

Miller Children's Hospital
Pediatric Inpatient Addition
Long Beach, CA

The Pennsylvania State University
Architectural Engineering

Stephen Haines
Mechanical Option



**Miller Children's Hospital
Pediatric Inpatient Addition**
Stephen Holmes
Mechanical Option



Presentation Outline

- Building Background
- Existing Systems Summary
- Design Objectives
- Mechanical Depth – CHP
 - CHP Screening Process
 - Energy Analysis
 - Central Plant Redesign
 - Electrical System Integration
 - Cost Breakdown and Emissions
 - Summary and Recommendation
- Electrical Breadth – PV Panels
 - System Sizing
 - Cost Estimate and Payback
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- Conclusions

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Building Background

• **General Building Information**

- Owner
 - Miller Children's Hospital
- Project Size
 - 127,000 square feet
- Total Cost
 - \$151,000,000 (estimated)
- Design-bid-build
- Completion Date
 - Fall 2009



Building Background

- **The Pediatric Inpatient Addition**
 - 4-Story Hospital Facility
 - 7 Operating Rooms
 - Neonatal Intensive Care Unit
 - Utilizes Green Roof System



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Existing Systems Summary

Mechanical System

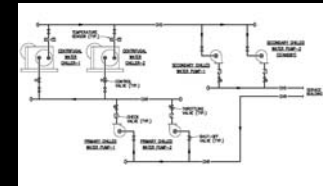


Presentation Outline

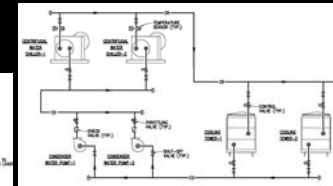
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- 7 Air Handling Units (located on roof)
- Constant Volume with Space Reheat
- HEPA Filters Used for Operating Rooms
- (2) 500 ton Centrifugal Water Cooled Chillers
- (2) Induced Draft Cooling Towers
- (2) 2,000 MBh Gas-Fired Hot Water Boilers

Existing Systems Summary

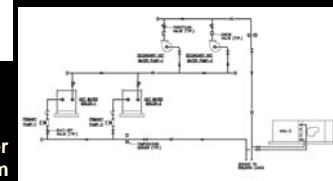
Chilled Water Flow Diagram



Condenser Water Flow Diagram



Hot Water Flow Diagram



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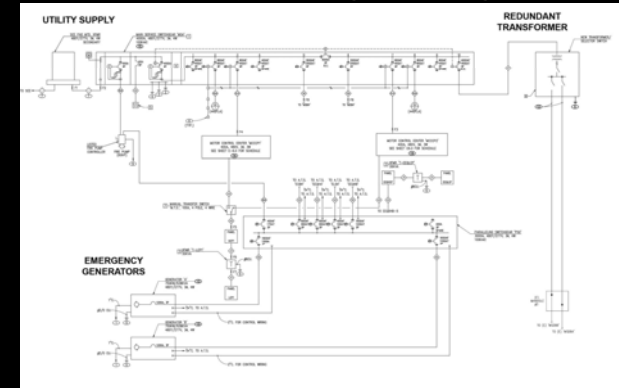
Existing Systems Summary

Electrical System



Existing Systems Summary

Electrical System Single Line Diagram



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- Electric Utility – Southern California Edison
- 480Y/277V 3-phase 4-wire secondary
- (2) 750 kW emergency generators
- 10,000 kW redundant transformer
 - Miller Children's Hospital
 - Does not serve loads
 - For future use and owner preference

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Design Objectives

Main Objectives



Design Objectives

Energy Consumption

- Electricity - 5,900,000 kWh/year
- Gas - 38,000 therms/year

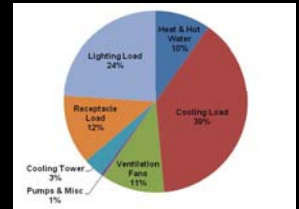
Operational Costs

- Electricity - \$1,100,000/year
- Gas - \$30,000/year

Emissions (Utility Generated)

- NO_x – 6,000 lbs/year
- SO_x – 5,000 lbs/year
- CO₂ – 3,800 lbs/year

Annual Energy Consumption



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- Reduce energy consumption
- Save money in operational costs
- Cut back on emissions

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**Mechanical Depth
Combined Heat & Power**

CHP Screening Process

- Spark Spread
 - The difference between electricity and gas rates in \$/MMBtu
 - Higher spread favors CHP
- Cost of electricity (> \$0.05/kWh)
- Cost of gas(< \$4.00/MMBtu)



**Mechanical Depth
Combined Heat & Power**

Energy Costs and Consumption

	Energy Costs	Energy Consumption
Electricity	\$0.187/kWh	5,915 MWh
Natural Gas	\$8.01/MMBtu	3,811 MMBtu

General Factors Affecting CHP

Factors Favoring	Spark Spread	Elec. Cost	NG Cost	Elect. Load	Thermal Load
CHP Feasibility:	\$/MMBtu > 12	\$/kWh	\$/MMBtu	Avg/peak	Avg/peak
	> 12	> 0.05	< 4.00	> 0.7	> 0.7
Value for Site:	46.78	0.187	8.01	0.74	0.25

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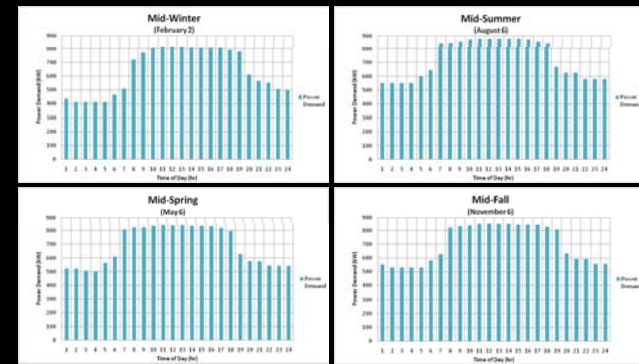


**Mechanical Depth
Combined Heat & Power**



**Mechanical Depth
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Electric Load Profiles



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• **Conclusions**

Energy Analysis

- **Peak Electric Load**
 - September 6 at 5:00 pm
 - 900 kW
- **Peak Heating Load**
 - January 1 at 7:00 am ($T_{OA} = 40^{\circ}\text{F}$)
 - 1,700 MBh
- **Peak Cooling Load**
 - September 6 at 5:00 pm ($T_{OA} = 91^{\circ}\text{F}$)
 - 225 tons

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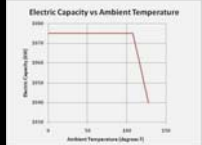
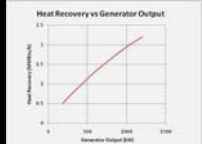
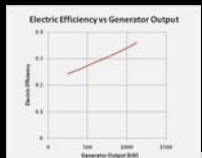
- Peak Electric Load – 900 kW
 - 15% over-sizing
 - 1,035 kW generator required
- Use reciprocating engine
 - Little heating needed
- Cannot use absorption cooling
 - Generator size too small
- Generator Operation Condition
 - Demand output



**Mechanical Depth
Combined Heat & Power**

Caterpillar Reciprocating Engine

Caterpillar Engine			
Model No. G3606 T 130 LE			
Electric Capacity	1,075 kW		
Fuel Rate	10.64 MMBtu/h (HHV)		
Heat Recovery	2.03 MMBtu/h		
% Efficiency	Electrical	Thermal	Overall
	34.47%	19.03%	53.50%
Emission Rates (lb/MMBtu)	CO2	CO	Nox Sox
	110	0.506	4.08 0.000588



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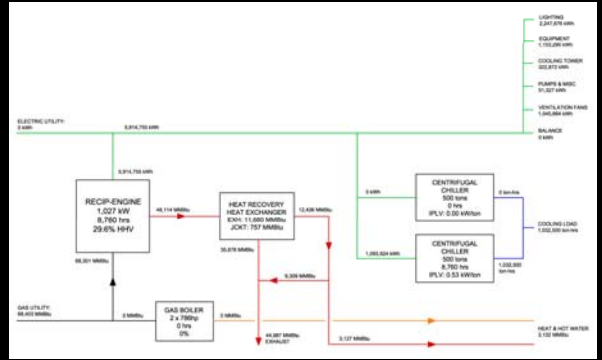


**Mechanical Depth
Combined Heat & Power**

Energy Analysis



**Mechanical Depth
Combined Heat & Power
CHP System Schematic and Annual Energy Use**



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- Recovered Heat Energy
- System Schematic

Heat Recovery Heat Exchanger Operation			
	Jacket (MBtu/h)	Exhaust (MBtu/h)	Total (MBtu/h)
Annual Operating Hours	8,760	8,760	8,760
Minimum Heat Recovery	0.54	0.45	0.98
Maximum Heat Recovery	0.94	0.92	1.77
Mean (Average) Heat Recovery	0.71	0.71	1.42

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**Mechanical Depth
Combined Heat & Power**

Central Plant Redesign

- Located north of the Pediatric Inpatient Addition
- Comprised of:
 - Pump Room
 - Chiller Room
 - Electrical Switchgear
 - Emergency Generator Room
 - Transformer Yard
- New Generator Room – 1,180 sq. ft.



**Mechanical Depth
Combined Heat & Power**

Existing Central Plant



Central Plant Area = 4,700 sq. ft.

CHP Plant Redesign



New Central Plant Area = 5,880 sq. ft.

25% Increase

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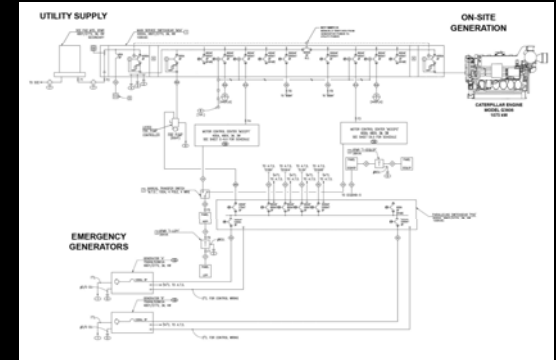
Electrical System Integration

- Generator replaces redundant transformer
- Key Switch
- Fire pump moved
- Emergency generators not required by code



**Mechanical Depth
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Existing Central Plant



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**Mechanical Depth
Combined Heat & Power**

Cost Breakdown and Emissions

- Decrease in SO_x and CO₂ emissions
- Increase in NO_x emissions
 - Generator less efficient at part-load
 - Higher emissions per unit of energy generated
 - Utility generator operates at higher efficiency
 - California guidelines in place for utility emissions
- Catalytic Reduction Systems
 - Treats exhaust gas after it leaves the engine
 - Uses toxic reagents such as ammonia
 - Potential health risks with venting and on-site storage



**Mechanical Depth
Combined Heat & Power**

Emissions Data

	Pounds of Emissions per Year	
	On-Site Generation	Utility Generation
NO _x	12,234	5,951
SO _x	232	5,029
CO ₂	3,761	3,782

**Cat Selective Catalytic
Reduction Systems**



- Reduces CO by 93%
- Reduces NO_x by up to 90%

Cat Oxidation Catalysts



- Reduces CO by 93%
- Reduces hydrocarbons by more than 40%

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**Mechanical Depth
Combined Heat & Power**

Summary and Recommendation

- Total System Cost: \$1,850,000
 - Includes Catalytic Reduction System
 - 1.5% increase in overall project cost
- Total Annual Savings: \$320,000/year
 - Includes maintenance costs for CRS
 - 30% reduction in operational costs
- Payback Period: Less than 6 years
- Reduced Emissions with CRS
- Recommendation: Install CHP System



**Mechanical Depth
Combined Heat & Power**

System Cost

CHP Equipment Costs: \$1,100,000
Central Plant Expansion: \$500,000
Catalytic Reduction System: \$250,000
Total CHP System Cost: \$1,850,000

Annual Savings

CHP Operation Savings: \$410,000/year
Maintenance Costs: \$90,000/year
Total Annual Savings: \$320,000/year

Maintenance Costs

CHP Maintenance Costs: \$65,000/year
CRS Maintenance: \$25,000/year
Total Maintenance Cost: \$90,000/year

Important Notes

- Efficient CHP systems utilize ALL recovered heat
- Size of building electric demand plays a big role (> 2 Megawatts)
- Utility rates very important factor

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**Electrical Breadth
Photovoltaic Panels**

System Sizing

- Photovoltaic array located on roof
 - Pediatric Inpatient Addition upper roof
 - Pediatric Inpatient Addition lower roof
 - Miller Children's Hospital roof
- Total panel coverage: 12,310 sq. ft.
- *BP Solar* panel selected
 - Model BP 175B
 - Rated power: 175W
 - 14% Nominal Efficiency
- 900 PV panels used



**Electrical Breadth
Photovoltaic Panels**

Areas

- Pediatric Inpatient Addition
 - Upper roof: 7,700 sq. ft.
 - Lower roof: 3,240 sq. ft.
- Miller Children's Hospital: 11,060 sq. ft.
- Assumed Coverage
 - PIA: 80%
 - MCH: 60% (rooftop equipment)
- Assumed 80% Usable PV Area
- Total Panel Coverage: 12,310 sq. ft.
- Individual Panel Area: 13.56 sq. ft.
- 900 Panels Calculated

PV Panel Coverage



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**Electrical Breadth
Photovoltaic Panels**

Cost Estimate and Payback



**Electrical Breadth
Photovoltaic Panels**

System Cost

- Development & Engineering Fees: \$70,000
- PV Modules: \$945,000
- Module Support Structure: \$123,100
- Inverter: \$100,800
- System Installation: \$236,000
- **Total Cost: \$1,482,250**

Incentives Package

- California State Rebate (Performance Based Incentive): \$478,980
- Federal Investment (10%) Tax Credit: \$197,582
- State Solar Energy (7.5%) Tax Credit: \$148,187
- Federal Accelerated Depreciation (34% tax rate): \$328,770
- State Depreciation Savings (8% tax rate): \$38,679
- **Total Package: \$1,192,200**

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- Renewable energy delivered: 245,000 kWh/year
- Maximum capacity: 140 kW AC
- Electricity savings: \$46,000/year
- System cost: \$1,482,250
- Incentives package: \$1,192,200
- Payback Period: 7 years

Net PV System Cost by Year

Year	Total System Cost	SCE PBI Program	10% Federal Tax Credit	7.5% State Tax Credit	Federal Depreciation Savings	State Depreciation Savings	Estimated Energy Savings	Net System Cost
1	(\$1,482,250)	\$478,980	\$196,123	\$147,092	\$197,262	\$7,736	\$45,933	(\$409,124)
2					\$52,603	\$12,377	\$45,478	(\$298,665)
3					\$31,562	\$7,426	\$45,028	(\$214,649)
4					\$18,937	\$4,456	\$44,582	(\$140,674)
5					\$18,937	\$4,456	\$44,141	(\$79,140)
6					\$9,469	\$2,228	\$43,704	(\$23,740)
7					Break even in 7 years		\$43,271	\$19,531
8							\$42,843	\$62,374
9							\$42,419	\$104,793
10							\$41,999	\$146,792

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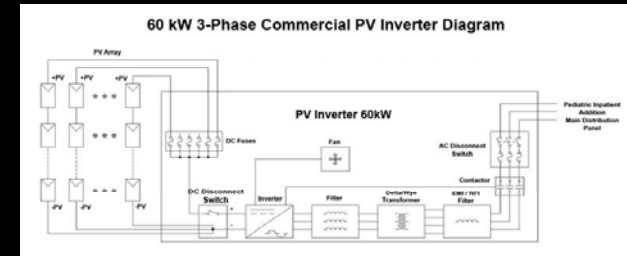
**Electrical Breadth
Photovoltaic Panels**

Electrical System Integration



**Electrical Breadth
Photovoltaic Panels**

Commercial PV Inverter Diagram



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• PV Inverter

- Converts DC current into AC current
- *Soletrix* PVI Gridtie Inverters
- Miller Children's Hospital: 60 kW
- Pediatric Inpatient Addition: 82 kW

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Photovoltaic Panels**

Electrical System Integration

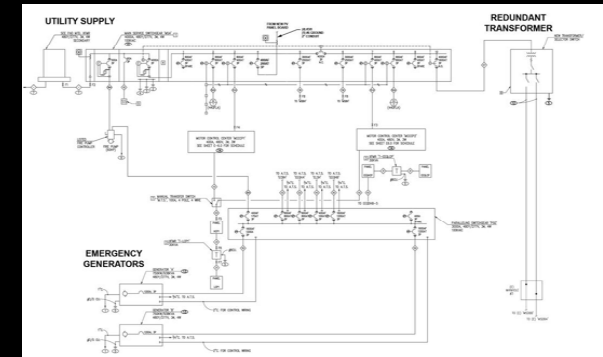
• Electrical System

- Spare breaker on main distribution panel (#4)
- New breaker size: 200A
- Inverters connected through single feeder
- Feeder size: (4) 3/0 + (1) #6 ground
- Conduit size: 2"
- Distance to main distribution panel: 240 ft
- % Voltage drop: 1.56% < 2%
- System sized using NEC 2005



**Electrical Breadth
Photovoltaic Panels**

PV Electrical System Single Line Diagram



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**Electrical Breadth
Photovoltaic Panels**

Summary and Recommendation

- \$46,000 annual savings
- Payback period of 7 years
- Not possible without incentives package
 - Costs more than to purchase from utility
- Risky decision
 - Available money fluctuates
 - Could be cut off if funds run out



**Electrical Breadth
Photovoltaic Panels**

Summary and Recommendation

- Non-renewable energy savings
- Greenhouse gas reductions
- Recommendation: Install PV System

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Conclusions

Design Goals

- Reduce energy consumption
- Save money on operational costs
- Cut back on emissions

Can be achieved with energy efficient mechanical systems and renewable energy sources



Questions?

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Long Beach, CA

The Pennsylvania State University
Architectural Engineering

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Special Thanks to:

- Dr. James Freihaut – AE Department
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- David Maino – Integrated Design Studios, Inc
- The JBA Costa Mesa office staff
- Kerry Hickman – Cashman Equipment

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