Science & Technology Center
Chestnut Hill Academy
Philadelphia, PA

Michael R. Pothering

Construction Management

Final Report

Advisor Dr. Messner

Spring 2009

Science and Technology Center
Chestnut Hill Academy
Philadelphia, PA

Project Team
Owner: Chestnut Hill Academy
Owners rep. : Aegis Property Group
Architect: Lilley.Dadagian Architects
Assoc. Architect: Krieger + Assoc., Inc.
CM/GC: Tuner Construction Company
Engineers: Roome & Guarracino. LLC
Cairone & Kaupp, Inc.
Bruce E. Brookes & assoc.

LEED/Sustainability
LEED for Schools certification
photovoltaic cells
solar panels
wind turbine
grey water system - porous paving and storm water retention system

Architectural Features
26,870 sq.ft.
two stories with mechanical attic
Stone & stucco veneer
court yard and aboretum
glass curtinwall and punched windows
ashphalt shingles

Electrical System
480/277V , 3 phase, 4 wire
power provided by campus grid
400A main distribution panel
primarily flouresent lighting
lutron eco system lighting control
HPS exterior parking lighting

Structural System
spread footing fountdation
slab on grade
steel braced frames for lateral loads
metal decking with concrete slabs
structural steel beams and columns
metal stud framed walls

Mechanical System
two AHU's 6500 cfm & 8000 cfm with packaged enthalpy wheels
57.1 ton chiller
VAV controlled ductwork

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Acknowledgements

I would like to thank the following individuals for their cooperation and guidance throughout my senior thesis and college career.

Pennsylvania State University
Dr. John Messner
Professor Robert Holland
Dr. M. Kevin Parfait
Dr. David Riley
Professor Moses Ling

Turner Construction
Mr. Doug Belling
Mr. Adam Rockmacher
Mr. Matthew Maderia

Chestnut Hill Academy
Ms. Mary Cardona
Ms. Elizabeth S. Longstreth
Mr. Matt Goetting (Previous CHA Employee)

Lilley Dadagian Architects
Mr. Stephen Dadagian
Mr. Jake Lilley

Aegis Property Group
Ms. Catherine M. Cantlin

Fellow AE Students
Paul Yingling
Jeremy McGrath

All my Family & Friends for their continued support, Especially
Mom, Dad, Melissa, David, & Tiff

Executive Summary

The 26,870 S.F. project is located in Philadelphia, PA on the private campus of the Chestnut Hill Academy which is an all-boy preparatory school. The building will house the Science & Technology Center on the campus of the academy. The students will have state-of-the-art laboratories and classrooms which will provide the valuable hands on learning environment needed with the science and technology topics.

The following report contains an overview of the project including the building's systems, construction schedule, estimated cost, and three areas of the Science & Technology Center that pose as a problem/challenge during construction or is an opportunity for improvement. These areas will be researched and analyzed in hopes of decreasing the schedule or cost to the project.

Analysis #1 Exterior Façade Construction (Mechanical Breadth)

The lower portion of the exterior façade will be redesigned from a traditional field stone masonry wall to precast stone. This will allow for possible schedule acceleration and cost savings. This change will impact the wall assembly by changing the insulation properties of the envelope. If the material changes impacts the wall significantly there will need to be extra consideration towards adding or removing insulation, therefore, making it a mechanical breadth

Analysis #2 Sustainable Energy

The solar energy for this project is small and discrete on top of the roof. Changing the solar energy system from roof top panels to a Building Integrated Photovoltaic (BIVP) roofing material will be investigated. The value of these systems will be reviewed to find if the change will be worthy of the initial cost. This topic area results in the second breadth for electrical.

Building Information Modeling

Building Information Modeling (BIM) will be researched in hopes of understanding what possible impact it may have had on the Science & Technology Center. The use of a BIM to improve the overall construction methods of projects throughout the world is becoming extremely popular. The growth of BIM in the market has established it as critical issue of research for this study. The implementation of BIM on projects will be researched to understand the good or bad qualities of this rising technology as well as its possible use after construction.

Project Information and Background

Client Information

Chestnut Hill Academy is the owner of the New Science and Technology Building. The school is an all-boy predatory school grades K through 12, dedicated to providing its students with the environment to grow, learn and mature into well educated driven individuals.

The building is being built to serve as a hands-on learning environment for students and visitors. The building includes photovoltaic cells, solar panels, a wind turbine, and state of the art monitoring panels that shows the buildings energy use and other systems displays. It will have classrooms and laboratories for biology, chemistry, physics, and robotics. All are designed to be visible to passing by students stimulating their curiosity in the sciences.

Chestnut Hill Academy hired Turner Construction Co. as the CM/GC on the project due to their experience with the construction of other LEED rated school and laboratory buildings. All contracts held with Turner are lump sum.

Building Overview

The Science and Technology Center will be a dedicated classroom and laboratory building with office space. The two and a half story masonry and stucco building will blend with the school's material and building design throughout the campus. The building and site work has been designed to reach LEED Silver/Gold certification. The exterior frame will be comprised of metal studs with sheeting, vapor barrier and rigid insulation. The frame will be faced with a façade consisting of punch windows as well as a glass curtain wall all framed with brick veneer and stucco. The sloped roofs will be comprised of asphalt shingles and the flat roofs will make use of high reflective membrane as well as metal panels. The roof tops will be outfitted with photovoltaic cells, solar panels and a wind turbine. The energy gathered from these renewable sources will partially provide energy to the outside arboretum lighting as well as power the robotics lab and aid in domestic hot water. A parking lot made of porous paving with an underground retention system will catch and reuse grey water. A court yard and arboretum will tie the building together with the rest of campus and also allowing students an educational learning experience.

Site Development and Conditions

The Science & Technology Center is being built on the campus of the Chestnut Hill Academy. It is being constructed on an existing parking lot and grass lawn. The location of an existing building approximately 75' to the Southwest of the site adds a small amount of congestion. The opposing side of the site has an open field next to an athletic track, which will provide ample lay down and storage room for the site. Since all the deliveries to site will be timed according to demand, there will only be primary storage of essential items on site providing sufficient room for maneuvering. Offsite parking will be available for workers on the surrounding streets. Deliveries will be taken from the South entrance of the site in the existing road loop allowing for one way traffic. Trucks will enter and unload then continue around the loop keeping efficient flow of deliveries.

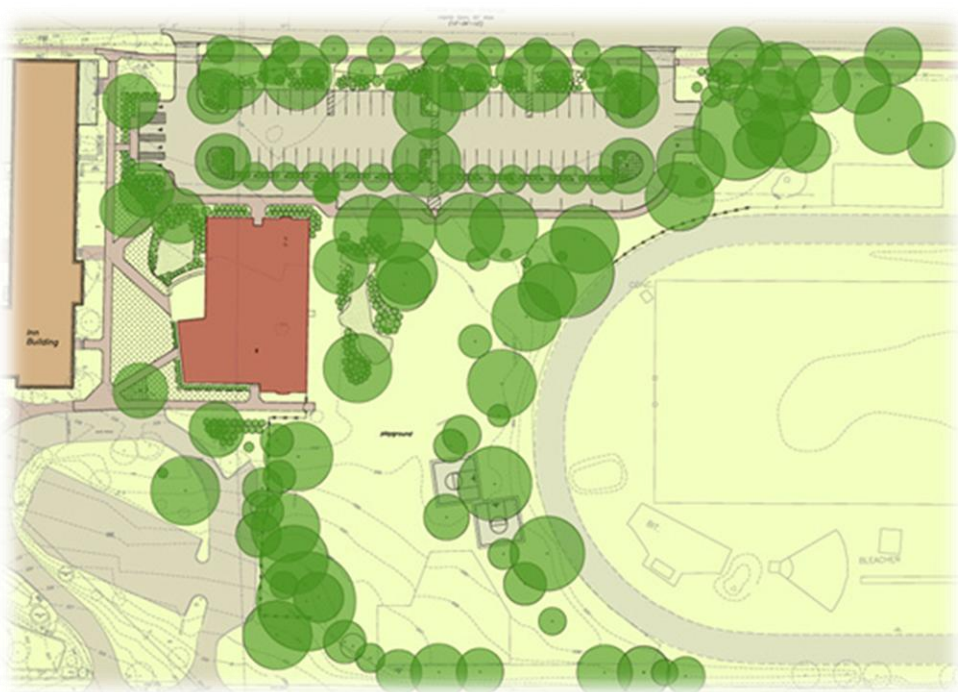
The excavation phase of the project will last three weeks. The bottom of foundation will be a minimum of 3' below grade; therefore there will be no need for excavation support. A temporary soil stock pile will be located to the North of the site during excavation. Once the foundation is in place, the soil will return as suitable backfill. The remaining soil will be shipped off site and sold. After the backfill is completed the excavation phase will be complete and move to the construction/superstructure phase.
**See Appendix D for the Excavation Site Plan*

The construction phase will begin with the placement of the slab on grade. The commencement of the steel erection will begin after the concrete cured adequately. The steel will be erected by a 60 Ton hydraulic mobile crane. The crane will place the steel frame from the Northeast and Southwest side of the site. Shakeout for steel members will be separated into corresponding picks for crane locations. Deliveries will be made on the South end of the site. Dumpers will be located around site for access by all workers.
**See Appendix F for Construction Site Plan*

There is one side of the site which is somewhat restricted due to an existing structure which is only 75' away from the exterior wall. This area is the Southeast side of the Science& Technology Center. This area must be restricted access so the pedestrians are not in the construction area.

Due to the soil consistency on the site being made of decomposed rock and rock below elevation 332.5, heavy equipment will need to be used for removal. There are also existing and abandoned underground utilities that the excavation team will need to mark.

Satellite Aerial View by Google Maps



Rendered Site Plan by Lilley Dadagian Architects

Building Summary

Construction

Chestnut Hill Academy hired Turner Construction Co. as the CM/GC on the project due to their experience with the construction of other LEED rated school and laboratory buildings. All contracts held with Turner are lump sum. The Science & Technology Center is located between Willow Grove Ave. and Springfield Avenue. To the front of the building is the existing Inn Building which is approximately 75' away from the entrance. A track field is located directly behind the building. All deliveries to site were timed for specific stages of the construction process. The erection of the building was done using a 60 ton hydraulic crane.

Electrical System

The electrical power will be an extension of the campuses infrastructure. The main feeder will be branched from the neighboring inn building providing 480/277V to the Science & Technology Center. A 400A breaker at the main distribution panel will receive the supply. The overall system consists of 12 electrical panels. The emergency power will also be provided from the Inn buildings power grid.

Lighting System

The buildings lighting system will be primarily florescent with Lutron's EcoSystem digital electronic dimming ballasts. The EcoSystem utilizes sensors to detect additional outside light levels then automatically dims the interior lights to save energy. It also has occupancy sensors to turn the lights off when the rooms are unoccupied. The system has controls to allow an individual to control their light increasing or decreasing output to improve productivity and increase energy savings. This system could potentially save 50% of lighting electricity in return saving energy.

Mechanical System

The majority of the mechanical system is located on the half story above the second floor. It will consist of two air handling units (AHU) 6,500 & 8,000 CFM with packaged energy recovery wheels and economizer systems. The first floor will be supplied from the 6,500 CFM AHU and the second floor will be supplied by the 8,000 CFM AHU. The supply air will be controlled by a variable air volume system. There will be a 57.1 ton chiller installed at a remote location for system use. The domestic water, fire suppression, heated water and power will be supplied from the campuses central plant as an extension of the campuses infrastructure.

Structural System

The primary structural system for the Science & Technology Center will be structural steel with steel braced frame for lateral support. The foundation system will be 4000 PSI reinforced concrete strip footing and concrete wall. The bottom of footing will need to be located at a minimum depth of 3' for frost protection. Reinforced concrete spread footings will be used as the base for each structural steel column. The first floor will consist of a 5", 4000 PSI 6 x6 welded wire fabric (WWF) reinforced concrete slab-on-grade. The second and attic floor slabs will be 5 1/4" concrete and metal deck reinforced with WWF and rebar ties to the steel columns. The use of shear studs which will protrude through the metal deck and will be welded to the steel beams create a composite reaction with the steel members and the concrete slab. The structural steel system will be comprised of columns ranging from W8x24 to W8x48 and beams/girders ranging from W8x10 to W24x84. The steel braced frame will have a combination of hollow structural steel (HSS) and wide flange sections. The HSS will be field welded to plates connecting the HSS to the structural wide flange sections creating a resistance to lateral forces.

Fire Protection System

The fire protection system will be a wet pipe sprinkler system designed for a NFPA 13 light hazard and ordinary hazard occupancy. Supply water for fire suppression will be provided by the campus infrastructure. There will also be fire department connections on the exterior of the building to provide additional water.

Transportation System

There will be one passenger traction elevator for the building. It will be a 2500 lb capacity elevator with a 6.7 hp motor and travel at 150 feet per minute. There will be a stop on each of the two floors. There will be two sets of stairs in the building one in the Northeast corner and the other in the Southwest corner.

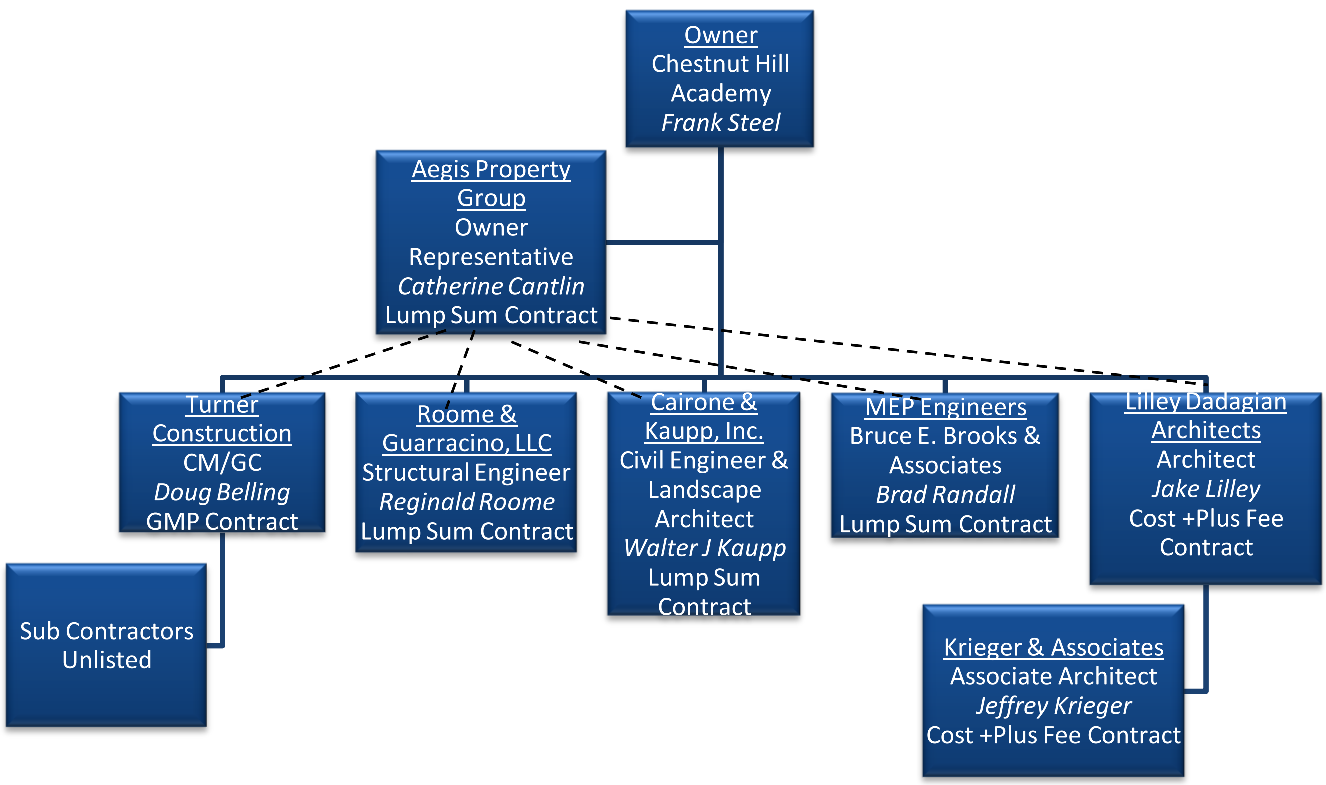
Special Systems

The New Science & Technology Center will be seeking LEED Silver rating. The certification will be gained by several sustainable features such as photovoltaic cells, solar panels, a wind turbine, grey water collection system and porous paving. The electricity gathered from the photovoltaic cells and wind turbine will be used as additional electricity for building use. The solar thermal panels will help heat water which will cut the amount being taken from the campus infrastructure. The designers planned on using innovative technology with the use of a roof top weather station which can monitor temperature, wind speed, and direction. As well as an interactive meter wall which will display information collected from the energy saving devices and environmental monitoring station, which teachers may use in their lessons.

Project Delivery System

The Science & Technology Center was designed by Lilley Dadagian and is being constructed by Turner. Both firms have had experience with school projects that had green design technologies involving classroom and laboratory buildings. There were no sub bonds required by owner. The owner hired a representative to act as a middle man between the GC, engineers, and architects. Having only one person reporting to them with updates and issues keeps the project running smoothly.

All contracts held between Tuner and their subcontractors are lump sum. This allows for easy payment requests as well as cost reimbursement for possible change orders.

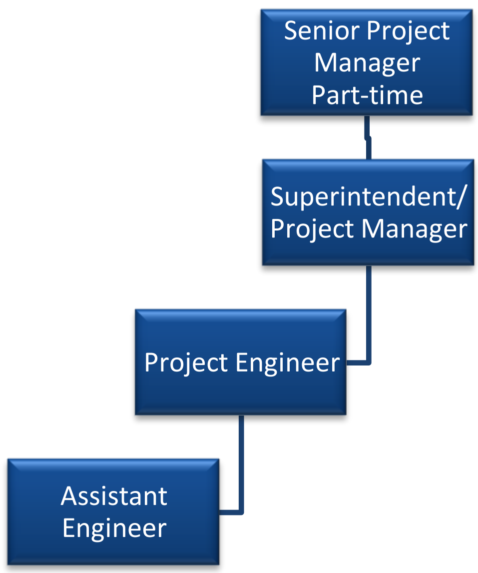


Turner Construction Staffing

Tuner Construction's staffing plan is as follows. The Senior Project Manager was only part time, the need for a Senior PM committed 100% of the time is not necessary for a project of this scope, Senior PM can act as a liaison between owner and contractor.

The PM/Superintendent will act as the operations lead and take charge of the team to mediate problems. He will also answer the RFI's that arise.

The project team worked very closely together on this project. Since the project was a smaller scale project in size, there was not much need for extended assistants and site managers.



Project Cost Evaluation

Project Cost information for the Science & Technology Center. These's costs are all initial construction design costs taken from an AIA G702 payment application from a contractor.

Project Construction Costs	Amount
Construction Cost	$ 8,383,700.00
Cost Per Square Foot	$ 312.01
Total Project Costs	Amount
Project Cost	$ 9,623,041.00
Cost Per Square Foot	$ 358.13

Construction Cost Break Down	Total	SF
Steel	$ 744,600	$ 27.71
Earthwork	$ 786,100	$ 29.25
Concrete	$ 424,600	$ 15.80
Surveying	$ 14,300	$ 0.53
Elevator	$ 76,500	$ 2.85
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
Misc. Metals	$ 126,600	$ 4.71
Millwork	$ 57,400	$ 2.14
Glass, Glazing, Curtain wall	$ 450,800	$ 16.78
Laboratory casework	$ 587,100	$ 21.85
Drywall, Carpentry	$ 713,000	$ 26.53
Flooring	$ 73,900	$ 2.75
Stucco	$ 51,500	$ 1.92
Ceramic Tile	$ 73,200	$ 2.72
Painting	$ 36,500	$ 1.36
Specialties	$ 16,600	$ 0.62
Window Treatments	$ 22,400	$ 0.83
Joint Sealants	$ 25,900	$ 0.96
Testing and Balancing	$ 16,900	$ 0.63
Landscaping	$ 12,600	$ 0.47
General Requirements	$ 166,100	$ 6.18
Total Direct Costs		**$ 8,358,200**

For a D4Cost estimate breakdown see Appendix B

Detailed Project Schedule Summary

The schedule for the Science & Technology Center starts in the design phase on 3/7/07 and last until 11/28/08 for an overall project time of 93 weeks. (*See Appendix F for Detailed Project Schedule)*

Project Milestones:	Begin	End
• Proposal/Award Phase	**3/7/07**	**3/20/07**
• Preconstruction Period	**3/7/07**	**11/26/07**
• Procurement	**6/11/07**	**12/11/07**
• Construction Begins	**11/23/07**	**11/23/07**
○ Site work	**11/23/07**	**1/25/08**
○ Structure	**12/19/07**	**4/25/08**
○ Building Envelope	**3/31/08**	**9/12/08**
○ MEP Systems	**1/7/08**	**11/28/08**
○ Interiors	**5/26/08**	**11/7/08**
• Substantial Completion	**11/28/08**	**11/28/08**

Analysis 1: Exterior Façade Construction Redesign (Mech. Breadth)

Introduction

The façade of the building consists of field stone masonry and stucco. The lower portion of the exterior wall is made up of various sized ashlar patterned stone masonry units. The construction of this must be done by experienced masons and done so that the weight of the stone does not crush the mortar joints, which limits the number of rows of stone that can be placed before the mortar sets.

Reasoning for Redesign

The use of the natural stone slows down production of the activity which also slows down the remaining façade activities such as the upper stucco portion. This area of the wall itself takes 12 weeks to erect and is the longest activity of the building envelope. The remaining trades must follow the stone mason around the building finishing each portion of their work at a slow pace.

Figure 1 Existing Stone Veneer Construction

Goal

In an effort to speed up this activity as well as save money, the stone masonry system will be examined in its worth compared to a precast stone wall. The precast stone by Owens Corning called Cultured Stone from has the potential of saving material cost as well as schedule time. Erecting the precast could possibly reduce the original stone duration significantly; therefore, the schedule acceleration impact will be studied. Quality control will also be a bonus due to the automated manufacturing processes.

Figure 2 Proposed Cultured Stone Veneer

In order for this system to work, the owner and architect would need to approve of the aesthetic qualities in comparison to the natural field stone. Due to the projects sustainability background the LEED issues must also be investigated in the areas of recyclability and local manufacturer availability.

The mechanical impact on the exterior wall due to R value change must be studied to find out if any addition insulation will need to be added to bring the R-value back to its required value.

Steps

1. Review existing make up of exterior wall
2. Select Precast Stone (Cultured Stone) to replace existing natural stone
3. Determine Costs and Schedule changes
4. Compare costs and durations with existing wall
5. Analyze impact on exterior wall R-value and mechanical loads
6. Review and make Recommendations

Tools

- Cultured Stone Manufacture
- Athenia Mason Supply
- R.S. Means 2009
- Green Building Design Studio
- Revit Architecture / MEP

Constructability Issues

The previous façade material was placed by the masons and took 12 weeks long. Since this task was 12 weeks long it was the longest activity of the enclosures. The reason for this was due to the stones weight (approx. 60lbs/sf) crushing the mortar joints, the stone had to be placed in lifts allowing for the lower lift's mortar joints to cure enough that the weight of the next lift would not crush them.

The precast stone product by Owens Corning called Cultured Stone weighs approximately 15lbs/sf which is significantly lighter then natural stone. This will allow the masons to place the stone all at once without the fear of the mortar crushing. Since the stone will no longer be placed in lifts the overall time for the stone placement will be reduced, speeding up the activity as well as the others following it.

Advantages of Precast Stone
Cheaper than natural stone
Faster construction time
Reduces field labor costs
Easy to maintain
Less site congestion

The backing of the stone will not need to change much except for the metal lath and scratch coat of mortar which is required to apply the stone. The following picture shows a common backing for the stone, they material will vary slightly for the Science Center

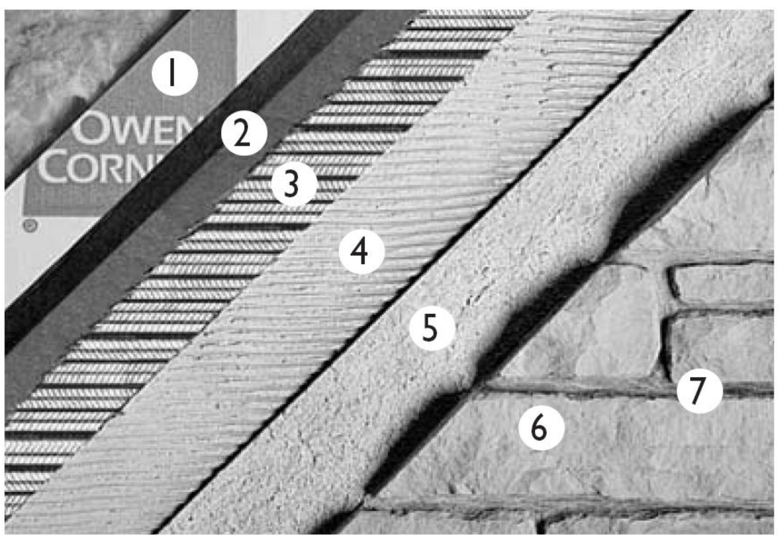


Figure 3: In sequence: (1) rigid foam insulation, (2) two layers of weather-resistant barrier, (3) metal lath, (4) scratch coat, (5) mortar setting bed, (6) Cultured Stone ® manufactured stone veneer, (7) mortar joint

The following wall detail is taken from the Cultured Stone manufactures details shows the stone product placed over the rigid insulation. Although the Science & Technology Center's cavity walls do not have fiberglass batt insulation, the wall detail is extremely similar.

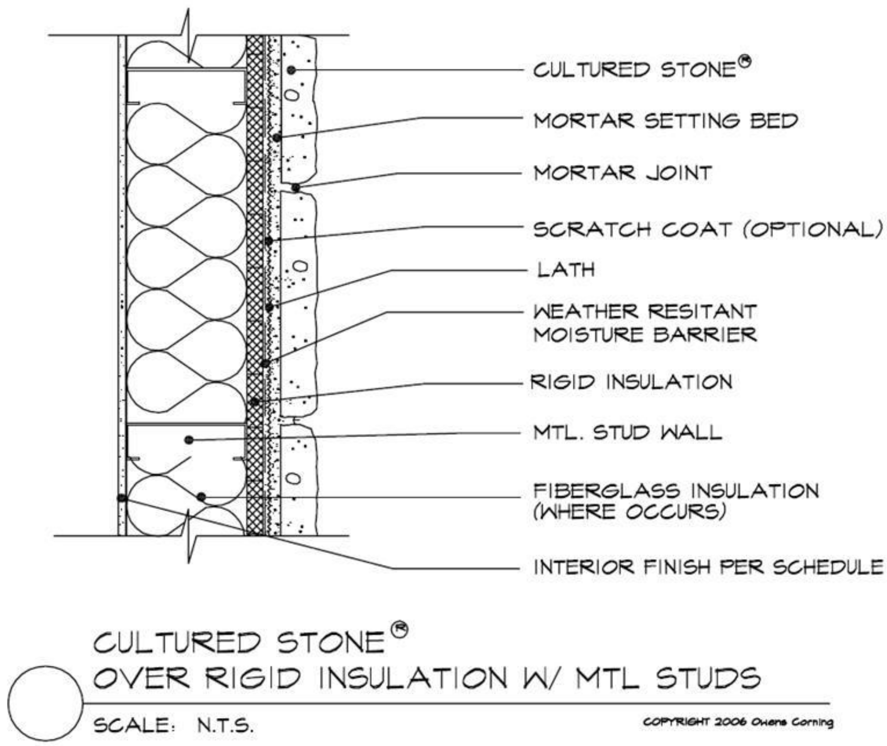


Figure 4 Wall Detail from Owens Corning Details

Steps to prepare the exterior surface:

1. Cover the wall surface (plywood, drywall, paneling, etc.) with a weather resistant (15 pound felt)barrier, lap joints by applying felt horizontally with the upper layer lapped over the lower layer not less than 2" and end laps not less than 6".
2. Install a minimum of 2.5 lbs diamond mesh metal lath. Use galvanized lath for exterior and black metal lath (non-galvanized) may be used for interior.
3. Lap lath sides not less than ½" and end laps not less than 1". Please note it is critical that the lath is attached with the small diamonds pointing upwards. On the inside and outside corners turn the corner 16" minimum each way.
4. Attach wire lath using a minimum of 1 ½ " galvanized nails or Staples on 4" centers vertically and to 16"centers horizontally penetrating studs a minimum of I".
5. After attaching the lath, apply a mortar scratch coat to cover the metal lath and apply the stone will the scratch coat is still moist. If the scratch coat dries before applying the stone, the scratch coat should be remoistened by spraying it with water.

Cost Estimation

The material quantities are determined by the following formulas. Special consideration must be taken for the corners because there are special corner pieces which wrap the edge to produce a seamless appearance. I contacted a material supplier for a product quote which can be seen in the following image:

Length x Height = Wall Area
Window Width x Window Height = Window Area
Lineal Feet of Corners Required x .75 = Wall Area Covered by Corners
Wall Area – Window Area – Wall Area Covered

ATHENIA *** INVOICE ENTRY *** tk
1)BILL TO: 100 2)SHIP TO: DELIVERED TO PHILADELPHIA,PA
COD SALE CONTRACTOR FLAT BED MUST HAVE LIFT ON JOB

INVOICE DATE: 03/26/09

JOB DESC: MIKE POTHERING 570-617-1833
EMAIL: MPOTHERING21@GMAIL.COM

SEQ	ITEM NUMBER	DESCRIPTION	QUANTITY	U	PRICE	EXTENSION
1	SSBBCCF1	B.B. CHARDONNAY COBBLEFIE	56.00	EA	499.00T	27,944.00
2	SSBBCCC2	B.B. CHARDONNAY COBBLEFIE	3.00	EA	474.00T	1,422.00
3	SSTWT1	PCS. TAUPE WATERTABLE/SIL	368.00	E	7.88T	2,899.84
4	WL25G	SHEETS #2.5 GALV WIRE LAT	313.00	E	4.00T	1,252.00

SALES TAX: 2,388.25 <F>REIGHT: 600.00 DISCOUNT: 0.00 TOTAL: 36,506.09

The final material cost amount which includes the exterior stone material, corner stone material, still cap stones, as well as the backing of galvanized wire lath totals to be **$36,506.09.** The estimated labor was taken at $16.15/SF. The total labor cost amounted to be **$85,165.** The total cost for the system is **$121,670.**

Façade System Pricing		
Precast Stone Veneer	**Material**	**Labor**
	$36,506	$85,165
	TOTAL	**$121,670**
Natural Stone Veneer	**Material**	**Labor**
	$126,564	$97,557
	TOTAL	**$224,119**
	Saving's	**$102,450**
	Percent Saving	**54.6%**

Mechanical Study

The study of the mechanical enclosure was done by the use of the program called Green Building Studio. This program is a feature used out of Autodesk Revit. It allows the users to evaluate the energy profile and carbon footprint of the building design. The system incorporates the building location, type, and size. The program takes the building details from the walls, roofs, and slabs then uses the information to calculate the estimated energy usage as well as carbon footprint. It is important to have a model that has accurate thicknesses as well as material types. The model also must have accurate room volumes, wall areas and the windows must be accurate for the values to be respectable. The information on the following page is the output taken from the Green Building Studio.

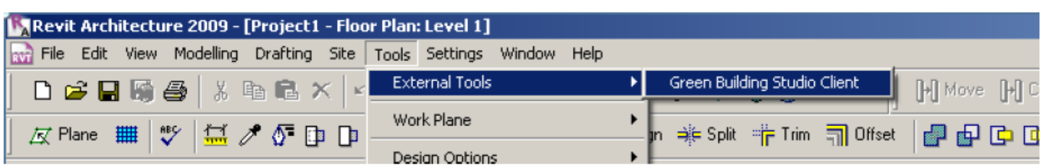
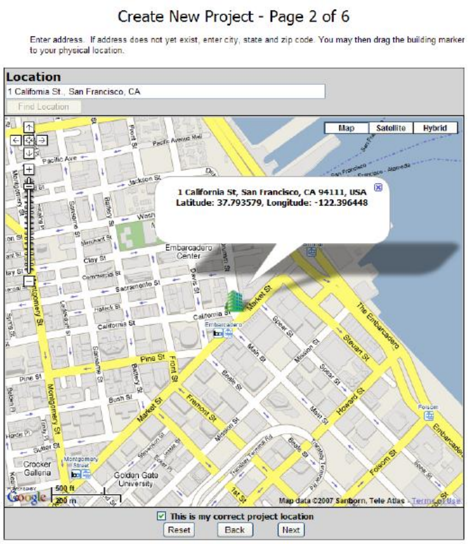


Figure 5 Exporting Revit Model to Green Building Studio



Name	CHA Science Center New	
Building Type*	SchoolOrUniversity	
Schedule	K-12 School	
Project Type	Actual Building Design Project Demonstration Only	
Country*	United States	
State/Province	Pennsylvania	
City	PHILADELPHIA	
Address		
Postal Code*	19119	
Currency*	$ - English (United States)	
Total Construction Budget	Make Selection	
Current Design Phase	Make Selection	
Estimated Construction or Renovation Start Date	Make Selection	
Green Building Goal	Make Selection	
Electric Utility	Pennsylvania state average	
Electric Cost	0.075 $0.00/kWh	
Fuel Utility	Pennsylvania state average	
Fuel Cost	0.321 $0.00/Therm	
Weather Location	GBS_04R20_251120 : 5.4 miles (8.7 km) - id = 54	Detailed weather information is viewable from the run result page.
Notes		
Data Access	Do not share any data associated with this project Share only summary data (e.g., bldg. type, floor area, etc.) Share all project data.	
Contact Preference	Only GBS may contact me regarding this project. GBS partners may contact me regarding this project	
Autodesk Green Building Studio Web Service Terms of Use (TOU)	Mike Pothering is authorized to accept the terms of the TOU and share project data with the GBS web service.	
* Building Type and Zipcode cannot be changed if runs are present		
Source of utility rates: Energy Information Administration (April 2008).		

Cancel

Figure 6 GBDS Project Information Settings

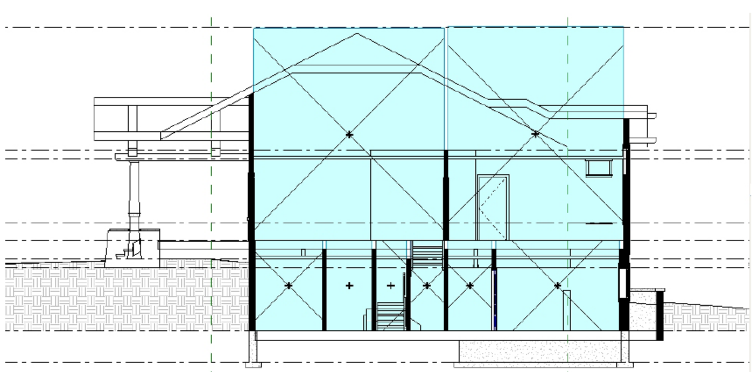


Figure 6—Revit MEP 2009 Section View: Height of Space Objects Correctly Defined

Figure 7 GBDS Correct Room Volume Modeling

Green Building Studio Analysis for Cultured Stone Veneer

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: SchoolOrUniversity

Floor Area: 23,272 ft²

Location Information

Building: PHILADELPHIA, PA 19119

Electric Cost: $0.08/kWh

Fuel Cost: $0.32/Therm

Weather: GBS_04R20_251120

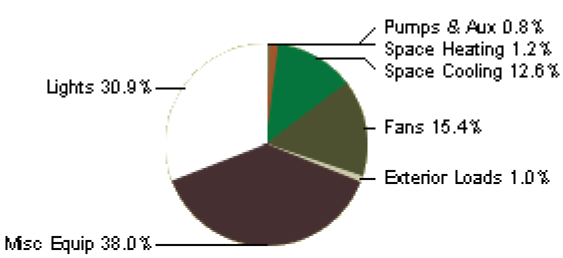
Estimated Energy & Cost Summary

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.

Energy End-Use Charts

Annual Electric End Use



Green Building Studio Analysis for Natural Stone Veneer

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: 6" Stone Wall

Building Type: SchoolOrUniversity

Floor Area: 23,194 ft²

Location Information

Building: PHILADELPHIA, PA 19119

Electric Cost: $0.08/kWh

Fuel Cost: $0.32/Therm

Weather: GBS_04R20_251120

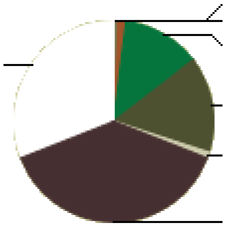
Estimated Energy & Cost Summary

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.

Energy End-Use Charts

Annual Electric End Use



When reviewing program's results the difference between the two materials became appartent and there is very little change between the two. The values calcuated for the lifecycle costs for the natural and Cultured Stone are **$271,719**and **$272,346** respectively. This is a difference of **$627**. Since the software's values were so similar, hand calculations for the wall's mechanical loads (heat loss and heat gain) were necessary. The following charts show the illustrate the calculations that were preformed for this study.

Mechanical Hand Calculations

Table 1 Natural Stone Veneer 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-Fº/BTU**
			U-Value	**0.0472**	**BTU/hr-sf-Fº**

Table 2 Cultured Stone Veneer R –Value Calculations

Cultured Stone Veneer	Item	Thickness	R-Value	Total R-Value	
Wall System					
	Outside Air Film	-	0.17	0.17	
	Cultured Stone	1.75"	-	0.62	
	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	**21.31**	**hr-sf-Fº/BTU**
			U-Value	**0.0469**	**BTU/hr-sf-Fº**

Table 3 Summer Temperatures in Philadelphia

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

Table 4 Winter Temperatures in Philadelphia

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

Table 5 Estimated Heat Loss comparison

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

Table 6 Estimated Heat Gain comparison

Estimated Heat Gain (summer)	U-Value (BTU/hr-sf-Fº)	Area (SF)	ΔT (ºF)	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

Mechanical Analysis Review

The R-value compositions of the two wall systems are extremely close, which embraced the fact that there would only be a small change in overall systems rated design. While the difference in the hand calculations heat loss is 66.74 BTU/hr and 0.002 tons of heat gain during the summer. Despite the change in wall thickness by a total of 4 inches the Cultured Stone product just closely out performs the natural stone veneer.

Recommendations

When reviewing both the Green Building Studio results and hand calculation results it is apparent that although the natural stone is 4” thicker then the precast stone, the impact on the walls thermal properties are relatively unnoticeable. The difference in the GBDS analysis is only $627 and the mechanical calculations are very small.

When looking at the cost savings from the precast stone being approximately $102,000 in material and installation alone would seem enough of a persuasion for the architect/owner to approve the change. Compared to the existing material it is a cost savings of 54% and the schedule acceleration of nearly 6 weeks. Its 50 year warranty is also excellent for the expected life cycle of this building. The Cultured Stone from Owens Corning ultimately would be recommended for the exterior façade.

Analysis 2: Solar System Redesign (Electrical Breadth)

Introduction

Today's building industry is heavily oriented in sustainable design. The use of solar powered energy systems to produced additional electricity to offset the user's reliance on grid supplied power is becoming extremely popular. The rising energy cost in America is one of the main driving forces pushing owners and developers to invest in solar energy. Another driving force is energy consumptions impact on the environment. Utilizing "free" energy from the power of the sun has reduced the impact on the environment immensely. Federal and State government have become wise to the importance of sustainable idea's and offer grants to owners who plan on using renewable energy on their projects.

Reasoning for Redesign

The Science & Technology center has chose to utilize PV panels on the upper flat roof of the building. These panels are the bracket mounted design from General Electric. Although this is a very good solar product, photovoltaic technology has advanced greatly in the past 10 years. Solar technology has allowed the systems to become integrated right into the building and used as part of the building envelope instead of attaching them to the roof or ground. This idea is called Building Integrated Photovoltaic's (BIPV) and is a relatively new technology. State-of-the-art systems can be blended into almost any part of the structure of the building. Using BIPV on the Science & Technology Center is a great opportunity for the school to show and express their love for sustainability not only by the idea but visually. The previous PV panels are placed on the upper flat portion of the roof which is 42'6" from the ground. Most students, staff, faculty and visitors will never see these panels which could make them go unnoticed and forgotten. The use of BIPV will allow the PV system to be constantly visible to all passerbies' which can express a great amount of free public relation for the school. This is important since the school relies on the public and government for some portions of their operation. The public will be much more willing to donate funds as well as possibly become active with the school.

Goal

The main goal for this analysis is to design a solar system which will not only generate supplemental electricity but to also give the Science & Technology Center the sustainable presence it was hoping to achieve. Also to research the use of BIPV systems on a building and to understand the process of installation and sizing. Furthermore address the benefits and downfalls of BIPV systems.

The Building Integrated Photovoltaic system, which will be researched for use on the Science & Technology Center, will be SUNSLATES by Atlantis Energy Systems, Inc. This solar product is integrated into the southern exposed roofing surface. It is used as the actual roofing system and fully encloses the area making it water tight and protected from all elements just like standard roofing materials. SUNSLATES are in the shape of a rectangular slate much like common concrete tile roofing. Although the Science & Technology Center's roof is constructed with asphalt shingles, these tiles are extremely aesthetically pleasing and will accent the roof extremely well. The slates have a 50 year limited warranty which is one of the longest warranties in the solar industry.

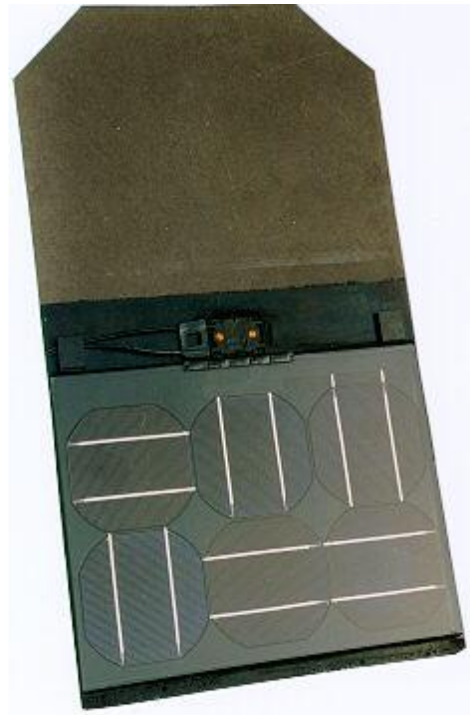


Figure 8 SUNSLATE by Atlantis Energy Systems, INC

Steps

1. Review existing photovoltaic system
2. Research new PV system roofing system
3. Determine new PV system size and layout
4. Determine potential energy output & savings
5. Analyze cost and schedule impact
6. Review payback period & system benefits
7. Make recommendation on PV system redesign

Tools:

- Surface meteorology and Solar Energy website sponsored by N.A.S.A's Earth Science Enterprise program
- Atlantis Energy Systems
- DSIRE Federal Incentives List
- Xantrex

Constructability Issues

The application of this BIPV system will be studied in two different applications. The first being installing two small areas of approximately 150 SF each on the southern facing roof. This application will be done for a smaller application of the system so it is comparable to the PV panel system already in designed. The second study with this BIPV system will be an entire south facing roof covered by the SUNSLATE's *(approximately 3,071 SF).* This will be done to compare the effectiveness of a larger system.

Figure 9 Small Area Roof Elevation

Figure 10 Entire Area Roof Elevation

Figure 11 2x2 Batten Example

The slates are attached to the roof by with the installation of a double overlap system. This system starts by laying a grid of fixed 2x2 battens arranged so the panels are attached in the double overlapping manor. This raised grid is attached directly to the roofs sheathing and creating a baffle for air to flow between the insulation and the slates. The overlapping of the slates provides a watertight seal creating the overlay much like standard shingles

and roofs are constructed. The system is somewhat labor intensive compared to standard shingles, but the outcome is well worth it. The slates can be installed by a regular roofing contractor who has the short training required to install this system.

The PV slates are connected with 20 slates in a series. Each set of 20 slates have a homerun which is fed back to a junction box which combines all the homeruns and is routed to the inverter. This short series helps minimize the amount of voltage drop across the junctions. The inverter converts the DC power created from the PV panels and converts it into usable AC electricity. This wiring can be done by the projects electrical contractor using standard wiring techniques.

The schedule impact for this system could be significant. The small area delay would be negligible due to the small amount of area, at the most it would add 3-5 hours more. The large area on the other hand would add potentially an additional 1-2 days. This added time is only taking account for replacing the asphalt shingles with this system. The remaining substrate construction time would not be impacted. Since the electrical work can be done by the electrical contractor on site that would possibly add an additional day to the electrical schedule. These times are all estimated and based on the type and amount of work to be done.

Figure 12 SUNSLATE installation

Calculated System Cost/ Savings

The calculated energy produced by each system can be found in the *Appendix G*. The following prices have numbers taken from those calculations. Each shingle can produce 12.2 watts. The shingles were priced at $15 per watt. Therefore the following calculation shows the prices of each system.

Existing System:

# of panels:

5

cost per panel:

$1235.29/panel

Total Cost of Panel's:

5 panels * $1,235.29 = **$6,176**

Small Area System:

# of shingles:

231

cost per shingle:

12.2W * $15/W= **$183/shingle**

Total Cost of Shingle's:

231 shingles * $183/shingle = **$42,273**

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**

The projected savings of the systems is based on the amount of energy it produces in a year. This was calculated by multiplying the kWh/year produced by the system by the cost of electricity, which is $0.0753 taken from PECO. The following short calculations support the tables which are found in *Appendix G.*

<u>Existing Panel's Savings</u>:

Savings Per Year

4,445.78kWh/year * $0.0753/ kWh = **$335 / year**

Payback Period

$6,176÷ $335/year = **18.4 years**

<u>Small Area Savings</u>:

Savings Per Year

12,529kWh/year * $0.0753/ kWh = **$943 / year**

Payback Period

$42,273 ÷ $943/year = **44.8 years**

<u>Entire Roof Savings:</u>

Savings Per Year

128,274 kWh/year * $0.0753/ kWh = **$9,659 / year**

Pay back Period

$432,795 ÷ $9,659/ year = **44.8 years**

Recommendations

The prices calculated for these figures are drastically different. When sizing the initial system of roof mounted PV panels, the idea was to incorporate solar technology without putting a large strain on the budget of the building. The existing roof system consisting of the 5 200W panels costs approximately $6,200 and will take nearly 19 years to payback.

The advantages/disadvantages to using the new SUNSLATES by Atlantis Energy Systems are:

Advantages	Disadvantages
Architecturally Pleasing	Very Costly
Long life span	Unable to control Tilt
Produces renewable energy	Can be Labor Intensive
Integrated into building	Difficult to remodel
Replaces conventional materials	Long payback period
Public Relations	

Chestnut Hill Academy received a $50,000 dollar grant for the implementation of the solar technology on the building. This grant no without a doubt will cover the cost of the existing panel's as well as the installation with money to spare. The small area system with materials itself costs $42,273 the grant received would cover a large portion of the material/labor costs for the smaller system. The large area system costs $432,795 which is drastically larger and the small grant of $50,000 dollars would not impact the price very much. There also is the possibility of applying for a Federal grant from the USDA Rural Development program with which could be up to $100,000 would save ¼ of the price, but still not impact it enough to make the initial investment of $432,795 to be appealing to Chestnut Hill Academy.

Although it takes approximately the same amount of time to payback the two proposed systems, the existing system in place would better suit the owner since they do not want to kill their budget on solar energy alone. Therefore I would recommend using the existing system in place.

Analysis 3: Building Information Modeling

Introduction

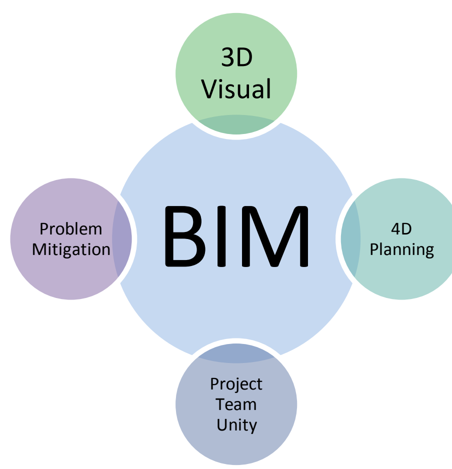
The construction industry today has a rising technology at its disposal in Building Information Modeling. This technology has a great potential for helping the construction process with overall quality, speed, and clarity. The ever more complex buildings of today and the future along with the standards we've become custom to can benefit with this technology in countless ways from 3D MEP models with clash detection to 4D animated models. The problem with this technology is that it is still not being utilized on some projects.

Problem Statement

The Science & Technology Center does not implement BIM technologies, which could greatly help in project coordination as well as serve the school as a teaching tool for the academy. The contractor RFI's and misunderstandings would be reduced with the ability to see the project in additional dimensions. The construction manager would be able to use the programs to assist in site layout as well as sequencing.

Goal

The goal of this research is to identify the benefits of implementing BIM on a project and develop an understanding of its use. As well as determine what is expected of the contributing parties in order to establish a comfortable and efficient construction environment. A basic 3D and 4D computer model will be created to help express the usefulness. Furthermore, a study of the usefulness of the models as an educational tool after completion for both client and builder will be conducted. Interviewing construction professionals for their opinions on BIM technology and if it would be a good investment for a project of this size. Contact current project team for their ideas and views regarding the BIM application.



Steps

1. Research Building Information Modeling
2. Research the use of 4D and 3D combination with the project
3. Develop 3D model using appropriate software
4. Develop a basic 4D model utilizing the construction schedule
5. Interview project members about the use of BIM
6. Summarize/Recommendations

Figure 13 Revit model rendered Images of the Science & Technology Center created by MRP

Tools

- Revit Architecture/Structure/MEP 2009
- NavisWorks Manage 2009
- Microsoft Project 2007

3D Modeling Process

When creating a 3D model in the industry there is much needed group coordination between everyone in the project. Beginning the design of the 3D model early in the process creates a very unique tool for architects, owners, and contractors which will allow them to review possible conflicts from design oriented ideas to construction layout conflicts.

A typical process for implementing BIM on a project consists of the following steps:

1. Contacting a design service which creates BIM models and explaining the project in detail
2. Sending the design firm the drawing/designs to allow the firm to study and become familiar with the layout and design
3. After the firm contacts the designers/engineers for any clarifications the modeling firm will quote the project including cost and time for creation
4. Once an agreement is reached the modeling firm will begin creation of the preliminary drawings/model
5. The preliminary drawings/model are sent to the owner & designer for approval
6. Once the preliminary stage is approved the modeling firm will complete the final model/drawings and put them through a Quality Check & Auditing for Quality Assurance

The process used to create the 3D model for the Science & Technology Center began by reviewing the construction documents provided by Turner Construction. Once familiar with the building, floor plans were created in Revit Architecture using the wall feature. This command allowed the walls to be the correct thickness as well as height which would later benefit the 3D view. Once the exterior walls are laid out the foundation walls and spread footings could accurately be placed below grade. Following that the upper floors were placed along with the roof. Once the shell of the building is designed the interior partitions can be measured and placed much more efficiently, making it easier to place the structural steel frame. It was important to ensure the correct connections between the models elements were made since the model would later be used to create the basic 4D model.

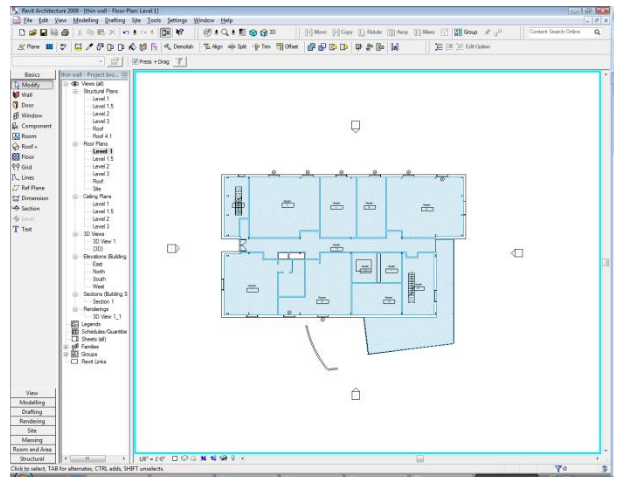
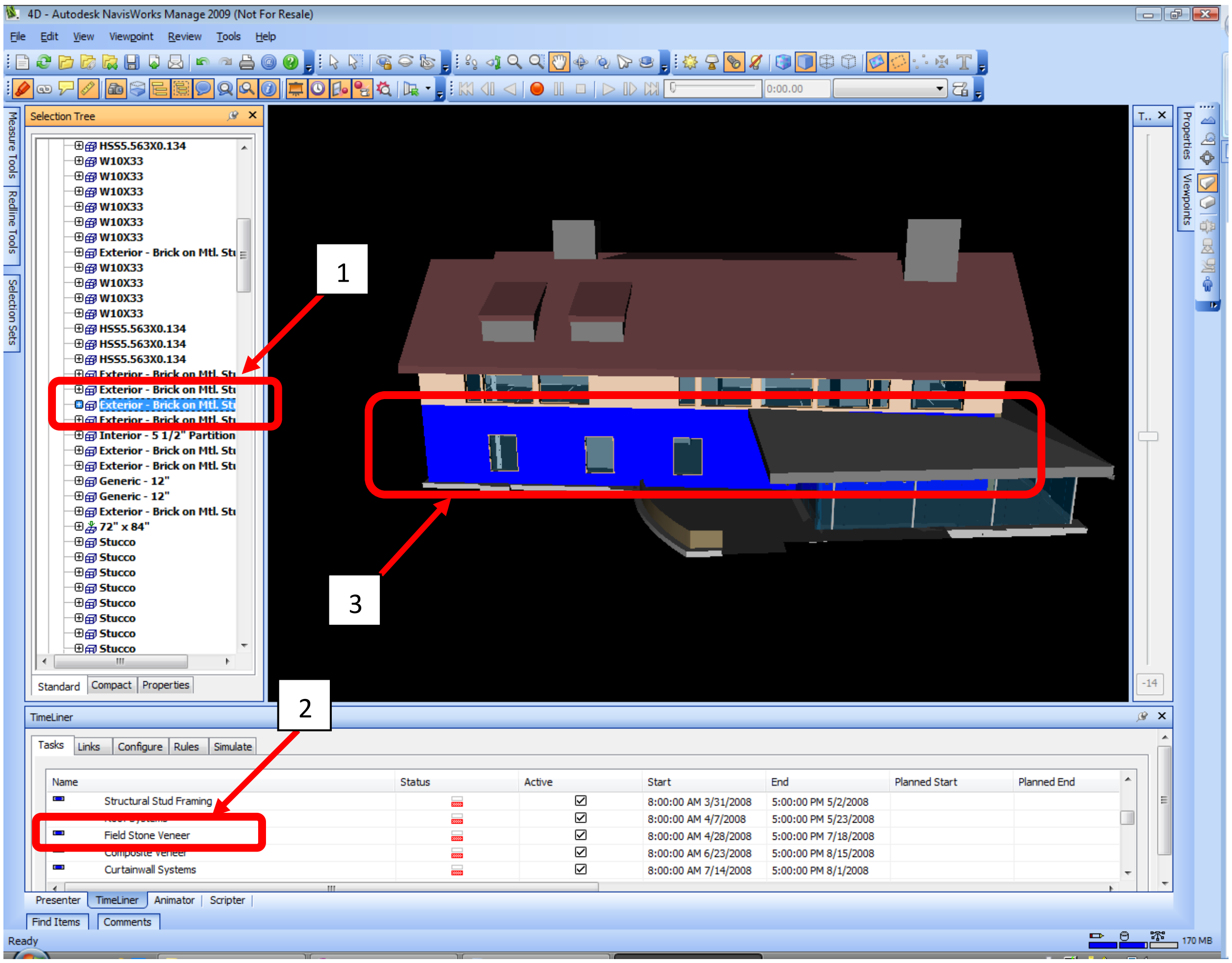


Figure 14 Snapshot of the Revit Model Creation

4D Modeling Process

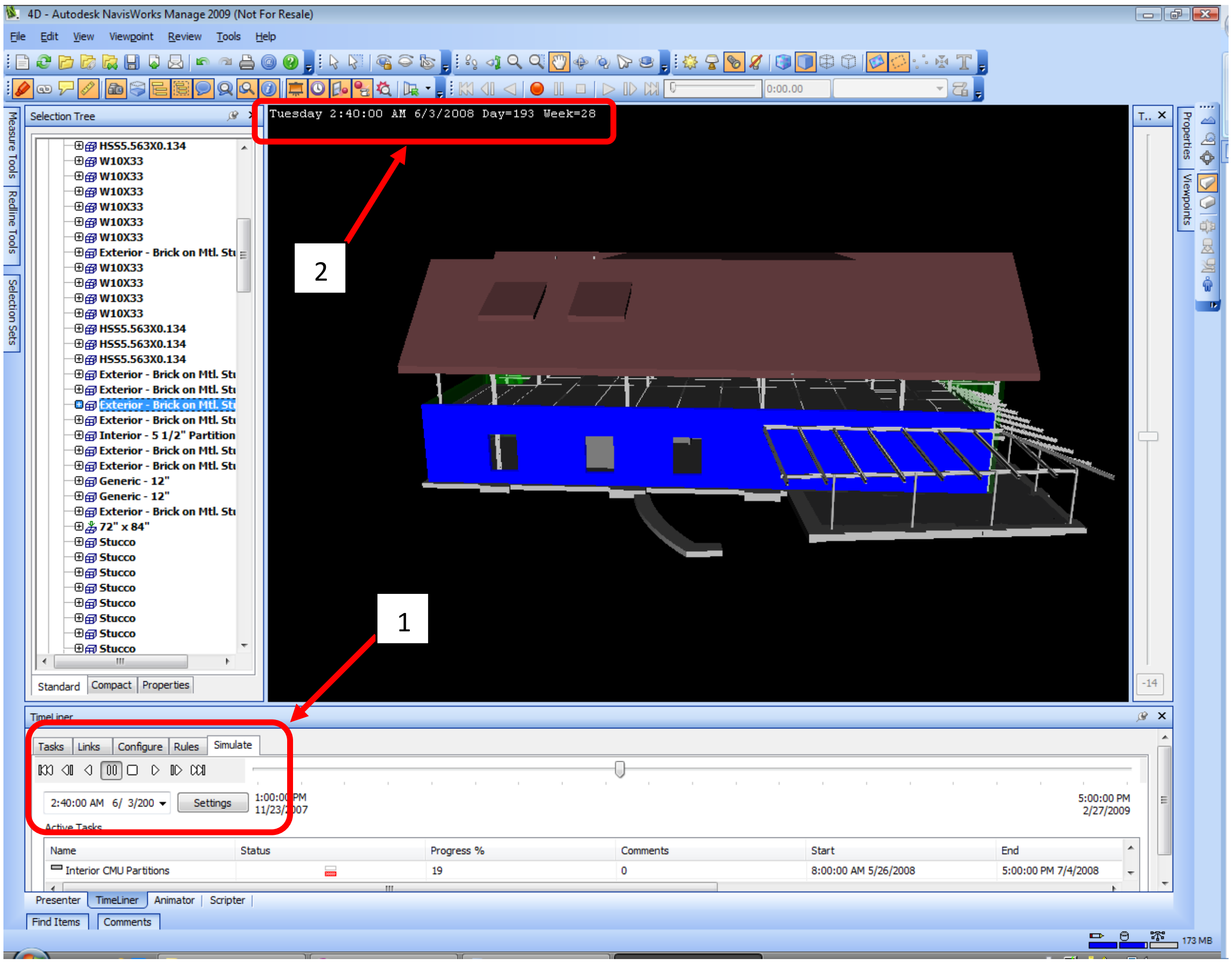
The methodology behind creating a 4D model follows much of the same ideas as designing the 3D model. The 4D model is an addition dimension of time added to the 3D model. This model shows the construction process visually by orienting the elements used to create the 3D model and linking them to a construction schedule imported into the software. The more detailed the project schedule is will directly affect how the 4D model will effectively convey the construction sequencing and processes. The 4D model allows every member of the project team to visualize the sequence and phasing of a building as the schedule progresses.

Once the 3D model is completed it can be combined with the projected schedule in a software package from Autodesk called NavisWorks Manage 2009. This software provides groups of each of the individual elements that make the 3D model. These elements can be associated with the schedule's line items and visually erected in a construction simulation. The following images show this process with screen shots from the NavisWorks program.



Notes:

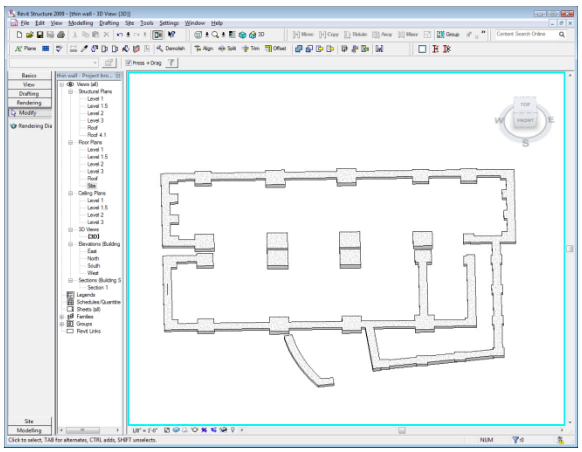
1. Selecting the model element which you wish to link to the schedule activity in the Selection Tree tab highlights the element BLUE in the 3D model.
2. While having the model element selected, select the schedule activity from the Timeliner's list of Tasks which were imported from the project schedule and attach/append the element to the activity.
3. The selected element glows blue while having it selected in the Selection Tree tab.



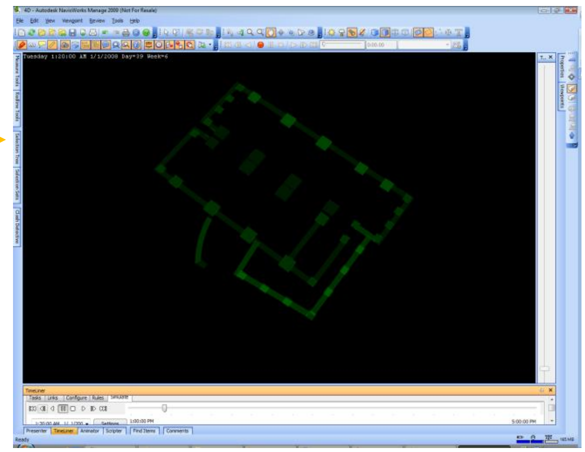
Note:

1. Once you have the model elements linked you can click the Simulate tab in the TimeLiner menu to view the 4D erection of your elements.
2. A time tracker will appear in the top left corner of the simulation showing the (Week Day, Time, Date, Project Day, Project Week) this will update every time an activity is being performed and finished.

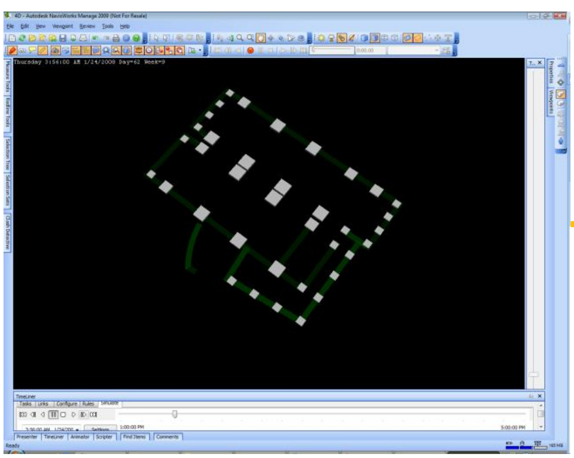
An example of how the 3D and 4D models correlate with each other can be expressed by showing the structural system modeled in the 3D modeling program. Then by showing how the 4D model step by step constructs the building by the projects schedule. The following images show how the sequence can be expressed through the programs.



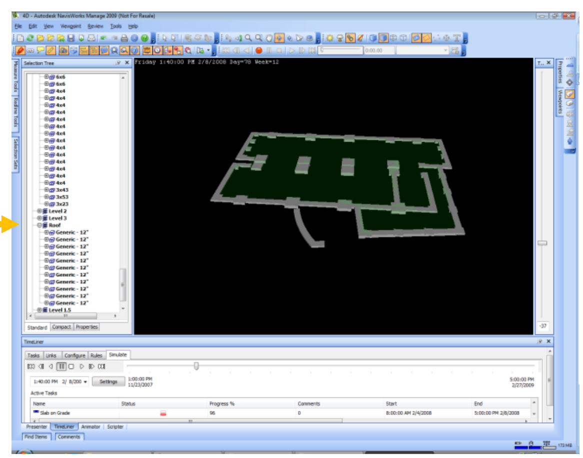
Foundation elements designed in 3D model



Foundation being constructed in 4D model



Foundation construction in 4D continued



Structural System designed in 3D Model

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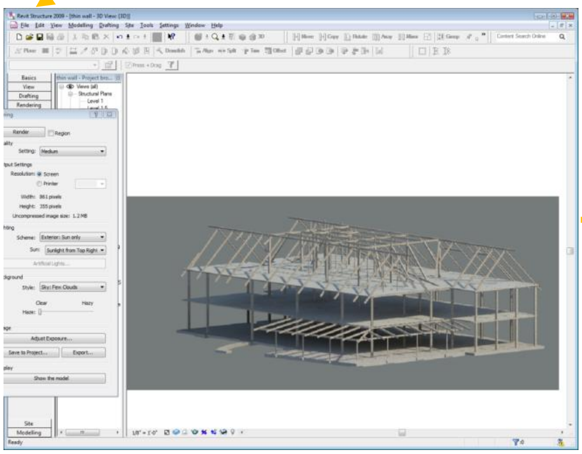
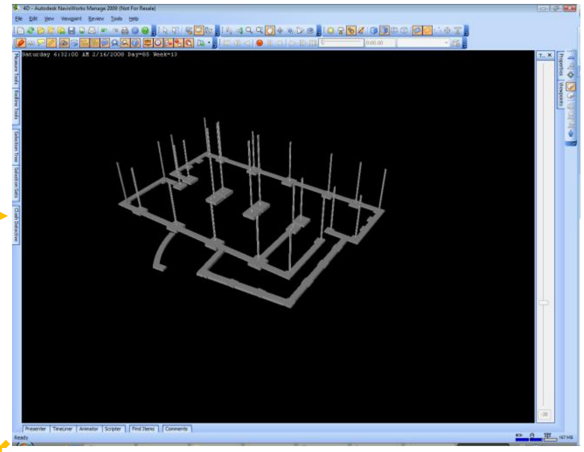
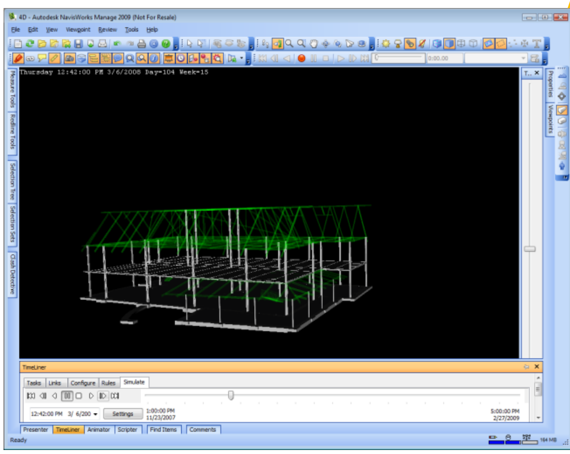


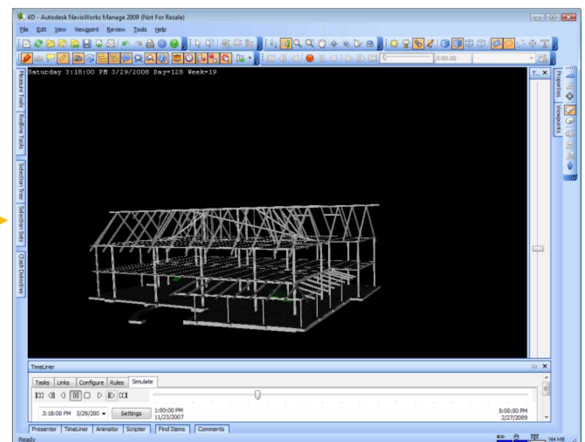
Structural System designed in 3D Model



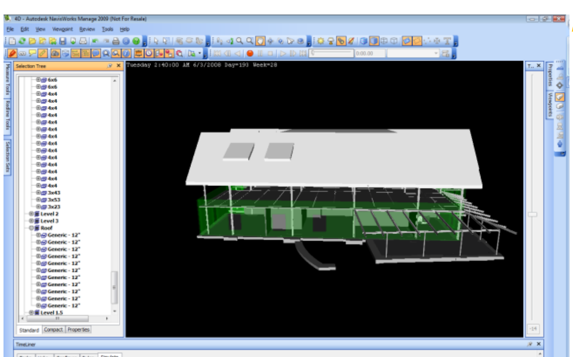
Foundation system in place with Steel Columns being erected in 4D



Steel members erected while addition members are being set in place in 4D



Structural Steel columns, beams, roof rafters all erected in 4D



Roof Decking in place while exterior wall construction begins in 4D

Actual picture of Structural System erected on schedule showing the accuracy of the 4D & 3D combination

BIM Questionnaire

Consulting the project team on the implementation of BIM technology on the Science & Technology Center was an important part to fully understand its capabilities and limitations on this project. There were several questions asked of the project manager as well as the project architect to gain their views on BIM technology. The following questions were asked of each individual with their reply's respectively following:

Questions

1. What do you believe would be the benefits of having BIM technology's on the Science & Technology Center?
2. What are the necessary steps required in implementing BIM on the project?
3. Why was BIM not used on this project?
4. How does your company initiate BIM on projects?
5. Were there any conflicts that could have been avoided if BIM was used?
6. How can BIM be used after the completion of a project for educational purposes?

Project Architect Response

Steve Dadagian from Lilley.Dadagian Architects

1. What do you believe would be the benefits of having BIM technology's on the Science & Technology Center?
   - "We used some 3-D modeling during design on Rhino (see Image1) , using it to help us with the massing/scale issues and also used it at the interview to get the job"
   - "At some level we render all of our projects during the design phase to help the client and ourselves visualize"

Figure 15 Rhino Rendering from Lilley Dadgian

2. What are the necessary steps required in implementing BIM on the project?
   - "We sketch by hand then input a project into CAD"
   - "Send CAD file to a consultant to render a schematic model usually in the Rhino software"

3. Why was the BIM technology such as the 3D/4D models not used for this project?
   - See Question #1
     - "We used some 3-D modeling during design on Rhino, using it to help us with the massing/scale issues and also used it at the interview to get the job. "
     - "At some level we render all of our projects during the design phase to help the client and ourselves visualize"
   - We had the watercolor rendering done (see Image 2) to appeal to the local agencies i.e. historical commission to present a more artistic and warm image consistent with the architecture. We have not been able to purchase BIM yet – it is a whole different way of working – once it is better tested and the bugs worked out (and less $$$) we will probably adopt it.


Figure 16 Water Color Image from Lilley Dadagian

4. How does your company initiate BIM on projects?
   - Not used

5. Were there any conflicts that could have been avoided if BIM was used?
    - "We probably would have avoided some coordination issues but on a project of this size (medium size) it probably would not have helped much relative to the amount of effort required to input the data into say Revit. This software is ideal for complex projects where your consultants are using the same software – right now large firms that afford the investment in the software and training"

6. How can BIM be used after the completion of a project for educational purposes?
    - I could see it as a fun tool to teach how a building goes together
    - I wish I had it in school, of course when I was in school we drafted by hand!

<u>Project Construction Manager Response</u> – Done over phone, answers are interpreted
Mr. Adam Rochmacker from Turner Construction

1. What do you believe would be the benefits of having BIM technology's on the Science & Technology Center?
    - The coordination between trades
    - Would help minimize confusion

2. What are the necessary steps required in implementing BIM on the project?
    - To implement BIM on a project it would require training, as for he has little training with much of this technology

3. Why was the BIM technology such as the 3D/4D models not used for this project?
    - A 3D model was used for the steel construction with the program called StruWalker, it was utilized to visualize the members & connections
    - The project is a smaller scale project, BIM is usually used on Large scale projects such as office buildings and hospitals
    - The cost savings from the implementation of BIM on this project would not be worth it compared to the cost of training and model production

4. How does your company initiate BIM on projects?
    - Turner has a team of trained BIM technicians that handle the BIM aspects of their larger jobs.
    - Turner also has a LEED trained person who takes care of the BIM LEED aspects

5. Were there any conflicts that could have been avoided if BIM was used?
    - Conflicts that could have been avoid during the construction of this were avoiding coordination errors between the ductwork and plumbing lines
    - It will also assist with the coordination of all the trades

6. How can BIM be used after the completion of a project for educational purposes?
    - The construction management team would be able to use the models to help show and visualize where the mistakes were made on the project
    - As well as what went good & bad along with how to avoid these situations. It may also show the challenges and what could have been done more effectively

Recommendations

The use of BIM technology in the industry is becoming an extremely valuable tool. Every project in some way or form could benefit from the use of BIM. The problem with using BIM on every project in the market today is that all the construction industry professionals are not training with its use. The cost of implementing BIM on projects can be costly from the initial personnel training and the modeling costs. I believe in the future the training for these individuals will become more standard and the prices will decrease.

The Science & Technology Center used some aspects of BIM technology like the Architects use of the Rhino modeling for massing purposes to the Steel member modeling to aid in construction. It was not totally implemented on this project due to its smaller scale and project budget. It would have been hard for the Architect and CM to justify the need for full scale BIM modeling. Although there could have been benefits from using BIM the cost and schedule savings would not have been enough to warrant its use. The Architect as well as the CM also lacked BIM training. Since the training was insufficient there would need to have been much more time and effort put towards it, which both companies did not believe was necessary for this project.

The educational side of the use of BIM technology after construction has several benefits towards owners as well as the construction/design professionals. Since the project was very science and technology oriented the use of 3D and 4D model could have been very unique. The 3D& 4D model could be displayed on monitors in the lobby for students and visitors to interact with and understand how the building design and construction process was completed. This side of BIM technology for client educational purposes after construction is an extremely new topic and can benefit the construction industry immensely by educating the owners on construction principles. As for its use with the construction professionals, it offers the chance for a better project review. They could use it to illustrate the problems and challenges faced on completed or ongoing projects which may help avoid similar situations.

In conclusion I believe the amount of BIM technology used on the Science & Technology Center was sufficient due to the lack of trained of personnel. However, it still may hold a unique educational opportunity for the academy.

Summary and Conclusions

The first analysis which researched the redesign of the exterior façade material to the precast stone showed to be a promising change due to its cost and schedule savings. The original façade system had natural full depth field stone masonry which is very heavy which slowed down production as well as expensive to purchase. The Cultured Stone product did not affect the buildings envelope's insulation or heating and cooling loads with adds to its benefits. The alternative material change of the material from natural stone would have to be approved by the architect and owner to ensure it will meet the quality and standards initially set in the project scope. If it was approved it would be a great replacement for the existing veneer.

The second analysis looked at redesigning the existing photovoltaic solar energy system to a building integrated photovoltaic system. The proposed system would have taken place of a portion of the shingle roof and act as the roofing envelope material. From this study it showed that alternative system although aesthetically pleasing it was extremely expensive and not as efficient as the existing system. The payback period for the proposed system was 41% longer than the existing system which is unfeasible for the school to purchase. Therefore, the proposed change to SUNSLATE solar shingles is not recommended.

The third analysis was researching the implementation of Building Information Technology (BIM) on the Science & Technology Center. This research was composed of designing a 3D & 4D model and interviewing the project team for their views on the use of BIM. The interviews resulted in learning that the project team lacked training with the use of BIM. It also showed that the project's smaller scale was a large reason that BIM was largely not used. The project team did believe that the use of the technology, although not practical, would have undoubtedly benefited the construction process. Another side of this research was how it may be used after the construction was completed for educational purposes. It was believe that the 3D and 4D model would be an excellent tool for the school to display for the students and visitors to see. They would be able to interact with the 3D & 4D model which would allow them to better understand the construction process that was used to build the Science & Technology Center.

<u>Appendix A</u>

General Conditions

General Conditions Estimate

Item Description	Quantity	Unit	Cost/Unit	Total
Project Staff				
Senior Project Manager	40	Weeks	$3,375	$135,000
PM/Superintendent	53	Weeks	$2,750	$145,750
Project Engineer	53	Weeks	$2,100	$111,300
Assistant Project Engineer	53	Weeks	$1,800	$95,400
General Expense				
Job Trailer	12	Month	355	$4,260
Telephone/Fax	12	Month	88	$1,056
Daily Cleanup	370	Day	40.5	$14,985
Final Cleanup	1	% of Job	1%	$96,230
Office Supplies	12	Month	93.5	$1,122
Office Equipment	12	Month	171	$2,052
Dumpsters(2)	53	Week	550	$58,300
Portable Toilets (2)	53	Week	171	$9,063
Temporary Fencing	720	LF	4.92	$3,542
Temporary Utilities				
Lights & HVAC	12	Month	165	$1,980
Temp. Heat	268.7	CSF Flr	34.5	$9,270
Temp. Electric	268.7	CSF Flr	39.5	$10,614
Temp. Power	268.7	CSF Flr	51.7	$13,892
Insurance				
All Risk Insurance	1	% of Job	0.62	$59,662.85
Builders Risk Insurance	1	% of Job	0.24%	$23,095
Bonds				
Performance Bond	1	% of Job	2.50%	$240,576
			SUBTOTAL	**$1,037,150**
			Fee	$31,114
			Total	$1,068,264

Appendix B
D4Cost Software Estimate

Estimate of Probable Cost

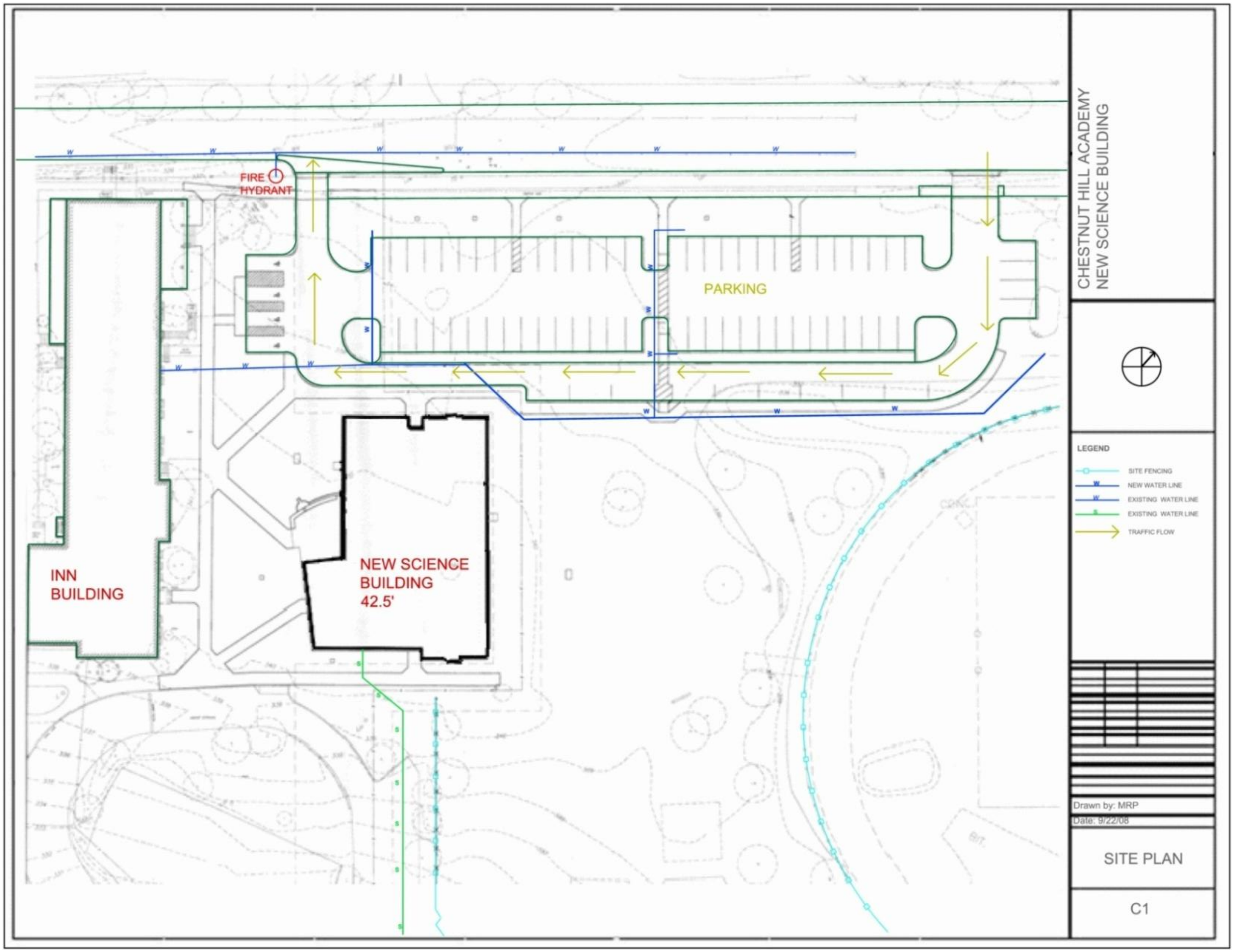
Project Information			
Prepared By	Michael Pothering	Prepared For	Technical Assignment 1
	,		,
	Phone:		Phone:
	Fax:		Fax:
Projected Size	26870	Projected Location	PA - Philadelphia
Building Height	42	Projected Date	Mar 2007
Building Use	Educational	Foundation	CON
Number of Buildings	1	Exterior Wall	STO
Site Size	1229130	Interior Wall	DRY
1st Floor Size	0	Roof Type	ASP
1st Floor Height	13	Floor Type	VCT
Number of Floors	2	Project Type	NEW

Building Costs

Division #	Label	Projected %	Projected Sq. Cost	Projected
00	Bidding Requirements	0.75	2.59	69,560
	Bidding Requirements	0.75	2.59	69,560
01	General Requirements	5.77	19.91	534,855
	General Requirements	5.77	19.91	534,855
02	Site Work	7.87	27.15	729,507
	Site Work	7.87	27.15	729,507
03	Concrete	3.28	11.30	303,610
	Concrete	3.28	11.30	303,610
04	Masonry	3.49	12.04	323,595
	Masonry	3.49	12.04	323,595
05	Metals	7.03	24.27	652,146
	Metals	7.03	24.27	652,146
06	Wood & Plastics	0.94	3.24	87,141
	Wood & Plastics	0.94	3.24	87,141
07	Thermal & Moisture Protection	2.11	7.29	195,838
	Thermal & Moisture Protection	2.11	7.29	195,838
08	Doors & Windows	1.53	5.28	141,820
	Doors & Windows	1.53	5.28	141,820
09	Finishes	4.10	14.16	380,548
	Finishes	4.10	14.16	380,548
10	Specialties	0.52	1.78	47,857

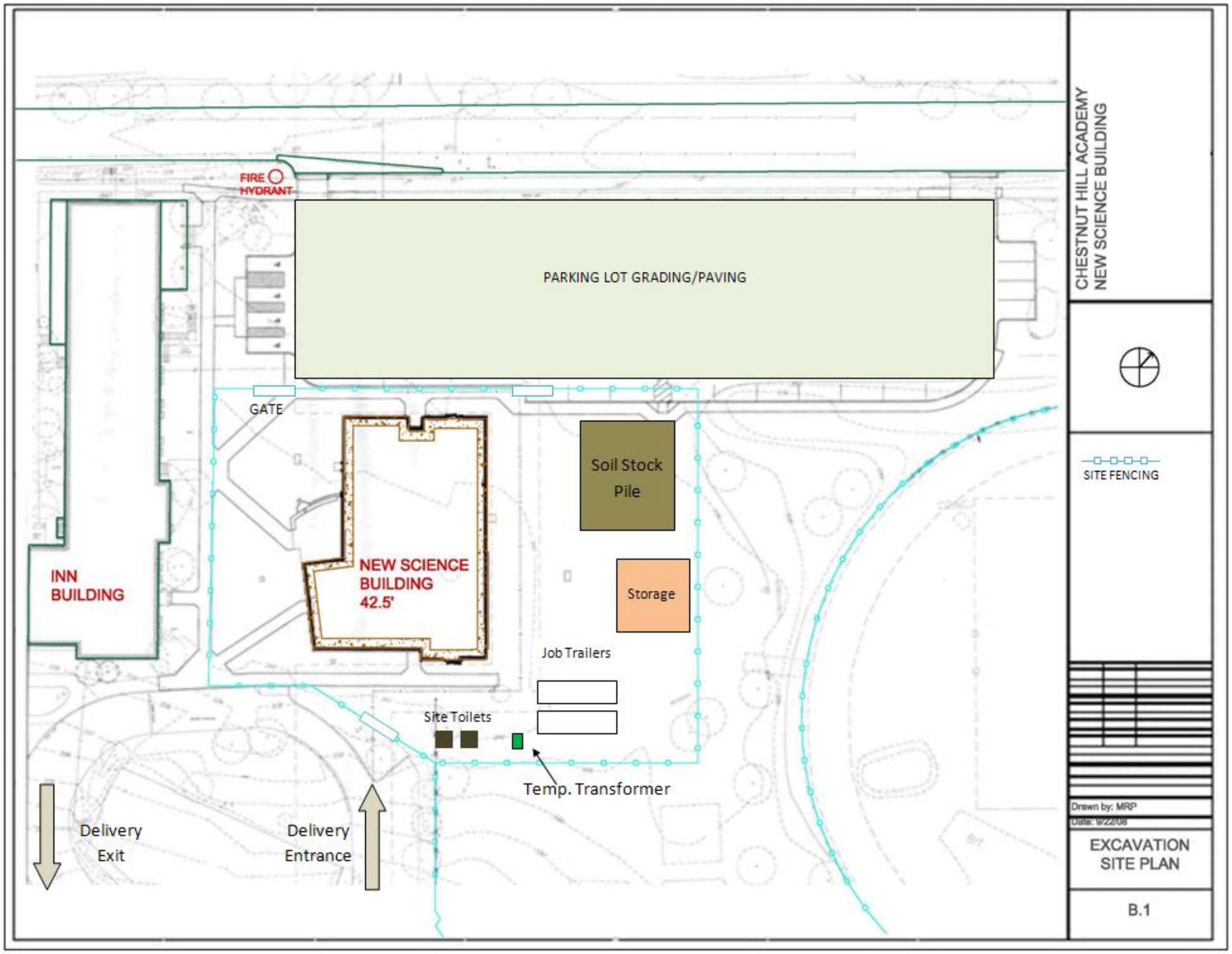
	Specialties	0.52	1.78	47,857
11	Equipment	4.00	13.80	370,841
	Equipment	4.00	13.80	370,841
12	Furnishings	3.71	12.78	343,523
	Furnishings	3.71	12.78	343,523
13	Special Construction	0.93	3.22	86,483
	Special Construction	0.93	3.22	86,483
14	Conveying Systems	0.43	1.50	40,254
	Conveying Systems	0.43	1.50	40,254
15	Mechanical	9.29	32.04	860,867
	Mechanical	9.29	32.04	860,867
16	Electrical	4.97	17.13	460,308
	Electrical	4.97	17.13	460,308
21	Fire Suppression	0.79	2.73	73,314
	Fire Suppression	0.79	2.73	73,314
22	Plumbing	2.48	8.57	230,236
	Plumbing	2.48	8.57	230,236
23	HVAC	17.88	61.69	1,657,616
	HVAC	17.88	61.69	1,657,616
26	Electrical	9.93	34.25	920,216
	Electrical	9.93	34.25	920,216
27	Communications	0.83	2.85	76,641
	Communications	0.83	2.85	76,641
28	Electronic Safety and Security	0.44	1.52	40,972
	Electronic Safety and Security	0.44	1.52	40,972
31	Earthwork	0.80	2.75	73,834
	Earthwork	0.80	2.75	73,834
32	Exterior Improvements	1.21	4.16	111,894
	Exterior Improvements	1.21	4.16	111,894
33	Utilities	4.93	17.01	457,040
	Utilities	4.93	17.01	457,040
	Total Building Costs	100	345.01	$9,270,515

Appendix C
Project Site Plan



FIRE HYDRANT
PARKING
INN BUILDING
NEW SCIENCE BUILDING 42.5'
CHESTNUT HILL ACADEMY
NEW SCIENCE BUILDING
LEGEND
SITE FENCING
NEW WATER LINE
EXISTING WATER LINE
EXISTING WATER LINE
TRAFFIC FLOW
Drawn by: MRP
Date: 9/22/08
SITE PLAN
C1

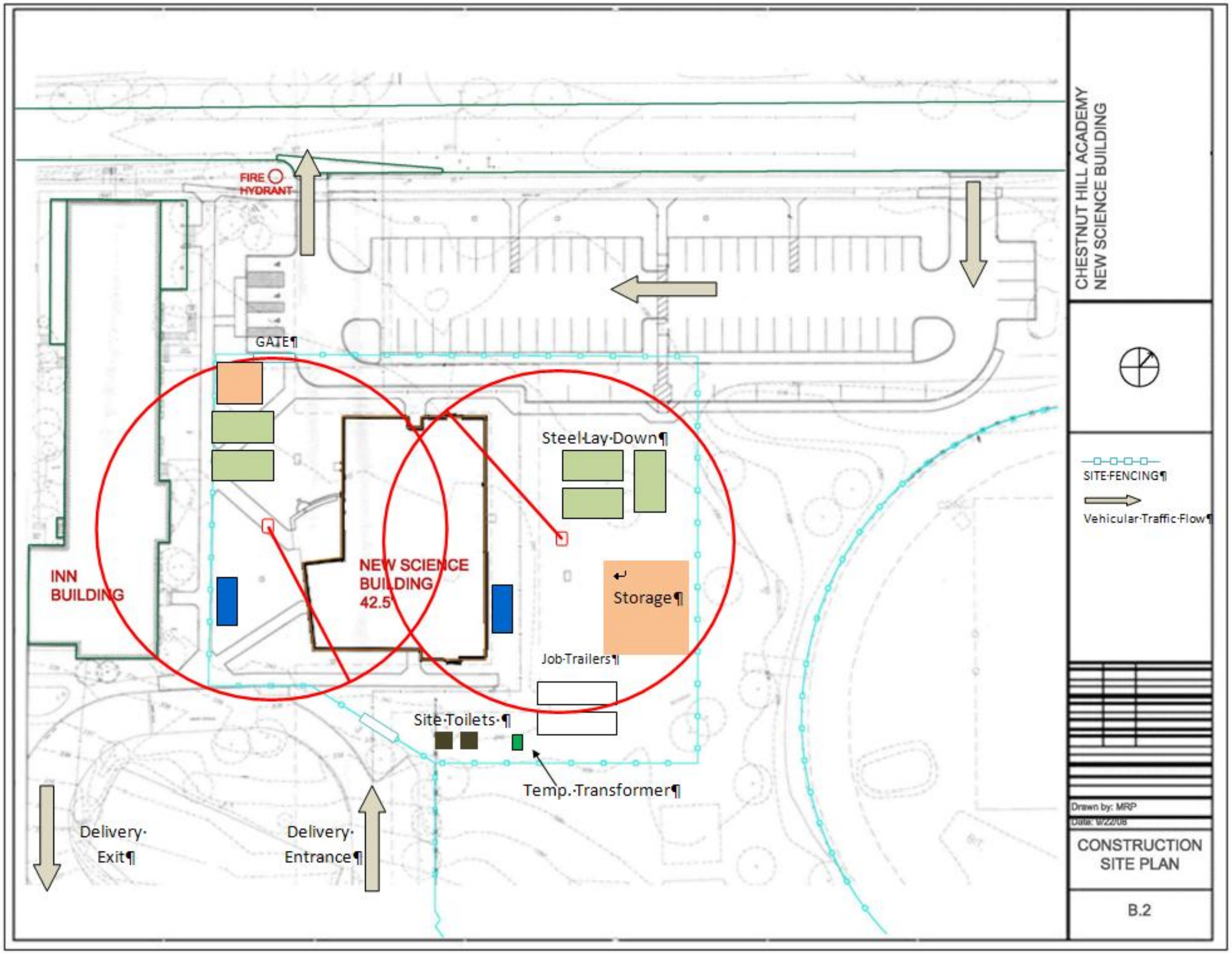
<u>Appendix D</u>
<u>Project Excavation Plan</u>



FIRE HYDRANT
PARKING LOT GRADING/PAVING
GATE
Soil Stock Pile
Storage
INN BUILDING
NEW SCIENCE BUILDING 42.5'
Job Trailers
Site Toilets
Temp. Transformer
Delivery Exit
Delivery Entrance
CHESTNUT HILL ACADEMY
NEW SCIENCE BUILDING
SITE FENCING
Drawn by: MRP
EXCAVATION SITE PLAN
B.1

Appendix E

Project Construction Plan

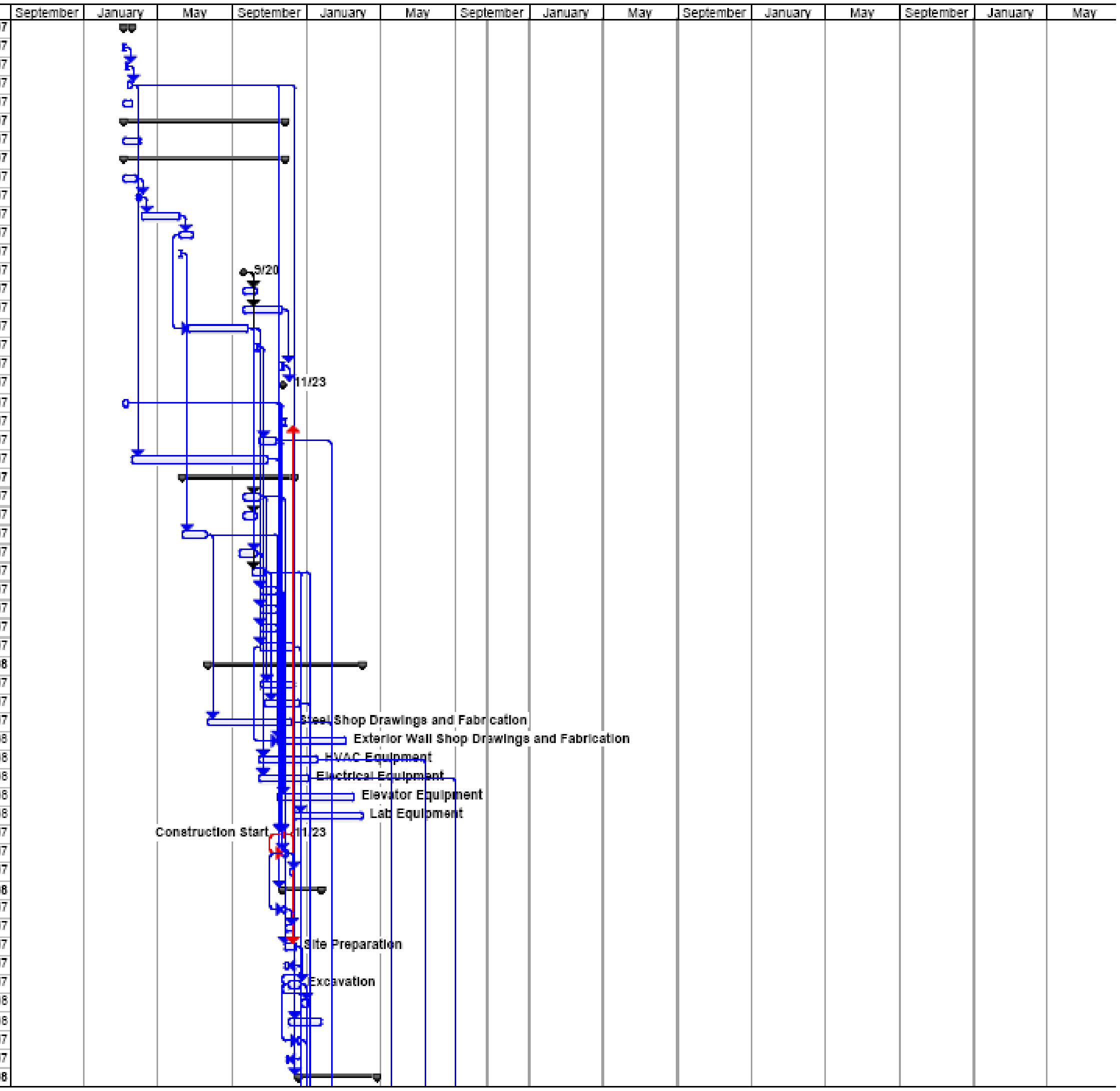


FIRE HYDRANT
GATE
Steel Lay Down
INN BUILDING
NEW SCIENCE BUILDING 42.5'
Storage
Job Trailers
Site Toilets
Temp. Transformer
Delivery Exit
Delivery Entrance
CHESTNUT HILL ACADEMY
NEW SCIENCE BUILDING
SITE FENCING
Vehicular Traffic Flow
Drawn by: MRP
CONSTRUCTION SITE PLAN
B.2

Appendix F
Detailed Project Schedule

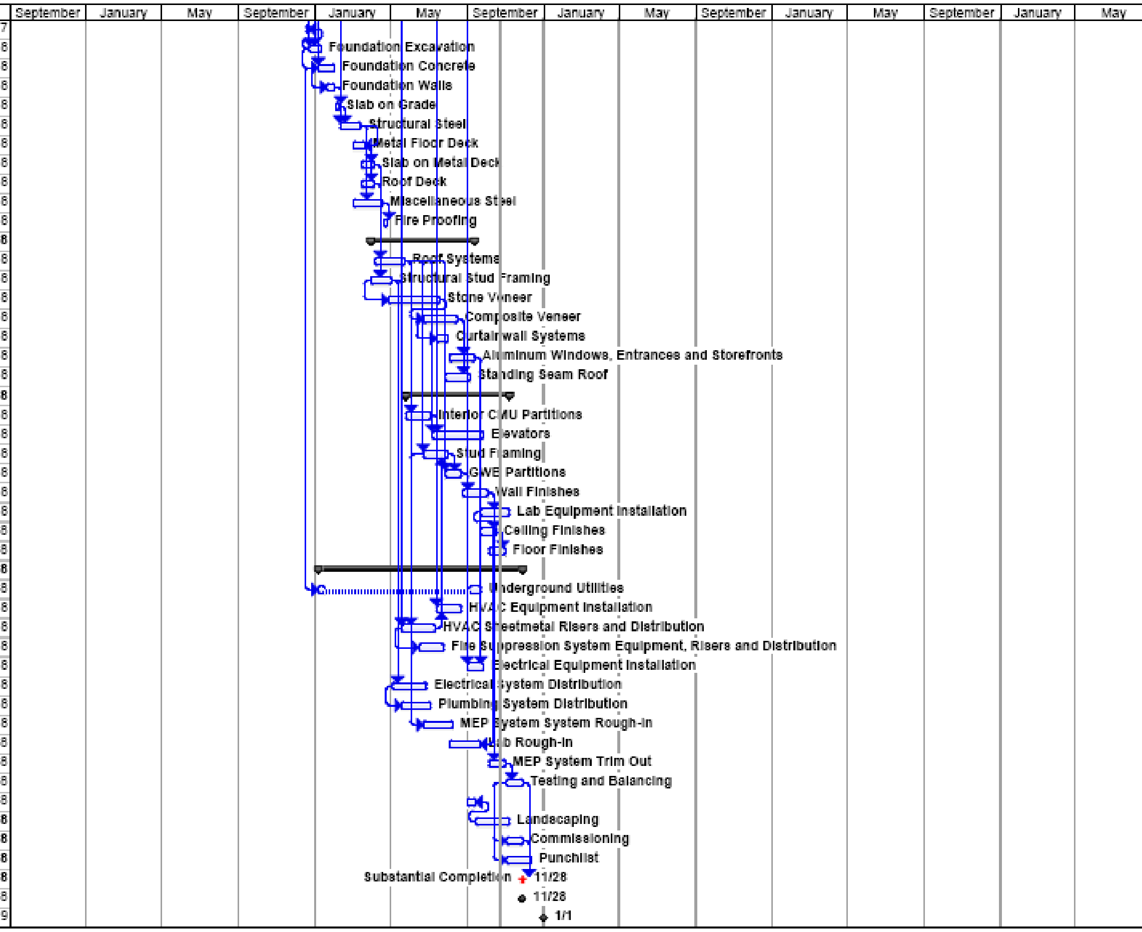
Detailed Project Schedule

ID	Task Name	Duration	Start	Finish
1	**PROPOSAL /AWARD PHASE**	**10 days**	**Wed 3/7/07**	**Tue 3/20/07**
2	Submit Proposal	1 day	Wed 3/7/07	Wed 3/7/07
3	Owner Review Period	1 day	Mon 3/12/07	Mon 3/12/07
4	Preconstruction Award Notice	1 wk	Tue 3/13/07	Mon 3/19/07
5	Contract Review / Execution	10 days	Wed 3/7/07	Tue 3/20/07
6	**Preconstruction Period**	**189 days**	**Wed 3/7/07**	**Mon 11/26/07**
7	LEED Design Charette	4 wks	Wed 3/7/07	Tue 4/3/07
8	**Document Review / GMP Development**	**189 days**	**Wed 3/7/07**	**Mon 11/26/07**
9	Constructability Review	3 wks	Wed 3/7/07	Tue 3/27/07
10	SD Estimate	1 wk	Wed 3/28/07	Tue 4/3/07
11	Design Document Development	9 wks	Thu 4/5/07	Wed 6/6/07
12	Design Document Estimate	3 wks	Thu 6/7/07	Wed 6/27/07
13	Receive Structural Drawings	1 day	Fri 6/8/07	Fri 6/8/07
14	80% Construction Documents	0 wks	Thu 9/20/07	Thu 9/20/07
15	Subcontractor Bid Phase	3 wks	Thu 9/20/07	Wed 10/10/07
16	Prepare GMP	9.1 wks	Thu 9/20/07	Thu 11/22/07
17	Construction Documents	14 wks	Thu 6/21/07	Wed 9/26/07
18	Receive Permit Docs	1 day	Fri 10/12/07	Fri 10/12/07
19	Submit Final GMP for CHA Approval	1 day	Thu 11/22/07	Fri 11/23/07
20	Chestnut Hill Academy Notice to Proceed	0 days	Fri 11/23/07	Fri 11/23/07
21	Receive Builders Risk Certificate	5 days	Wed 3/7/07	Tue 3/13/07
22	Receive Sub Insurance Certs and Bonds	1 day	Mon 11/26/07	Mon 11/26/07
23	Building Permit	21 days	Mon 10/15/07	Mon 11/12/07
24	Relocation of Gas Main (PGW)	32 wks	Tue 3/20/07	Mon 10/29/07
25	**Procurement**	**132 days**	**Mon 6/11/07**	**Tue 12/11/07**
26	Bid and Award Sitework Package on 80% CD's	4 wks	Thu 9/20/07	Wed 10/17/07
27	Bid and Award Site Electrical Package on 80% CD's	3 wks	Thu 9/20/07	Wed 10/10/07
28	Bid and Award Structural Steel and Metal Deck	6 wks	Mon 6/11/07	Fri 7/20/07
29	Bid and Award MEP Equipment	4 wks	Thu 9/13/07	Wed 10/10/07
30	Bid and Award Foundations and Concrete	3 wks	Thu 10/4/07	Wed 10/24/07
31	Bid and Award Elevators	4 wks	Wed 10/17/07	Tue 11/13/07
32	Bid and Award Mechanical	4 wks	Wed 10/17/07	Tue 11/13/07
33	Bid and Award Electrical	4 wks	Wed 10/17/07	Tue 11/13/07
34	Bid and Award the Remaining Packages	8 wks	Wed 10/17/07	Tue 12/11/07
35	**Material Lead Times After Procurement and Approvals**	**182 days**	**Mon 7/23/07**	**Tue 4/1/08**
36	Sanitary/Storm Structures	8 wks	Thu 10/18/07	Wed 12/12/07
37	Concrete Rebar Submissions and Fabrication	8 wks	Thu 10/25/07	Wed 12/19/07
38	Steel Shop Drawings and Fabrication	20 wks	Mon 7/23/07	Fri 12/7/07
39	Exterior Wall Shop Drawings and Fabrication	16 wks	Thu 11/15/07	Wed 3/5/08
40	HVAC Equipment	14 wks	Mon 10/15/07	Fri 1/18/08
41	Electrical Equipment	12 wks	Mon 10/15/07	Fri 1/4/08
42	Elevator Equipment	18 wks	Wed 11/14/07	Tue 3/18/08
43	Lab Equipment	16 wks	Wed 12/12/07	Tue 4/1/08
44	**Construction Start**	**0 wks**	Fri 11/23/07	Fri 11/23/07
45	Mobilize/Jobsite Trailers	6 days	Fri 11/23/07	Fri 11/30/07
46	Jobsite Trailer Electric & Tele/Data	5 days	Wed 12/5/07	Tue 12/11/07
47	**Sitework**	**46 days**	**Fri 11/23/07**	**Fri 1/25/08**
48	Identify, Mark & Protect Specimen Trees/ Site Fence	3 days	Fri 11/23/07	Tue 11/27/07
49	Tree Removal	2 wks	Wed 11/28/07	Tue 12/11/07
50	Site Preparation	3 wks	Mon 11/26/07	Fri 12/14/07
51	Survey & Layout Sitework	5 days	Mon 11/26/07	Mon 12/3/07
52	Excavation	3 wks	Mon 12/3/07	Fri 12/21/07
53	Parking Lot Utility Underground Rough-In	2 wks	Mon 12/24/07	Fri 1/4/08
54	Complete Parking Lot Substrate Work	8 wks	Mon 12/3/07	Fri 1/25/08
55	Building Pad Earthwork	1 wk	Mon 12/17/07	Fri 12/21/07
56	E & S Control	2 days	Thu 11/29/07	Mon 12/3/07
57	**Structure**	**93 days**	**Wed 12/19/07**	**Fri 4/25/08**



Detailed Project Schedule

ID	Task Name	Duration	Start	Finish
58	Survey & Stake Building Footprint	3 days	Wed 12/19/07	Mon 12/24/07
59	Foundation Excavation	3 wks	Mon 12/24/07	Fri 1/11/08
60	Foundation Concrete	4 wks	Mon 1/7/08	Fri 2/1/08
61	Foundation Walls	2 wks	Mon 1/21/08	Fri 2/1/08
62	Slab on Grade	1 wk	Mon 2/4/08	Fri 2/8/08
63	Structural Steel	5 wks	Mon 2/11/08	Fri 3/14/08
64	Metal Floor Deck	3 wks	Mon 3/3/08	Fri 3/21/08
65	Slab on Metal Deck	3 wks	Mon 3/17/08	Fri 4/4/08
66	Roof Deck	3 wks	Mon 3/17/08	Fri 4/4/08
67	Miscellaneous Steel	7 wks	Mon 3/3/08	Fri 4/18/08
68	Fire Proofing	5 days	Mon 4/21/08	Fri 4/25/08
69	**Building Envelope**	**120 days**	**Mon 3/31/08**	**Fri 9/12/08**
70	Roof Systems	7 wks	Mon 4/7/08	Fri 5/23/08
71	Structural Stud Framing	5 wks	Mon 3/31/08	Fri 5/2/08
72	Stone Veneer	12 wks	Mon 4/28/08	Fri 7/18/08
73	Composite Veneer	8 wks	Mon 6/23/08	Fri 8/15/08
74	Curtainwall Systems	3 wks	Mon 7/14/08	Fri 8/1/08
75	Aluminum Windows, Entrances and Storefronts	6 wks	Mon 8/4/08	Fri 9/12/08
76	Standing Seam Roof	6 wks	Mon 7/28/08	Fri 9/5/08
77	**Interiors**	**120 days**	**Mon 5/26/08**	**Fri 11/7/08**
78	Interior CMU Partitions	6 wks	Mon 5/26/08	Fri 7/4/08
79	Elevators	12 wks	Mon 7/7/08	Fri 9/26/08
80	Stud Framing	6 wks	Mon 6/23/08	Fri 8/1/08
81	GWB Partitions	4 wks	Mon 7/28/08	Fri 8/22/08
82	Wall Finishes	6 wks	Mon 8/25/08	Fri 10/3/08
83	Lab Equipment Installation	7 wks	Mon 9/22/08	Fri 11/7/08
84	Ceiling Finishes	4 wks	Mon 9/22/08	Fri 10/17/08
85	Floor Finishes	4 wks	Mon 10/6/08	Fri 10/31/08
86	**Mechanical & Electrical Systems**	**235 days**	**Mon 1/7/08**	**Fri 11/28/08**
87	Underground Utilities	4 wks	Mon 1/7/08	Mon 9/22/08
88	HVAC Equipment Installation	6 wks	Mon 7/14/08	Fri 8/22/08
89	HVAC Sheetmetal Risers and Distribution	8 wks	Mon 5/19/08	Fri 7/11/08
90	Fire Suppression System Equipment, Risers and Distribution	6 wks	Mon 6/16/08	Fri 7/25/08
91	Electrical Equipment Installation	4 wks	Mon 9/1/08	Fri 9/26/08
92	Electrical System Distribution	8 wks	Mon 5/5/08	Fri 6/27/08
93	Plumbing System Distribution	7 wks	Mon 5/19/08	Fri 7/4/08
94	MEP System System Rough-In	7 wks	Mon 6/23/08	Fri 8/8/08
95	Lab Rough-In	7 wks	Mon 8/4/08	Mon 9/22/08
96	MEP System Trim Out	4 wks	Mon 10/6/08	Fri 10/31/08
97	Testing and Balancing	4 wks	Mon 11/3/08	Fri 11/28/08
98	Layout Landscaping & Review w/ Landscape Arch.	10 days	Mon 9/1/08	Mon 9/15/08
99	**Landscaping**	**8 wks**	**Mon 9/15/08**	**Fri 11/7/08**
100	**Commissioning**	**4 wks**	**Mon 11/3/08**	**Fri 11/28/08**
101	**Punchlist**	**6 wks**	**Mon 11/3/08**	**Fri 12/12/08**
102	**Substantial Completion**	**0 wks**	**Fri 11/28/08**	**Fri 11/28/08**
103	Owner FF & E	0 days	Fri 11/28/08	Fri 11/28/08
104	Start of Classes	0 days	Thu 1/1/09	Thu 1/1/09



Appendix G
Solar Power Calculations

Monthly Averaged Daylight Hours (hours)												
Lat 40 Lon -76	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Average	9.68	10.7	11.9	13.2	14.3	14.9	14.7	13.7	12.5	11.1	10	9.4

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											

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											

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											