BUTLER HEALTH SYSTEM

NEW INPATIENT TOWER

BUTLER, PA

PENN STATE AE SENIOR CAPSTONE PROJECT

CHRIS DILORENZO | CONSTRUCTION OPTION

ADVISOR: DR. CHIMAY ANUMBA

PRESENTATION OUTLINE:

I. PROJECT BACKGROUND
II. ANALYSIS #1: PHOTOVOLTAIC ARRAY
  I. SITE AND BUILDING ANALYSIS
  II. ENERGY REDUCTION STUDIES
  III. SYSTEM LAYOUT AND DESIGN
  IV. STRUCTURAL IMPACT
  V. ENERGY IMPACT
  VI. FINANCIAL FEASIBILITY
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  IV. VIRTUAL MOCK-UPS
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BREADTH TOPICS

- **PHOTOVOLTAIC ANALYSIS**
  - **STRUCTURAL IMPACT ANALYSIS**
  - **RENEWABLE ENERGY/ELECTRICAL BREADTH**

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PROJECT BACKGROUND

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PROJECT LOCATION

- ONE HOSPITAL WAY, BUTLER, PA
- 35 MILES NORTH OF PITTSBURGH

BUILDING SIZE

- AREA : 209,678 SF
- 7 STORIES

PROJECT PARAMETERS:

- COST: $80 MILLION GMP
- SEPTEMBER 2008 – JULY 2010

ORIGINAL SITE

FINAL SITE

PROJECT BACKGROUND

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Butler Health System

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DesignGroup

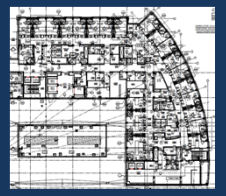
PROJECT PARTICIPANTS

- OWNER: BUTLER HEALTHCARE PROVIDERS
- GENERAL CONTRACTOR: TURNER CONSTRUCTION
- OWNER'S REPRESENTATIVE: RITTER CM
- ARCHITECT: DESIGN GROUP

FACILITY LAYOUT

- GROUND- 1ST FLOORS: SUPPORT SPACES
- 2ND FLOOR: OFFICES, EDUCATION, PUBLIC SPACES
- 3RD-7TH FLOORS: PROCEDURAL SPACES

2nd Floor Layout



Upper Floor Layout

BUTLER HEALTH SYSTEM
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PROJECT BACKGROUND

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BUILDING SYSTEMS

- STRUCTURAL SYSTEM
  - STEEL STRUCTURE
  - CAST-IN-PLACE CONCRETE FLOOR SLABS
- MECHANICAL SYSTEM
  - SEVEN AIR-HANDLING UNITS, VAV SYSTEM
- ELECTRICAL SYSTEM
  - TIES INTO GRID FROM EXISTING HOSPITAL CONNECTION
  - EACH FLOOR HAS DEDICATED ELECTRICAL ROOMS

Image Courtesy of Turner

BUILDING SYSTEMS

- FAÇADE DETAILS
  - MASONRY
  - GLAZING

Image Courtesy of Turner

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PHOTOVOLTAIC ARRAY

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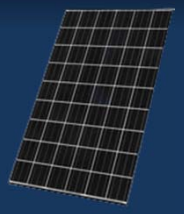


Kyocera Solar Panel

PROBLEM BACKGROUND

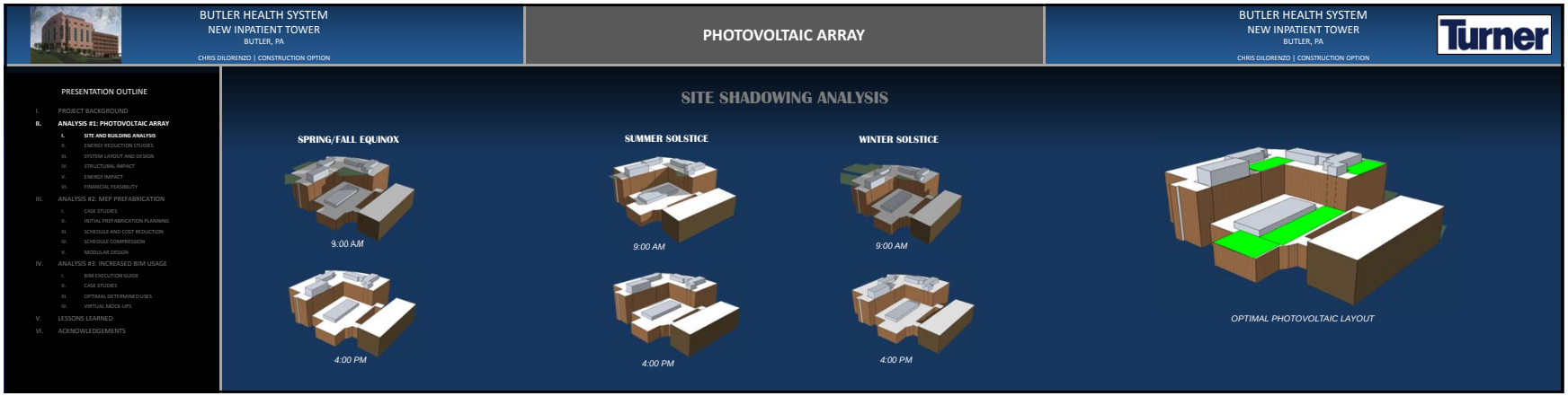
- **STATE-OF-THE-ART FACILITY**
- **SUSTAINABILITY NOT ADDRESSED**
- **LARGE ENERGY CONSUMPTION ($100,000/MONTH)**

POTENTIAL SOLUTION

- **ROOF-MOUNTED PHOTOVOLTAIC ARRAY**
- **TWO AVAILABLE ROOFS (5TH FLOOR, 8TH FLOOR)**

5th Floor Roof Space

8th Floor Roof Space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SITE SHADOWING ANALYSIS
SPRING/FALL EQUINOX
9:00 AM
4:00 PM
SUMMER SOLSTICE
9:00 AM
4:00 PM
WINTER SOLSTICE
9:00 AM
4:00 PM
OPTIMAL PHOTOVOLTAIC LAYOUT

PHOTOVOLTAIC ARRAY

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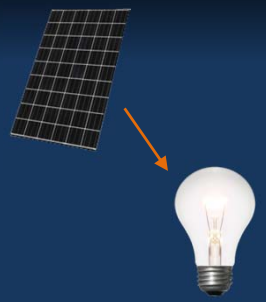

ENERGY REDUCTION STUDIES

- **DAILY ENERGY USE: 56,000 kwh**
- **INITIAL PLANS: POWER THE LIGHTING IN THE NEW TOWER**
  - **ALL LIGHTING = 3,276 kwh/day (4,000 PANELS NEEDED)**
  - **CORRIDOR LIGHTING: 1,224 kwh/day (1,500 PANELS NEEDED)**
- **REVISED PLAN: # OF PANELS BASED ON AVAILABLE SPACE**

Light Type	Description	Wattage	# of Lamps	Total Watts
CF1	4' Staggered Strip-Corridors	58	351	20358
DF1	Fluorescent Downlight 7" Aperture	52	316	16432
DF3	IC Rated Downlight	28	8	224
JF3	4' Wall Bracket	58	10	580
LF2	2x4 Lens Troffer	58	20	1160
MF4	2x2 Basket Style	31	208	6448
MF6	2x4 Basket Style	58	81	4698
NF1	6"x4' Industrial Wrap Around	58	8	464
TH3	Lobby Track Lighting	48	12	576
		Total Energy Usage per Hour (kw)		50.94

Corridor Lighting Calculations

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PHOTOVOLTAIC ARRAY

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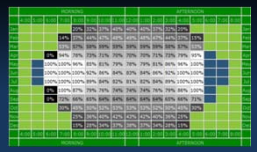
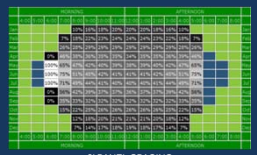


4' PANEL SPACING



2' PANEL SPACING

REVISED PHOTOVOLTAIC PLAN

- **ARRAY BASED ON DESIGN OF THE ROOF**
  - **AVAILABLE AREA**
  - **OPTIMAL TILT OF THE PANELS**
  - **SPACING BETWEEN ROWS**
- **SPACING: DETERMINES THE NUMBER OF PANELS TO BE INSTALLED**
  - **BASED ON SHADOWING**
  - **OPTIMAL: 4' BETWEEN ROWS**

EQUINOX: 10:00 AM SHADOWS

EQUINOX: 4:00 SHADOWS

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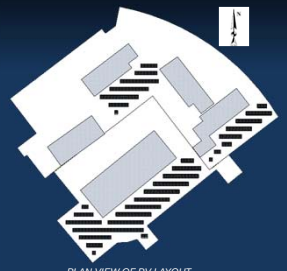
KYOCERA KD210GX-LP

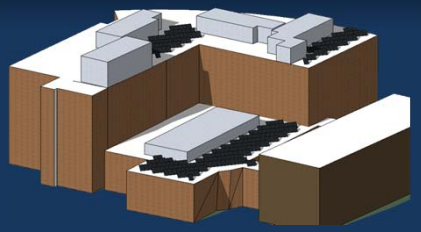
UNIRAC MOUNTING SYSTEM

FINAL ARRAY DESIGN

- **KYOCERA KD210GX-LP PANELS**
- **SPACED AT 4' BETWEEN ROWS**
- **UNIRAC ADJUSTABLE ROOF MOUNT**



PLAN VIEW OF PV LAYOUT



ISOMETRIC VIEW OF PV LAYOUT

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PHOTOVOLTAIC ARRAY

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TYPICAL 5TH FLOOR ROOF BAY

STRUCTURAL BREADTH: STRUCTURAL SYSTEM IMPACT

- **5TH FLOOR ROOF CALCULATED: DENSEST PV LAYOUT**
  - **ROOF LIVE LOAD: 115 PSF**
  - **MINIMUM ROOF DESIGN LOAD: 30 PSF**
- **W 18X40 STEEL BEAMS**
  - **SPAN 30', SPACED AT 7'**
- **W 24X62 GIRDERS**
  - **SPAN 28', SPACED AT 30'**

PV ARRAY IMPOSED ON STRUCTURAL SYSTEM

Weight of PV Panels	# of Panels/Beam Trib. Area	Total Load Added to Area	Total PV PSF
40.8 lbs	10	408 lbs	2.0

LOAD PRODUCED BY PHOTOVOLTAIC PANELS

- **INCLUDE 0.6 PSF FOR RACKING SYSTEM**

Steel Member	Deflection	Max Deflection	Result
W18x40 Beam	1.06"	1.5"	PASS
W 24x62 Girder	1.00"	1.4"	PASS

DEFLECTION CALCULATION RESULTS

Steel Member	Bending Moment (k-ft)	Max Bending Moment (k-ft)	Result
W 18x40 Beam	175.5	294	PASS
W 24x62 Girder	670.32	574	FAIL

MOMENT CALCULATION RESULTS

- **BENDING MOMENT CONTROLS DESIGN: GIRDER RESIZED TO W 24X76**

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PHOTOVOLTAIC ARRAY

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Station Identification	
City:	Pittsburgh
State:	Pennsylvania
Latitude:	40.50° N
Longitude:	80.22° W
Elevation:	373 m
PV System Specifications	
DC Rating:	51.2 kW
DC to AC Derate Factor:	0.77
AC Rating:	39.5 kW
Array Type:	Fixed Tilt
Array Tilt:	41.0°
Array Azimuth:	180.0°

PVWATTS- INPUTS

ENERGY IMPACT

- **SYSTEM SIZE OF 51,240 WATTS**
  - **244 PANELS**
  - **210 WATT PANELS**
- **PV WATTS FACTOR: 1098**
  - **USED FOR FINANCIAL FEASIBILITY CALCULATIONS**

PVWatts

Results			
	Solar Radiation	AC Energy	Energy Value
Month	(kWh/m²/day)	(kWh)	($)
1	2.66	3344	267.52
2	3.51	3983	318.64
3	4.24	5043	403.44
4	4.90	5618	449.44
5	5.16	5818	465.44
6	5.38	5688	455.04
7	5.24	5720	457.60
8	5.40	5913	473.04
9	4.64	5033	402.64
10	4.15	4827	386.16
11	2.64	3042	243.36
12	1.89	2205	176.40
Year	4.15	56235	4498.80

PVWATTS - RESULTS

PHOTOVOLTAIC ARRAY

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INITIAL SYSTEM COST

- **COST OF SYSTEM: $7/WATT (ENGINEERING NEWS-RECORD)**
- **REBATES AND INCENTIVES**
  - **FEDERAL TAX CREDIT: 30% OF GROSS INSTALLATION**
  - **PA SUNSHINE SOLAR: 35% OF COST (UP TO $5,000)**
  - **PA ALTERNATIVE ENERGY PRODUCTION: 15% AFTER ALL OTHER INCENTIVES**
- **FINAL INSTALLATION COST: $208,998.00**

Initial Cost of PV System		
Size (kW)	Price/Watt	Cost
51.2	$7.00	$358,400.00

INITIAL SYSTEM COST

Initial Cost of PV System After Incentives			
Incentive Name	Description	Cost Reduction	Adjusted Cost
-	Initial Cost	-	$358,400.00
Federal Tax Credit	30% of Gross Installation	$107,520.00	$250,880.00
PA Sunshine Solar	35% of Cost (up to $5,000)	$5,000.00	$245,880.00
PA Alternative Energy Production	15% After All Other Incentives	$36,882.00	$208,998.00
		Final Cost	$208,998.00

COST INCORPORATING INCENTIVES

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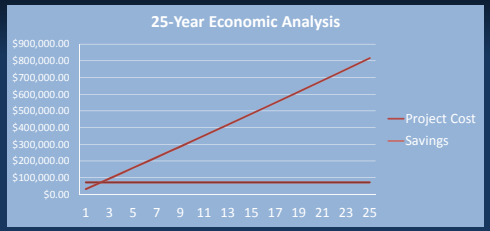
V. LESSONS LEARNED
VI. ACKNOWLEDGEMENTS

PAYBACK PERIOD

- **CALCULATED USING REBATE AND LOAN CALCULATOR**
  - **CREATED BY ANDREW MACKEY (M.S. CONSTRUCTION MANAGEMENT)**
- **ASSUMED COST WILL BE TIED INTO GMP**
  - **BANK LOAN**

- **25-YEAR VALUE: $745,127.93**
- **PAYBACK PERIOD: APPROXIMATELY 2 YEARS**



PV ARRAY CALCULATED PAYBACK

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PHOTOVOLTAIC ARRAY

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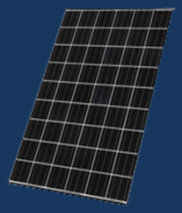
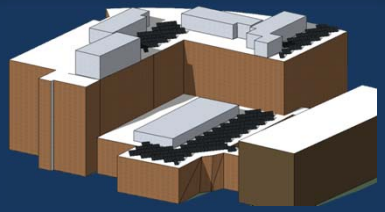
SUMMARY & RECOMMENDATION

- **SHORT PAYBACK PERIOD, OPTIMAL TO INSTALL THE SYSTEM**
- **244 PANEL SYSTEM, 51.5 KWH SYSTEM**
- **DESIGN AS SPECIFIED**
  - **4' SPACING**
  - **SOUTH-ORIENTED**





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MEP PREFABRICATION

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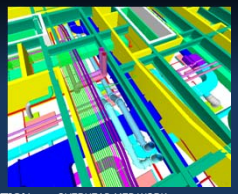
PROBLEM BACKGROUND

- SCHEDULE THE MAIN DRIVING FACTOR
- COMPLEX MEP SYSTEMS
- SMALL CEILING PLENUMS



OVERHEAD MEP WORK

POTENTIAL SOLUTION

- SYSTEM ALREADY MODELED FOR 3D CLASH DETECTION
- PREFABRICATED MEP RACKS
- REDUCE COST AND SCHEDULE
- REDUCE CONSTRUCTION WASTE

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CASE STUDIES

- MIAMI VALLEY HOSPITAL
  - 500,000 SF, 12-STORY ADDITION
  - LARGE GC/CM LED THE PROJECT (SKANSKA)
  - MEP SUBCONTRACTORS BROUGHT ON BOARD EARLY
  - PREFABRICATED CORRIDOR SPACES

COURTESY OF URBANOHIO.COM

- BENEFITS
  - ALL WORK DONE AT BENCH-HEIGHT
  - PRODUCTIVITY TRIPLED
  - LOWER WAGES FOR SHOP EMPLOYEES
  - INCREASED SAFETY: NO INJURIES
- SIMILAR CASE STUDY: WALSGRAVE (COVENTRY) HOSPITAL

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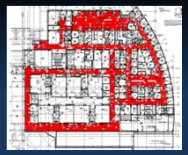
INITIAL PREFABRICATION PLANNING

- BIM ALREADY UTILIZED FOR 3D CLASH DETECTION
- CORRIDORS TO BE PREFABRICATED
  - PROCEDURAL SPACES TOO COMPLEX
  - 1ST FLOOR: MAIN CORRIDOR
  - 3RD FLOOR: CENTRAL CORRIDORS, O.R. CORRIDOR, PACU AREA
  - 5TH-7TH FLOORS: CENTRAL PATIENT HALLWAY CORRIDORS

1ST FLOOR PREFABRICATION



3RD FLOOR PREFABRICATION

5TH-7TH FLOORS PREFABRICATION

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ACTIVITY DURATION REDUCTION

- **CONSERVATIVELY, PRODUCTIVITY DOUBLED**
- **ONLY MAIN MEP SYSTEMS REDUCED, BRANCH SYSTEMS UNCHANGED**
- **REDUCTIONS CALCULATED BY CONTRACTOR**

Contractor	Original Duration	Prefabricated Duration	Reduction in Duration
Mechanical	221 Days	120 Days	101 Days
Electrical	228 Days	119 Days	109 Days
Plumbing	339 Days	175 Days	164 Days
Fire Protection	130 Days	69 Days	61 Days

DURATION COMPARISON BY CONTRACTOR

COST REDUCTIONS

Contractor	Hourly Rate
Mechanical	$31.38/Hour
Electrical	$38/Hour
Plumbing	$34.75/Hour
Fire Protection	$30.84/Hour

HOURLY CONTRACTOR RATES

Contractor	Hourly Rate	Number of Workers	Number of Days	Total Cost Savings
Mechanical	$31.38/Hr	9	101 Days	$228,195
Electrical	$38/Hr	12	109 Days	$397,632
Plumbing	$34.75/Hr	7	164 Days	$319,144
Fire Protection	$30.84/Hr	2	61 Days	$30,100
Total				**$975,071**

TOTAL COST SAVINGS BY TRADE

- **TOTAL COST SAVINGS = $975,071 (3% MEP CONTRACT SAVINGS)**

MEP PREFABRICATION

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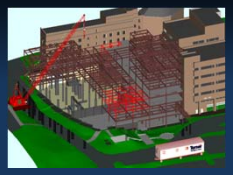
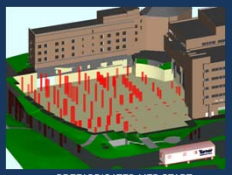
SCHEDULE COMPRESSION

- MEP PREFABRICATION CAN BEGIN AS STRUCTURE IS ERECTED
- ACTUAL MEP INSTALLATION START: JUNE 2ND, 2009
- PREFABRICATED MEP START DATE: OCTOBER, 2008
- APPROXIMATELY 9 MONTHS IN ADVANCE



ORIGINAL MEP START



PREFABRICATED MEP START

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MEP PREFABRICATION

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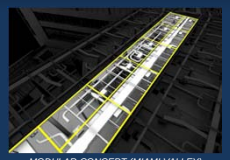
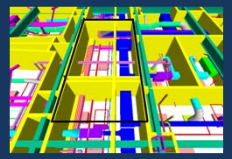


MODULAR CONCEPT (MIAMI VALLEY)

MODULAR DESIGN CONCEPT

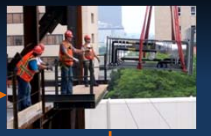
- **MODULES: 8' WIDE X 20' LONG**
- **MOST HALLWAYS: 8' WIDTH**



TYPICAL CORRIDOR MODULE

INDIVIDUAL MODEL (MIAMI VALLEY)

MODULE INSTALLATION



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SUMMARY & RECOMMENDATION

- PROCEED WITH MEP PREFABRICATION
- USE EXISTING 3D COORDINATION MODEL
- CORRIDORS TO BE PREFABRICATED
- JUST-IN-TIME DELIVERY
- CONSTRUCTION WASTE REDUCED
- NEARLY $1 MILLION IN SAVINGS
- EARLIER MEP START DATE

- MOST IMPORTANT, NEARLY ELIMINATE SAFETY CONCERNS

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BIM USAGE

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3D COORDINATION

4D MODELING

PROBLEM BACKGROUND

- BIM REQUESTED BY THE OWNER, NO STRICT REQUIREMENTS
- EXISTING BIM USES
  - 3D COORDINATION
  - 4D SCHEDULING MODELS
- SIGNIFICANT AREAS TO EXTEND BIM USAGE

POTENTIAL SOLUTIONS

- INCREASE BIM IMPLEMENTATION ON THE PROJECT
- BRING BIM INTO THE PROJECT EARLIER
- BIM EXECUTION GUIDE
- CASE STUDIES

BIM USAGE

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BIM EXECUTION GUIDE

- **CREATED BY THE COMPUTER INTEGRATED CONSTRUCTION (CIC) RESEARCH PROGRAM**
- **PROVIDES A PROCEDURE TO IMPLEMENT BIM ON A PROJECT**
- **21 BIM USES INCLUDED IN THE GUIDE**

Building Maintenance Scheduling	Design Authoring
Building Systems Analysis	Engineering Analysis
Asset Management	Sustainability Evaluation (LEED)
Space Management and Tracking	Code Validation
Disaster Planning	Design Reviews
Record Modeling	Programming
Site Utilization Planning	Site Analysis
Construction Sytem Design (Virtual Mock-up)	Phase Planning (4D Modeling)
Digital Fabrication	Cost Estimation
3D Control and Planning (Digital Layout)	Existing Conditions Modeling
3D Coordination	

BIM EXECUTION GUIDE: BIM USES

BIM USAGE

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CASE STUDIES

- **RESEARCH: HEALTHCARE PROJECTS**
  - ***"A UNIFIED APPROACH TO HEALTHCARE PROJECT DELIVERY: SYNERGIES BETWEEN GREENING STRATEGIES, LEAN PRINCIPLES, AND BIM"***
  - ***"CASE STUDIES IN BIM IMPLEMENTATION FOR PROGRAMMING OF HEALTHCARE FACILITIES"***
  - **WRITTEN BY PENN STATE FACULTY MEMBERS**

PENNSTATE
Department of
Architectural Engineering

ISSUES DISCUSSED

- **ELIMINATING WASTE**
- **FACILITY OPERATIONS**
- **SCENARIO SIMULATIONS**
- **FACILITY LAYOUT**
- **EARLY IMPLEMENTATION**
- **PREFABRICATION**

BIM USAGE

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OPTIMAL DETERMINED USES

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Building Systems Analysis	Engineering Analysis
Asset Management	Sustainability Evaluation (LEED)
Space Management and Tracking	Code Validation
Disaster Planning	Design Reviews
Record Modeling	Programming
Site Utilization Planning	Site Analysis
Construction System Design (Virtual Mock-up)	Phase Planning (4D Modeling)
Digital Fabrication	Cost Estimation
3D Control and Planning (Digital Layout)	Existing Conditions Modeling
3D Coordination	

OPTIMAL BIM USES

REASONS FOR DECISIONS

- 3D COORDINATION ALREADY IN PLACE
- AWARE OF MAINTENANCE ISSUES PRIOR TO PROBLEMS
- DISCUSSIONS WITH TURNER PERSONNEL
- STRICT CODE REQUIREMENTS AND INSPECTIONS
- QUICK BUDGET REVISIONS
- MAIN FOCUS: VIRTUAL MOCK-UPS

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VIRTUAL MOCK-UPS

- **PROJECT TEAM: MOST BENEFICIAL USE**
- **COMMUNICATE DESIGN TO THE OWNER**
- **MOST PROBLEMATIC AREAS: OPERATING ROOMS**
  - **DISPLAY MONITORS**
  - **CLASHES BETWEEN OVERHEAD BOOMS AND LIGHTS/DIFFUSERS**
  - **POWER OUTLETS**

OPERATING ROOM

PATIENT CARE ROOM

BIM USAGE

BUTLER HEALTH SYSTEM
NEW INPATIENT TOWER
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PRODUCING THE MOCK-UP

- FOCUS ON CYSTOSCOPY AND ENDOSCOPY OPERATING ROOMS
- PRINCIPLE CAN BE APPLIED TO REST OF BUILDING
- MODEL ORIGINALLY PRODUCED IN REVIT
- EXPORTED TO UNITY THROUGH 3D STUDIO MAX
  - GAME ENGINE
  - 3D AUTHORING TOOL
  - INTERACTIVE MODEL

CYSTO/ENDO HALLWAY

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BIM USAGE

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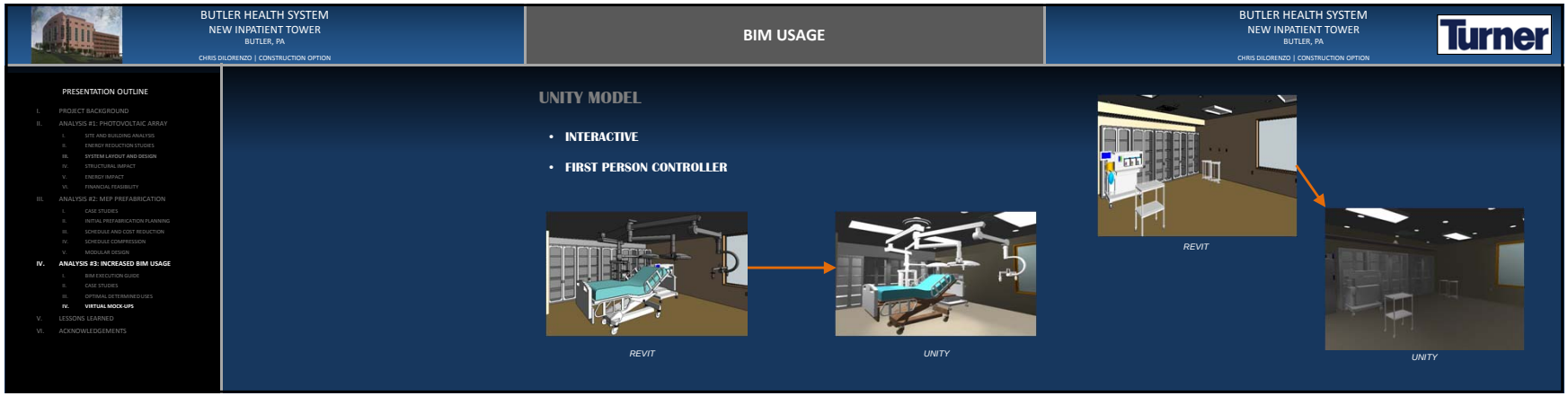
REVIT MODEL

- **CREATE FLOORPLAN**
  - **LIGHTING FIXTURES**
  - **DIFFUSERS AND REGISTERS**
  - **ELECTRICAL POWER OUTLETS**
  - **DATA OUTLETS**
  - **MEDICAL BOOM LOCATION**
  - **MOBILE MEDICAL EQUIPMENT**
  - **PLUMBING FIXTURES**

CYSTO/ENDO REVIT MODEL

ENDOSCOPY ROOM

CYSTOSCOPY ROOM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UNITY MODEL
INTERACTIVE
FIRST PERSON CONTROLLER
REVIT
UNITY
REVIT
UNITY

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UNITY WALKTHROUGH

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BIM USAGE

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SUMMARY & RECOMMENDATION

- INCORPORATE BIM AS EARLY AS POSSIBLE
- FULL TEAM COLLABORATION
- PROVIDES BENEFITS TO THE ENTIRE PROJECT TEAM
- VIRTUAL MOCK-UP PROVIDES THE MOST BENEFIT

MAE RESEARCH

- AE 598C: SUSTAINABLE CONSTRUCTION PROJECT MANAGEMENT
  - PHOTOVOLTAIC APPLICATIONS
- AE 597G: BIM EXECUTION PLANNING
  - BIM EXECUTION GUIDE
- AE 597F: VIRTUAL FACILITY PROTOTYPING
  - UNITY APPLICATIONS
  - INTERACTIVE MODELS

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LESSONS LEARNED

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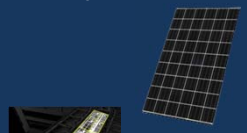
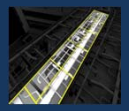
FINAL SUMMARY

- ANALYSIS #1: PHOTOVOLTAIC ARRAY
  - REBATES AND INCENTIVES ALLOW THE SYSTEM TO BE FEASIBLE
  - 2-YEAR PAYBACK PERIOD
- ANALYSIS #2: MEP PREFABRICATION
  - REDUCES COST AND SHORTENS SCHEDULE
  - IMPROVES SAFETY AND PRODUCTIVITY
  - REDUCES CONSTRUCTION WASTE





- ANALYSIS #3: INCREASED BIM USAGE
  - EARLY IMPLEMENTATION PRODUCES THE MOST BENEFIT
  - VIRTUAL MOCK-UP DEEMED AS MOST BENEFIFICAL

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INDUSTRY

- TURNER CONSTRUCTION
  - MEGAN CORRIE (WORTMAN) : AE CLASS OF 2008
  - RYAN LUDWIG
- DESIGN GROUP

ACADEMIC

- DR. CHIMAY ANUMBA: ADVISOR
- SONALI KUMAR: AE GRADUATE STUDENT
- DR. JOHN MESSNER

SPECIAL THANKS

- TURNER CONSTRUCTION
- BUTLER HEALTH SYSTEM
- PACE INDUSTRY MEMBERS
- FAMILY & FRIENDS

PENNSTATE Department of Architectural Engineering

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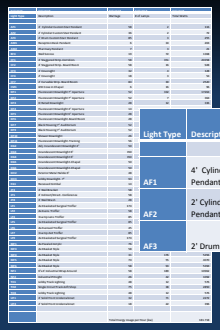
ELECTRICAL LOAD CALCULATIONS

- TOTAL ENERGY USAGE PER DAY: 3,276 KWH
- PER MONTH: 98,290 KWH
- WATTAGE OF PANELS: 300 W
- TOTAL PANELS NEEDED: APPROXIMATELY 4,000



Light Type	Description	Wattage	# of Lamps	Total Watts
AF1	4' Cylinder Custom Stair Pendant	58	2	116
AF2	2' Cylinder Custom Stair Pendant	36	2	72
AF3	2' Drum Custom Stair Pendant	85	3	255

PHOTOVOLTAIC ARRAY

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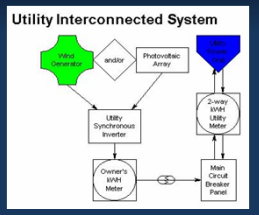
SYSTEM TIE-IN

- **EXISTING HOSPITAL TIED INTO GRID**
- **SUPPLY-SIDE INTERCONNECTION**
- **NATIONAL ELECTRIC CODE**
  - **PV GENERATED POWER MUST TIE-IN PRIOR TO REACHING MAIN DISTRIBUTION PANEL**
  - **TIES-IN AT A METER BOX**
- **REMAINING POWER STILL PULLED FROM THE GRID**



SUPPLY SIDE INTERCONNECTION
- COURTESY OF ALLSTAR ELECTRIC

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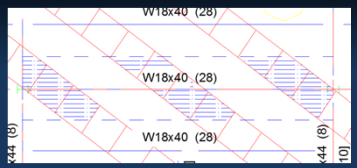
STRUCTURAL LOAD CALCULATIONS

Beam Loading Calculations (W18x40)
Factored Load: 1.2 (30 PSF +2.6 PSF) + 1.6 (115 PSF) = 223.12 PSF
Load (PLF) = (223.12 PSF) x (7' Tributary Area) = 1561.9 plf = 1.56 klf
Load per Support: (1.56 klf) x (30') / 2 Supports = 23.4 k
Bending Moment = $w_u l^2/8$ = (1.56 klf) $(30')^2/8$ = 175.5 kip-ft
W18x40: Max Bending Moment = 294 > 175.5, OK (AISC Steel Construction Manual)

Deflection Calculations
Load: 32.6 PSF + 115 PSF = 147.6 PSF, 147.6 PSF x 7'Trib. Width = 1033.2 PLF
Deflection Max: L/240 = (30'x12"/1') / 240 = 1.5"
Deflection = $(5wl^2)$ / (384EI) = $\frac{5\ (1033.2\ PLF)\ (30')^4\ (1728\ Conversion)}{(384)(29{,}000{,}000\ psi)\ (612\ in^4)}$ = 1.06"<1.5", OK



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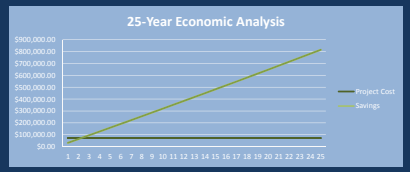
PAYBACK CALCULATOR



Market	
Retail Cost of Electricity	0.16 $/kWh
Elec. Rate increase	1.00%
RECs Value	400 $/MWh
Loan	
Percentage Borrowed	100.00%
Loan Value	$208,998.00
Interest rate	2.50% APY
Period	25 Years
CRF	0.004496169
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	51.2 kW DC
Cost / W	$7.00 $/W
Total Cost	$358,400.00
PVWatts Factor	1090
Annual AC production	56288 kWh
Roof Area Needed	5120 sq.ft.
Value	
Up Front Expense	-$210,189.55
Loan Cost	$281,280.00
Total Expense	$71,090.45
25 yr Value	$745,127.93

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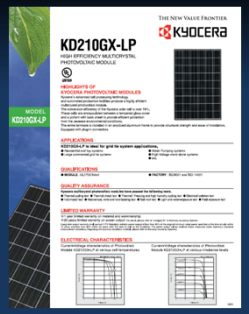
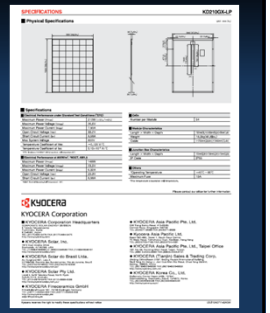
PV SPECIFICATIONS

- 244 PANELS
- 210 WATTS





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MEP SYSTEM DURATION REDUCTION

Contractor	Original Duration	Prefabricated Duration	Reduction in Duration
Mechanical	221 Days	120 Days	101 Days
Electrical	228 Days	119 Days	109 Days
Plumbing	339 Days	175 Days	164 Days
Fire Protection	130 Days	69 Days	61 Days

Contractor	Hourly Rate	Number of Workers	Number of Days	Total Cost Savings
Mechanical	$31.38/Hr	9	101 Days	$228,195
Electrical	$38/Hr	12	109 Days	$397,632
Plumbing	$34.75/Hr	7	164 Days	$319,144
Fire Protection	$30.84/Hr	2	61 Days	$30,100
Total				**$975,071**

Activity Name	Original Duration (Days)	Prefabricated Duration (Days)	Reduction in Schedule (Days)
First Floor MEP Work			
First Floor Ductwork			
Install S.A. Main Duct- AHU#1	10	5	5
Install R.A. Main Duct- AHU#1	10	5	5
Install Relief Main Air Duct	5	3	2
Install S.A. Main Duct- AHU#6	3	2	1
Install S.A. Main Duct- AHU#7	3	2	1
First Floor Mechanical Piping			
Install 4" Chilled Water Piping	5	3	2
First Floor Plumbing			
Install Rough-In Water/Vent/Waste			
Install Rough-In Domestic Water			
Install Roughing Med Gas Piping			
First Floor Fire Protection			
First Floor Electrical			
Install Power Distribution- Conduit			
Install Power Distribution- Wire			
Install Lighting Fixtures			
Third Floor MEP Work			
Third Floor Ductwork			
Install 35 S.A. Main Duct-AHU#1			
Install 35 R.A. Main Duct- AHU#1			
Install 35 S.A. Main Duct-AHU#6			
Install 35 R.A. Main Duct-AHU#6			
Install 35 S.A. Main Duct-AHU#6			
Install 35 R.A. Main Duct-AHU#6			
Install 35 S.A. Main Duct-AHU#7			
Install 35 R.A. Main Duct-AHU#7			
Install 35 S.A. Main Duct-AHU#7	4	2	2
Install 35 R.A. Main Duct-AHU#7	4	2	2
Third Floor Mechanical Piping			
Install 35 Main Mechanical Piping	10	5	5
Install 35 Main Mechanical Piping	11	6	5
Third Floor Plumbing			
Install 35 Plumbing Rough-In- W/V's	15	8	7
Install 35 Roughing Domestic Water	16	8	8
Install 35 Plumbing Rough-In- W/V's	16	8	8
Install 35 Roughing Domestic Water	16	8	8
Install 35 Rough-In Domestic Water	10	5	5