Architectural Engineering

Construction Management

Senior Thesis

April 12th, 2010

Consultant: Dr. Magent

Rydal Park:
Medical Center Addition

Matthew Dabrowski

Aerial View of the Medical Center Addition

Presentation Outline

I. Introduction
II. Analysis I: Integrated Project Delivery
III. Analysis II: Mechanical System Energy Efficiency
IV. Analysis III: Photovoltaic Array Feasibility
V. Final Conclusions and Recommendations
VI. Acknowledgements
VII. Questions

Architectural Engineering Spring 2010 – Senior Thesis

Presentation Outline:

I. Introduction
   A. Project Background
II. Analysis I: Integrated Project Delivery
III. Analysis II: Mechanical System Efficiency
IV. Analysis III: Photovoltaic Array Analysis
V. Final Conclusions and Recommendations

Project Background

Project Title:	Rydal Park CCRC Medical Center
Function:	Facility for the Memory Impaired
Location:	Rydal Park, Jenkintown, PA
Project Cost:	$26,590,000
Construction Duration:	Nov 2009 – May 2011
Building Size:	142,862 SF / 5 Stories (2 Parking / 3 Living)
Project Delivery Method:	Design-Bid-Build & Negotiated GMP

Figure: Location – Jenkintown, PA

Presentation Outline:

I. Introduction

B. Project Team

II. Analysis I: Integrated Project Delivery

III. Analysis II: Mechanical System Efficiency

IV. Analysis III: Photovoltaic Array Analysis

V. Final Conclusions and Recommendations

Project Team

Owner:	Presby's Inspired Life
Architect:	Stewart & Conners Architects
Construction Manager:	Whiting- Turner
Developer:	Greenbrier Development
Structural Engineer:	WK Dickson & Co.
MEP Engineer:	Moore Enigneering Co.

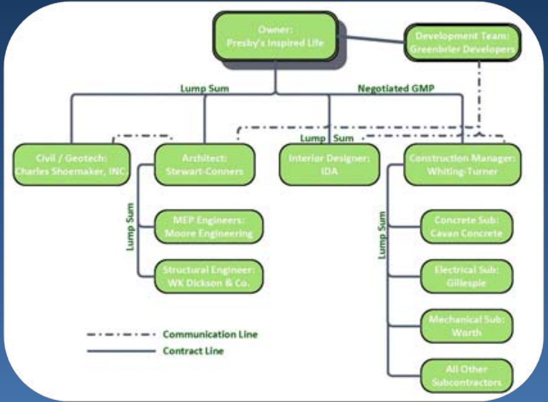


Figure: Project Delivery Org Chart

Presentation Outline:

I. Introduction

C. Analyses Overview

II. Analysis I: Integrated Project Delivery

III. Analysis II: Mechanical System Efficiency

IV. Analysis III: Photovoltaic Array Analysis

V. Final Conclusions and Recommendations

Overview of Analysis

Analysis I: Integrated Project Delivery

- Critical Industry Issue / MAE
- Pinpoint elements of success to guide future projects

Analysis II: HVAC System energy Efficiency

- Mechanical Breadth
- Decrease energy consumption with an Alt. HVAC system

Analysis III: Photovoltaic Panel Feasibility

- Structural Breadth / MAE
- Determine appropriateness with a Life Cycle Cost

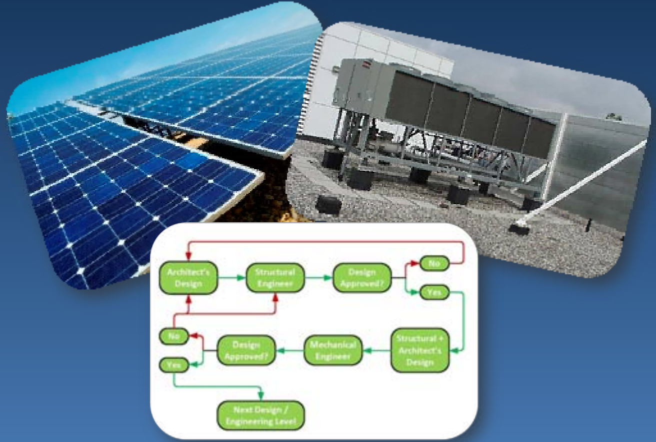


Figure: Various Analysis Images

Presentation Outline:

I. **Introduction**

II. Analysis I: Integrated Project Delivery

A. Introduction and Background

III. Analysis II: Mechanical System Efficiency

IV. Analysis III: Photovoltaic Array Analysis

V. Final Conclusions and Recommendations

Introduction and Background

PACE Fall 2009: Participant, "A successful Design-Build Project?"

Owner, Architect, Contractor Project Team:

- Disconnected, Lacking Collaboration
- Fragmentized preconstruction period

Research Goal (critical industry issue)

- pinpoint successful elements within the Integrated Project Delivery model
- Outline IPD characteristics for improving efficiency within the Rydal Park OAC project team
- Improve efficiency within the CM industry

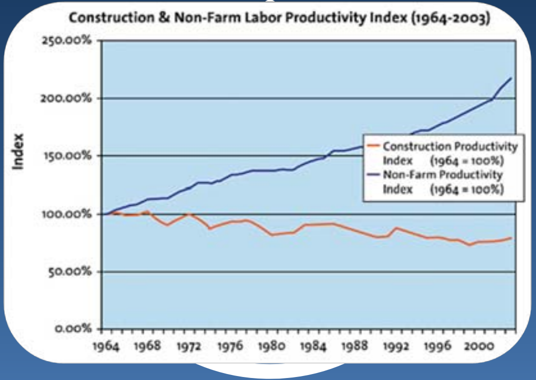


Figure: S:PACE logo & Productivity Index

Presentation Outline:

I. **Introduction**

II. Analysis I: Integrated Project Delivery

C. AIA IPD

III. Analysis II: Mechanical System Efficiency

IV. Analysis III: Photovoltaic Array Analysis

V. Final Conclusions and Recommendations

Integrated Project Delivery

Defining Elements:

- Early involvement of key participants
- Shared risk / reward through multi-party contracting
- Collaborative decision making
- Liability waivers / indemnification

Traditional vs. IPD

- Reallocation of upfront efforts
- Linear Design Process vs. Radial Inputs

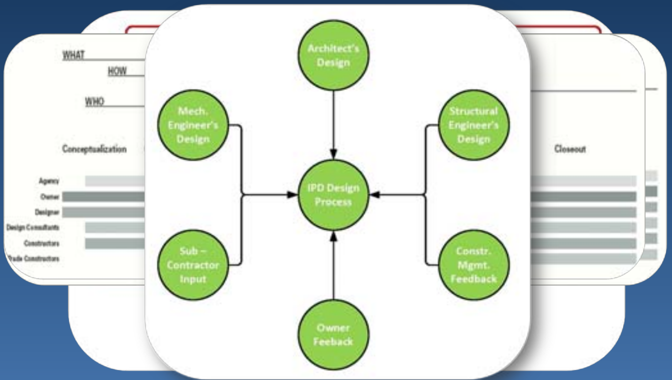


Figure: Design Process

Presentation Outline:

I. **Introduction**

II. Analysis I: Integrated Project Delivery

C. AIA's IPD: Contract Language

III. Analysis II: Mechanical System Efficiency

IV. Analysis III: Photovoltaic Array Analysis

V. Final Conclusions and Recommendations

AIA's Contract Language

AIA's 195 Family of Documents

- No significant differences to AIA CM @ risk contract

Tom Krajewski, DPR Project Executive:

"I call these AIA 195 documents CM (@ risk) with a hug. The contractor becomes the hook to keep the design within the GMP. The general conditions are supposed to bind everyone but the language still allows people to point fingers at other parties."

Figure: AIA, IPD and DPR logos

Presentation Outline:

I. **Introduction**

II. Analysis I: Integrated Project Delivery

D. Case Studies

III. Analysis II: Mechanical System Efficiency

IV. Analysis III: Photovoltaic Array Analysis

V. Final Conclusions and Recommendations

Case Studies

Five Case studies Analyzed (2005-2009):

- Autodesk Inc. Solutions Headquarters
- Sutter Health Fairfield Medical Office Building
- St. Clare health Center
- Encircle Health Ambulatory Care Center
- Cardinal Glennon Children's Hospital

Case studies were explored for:

- Lessons learned
- Elements of success

Project Info	Autodesk Inc. Headquarters	Sutter Health Med Office	St. Clare Health Cent	Encircle	Cardinal Glennon
Total Cost	$13.3 mil	$19.5 mil	$157 mil	$38.6 mil	$45.6 mil
Design Est. Delta	-0.9%	N / A	+1.12%	+19.87%	N / A
Constr. Est. Delta	-0.9%	+2.33%	+5.18%	+3.85%	-3.04%
Procurement RFIs	76	123	278	0	0
Construction RFIs	49			0	0
LEED Goal	Platinum	None	None	Gold	None

Figure: Summary of IPD Case Studies

Presentation Outline:

I. Introduction

II. Analysis I: Integrated Project Delivery

E. Rydal Park OAC Project Team

III. Analysis II: Mechanical System Efficiency

IV. Analysis III: Photovoltaic Array Analysis

V. Final Conclusions and Recommendations

OAC Project Team

AE 572: Project Delivery and Contract Strategies
- Pinpointed critical project success factors
- Design build extremely viable option

Owner (Presby's Inspired Life):
- Lacking experience, looking to improve

Architect (Stewart-Conners):
- Young Company, specializing in Lodging

Construction Manager (Whiting-Turner):
- Experienced, well established in SE Pennsylvania

Developer (Greenbrier):
- Experience, Specializes in CCRC's, Located in Texas

Factor Action Statement	Trad. DBB with Early Procurement	Trad. DBB with Early Procur. and Agent	Construction Manager at Risk	Design-Build (Best IPD Alternative)
Control Cost Growth	50	50	60	90
Ensure Lowest Cost	100	60	40	80
Facilitate Early Cost Estimates	20	20	70	90
Reduce / Transfer Risk	50	20	70	90
Control Time Growth	50	50	70	90
Ensure Shortest Schedule	50	40	80	100
Promote Early Procurement	90	90	100	100
Ease Change Incorporation	80	70	60	10
Capitalize on Familiar Project Conditions	50	40	70	100
Maximize Owner's Control	100	80	60	10
Maximize Owner's Involvement	90	80	40	10
Efficiently Utilize Poorly Defined Scope	80	70	60	0

Figure: Delivery and Contract Stragieies

Presentation Outline:

I. **Introduction**

II. Analysis I: Integrated Project Delivery

F. Detailed Preconstruction Timeline

III. Analysis II: Mechanical System Efficiency

IV. Analysis III: Photovoltaic Array Analysis

V. Final Conclusions and Recommendations

Preconstruction Timeline

Timeline developed after a project manager interview (Chip Cinamella) and reviewing precon documents

Inefficient Elements:

- CM hired April 2008, not utilized for 7 months
- Locations of the Architect and Developer
- Owner placed project out to bid 9 months after CM was already awarded contract
- Improperly utilized "Value Engineering" session begins
- January-October 2009: Project hanging on 1.5% of total estimate

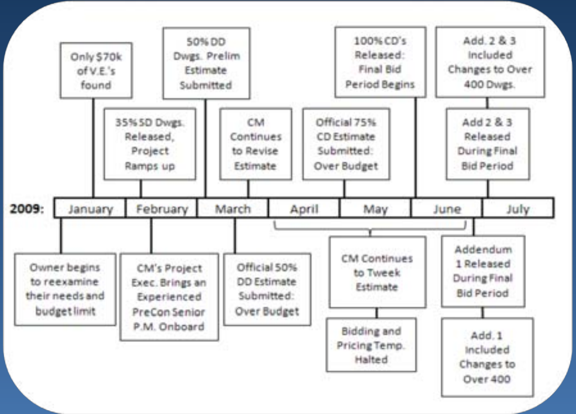


Figure: Precon Timeline Jan – July 2009

Presentation Outline:

I. Introduction

II. Analysis I: Integrated Project Delivery

G. IPD Strategies Outline

III. Analysis II: Mechanical System Efficiency

IV. Analysis III: Photovoltaic Array Analysis

V. Final Conclusions and Recommendations

IPD Strategies Outline

12 Key elements:

1. **Owner Involvement**: Determine Level and Adhere
2. **Budget Estimate**: Determine if project is feasible
3. **Core Team**: Establish early, Utilize all parties
4. **Contracting**: Indemnification, "No-Sue" and relational
5. **Project Team Norms**: Transparent / Cooperative Mgmt
6. **100% Open Books**: All parties develop GMP, New Fee Structures required, Potential to create industry standard
7. **BIM Execution**: Utilized new and effective technology

12 Key Elements:

8. & 9. **Designer / CM Roles** (Different during Design & Constr. Phases): Outline professional boundaries

10. **Meetings**: Weekly face-to-face collaborative discussions

11. **Drawings and Specifications**: Manage releases of addenda material properly, don't hind info from subs

12. **Closeout**: All parties on excellent business terms by end of project, Owner confident with IPD

Do not undermine: **TRUST**

Presentation Outline:

I. **Introduction**

II. Analysis I: Integrated Project Delivery

III. Analysis II: Mechanical System Efficiency

A. Introduction and Research Goal

IV. Analysis III: Photovoltaic Array Analysis

V. Final Conclusions and Recommendations

Introduction and Research Goal

Research Goal (Mechanical Breadth):

- Model building with Energy 10 software
- Analyze the medical facility's heating and cooling efficiency
- Reduce electricity consumption
- Indentify an alternate HVAC system for heating and cooling

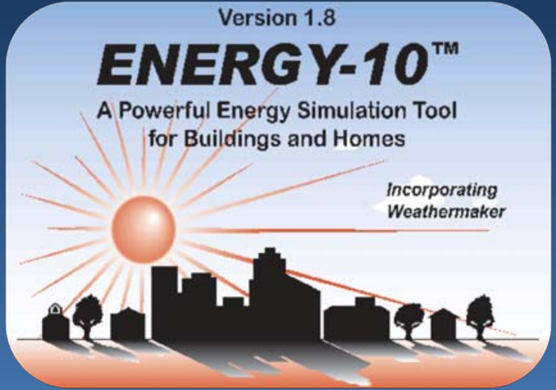


Figure: Energy 10 Software Logo

Presentation Outline:

I. **Introduction**

II. Analysis I: Integrated Project Delivery

III. Analysis II: Mechanical System Efficiency

B. Research Process

IV. Analysis III: Photovoltaic Array Analysis

V. Final Conclusions and Recommendations

Research Process

Building modeled in Energy 10

- Original four-pipe, air-water system best approximated by fixed COP with heat pump
- Several HVAC systems analyze
- Packaged Terminal Air Conditioner Pinpointed

Amana PTAC

- Occupancy Sensors
- Integrate property management software w/ energy management
- Remote maintenance alerts
- Improve PTAC efficientcy by 35%

Figure: Results / Amana PTAC

Presentation Outline:

I. **Introduction**

II. Analysis I: Integrated Project Delivery

III. Analysis II: Mechanical System Efficiency

B. Research Process

IV. Analysis III: Photovoltaic Array Analysis

V. Final Conclusions and Recommendations

Research Process

Alternate Mechanical System:

- Packaged Terminal Air Conditioner (PTAC) with an Air-Air heat pump and ER backup

Department of Energy Report (released 2002):

listed PTAC "as one of the most promising opportunities for technology as a smaller HVAC unit"

- Energy Savings Potential: 33%
- Simple Payback: 2.6 Years

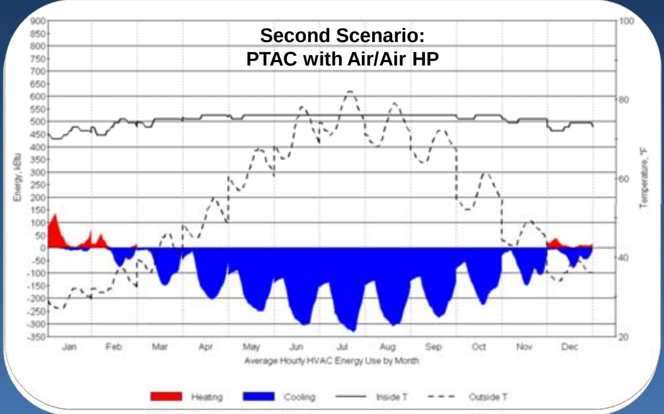


Figure: HVAC Energy Usage

Presentation Outline:

I. **Introduction**

II. Analysis I: Integrated Project Delivery

III. Analysis II: Mechanical System Efficiency

C. Research Results

IV. Analysis III: Photovoltaic Array Analysis

V. Final Conclusions and Recommendations

Research Results

Energy Reduction Results:

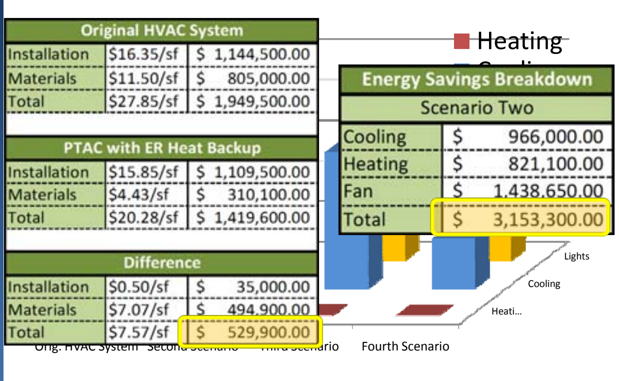
- Four Scenarios Generated
- Second Scenario best outcome
- Energy Reduced by 16.6%

Schedule Impacts

- Remove critical activity: Ductwork (22 days per floor)
- Reduce installation complexity
- Eliminate equipment procurement

Savings

- 50 year savings approximately around $3 million



Original HVAC System		
Installation	$16.35/sf	$ 1,144,500.00
Materials	$11.50/sf	$ 805,000.00
Total	$27.85/sf	$ 1,949,500.00

PTAC with ER Heat Backup		
Installation	$15.85/sf	$ 1,109,500.00
Materials	$4.43/sf	$ 310,100.00
Total	$20.28/sf	$ 1,419,600.00

Difference		
Installation	$0.50/sf	$ 35,000.00
Materials	$7.07/sf	$ 494,900.00
Total	$7.57/sf	$ 529,900.00

Energy Savings Breakdown	
Scenario Two	
Cooling	$ 966,000.00
Heating	$ 821,100.00
Fan	$ 1,438,650.00
Total	$ 3,153,300.00

Figure: Energy / Cost Savings

Presentation Outline:

I. **Introduction**

II. Analysis I: Integrated Project Delivery

III. Analysis II: Mechanical System Efficiency

IV. Analysis III: Photovoltaic Array Analysis

A. Introduction and Background

V. Final Conclusions and Recommendations

Introduction

Why this Project:

- New LEED v3.0 standards
- Offset rising electricity costs
- 100% Open unobstructed roof

Research Goal (Structural Breadth):

- Perform a photovoltaic feasibility
- determine the appropriate system size
- Establish Support requirements
- Examine associated life cycle costs

Figure: Sketch-Up Solar Model

Presentation Outline:

I. **Introduction**

II. Analysis I: Integrated Project Delivery

III. Analysis II: Mechanical System Efficiency

IV. Analysis III: Photovoltaic Array Analysis

C. Targeting a building element

V. Final Conclusions and Recommendations

Targeting a building element

Building Power:

- Panelboards summed: 1200W (.8 PF)
- Would require 5,700 16ft^2 solar panels

Building Element:

- Two-story parking deck
- 156 two lamp Fluorescent Luminaires
- 5.25% of total building load (max peak load)

Starting point:

- Establish pertinent location information

Station Identification	
City:	Philadelphia
State:	Pennsylvania
Latitude:	39.88° N
Longitude:	75.25° W
Elevation:	9 m
PV System Specifications	
DC Rating:	63.0 kW
DC to AC Derate Factor:	0.77
AC Rating:	48.5 kW
Array Type:	Fixed Tilt
Array Tilt:	35.0°
Array Azimuth:	180.0°
Philadelphia Utility Costs	
Cost of Electricity:	0.2 ¢/kWh

AC Energy Generated			
Month	Solar Radiation (kWh/m^2/day)	AC Energy (kWh)	Energy Value ($)
January	3.30	5197	8.16
February	4.16	5805	9.29
March	4.74	6998	11.20
April	5.06	7014	11.22
May	5.20	7176	11.48
June	5.43	7032	11.25
July	5.51	7279	11.65
August	5.67	7548	12.08
September	5.07	6690	10.70
October	4.59	6538	10.46
November	3.37	4804	7.69
December	2.67	4085	6.39
Year	4.57	76166	121.57

Figure: Prelim location info

Presentation Outline:

I. **Introduction**

II. Analysis I: Integrated Project Delivery

III. Analysis II: Mechanical System Efficiency

IV. Analysis III: Photovoltaic Array Analysis

C. Sizing the System

V. Final Conclusions and Recommendations

Sizing the System

Kyocera Solar Five Step Process involves:

- Determine sun hours (4.5)
- Calculate energy load of parking decks(138 kWh)
- Number of modules required (300)

Final System Size:

- 300 Module system in Philadelphia: 63kW

Determining Shading Layout:

- Six 50 module arrays
- Parapet wall, stairwells, other support structures

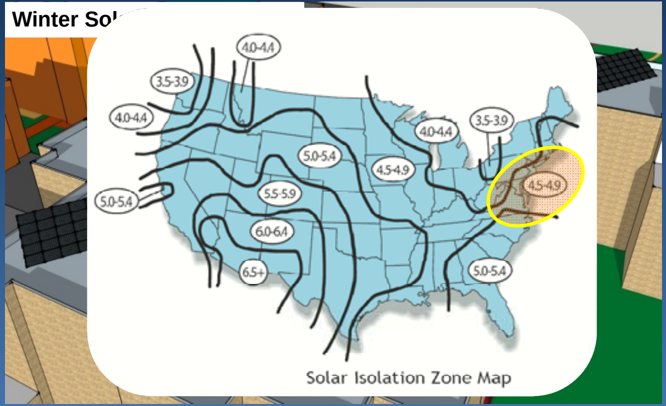


Figure: Layout Configuration

PRESBY'S INSPIRED Life
RYDAL PARK
MEDICAL CENTER ADDITION

Presentation Outline:

I. **Introduction**

II. Analysis I: Integrated Project Delivery

III. Analysis II: Mechanical System Efficiency

IV. Analysis III: Photovoltaic Array Analysis

D. Supporting the PV Modules

V. Final Conclusions and Recommendations

Supporting the PV Modules

UNIRAC: various mounting solutions

- Large array mounting system selected
- Adjustable tilt angle
- Supported by aluminum wide flange

Information received after contacting:

- Custom quotation providing cost per watt
- Engineering report determined max load (PSF)

UNIRAC

Load Combination Variable (psf)

Dead Load:	4.95	Assumed
Snow Load:	25	

Max Load Results (psf)

	Down Force	Uplift
Front Leg:	54.31	-22.16
Rear Leg:	53.21	-29.48
Max (Absolute):	53.21	

Load Combination Factors

	Dead Load	Snow Load	Wind Load
Load Case 1 (downforce):	1	1	0
Load Case 2 (downforce):	1	0	1
Load Case 3 (downforce):	1	0.75	0.75
Load Case 4 (uplift):	0.6		1

Front Leg Load Combinations (psf)

	Wind Load Case A	Wind Load Case B
Load Case 1 (downforce):	32	32
Load Case 2 (downforce):	39.22	45.08
Load Case 3 (downforce):	49.92	54.31
Max Downforce:	49.92	54.31
Load Case 4 (uplift):	-22.16	-6.05

Rear Leg Load Combinations (psf)

	Wind Load Case A	Wind Load Case B
Load Case 1 (downforce):	32	32
Load Case 2 (downforce):	43.61	27.5
Load Case 3 (downforce):	53.21	41.13
Max Downforce:	53.21	41.13
Load Case 4 (uplift):	-19.23	-29.48

Figure: Support Structure / Load Comb.

Presentation Outline:

- I. **Introduction**
- II. Analysis I: Integrated Project Delivery
- III. Analysis II: Mechanical System Efficiency
- IV. Analysis III: Photovoltaic Array Analysis
  - E. Structural Loading Check
- V. Final Conclusions and Recommendations

Structural Loading Check

Determining Load Combination:

- ASCE 7-05 Load Combination
- Max Deflection: Roof members not supporting a plaster ceiling

Load Combination Utilized:

$(1.2^*D) + (1.6^*\ L_{ROOF} \text{ or } S_L)$

Allowable Deflection: l / 180

Load Resistance Factor Design		
Live Load:	25 psf	
Dead Load:	29 psf	
PV Rack Support:	55 psf	
PV Panels:	5 psf	
Snow Load	23 psf	
Load Comb:	74.8 psf	w/out PV
Load Comb:	146.8 psf	w/ PV

Photovoltaic array layout overlaid onto the structural roof drawing

Figure: Layout overlaid on Structural

Presentation Outline:

I. **Introduction**

II. Analysis I: Integrated Project Delivery

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IV. Analysis III: Photovoltaic Array Analysis

E. Structural Loading Check

V. Final Conclusions and Recommendations

Structural Loading Check

Targeted Structural Elements:

- Strength Checked (Direct Loading)
- Deflection checked (solving for moment of inertia, I_X)

Sample Calculation:

$$\text{Deflection}_{MAX} < (5)(\omega)(\ell)^4/(384)(EI) < L/180$$

$$I_X < (5 * \omega * \ell^4) / (384 * 29{,}000{,}000\text{psi} * D_{MAX})$$

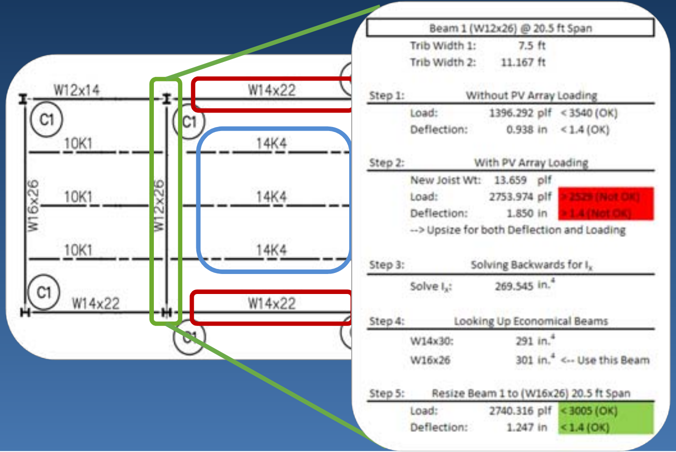

Figure: Targeted Structural Elements

Presentation Outline:

I. **Introduction**

II. Analysis I: Integrated Project Delivery

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H. Life Cycle Cost Feasibility

V. Final Conclusions and Recommendations

Life Cycle Cost Feasibility

Two financing scenarios analyzed:

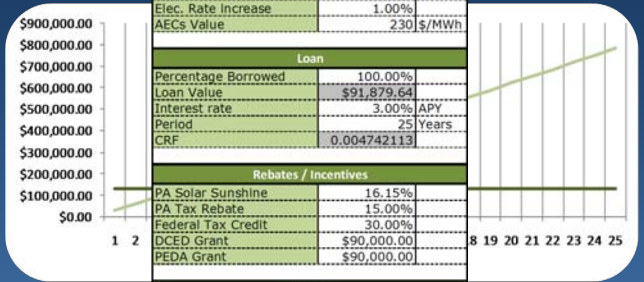
- 0% borrowed
- 100% Borrowed (Embedded into GMP)

Expenses:

- Total cost $545,000
- Loan value of $131,00

Potential Savings:

- Approximately $38,000 utility savings per year



Market		
Retail Cost of Electricity	0.16	$/kWh
Elec. Rate Increase	1.00%	
AECs Value	230	$/MWh
Loan		
Percentage Borrowed	100.00%	
Loan Value	$91,879.64	
Interest rate	3.00%	APY
Period	25	Years
CRF	0.004742113	
Rebates / Incentives		
PA Solar Sunshine	16.15%	
PA Tax Rebate	15.00%	
Federal Tax Credit	30.00%	
DCED Grant	$90,000.00	
PEDA Grant	$90,000.00	
System		
Size	63	kW DC
Cost / W	$8.65	$/W
Total Cost	$544,950.00	
PVWatts Factor	1209	
Annual AC production	76167	kWh
Roof Area Needed	6300	sq.ft.

Figure: Rebate & Loan Calculator

Presentation Outline:

I. Introduction

II. Analysis I: Integrated Project Delivery

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V. Final Conclusions and Recommendations

A. Final Conclusions and Lessons Learned

Final Conclusions and Lessons Learned

Integrated Project Delivery

- New delivery style needed for the next century
- Assisted targeting the Rydal Park inefficiencies

Mechanical System Efficiency

- PTAC systems potentially reduce energy by 16.6%
- Many beneficial cost and schedule impacts

Photovoltaic Array Feasibility

- Energy equivalence for 156 Luminaires
- Potential payback under five years

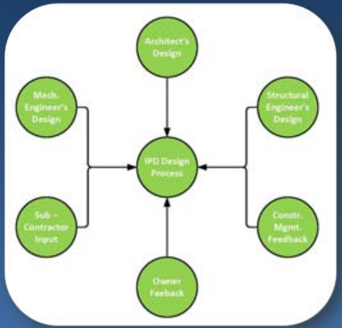

Figure: various analysis images

Presentation Outline:

I. Introduction

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IV. Analysis III: Photovoltaic Array Analysis

V. Final Conclusions and Recommendations

B. Acknowledgements

Acknowledgements

Whiting-Turner:

- Chip Cinamella
- Jesse Beam
- Jack DaSilva

Stewart-Conners Architects:

- Jeff Mullen

Penn State Faculty and Peers

- Christopher Magent
- Andrew Mackey

Presby's Inspired Life:

- Garry Hennis

Thank you for support from family and friends

Presby's Inspired Life
At the heart of experience and vision.

Greenbrier

Stewart & Conners Architects, PLLC

WT Whiting-Turner

Figure: Various Participant Logos

PRESENTATION OUTLINE:

I. **INTRODUCTION**

II. ANALYSIS I: INTEGRATED PROJECT DELIVERY

III. ANALYSIS II: MECHANICAL SYSTEM EFFICIENCY

IV. ANALYSIS III: PHOTOVOLTAIC ARRAY ANALYSIS

V. FINAL CONCLUSIONS AND RECOMMENDATIONS

C. QUESTIONS

QUESTIONS

FIGURE: