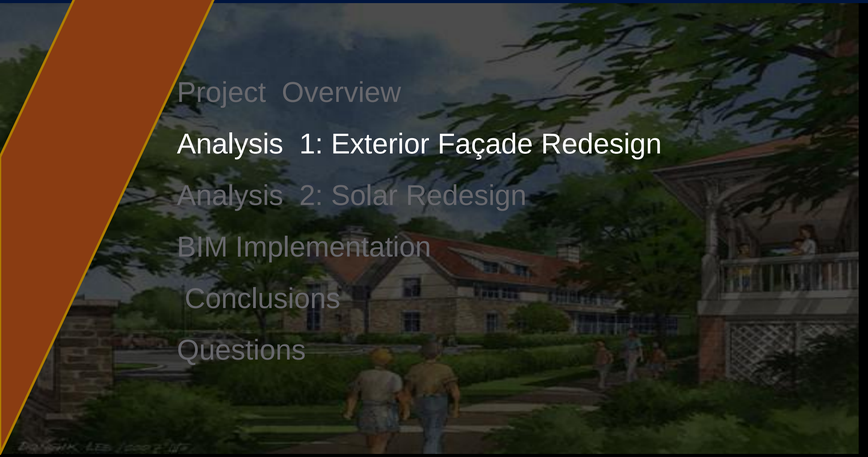

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Green Building Design Output
General Information

General Information
Project Title: CHA Science Center New
Template Title: CHA Science Center New
(Last updated on: 3/27/2009 4:12:00 AM)
Run Title: thin wall
Building Type: School or University
Floor Area: 23,272 ft²

GREEN BUILDING STUDIO

Location Information
Building: PHILADELPHIA, PA 19119
Electric Cost: $0.08/kWh
Fuel Cost: $0.32/Therm
Weather: GBS_04R20_251120

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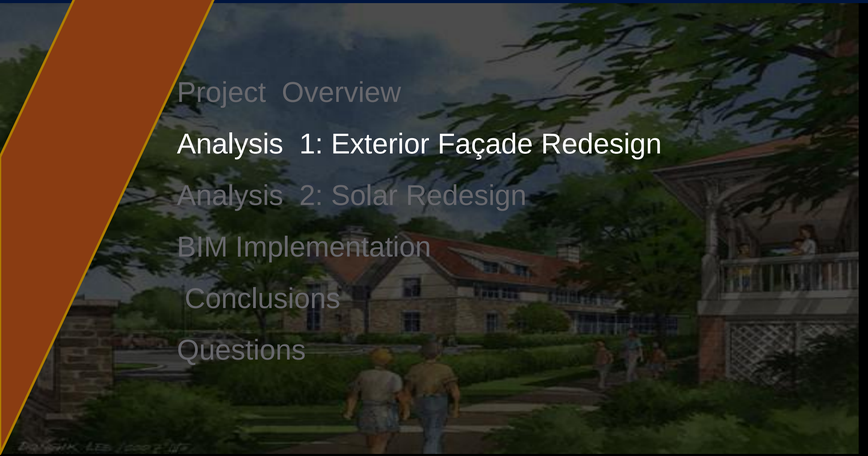

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Green Building Design Output

Existing Façade System

Estimated Energy & Cost Summary

Annual Energy Cost	$19,996
Lifecycle* Cost	$272,346
Annual CO_2 Emissions	
Electric†	124.6 tons
Onsite Fuel	67.9 tons
Large SUV Equivalent	17.5 Large SUV's
Annual Energy	
Electric	216,543 kWh
Fuel	11,699 Therms
Annual Peak Electric Demand	133.0 kW
Lifecycle* Energy	
Electric	6,496,296 kWh
Fuel	350,964 Therms

* 30 -year life and 6.1 % discount rate for costs.
† Does not include electric transmission losses or the renewable and natural ventilation potential.

Natural Stone

Proposed Facade System

Estimated Energy & Cost Summary

Annual Energy Cost	$19,950
Lifecycle* Cost	$271,719
Annual CO_2 Emissions	
Electric†	124.3 tons
Onsite Fuel	67.7 tons
Large SUV Equivalent	17.5 Large SUV's
Annual Energy	
Electric	216,010 kWh
Fuel	11,680 Therms
Annual Peak Electric Demand	132.8 kW
Lifecycle* Energy	
Electric	6,480,297 kWh
Fuel	350,397 Therms

* 30 -year life and 6.1 % discount rate for costs.
† Does not include electric transmission losses or the renewable and natural ventilation potential.

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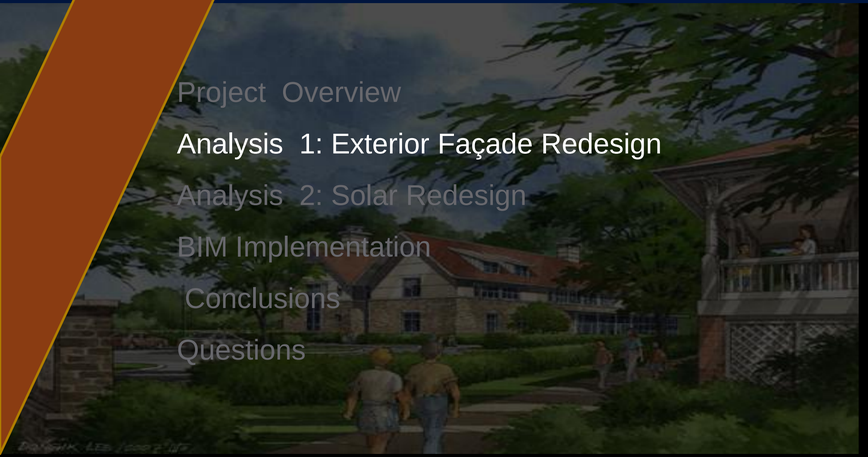

Natural Stone R-Value Calculations

Natural Stone Veneer	Item	Thickness	R-Value	Total R-Value
Wall System				
	Outside Air Film	-	0.17	0.17
	Stone Masonry	6"	0.08	0.48
	Airspace	0.5"	1	0.5
	Rigid insulation	2.5"	5	12.5
	Vapor barrier	40mm	-	-
	Dens-Glass	0.5"	0.56	0.28
	Metal Stud Space	6"	1	6
	Drywall	5/8"	-	0.56
	Inside Air Film	-	0.68	0.68
			Total R-Value	21.17 hr-sf-F°/BTU
			U-Value	0.0472 BTU/hr-sf-F°

Natural Stone

Precast Stone R-Value Calculations

Cultured Stone Veneer	Item	Thickness	R-Value	Total R-Value
Wall System				
	Outside Air Film	-	0.17	0.17
	Stone Masonry	1.75"	-	0.62
	Rigid insulation	2.5"	5	12.5
	Vapor barrier	40mm	-	-
	Dens-Glass	0.5"	0.56	0.28
	Metal Stud Space	6"	1	6
	Drywall	5/8"	-	0.56
	Inside Air Film	-	0.68	0.68
			Total R-Value	21.31 hr-sf-F°/BTU
			U-Value	0.0469 BTU/hr-sf-F°

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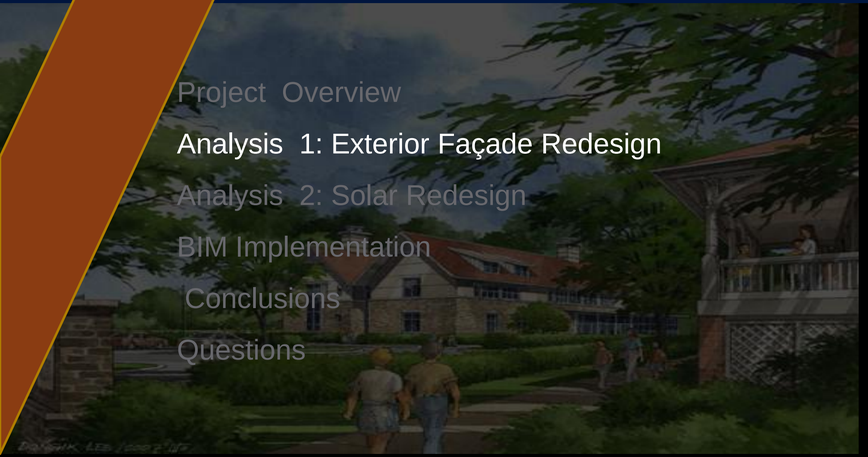

Exterior Wall
Heat Loss Calculations

Winter Temperatures	°F
To (outside)	25.5
Ti (inside)	71
ΔT	45.5

Estimated Heat Loss (winter)	U-Value (BTU/hr-sf-F°)	Area (SF)	ΔT (°F)	Heat Loss (BTU/hr)
Natural Stone	0.0472	4890	45.5	10501.76
Cultured Stone	0.0469	4890	45.5	10435.02

Exterior Wall
Heat Gain Calculations

Summer Temperatures	°F
To (outside)	85.5
Ti (inside)	71
ΔT	14.5

Estimated Heat Gain (summer)	U-Value (BTU/hr-sf-F°)	Area (SF)	ΔT (°F)	Heat Gain (BTU/hr)	Heat-Gain (tons)
Natural Stone	0.0472	4890	14.5	3346.72	0.279
Cultured Stone	0.0469	4890	14.5	3325.44	0.277

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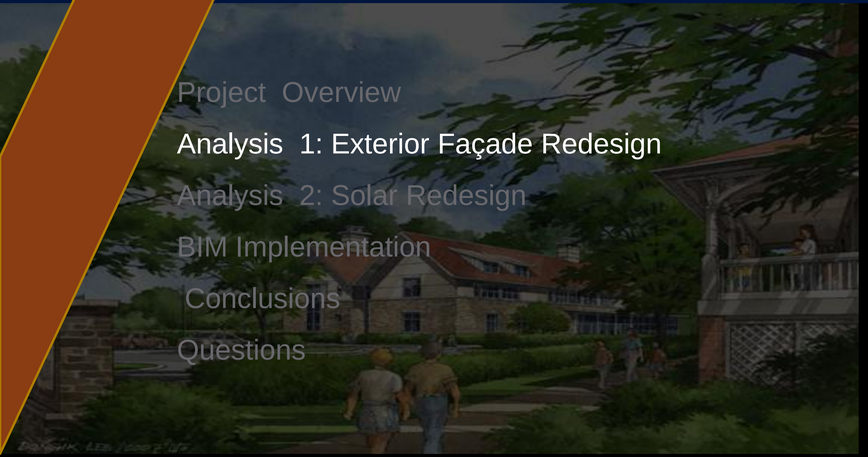

Project Overview

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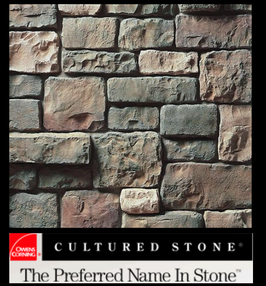
Façade Redesign Recommendations

Advantages of Cultured Stone Veneer

- Cost savings of 54.6% approx. $102,000
- Schedule acceleration of approx. 6 weeks
- Less Site Congestion
- 50 year warranty



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Problem & Goal

Problem Statement:

- Small 1kW capacity
- Invisible to public eye

Goal:

- Redesign the solar system to utilize Building Integrated Photovoltaic's (BIPV)
- Integrate BIPV into Southern exposed roof allowing the shingles to be visible to public, staff, and students
- Utilize more solar energy to offset energy consumption

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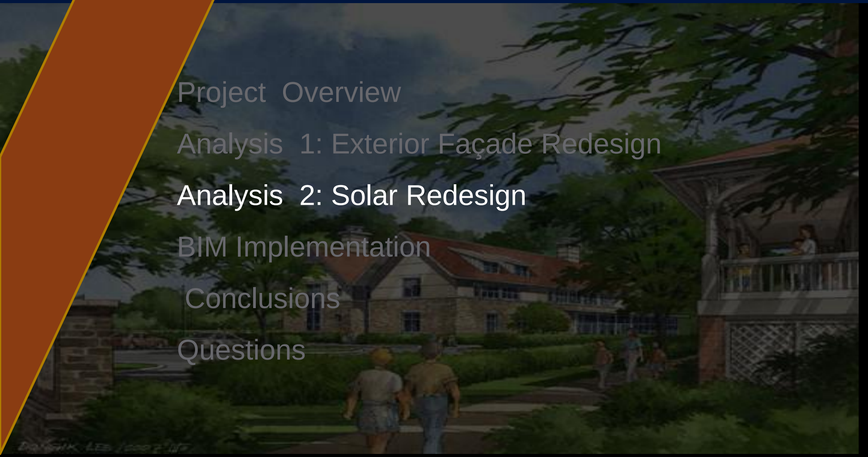
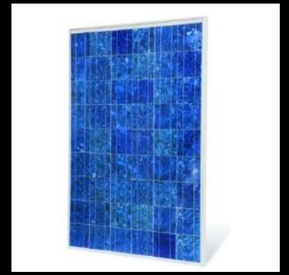


Existing Panel System



GEPV-200-M Panel by General Electric

Product Description

- Peak power of 200 W of energy produced per panel
- Bracket Mounted above roof
- Grid tied system

Proposed BIPV Roofing System

SUNSLATES by Atlantis Energy Systems

Product Description

- Peak power of 12.2 W of energy produced per slate
- Mounted directly to roofing substrate and used as building envelope
- Aesthetically pleasing
- Grid tied system

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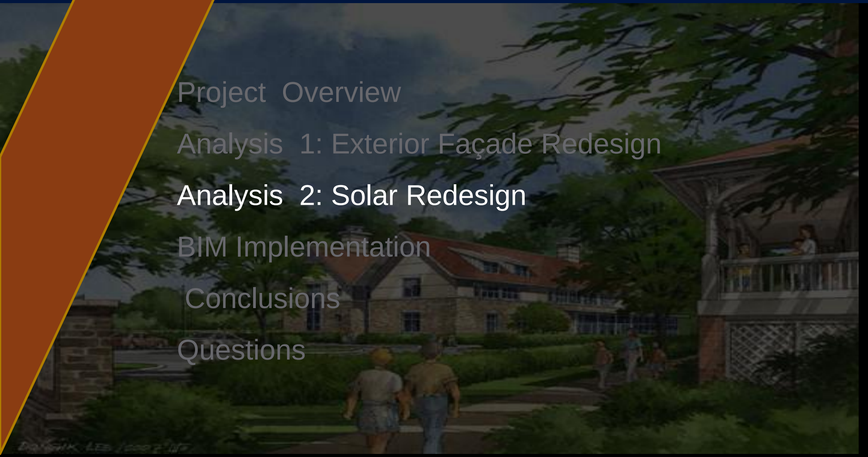

Installation Process:

- SUNSLATESs are mounted on a 1x4 nailers resting on 2x2 sleepers which form a grid anchored to roof deck
- Slates are then attached to the wood battens with storm anchor hooks
- Each tile is then attached to the adjacent tiles by the connecting wires
- At the end of each course a home run is ran to a splice box under the roof deck which is then ran to the inverter.

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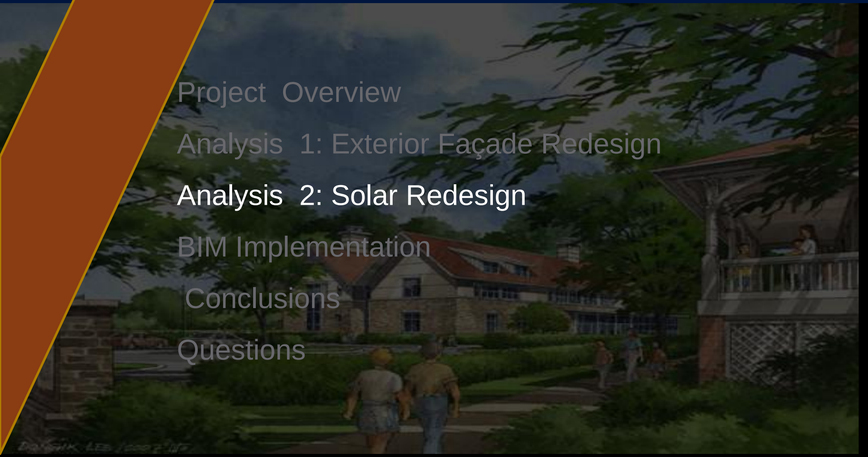

SUNSLATE Energy Calculations

Small Area Design

Calculated Energy Production for Small Areas of SUNSLATES												
# of Slates	231											
Watts/slate	12.2											
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days/month	31	28	31	30	31	30	31	31	30	31	30	31
kWh/day	27.28	30.15	33.54	37.20	40.30	41.99	41.43	38.61	35.23	31.28	28.18	26.49
kWh/month	845.69	844.33	1,039.63	1,116.01	1,249.31	1,259.74	1,284.25	1,196.89	1,056.83	969.74	845.46	821.22
kWh/Year	12,529.10											

SUNSLATE Cost – Savings – Payback Period

Small Area System:

# of slates:

231

cost per slate:

12.2W * $15/W

= **$183/slate**

Total Cost of Shingle's:

231 shingles * $183/slate

= **$42,273**

Small Area Savings:

Savings Per Year

12,529kWh/year * $0.0753/ kWh

= **$943 / year**

Payback Period

$42,273 ÷ $943/year

= **44.8 years**

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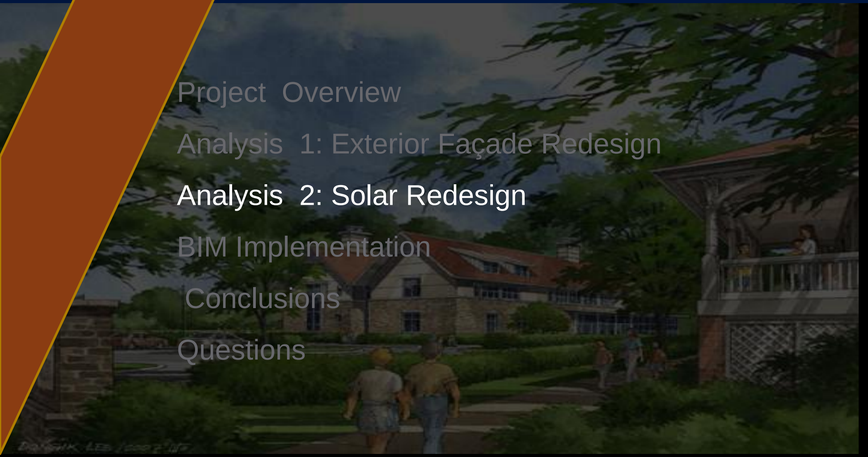

SUNSLATE Energy Calculations

Entire Roof Design

Calculated Energy Production for Entire Roof of SUNSLATES												
# of Slates	2365											
Watts/slate	12.20											
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days/month	31	28	31	30	31	30	31	31	30	31	30	31
kWh/Day	279.30	308.73	343.35	380.86	412.60	429.91	424.14	395.29	360.66	320.27	288.53	271.22
kWh/Month	8,658.21	8,644.36	10,643.87	11,425.79	12,790.53	12,897.29	13,148.31	12,253.87	10,819.88	9,928.32	8,655.90	8,407.76
kWh/yr	128,274.09											

SUNSLATE Cost – Savings – Payback Period

Entire Roof Area System:

# of shingles:

2365

cost per shingle:

12.2W * $15/W

= **$183/shingle**

Total Cost of Shingle's:

2365 shingles * $183/ shingle

= **$432,795**

Entire Roof Savings:

Savings Per Year

128,274 kWh/year * $0.0753/ kWh

= **$9,659 / year**

Pay back Period

$432,795 ÷ $9,659/ year

= **44.8 years**

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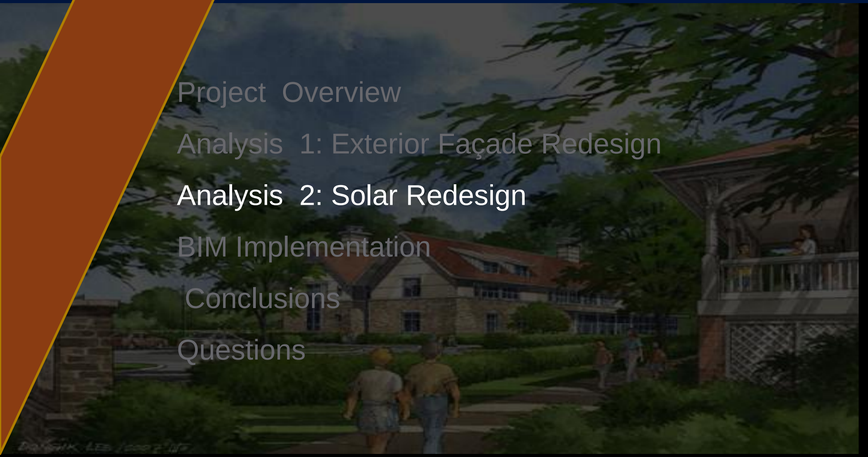

Existing Energy Calculations

Existing Solar Panel Design

Calculated Energy Production for Existing GE Solar Panels												
# of Panels	5											
Watts/panel	200											
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Days/month	31	28	31	30	31	30	31	31	30	31	30	31
kWh/Day	9.68	10.70	11.90	13.20	14.30	14.90	14.70	13.70	12.50	11.10	10.00	9.40
kWh/Month	300.08	299.60	368.90	396.00	443.30	447.00	455.70	424.70	375.00	344.10	300.00	291.40
kWh/yr	4,445.78											

Existing Cost – Savings – Payback Period

Existing System:

# of panels:

5

cost per panel:

$1235.29/panel

Total Cost of Panel's:

5 panels * $1,235.29

= **$6,176**

Existing Panel's Savings:

Savings Per Year

4,445.78kWh/year * $0.0753/ kWh

= **$335 / year**

Payback Period

$6,176÷ $335/year

= **18.4 years**

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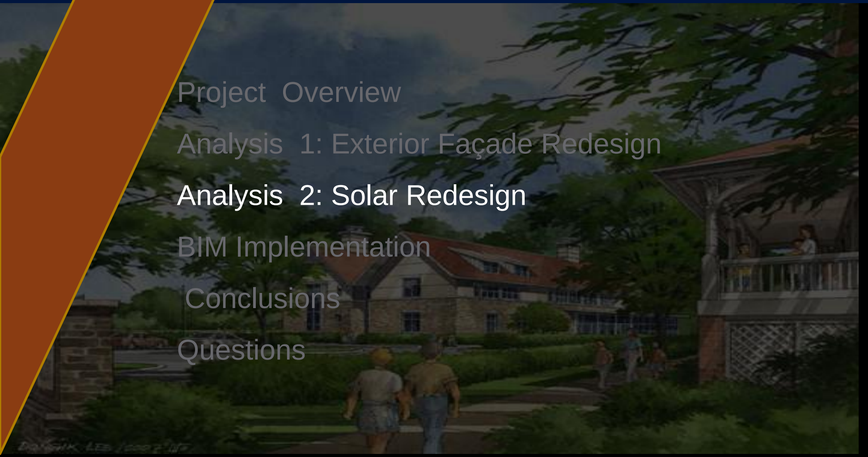
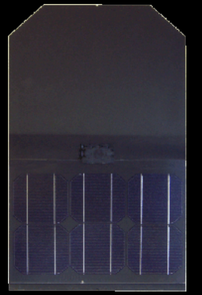


Summary

	kWh/yr	Cost Savings / yr	System Cost	Payback Period
Existing	4,445.78	$335	$6,176	18.4 years
Small Area	12,529	$943	$42,273	44.8 years
Entire Roof	128,274	$9,659	$432,795	44.8 years

- Proposed system is extremely costly, Inefficient , and has potential delays
- Small Area system has high initial cost but can be feasible with energy grants
- Entire Roof system is unfeasible due to extreme initial investment
- Existing system is cheapest , fastest, and has an easy installation

Recommendations



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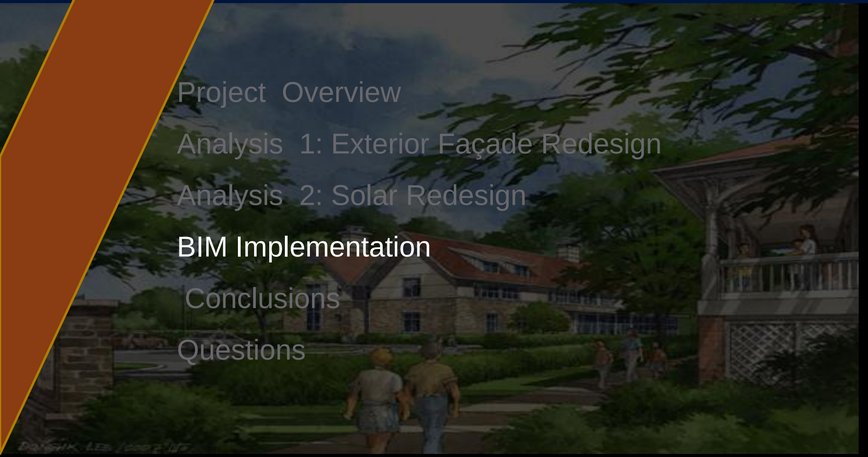
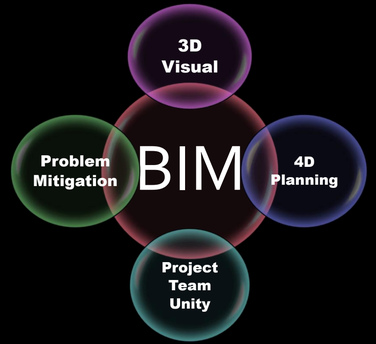


Building Information Modeling



Problem & Goal

Problem:

The Science & Technology Center did not fully use BIM, which could have been an extremely valuable asset to the project.

Goal:

- Identify the benefits of BIM on projects
- Develop an understanding of the basic process used to create things such as the 3D and 4D models
- Gain an understand of why it was not used on the project

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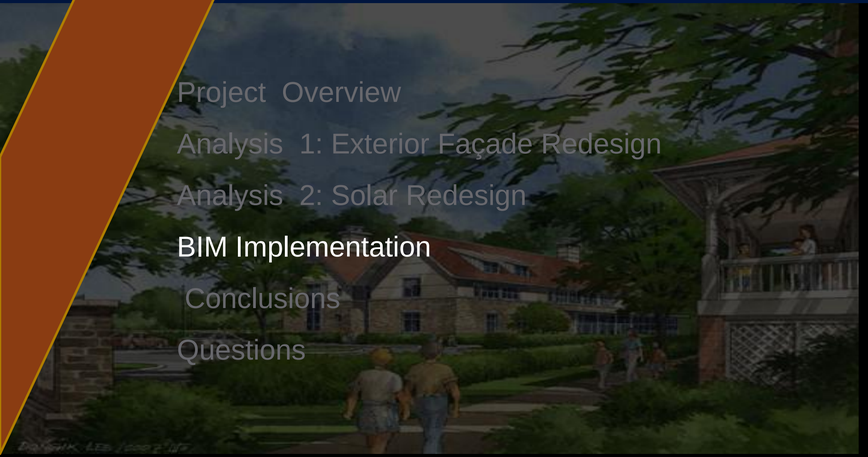

BIM Process

Typical process for implementing BIM

1. Contact a design service which creates BIM models & explain the project
2. Send the design firm drawings/designs to allow them to become familiar with the project design and layout
3. Design firm will contact architect/engineers for clarifications
4. Once clarifications are received the design firm will develop a quote
5. Once the agreement is reached the design firm will begin creation of preliminary models/drawings
6. Preliminary models/drawings are sent to owner for approval
7. Once approved the models/drawings will be finalized and given one last check for Quality and Consistency

BIM Software

The following software titles were used to gain the understanding of the creation of the BIM 3D & 4D models

Microsoft Office Project

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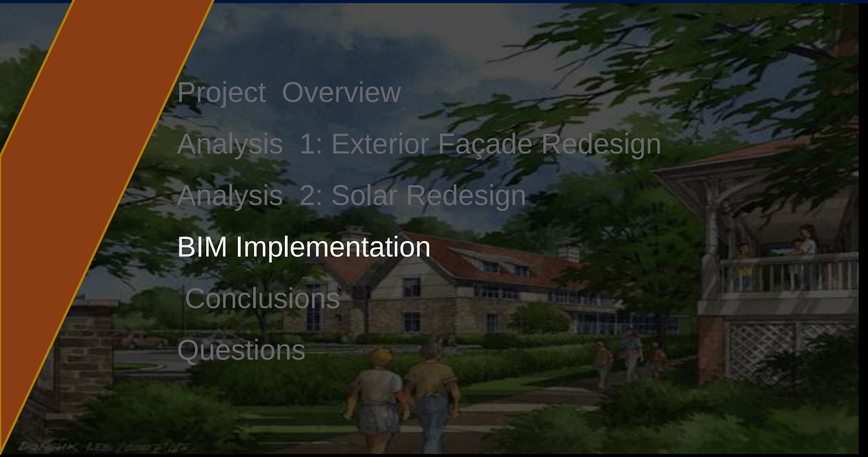

3D Model Design

3D Model Benefits
- Visualization
- Express Changes
- Work Flow Management
- Construction Clarification
- Phasing

Important Considerations
- In-depth understanding of CD's
- Attention to detail
- The more accurate your measurements results in a better quality model
- 3D model will later impact quality of the 4Dmodel

Revit Output

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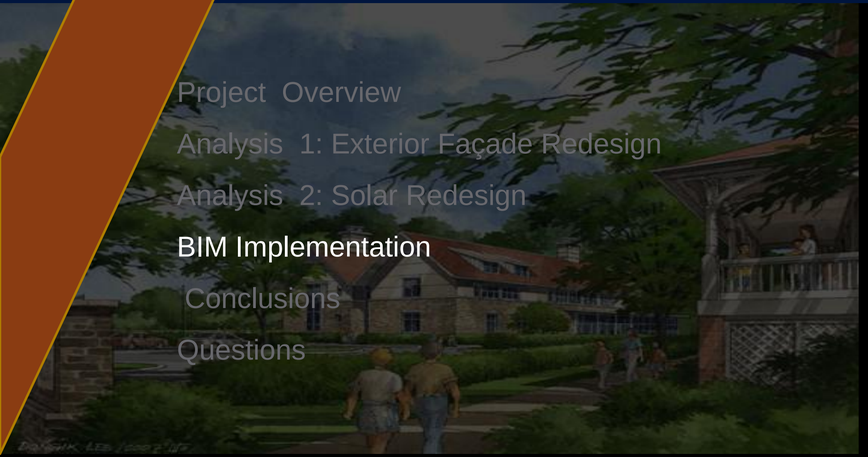


4D Model Design

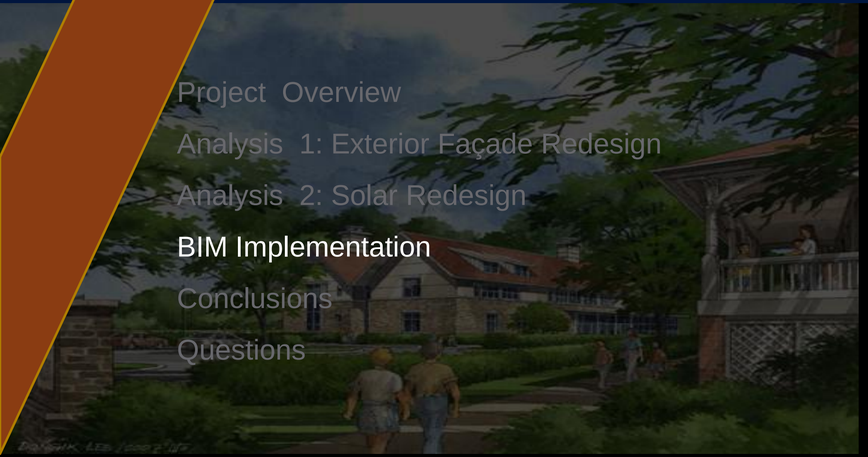
4D Model Benefits

- Adds time dimension to 3D
- Visualize time constraints
- Sequencing and Phasing
- Contractor Flow
- Improved Schedule Efficiency

Important Considerations

- Time consuming attaching each individual member to a schedule task
- Detailed project schedule allows for a more accurate 4D model
- Ensure 3D Model is 100% finalize before beginning 4D model

NavisWorks 4D Model



Project Team – BIM Survey Results

Architect Interview Results:

- Utilized 3D model with Rhino software for massing issues
- Small Architecture firm which cannot afford BIM software and training
- Would later adopt BIM technology once the technology has the “bugs” worked out
- Believed that use full use of BIM would not have been warranted for a project of this scale. Would be better used on more complex projects

Project Team – BIM Survey Results

Project Manager Interview Results:

- Limited training with BIM technology
- Believes it would aid with trade coordination and minimize confusion
- Steel erecters utilized 3D model for steel erection from StruWalker software
- Cost savings from BIM on a project of this size would not be worth the cost of training and model production

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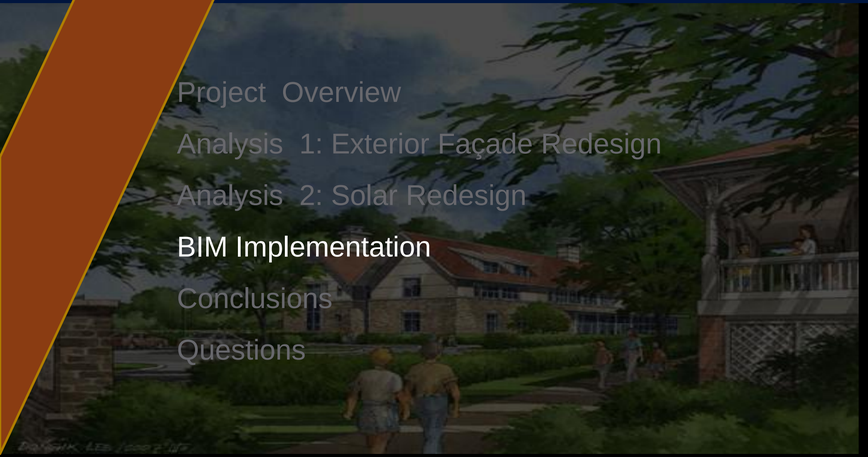

BIM Implementation

- The use of this technology could benefit the project in numerous ways, but due to the lack of training and budget of the project team. It is better left at the current amount.

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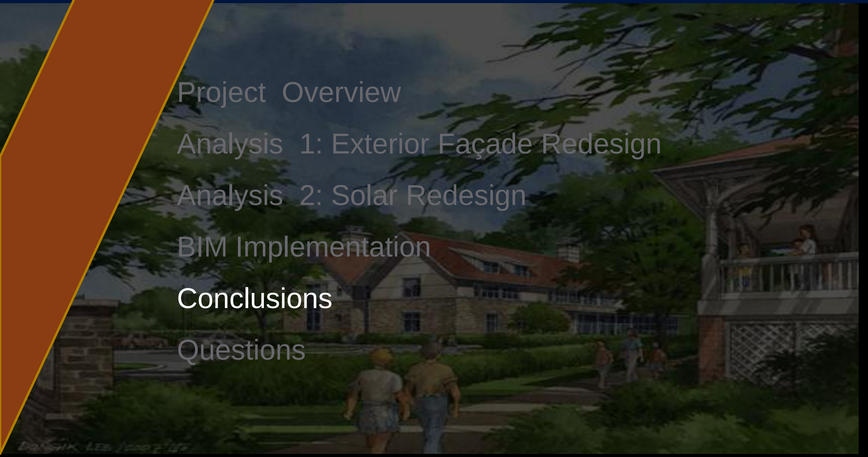

Conclusions

Exterior Façade Redesign

- Cost and Schedule reduced
- Thermal& Mechanical was not impacted

Solar Energy System Redesign

- Proposed system is very expensive with a long payback period
- Installation of proposed system is labor intensive
- Schedule delay due to intensive labor
- Existing system is a better fit for the project

BIM Implementation

- BIM Technology has potential to improve any project but comes at a cost
- Industry members are aware of BIM but lack training or budget to implement

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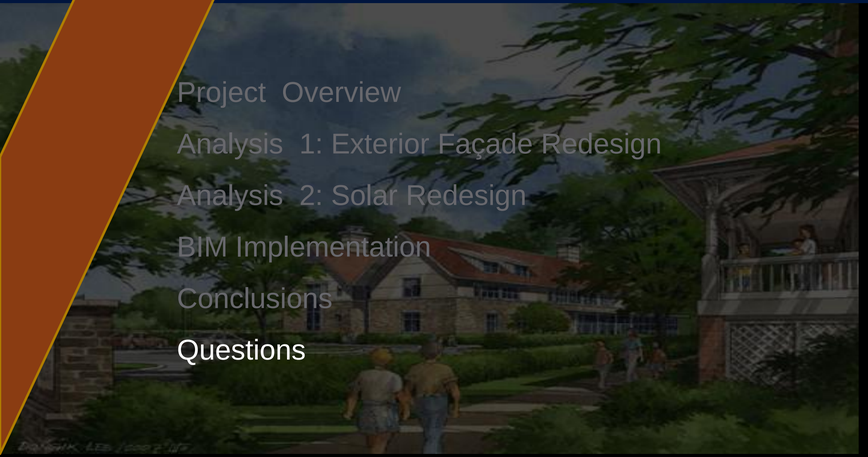

Project Overview

Analysis 1: Exterior Façade Redesign

Analysis 2: Solar Redesign

BIM Implementation

Conclusions

Questions

Questions

Acknowledgements

Turner Construction Company

Chestnut Hill Academy

Penn State AE Faculty and Staff

My family and friends for their continued support