PRESENTATION OUTLINE:

I. PROJECT BACKGROUND
II. ANALYSIS #1: Energy Analysis
III. ANALYSIS #2: Photovoltaic Array
IV. ANALYSIS #3: Structural Modification
V. ANALYSIS #4: Bathroom Prefabrication
VI. LESSONS LEARNED
VII. ACKNOWLEDGEMENTS

WEST FUALA PLANT EXPANSION

JAAFAR AL AIDAROOS | CONSTRUCTION MANAGEMENT
PENN STATE AE SENIOR CAPSTONE PROJECT
ADVISOR: DR. CHIMAY ANUMBA

BREADTH TOPICS

- RENEWABLE ENERGY/ELECTRICAL BREADTH
- STRUCTURAL IMPACT ANALYSIS

WEST FUALA PLANT EXPANSION

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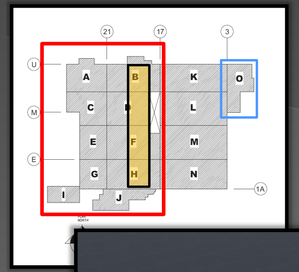
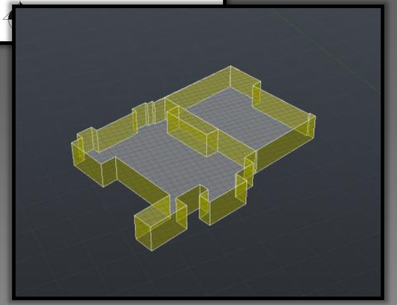
ADVISOR: DR. CHIMAY ANUMBA

PRESENTATION OUTLINE:





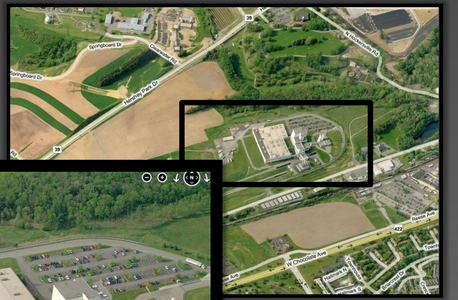
West Expansion

PROJECT BACKGROUND

Building Name: Confidential – West Fuala Expansion
Location: Confidential – Harrisburg, PA

Gross Building Area: 350,545 SF
Number of Stories: ½ Basement + First floor + Mezzanine
Building Type: Food processing and packaging plant

Contractor: Turner Construction Company
Project Delivery Method: Design-Bid-Build
GMP contract: $83 Million
Construction Dates: June 2010 – February 2012



Plant before the expansion

WEST FUALA PLANT EXPANSION

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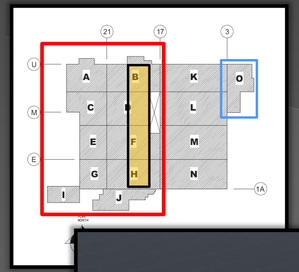
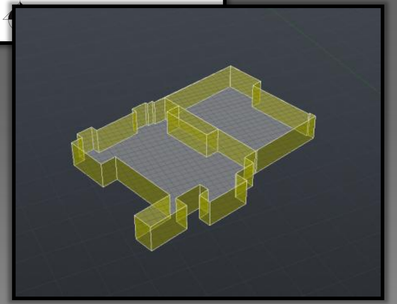
ADVISOR: DR. CHIMAY ANUMBA

PRESENTATION OUTLINE:





West Expansion

PROJECT BACKGROUND

Structural System

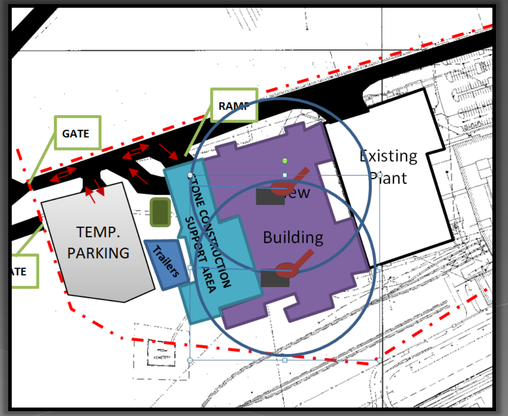
- **First Floor:** Precast concrete
- **Mezzanine:** Steel
- **Area O:** CMU walls

Lighting System

- 650 Volt-Amperes

Construction Phases

- Mobilization
- Sitework
- Foundation
- Erection of Envelope
- Building Water-tight and fitouts



Erection of Envelope Phase

WEST FUALA PLANT EXPANSION

PROJECT BACKGROUND

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PENN STATE AE SENIOR CAPSTONE PROJECT
ADVISOR: DR. CHIMAY ANUMBA

PRESENTATION OUTLINE:

Issue

- **100 Years**
- Energy issue - High energy demand
- Many Structural trades
- Congestion in Area O

Thesis Proposal

- Energy Analysis
- Photovoltaic Panels
  - Breadth
- Structure modification to Precast Concrete Mezzanine
  - Breadth
- Precast Prefabrication of Bathroom walls in Area O

Type of Analysis

- Promote a better long term sustainable design
- Generate Sustainable Energy
- Modify Structure
- Utilizing prefabrication to reduce congestions

WEST FUALA PLANT EXPANSION

PRESENTATION OUTLINE:

I. PROJECT BACKGROUND

II. ANALYSIS #1: Energy Analysis

I. Information

II. Energy Model

III. Solar Analysis

I. Solar Studies

II. Ecotect Solar Radiation

III. Propose Solar Design Change

IV. Effect on Energy model

IV. Recommendations

III. ANALYSIS #2: Photovoltaic Array

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ENERGY ANALYSIS

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PENN STATE AE SENIOR CAPSTONE PROJECT
ADVISOR: DR. CHIMAY ANUMBA

Energy Analysis

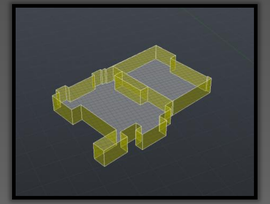
- Produces an Energy model
- Used throughout design stage to assess the effect of design changes on the energy usage

Tools

- AutoDesk - Project Vasari
- BIM Model

Energy model

1. Create or import building model
2. Import parameters
3. Run Energy model Analysis
4. Analyze BIM model



Parameters:

- Manufacturing
- Harrisburg, PA
- 24/7 facility
- One HVAC system

WEST FUALA PLANT EXPANSION

ENERGY ANALYSIS

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ADVISOR: DR. CHIMAY ANUMBA

PRESENTATION OUTLINE:

BIM - Energy Analysis
Energy model

Information produced:

- Building performance Factor
- Energy Use intensity
- Life Cycle Energy Use
- Renewable Energy Potential
- Emissions
- Annual Energy Use
- Et cetera

Energy Model Report

Building Performance Factors

Location:	Hershey, PA, USA
Weather Station:	53158
Outdoor Temperature:	Max: 82°F/Min: -10°F
Floor Area:	140,337 sf
Exterior Wall Area:	127,669 sf
Average Lighting Power:	1.30 W / ft²
People:	326 people
Exterior Window Ratio:	0.20
Electrical Cost:	$0.09 / kWh
Fuel Cost:	$1.03 / Therm

Renewable Energy Potential

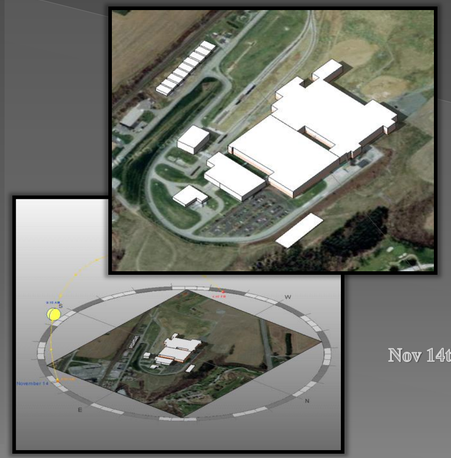
Roof Mounted PV System (Low efficiency):	789,717 kWh / yr
Roof Mounted PV System (Medium efficiency):	1,579,434 kWh / yr
Roof Mounted PV System (High efficiency):	2,369,151 kWh / yr
Single 15' Wind Turbine Potential:	2,969 kWh / yr

*PV efficiencies are assumed to be 5%, 10% and 15% for low, medium and high efficiency systems

WEST FUALA PLANT EXPANSION

PRESENTATION OUTLINE:

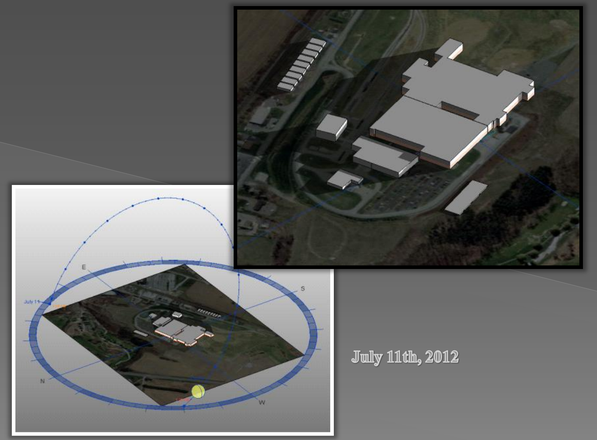
Solar Studies



Nov 14th, 2012

ENERGY ANALYSIS

Solar Analysis



July 11th, 2012

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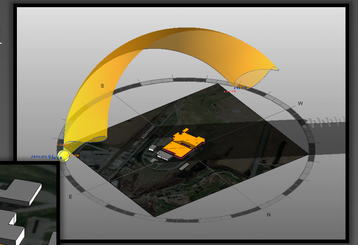
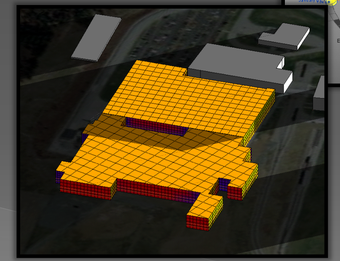
PENN STATE AE SENIOR CAPSTONE PROJECT

ADVISOR: DR. CHIMAY ANUMBA

Ecotect Solar Radiation





WEST FUALA PLANT EXPANSION

ENERGY ANALYSIS

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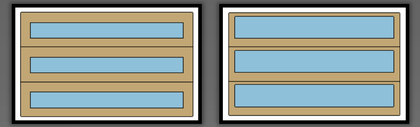
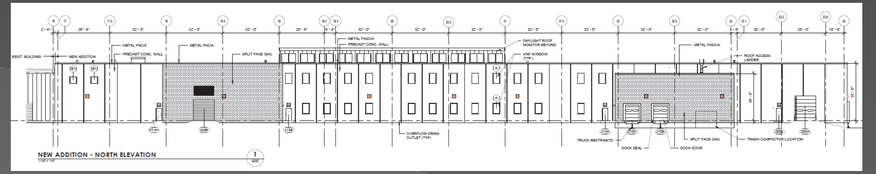
ADVISOR: DR. CHIMAY ANUMBA

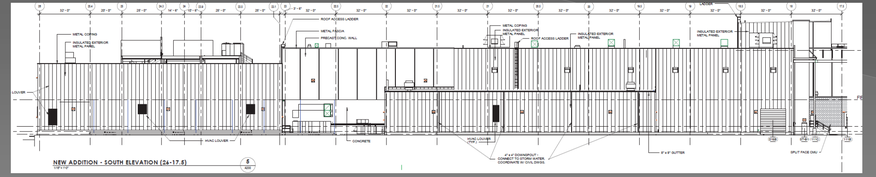
PRESENTATION OUTLINE:

Example of design change from Solar Analysis

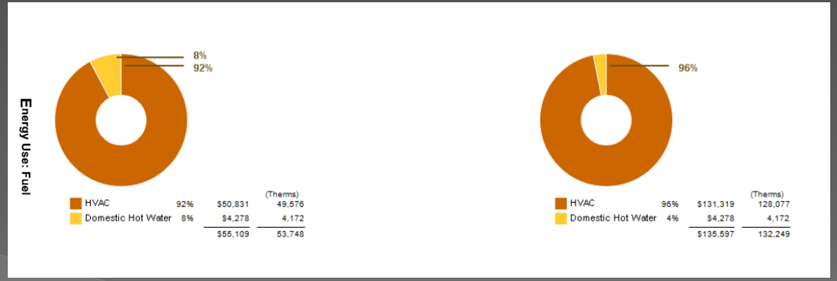
Proposed Design Changes:
• Glazing from 20% to 40%







Energy Model Report



HVAC Cost increases from $55,000 to $131,000

WEST FUALA PLANT EXPANSION

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ENERGY ANALYSIS

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PENN STATE AE SENIOR CAPSTONE PROJECT
ADVISOR: DR. CHIMAY ANUMBA

Energy Analysis

Conclusion:

- Does not affect schedule
- No cost
- A more sustainable long-term design
- High possibility of cost reduction
- Up to 25% of Energy requirements at day through lighting concepts

Recommendation:

• Project Team utilize this tool to enhance and produce a more sustainable design in the long run

WEST FUALA PLANT EXPANSION

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ADVISOR: DR. CHIMAY ANUMBA

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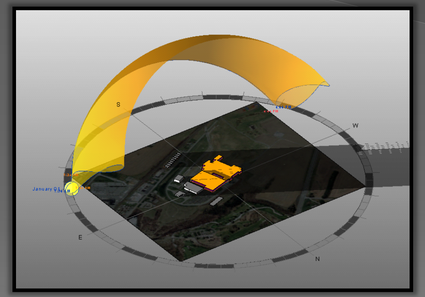
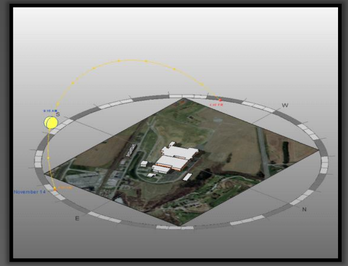


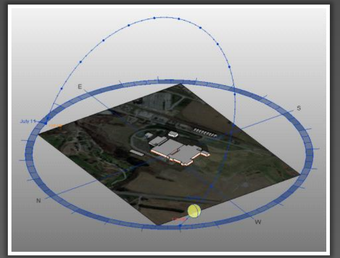
PHOTOVOLTAICS

Incorporating Photovoltaic systems

Problem Id: High Electric energy Usage
No sustainable systems incorporated
Great potential for Renewable Energy

Proposal: Generate sustainable energy
Determine Feasibility of a PV system





Renewable Energy Potential

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WEST FUALA PLANT EXPANSION

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  II. PV systems
  III. Breadth:
    I. Electrical Systems Analysis
    II. Electric output of PV
  IV. Layout
  V. Financial Analysis
  VI. Recommendation
IV. ANALYSIS #3: Structural Modification
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Solar Sky Giddied Systems	Astronergy	Sharp Grid
Array Size Ideal / Actual Watts	19,200/17,448	18,800/16,944
Monthly Output	up to 2,617 kWh	up to 2,542 kWh
Number of Solar Panels	80 panels	80 panels
Watts	240	235
Price	$37,889	$42,110
Price Per Watt	$1.97	$2.24

PHOTOVOLTAICS

Solar Analysis

Project location: **Harrisburg, PA**
Latitude: N 40° 22’
Longitude: W 76° 85’
Optimum Orientation: South facing side
Optimum Tilt Angle: Summer: 25°15’
Winter: 55°
(latitude ± 15°)
Sun Hours Per Day: ***4.6***

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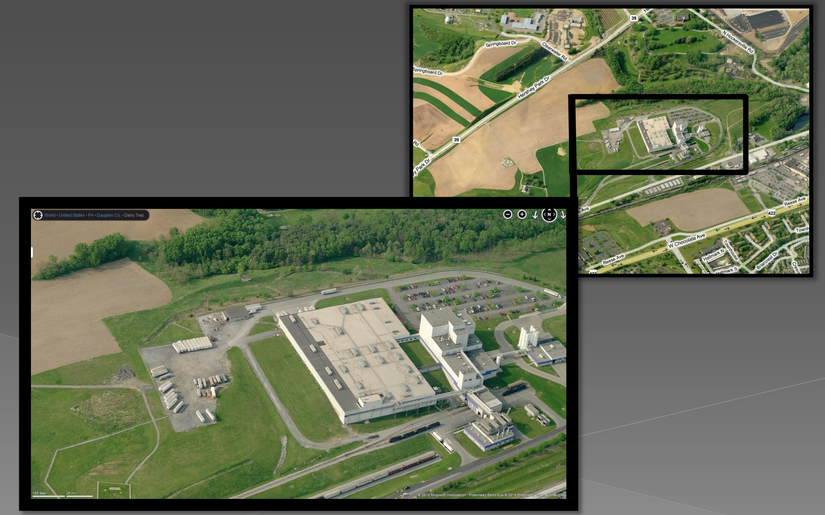

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PHOTOVOLTAICS

Electric Energy Output (Breadth)

Lighting System Energy Usage = 650 Volt-Amperes

Photovoltaic Energy output:
1 set of 80 Astronergy = 17,448 Watts = 2.68%
10 Sets of 80 Astronergy = 174,480 Watts = 26.84 %

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National Renewable Energy Energy Lab
Photovoltaic system calculator

Location= Harrisburg, PA
DC Rating =174 kW Photovoltaic System
(10 sets of 80 Astronergy)
Cost of electricity = 14.3 ¢/kWh

Report:
AC Rating: **134.4 kW = 20% of Lighting System**
Annual AC Energy produced: **206,937 kWh**
Annual Energy Value Savings: **$29,592**

WEST FUALA PLANT EXPANSION

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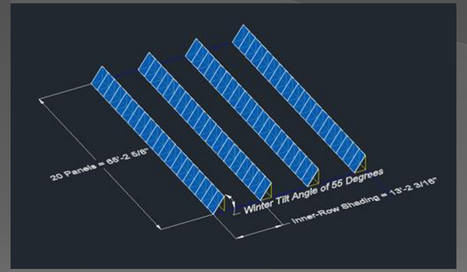
Layout of PV Panels



PHOTOVOLTAICS

Site Layout

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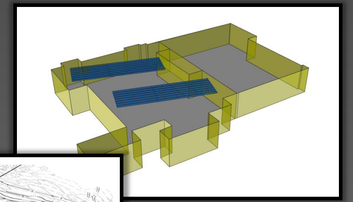

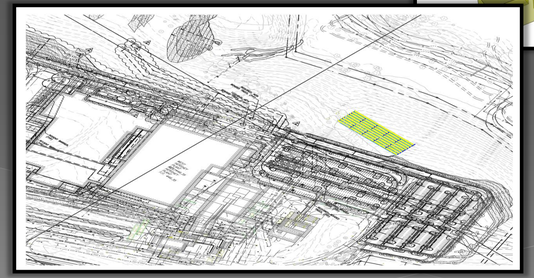

WEST FUALA PLANT EXPANSION

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System Cost per Watt:

Cost of Astronergy System= $1.97 per DC watt
Gross Cost of installation = $5 per DC watt *(U.S. Dept of Energy)*

PHOTOVOLTAICS

Financial Analysis

Solar System Calculator

Cost of System = $6.97 per DC watts
Harrisburg, PA
Electric rate: $0.143/kWh

Final Price of 10 Sets of 80 Astronergy Panels = $8,771,723

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ADVISOR: DR. CHIMAY ANUMBA

Table 8.8.2:	Description	Monetary Values ($)	COST
Estimated System Cost	Assumed Installation Gross Cost		$8,771,723
FINANCIAL INCENTIVES	Pennsylvania SREC Market	$ 3,129,987	
	PA State SunShine Rebate	$ 52,500	
	Federal Tax Credit	$ 2,631,517	
TOTAL SAVINGS		($ 2,957,719)	
ESTIMATED NET COST AT INSTALLATION:			$ 6,087,706

WEST FUALA PLANT EXPANSION

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ADVISOR: DR. CHIMAY ANUMBA

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PHOTOVOLTAICS

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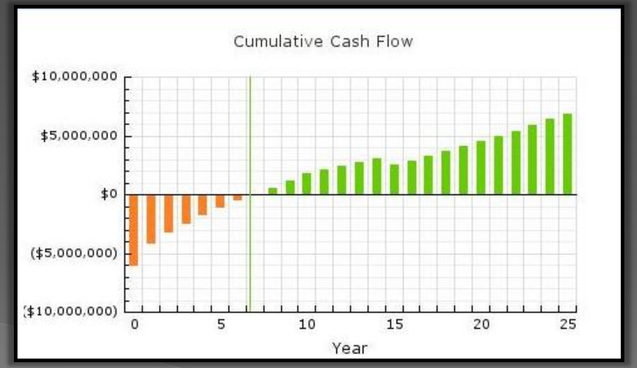

Payback Period = 7th Year

WEST FUALA PLANT EXPANSION

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PHOTOVOLTAICS

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ADVISOR: DR. CHIMAY ANUMBA

Final Conclusion

- 20% of lighting electric demand generated
- $29,591 Annual Savings
- Payback in 7 Years
- Large available area for more Panels

Recommendations:

- Owner should consider Incorporating Solar PV-Panels
- Limited budget by government for incentives

WEST FUALA PLANT EXPANSION

PRESENTATION OUTLINE:

I. PROJECT BACKGROUND
II. ANALYSIS #1: Energy Analysis
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IV. ANALYSIS #3: Structural Modification
  I. Breadth
    I. Steel Loads
    II. Precast Concrete Loads
    III. Precast Concrete Column Design
  II. Financial
  III. Schedule
  IV. Recommendation
V. ANALYSIS #4: Bathroom Prefabrication
VI. LESSONS LEARNED
VII. ACKNOWLEDGEMENTS

PRECAST CONCRETE

Problem Identification:

•Precast for Food plants than Steel - FDA
•A lot of Precast concrete work
•Mezzanine only major steel task
•Many Trades

Research Proposal:
• Study the viability and changes from changing Mezzanine from Steel to Precast

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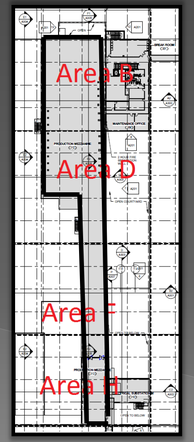

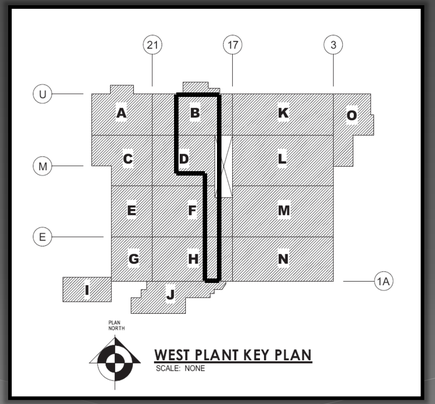

WEST FUALA PLANT EXPANSION

PRECAST CONCRETE

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ADVISOR: DR. CHIMAY ANUMBA

PRESENTATION OUTLINE:

Current Steel System

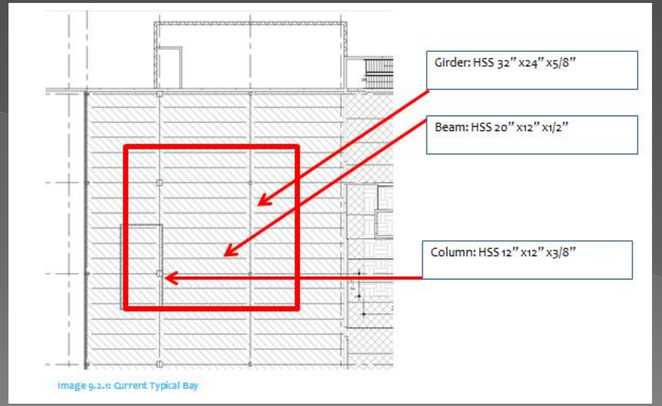
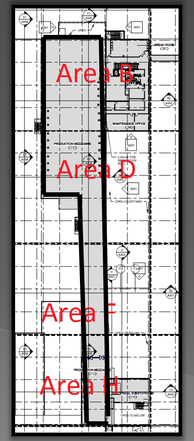
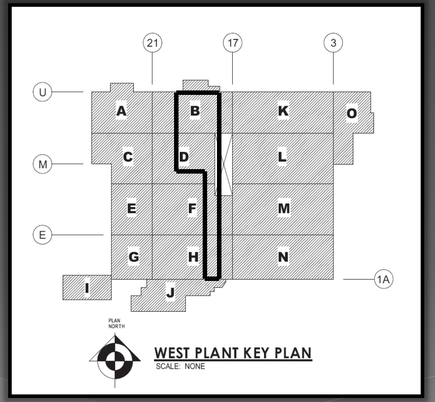


Image 9.2.1: Current Typical Bay





WEST FUALA PLANT EXPANSION

PRESENTATION OUTLINE:

I. PROJECT BACKGROUND
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III. ANALYSIS #2: Photovoltaic Array
IV. ANALYSIS #3: Structural Modification
  I. Breadth
    I. Steel Loads
    II. Precast Concrete Loads
    III. Precast Concrete Column Design
  II. Financial
  III. Schedule
  IV. Recommendation
V. ANALYSIS #4: Bathroom Prefabrication
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Current Steel System

PRECAST CONCRETE

Breadth
Steel load Calculation

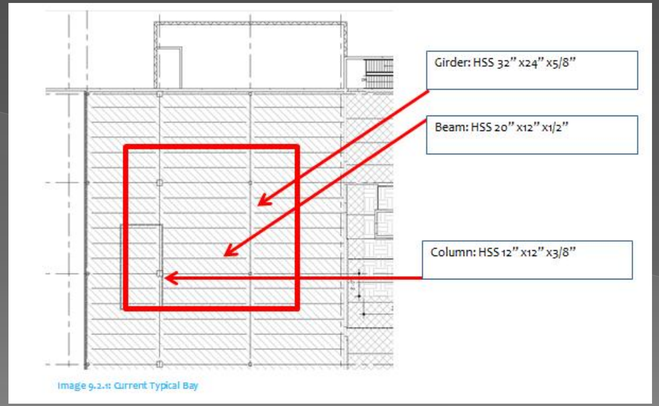

Image 9.2.1: Current Typical Bay

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Table 9.2.1: Current System	Name	Weight	Span
Columns	HSS 12" x 12" x 3/8"	78.52	17 feet
Girders	HSS 32" x 24" x 5/8"	225.8	32 feet
Beams	HSS 20" x 12" x 1/2'	103.3	32 feet

Table 9.2.3	Loads
Columns	607 kips
Girder	17.62 klf
Beams	2.8 klf
6" Deck Self Weight	90 psf

WEST FUALA PLANT EXPANSION

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Proposed precast System Loads

Table 9.2.3	Loads
Columns	1577 kips
Girder	42.56 klf
Beams	4.3 klf
Flat Slab Self Weight	275 psf

PRECAST CONCRETE

Breadth Work

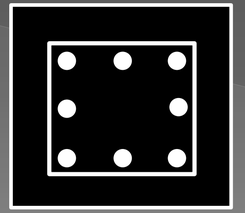
Precast Concrete Column Design

12”x12” HSS → 20” x 20” Precast Concrete

The Column will have to have the following properties:

f’c (ksi)= 4
Fy (ksi) = 60
Tie = Rectangular Tie
8 No. 18 (US)
3 Bars in 20 in line
AS = 32 sq.in
Steel ratio = 0.08

Loads = 1730 kips



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Summary of loads

Column Designed can carry = 1730 kips
Required Load to be Carried = 1577 Kips

Column Design can Carry intended Load!
1730 kips > 1577 kips

WEST FUALA PLANT EXPANSION

PRECAST CONCRETE

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PRESENTATION OUTLINE:

Cost of Both Systems (Nitterhouse concrete & RS Means)

Members in a Typical Bay	Description	Cost ($)	No. of units	Total Cost ($)
Girders	HSS 32" x 24" x 5/8"	310 /ft.	2	$19,840
	2'-0" wide x 3'-6" deep	185 /ft.		$11,840
Beams	HSS 20" x 12" x 1/2'	201 /ft.	7	$45,024
	1'-0" wide x 2'-0" deep	160 /ft.		$35,840
Slabs	Cast in Place concrete	25 /sqft	1	$25,600
	Precast Concrete slab	20 /sqft		$20,480
Columns	HSS 12" x12" x 3/8"	259 /ft.	1	$9,522
	Precast Concrete 20" x 20"	200 /ft.		$3,600

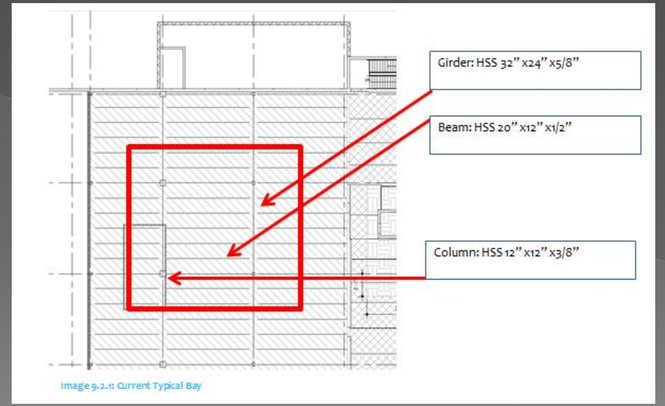

Image 9.2.1: Current Typical Bay

Comparison of Systems costs

System	Cost of erecting a typical bay	Cost per sqft	Cost of Entire Mezzanine (32,251 SF)
Precast Concrete	$71,760	$70.10	$ 2,260,795.10
Steel	$99,986	$97.64	$ 3,148,987.64

Total Savings = $888,193 = 28.21%

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PRECAST CONCRETE

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PRESENTATION OUTLINE:

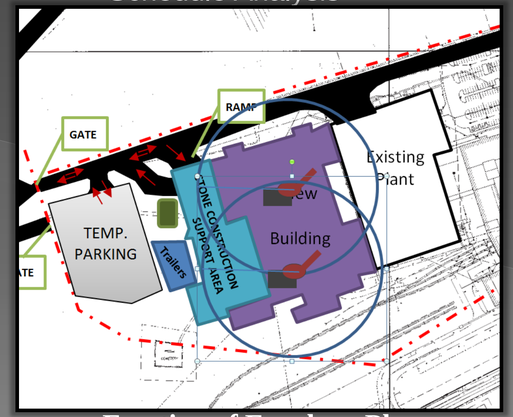
Using RS Means

Member	Quantity in a typical bay	Total quantity	Daily Output	Number of days
Girders	2	66	16	4.125
Beams	7	231	24	9.625
Columns	1	33	144	1
Slab	3	99	18	5.5

Duration for Entire Bay:

21 days with 1 crane
11 days with 2 cranes

Schedule Analysis



Erection of Envelope Phase

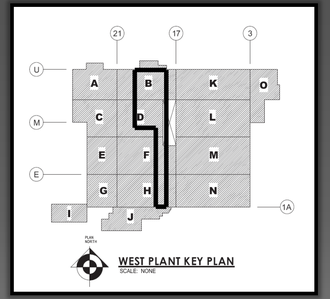
Using Current Schedule and durations

	Duration for an area
Girder	3 days
Beam	3 days
Column	2 days
Slab	5 days

13 days for an entire Area

Mezzanine is Considered 2.5 times a typical Area

32.5 days



WEST FUALA PLANT EXPANSION

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PRECAST CONCRETE

Using RS Means

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Beams	7	231	24	9.625
Columns	1	33	144	1
Slab	3	99	18	5.5

Duration for Entire Bay:

21 days with 1 crane

11 days with 2 cranes

Schedule Analysis

Summary of Schedule Analysis

Steel Mezzanine Duration = 35 Days

More Realistic Approach = 32.5 Days

Minor reduction in Schedule

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Using Current Schedule and durations

	Duration for an area
Girder	3 days
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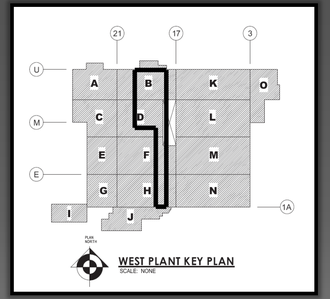
13 days for an entire Area

Mezzanine is Considered 2.5 times a typical Area

32.5 days



WEST FUALA PLANT EXPANSION

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PRECAST CONCRETE

Final Conclusion

- $ 888,192.54 cost reduction
- Minor Schedule Reduction
- 28 day Curing wait of C.I.P. concrete eliminated
- Less trades on Site
- Substantially Heavier structural System

Recommendations:

- Owner should consider Changing Structure from Steel to Precast Concrete
- Potential Cost savings and Schedule Reductions
- Better design for a food plant

System	Cost of erecting a typical bay	Cost per sqft	(32,251 SF)	Duration
Precast Concrete	$71,760	$70.10	$ 2,260,795.10	32.5 Days
Steel	$99,986	$97.64	$ 3,148,987.64	35 Days

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WEST FUALA PLANT EXPANSION

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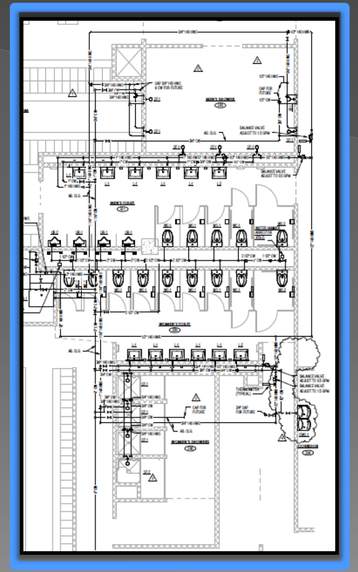

PREFABRICATION

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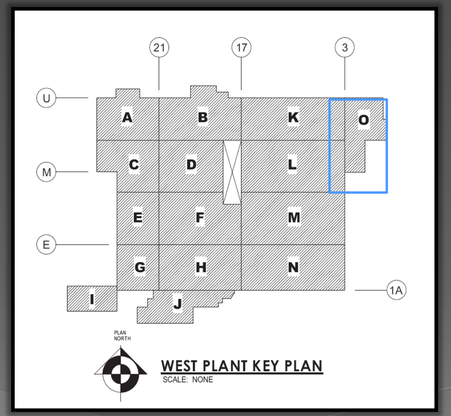
Problem Identification:

- Many Tasks taking place at the same time - Site Congestion
- CMU Walls for bathrooms in Area O
- A lot of Precast concrete work for Project

Research Proposal:

- Determine systems that could be prefabricated
- Reduce Site Congestion
- Cost and Schedule Impacts



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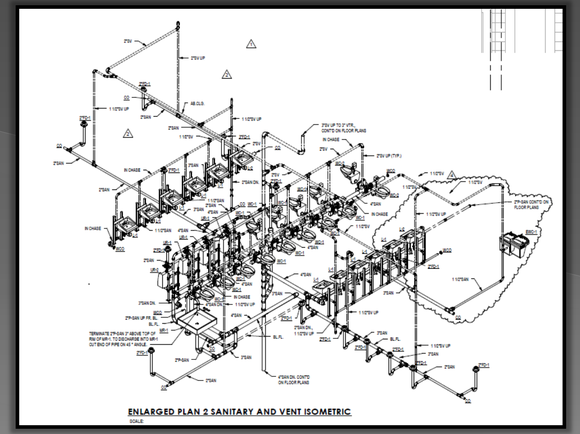
PREFABRICATION

What will be Prefabricated:

Bathroom Walls as precast concrete with Piping and electric rough-ins

Bathroom finishes Prefabrication

What to Prefabricate?



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WEST FUALA PLANT EXPANSION

PRESENTATION OUTLINE:

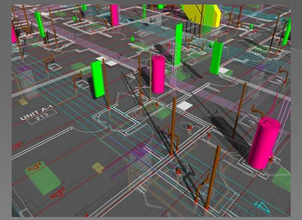
PREFABRICATION

Precast Concrete Bathroom prefabrication

Assumptions for proposed precast walls:

The same methods used for the current precast concrete envelope would be used for the precast bathroom walls:

- Procurement
- Prefabrication
- Transportation
- Hoisting
- Connecting



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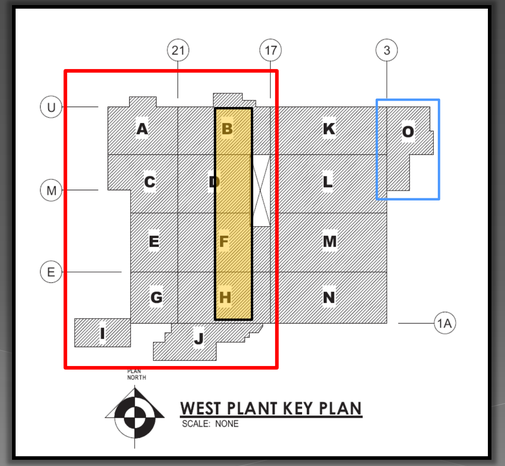

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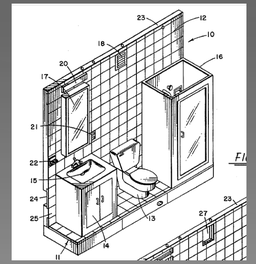
Bathroom Finishings:

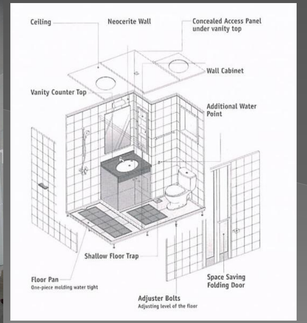
- Toilet Paper Dispenser
- Paper Towel Dispenser
- Sanitary Napkin Disposal
- 24”x26” mirror
- Soap dispenser



PREFABRICATION

On-Site Prefabrication

Walls and finishes assembled at site and then hoisted into place



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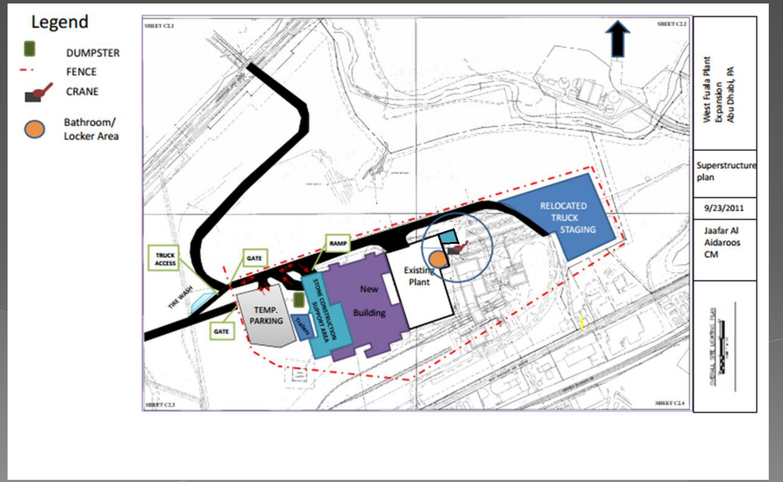
Site Logistics



WEST FUALA PLANT EXPANSION

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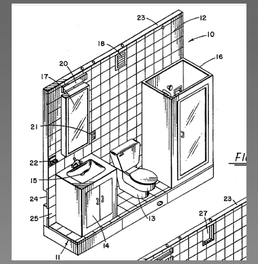

PREFABRICATION

Hoisting Prefabricated units

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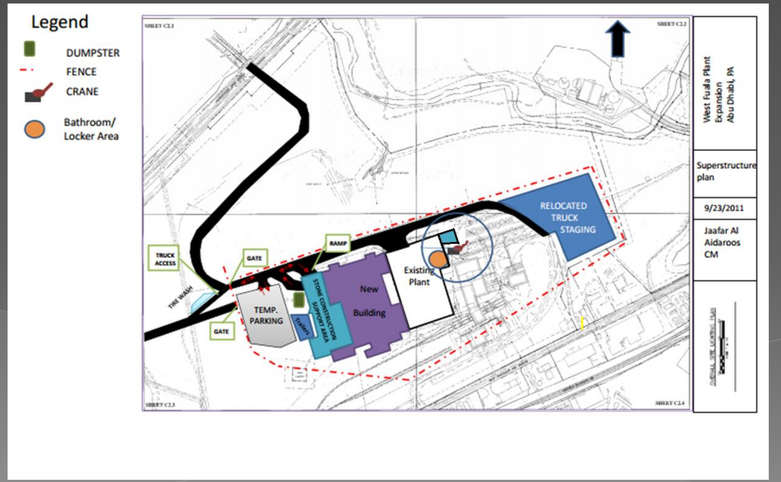
Site Logistics



WEST FUALA PLANT EXPANSION

PRESENTATION OUTLINE:

PREFABRICATION

Current Schedule

Critical Path task

Task	Early Start	Early Finish
Install Masonry Walls	**22 Jun**	**07 Sept**
In-Wall plumbing	24 Jun	19 July
In-Wall Electric Rough-in	27 Jun	07 Sept
HVAC Main Duct Work	01 July	07 Sept
Plumbing Insulation	06 July	07 Sept
Piping and ductwork connections	25 July	07 Sept

Schedule impact:

Current Duration: 45 days of construction for CMU walls

Using RS Means & actual Project Schedule
Proposed system Duration:
2 days for hoisting precast walls

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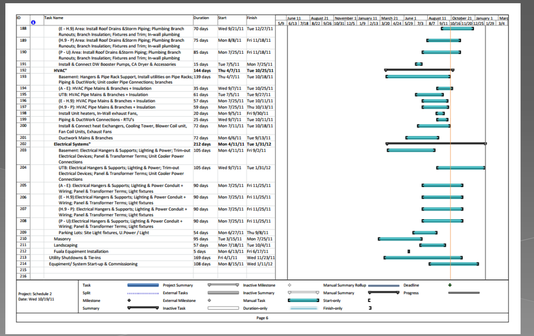
General Conditions Impact

GC Calculated to be $992,000 over 22 Months
Around 43 Days of Project Schedule Saving = $67,500 of GC Savings



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PREFABRICATION

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PRESENTATION OUTLINE:

Final Conclusion of prefabrication

- 43 Days of Schedule Reduction
- $62.5K Worth of GC Savings
- Major Reduction in site congestions
- Increased Safety, Quality
- Less Waste

Recommendation

- Pursue Prefabrication of Bathrooms in Area O
- Met goals of reducing site congestions

WEST FUALA PLANT EXPANSION

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LESSONS LEARNED

Lessons learned

Analysis 1: Energy Model
No cost to produce a design with less energy usage

Analysis 2: Photovoltaic Panels
Sustainable Energy with a 7 year payback period

Analysis 3: Structure modification
Reduction in Schedule and Cost

Analysis 4: Bathroom prefabrication
Many Advantages: reduced Congestion, schedule, safety, quality

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WEST FUALA PLANT EXPANSION

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ACKNOWLEDGEMENT

Family

Friends

AE Classmates

Pennsylvania State University
AE Department

PENNSTATE Department of Architectural Engineering

Dr. Moses Ling **Dr. Chimay Anumba**

Turner Construction Company

Turner

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Thank You!
Questions?

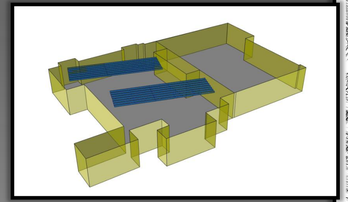
WEST FUALA PLANT EXPANSION

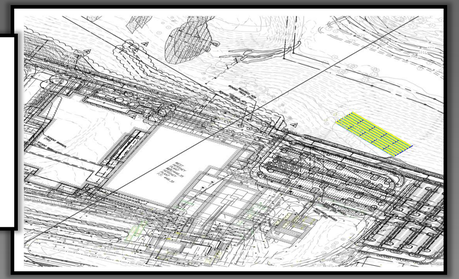
Electric Loads & Layout

Summary of Calculations

System Covers 20% of the lighting system
Annual Savings of $29,591 on Electric Bill

Power Factor = 1.0 of Lighting system
134 kW / 650 kW = 20.615%





PHOTOVOLTAICS

Photovoltaic Panels

System Cost per Watt:

Cost of Astronergy System= $1.97 per DC watt
Gross Cost of installation = $5 per DC watt *(U.S. Dept of Energy)*

Table 8.8.2:	Description	Monetary Values ($)	COST
Estimated System Cost	Assumed Installation Gross Cost		$8,771,723
FINANCIAL INCENTIVES	Pennsylvania SREC Market	$ 3,129,987	
	PA State SunShine Rebate	$ 52,500	
	Federal Tax Credit	$ 2,631,517	
TOTAL SAVINGS		($ 2,957,719)	
ESTIMATED NET COST AT INSTALLATION:			$ 6,087,706

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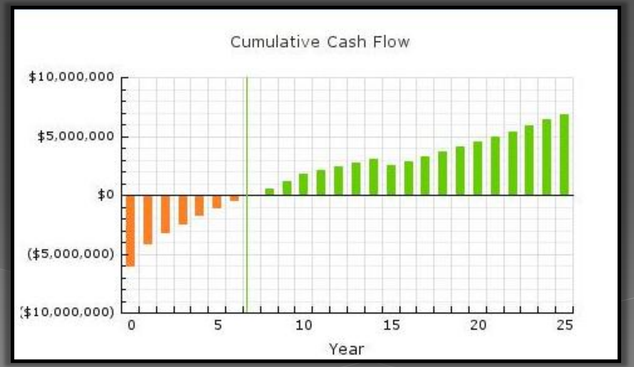
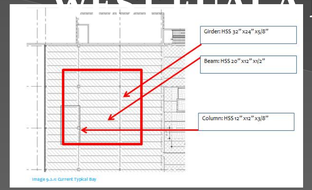
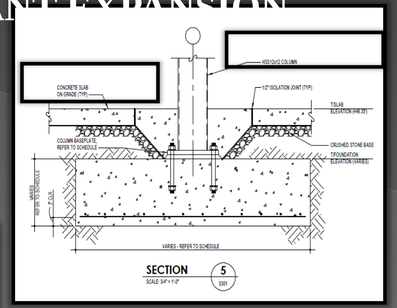
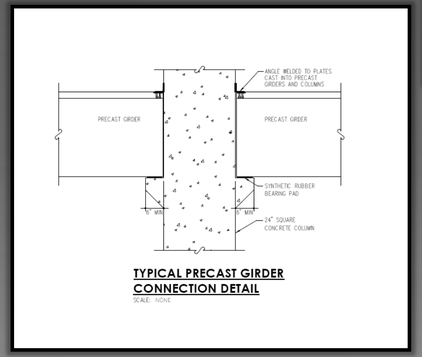
Financial



WEST FUALA PLANT EXPANSION







PRECAST CONCRETE

Changing the Structure of the Mezzanine
Assumptions and parameters

- Process equipment penetration were not known, so structure was switched to steel to prevent delay
- There is enough space for minor design modification
- Typical Bay method fro calculations
- Maintain original design of mezzanine

System	Cost of erecting a typical bay	Cost per sqft	(32,251 SF)	Duration
Precast Concrete	$71,760	$70.10	$ 2,260,795.10	35 Days
Steel	$99,986	$97.64	$ 3,148,987.64	32.5 Days

Breadth
Steel load Calculation

Typical Bay	Description	Cost ($)	No. units	Total Cost	Loads
Girders	HSS 32" x 24" x 5/8"	310 /ft.	2	$19,840	17.62 klf
	2'-0" wide x 3'-6" deep	185 /ft.		$11,840	42.56 klf
Beams	HSS 20" x 12" x 1/2'	201 /ft.	7	$45,024	2.8 klf
	1'-0" wide x 2'-0" deep	160 /ft.		$35,840	4.3 klf
Slabs	CIP concrete	25 /sqft	1	$25,600	90 psf
	Precast slab	20 /sqft		$20,480	275 psf
Columns	HSS 12" x12" x 3/8"	259 /ft.	1	$9,522	607 kips
	Precast Concrete 20" x 20"	200 /ft.		$3,600	1577 kips

WEST FUALA PLANT EXPANSION

Breadth Work

Precast Concrete Column Design

12”x12” HSS 20” x 20” Precast Concrete

The Column will have to have the following properties:

AS = 32 sq.in
Steel ratio = 0.08
f’c (ksi)= 4 x 0.92 = 3.68
Fy (ksi) = 60 x 0.08 = 4.8
Total = 8.48 x 17 ft x 12in/ft) = 1729.92 kips
8 No. 18 (US)

PRECAST CONCRETE

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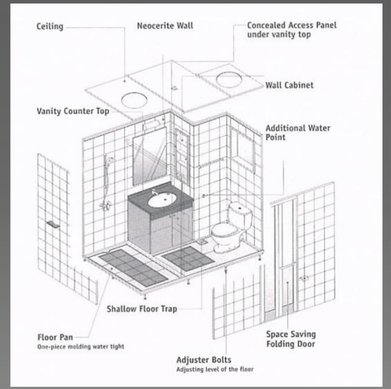
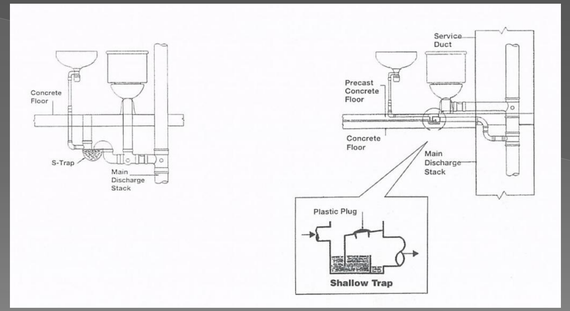
WEST FUALA PLANT EXPANSION

Finishes installed to walls on site and then hoisted into place



Finishes and wall preassembled in factory. Delivered and hoisted

PREFABRICATION



PENN STATE AE SENIOR CAPSTONE PROJECT

JAAFAR AL AIDAROOS | CONSTRUCTION MANAGEMENT

ADVISOR: DR. CHIMAY ANUMBA

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PENN STATE AE SENIOR CAPSTONE PROJECT
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- Contingency pipes should be cast in structural Slabs as an outlet pipe for seepage
- Electrical service shall also be connected to the main switch
- Gap in the between bathroom and structural slab will be packed with non-shrink grout around perimeters

PRESENTATION OUTLINE

WEST FUALA PLANT EXPANSION

I. PROJECT BACKGROUND
II. ANALYSIS #1: Energy Analysis
  I. Conceptual Design
  II. Energy Model
  III. Solar Analaysis
    I. Solar Studies
    II. Ecotect Solar Radiation
  IV. Application to Energy Model
  V. Recommendations
III. ANALYSIS #2: Photovoltaic Array
  I. Electrical Systems Analysis
  II. Solar Analysis
  III. PV systems
  IV. Layout
  V. Electrical Energy production
  VI. Financial Analysis
  VII. Recommendation

West Fuala Plant Expansion

Abu Dhabi, PA

Bathroom Prefabrication

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Breadth

Steel load Calculation

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