CALVIN REDUNDANT DATA CENTER

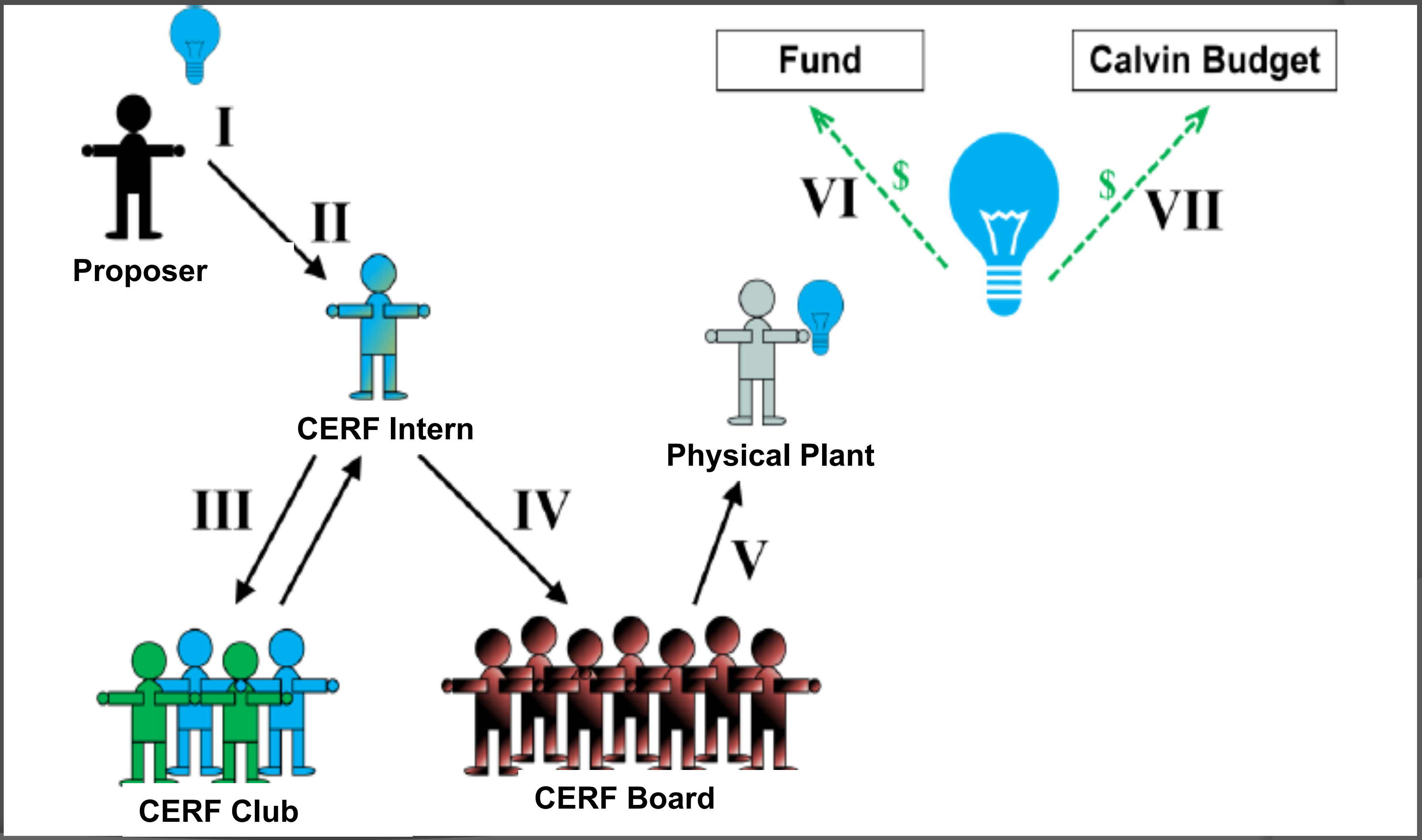
Project Introduction

- Goal: Design a new energy efficient redundant data center for Calvin College
- Requirements:
  - 30% more efficient
  - Has capacity for expansion
  - Potential to utilize Calvin Energy Recovery Fund (CERF) application

CERF Project Types

- Blue Projects
  - Short term energy efficiency projects
  - ≤ 10 yr payback
- Green Projects
  - Reduce Carbon Emissions
  - Raise awareness for sustainability and renewable energy
  - Long term energy efficiency projects
  - > 10 yr payback

CERF Organization



Project Organization

- Envelope
  - Wall design and heat transfer calculations
- Power Supply
  - Investigated uninterruptable power supplies
- Heat Ventilation Air Conditioning (HVAC)
  - Designed data center cooling system
- Instrumentation
  - Designed measurement system
- Finance
  - Determined cost and CERF viability

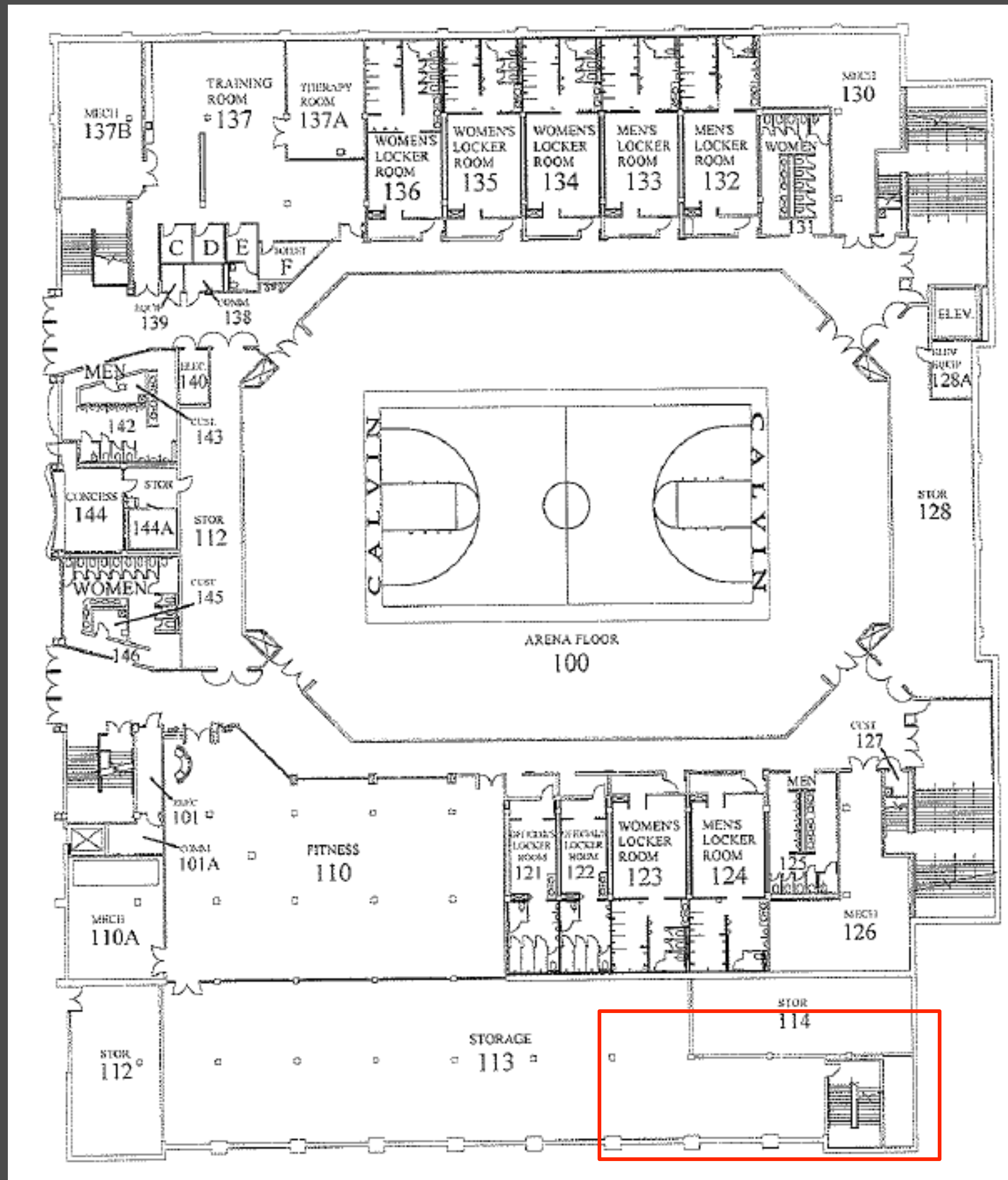
Project Organization

- Each team presents in turn
- Topics
  - Base case
  - CERF case

Envelope Team

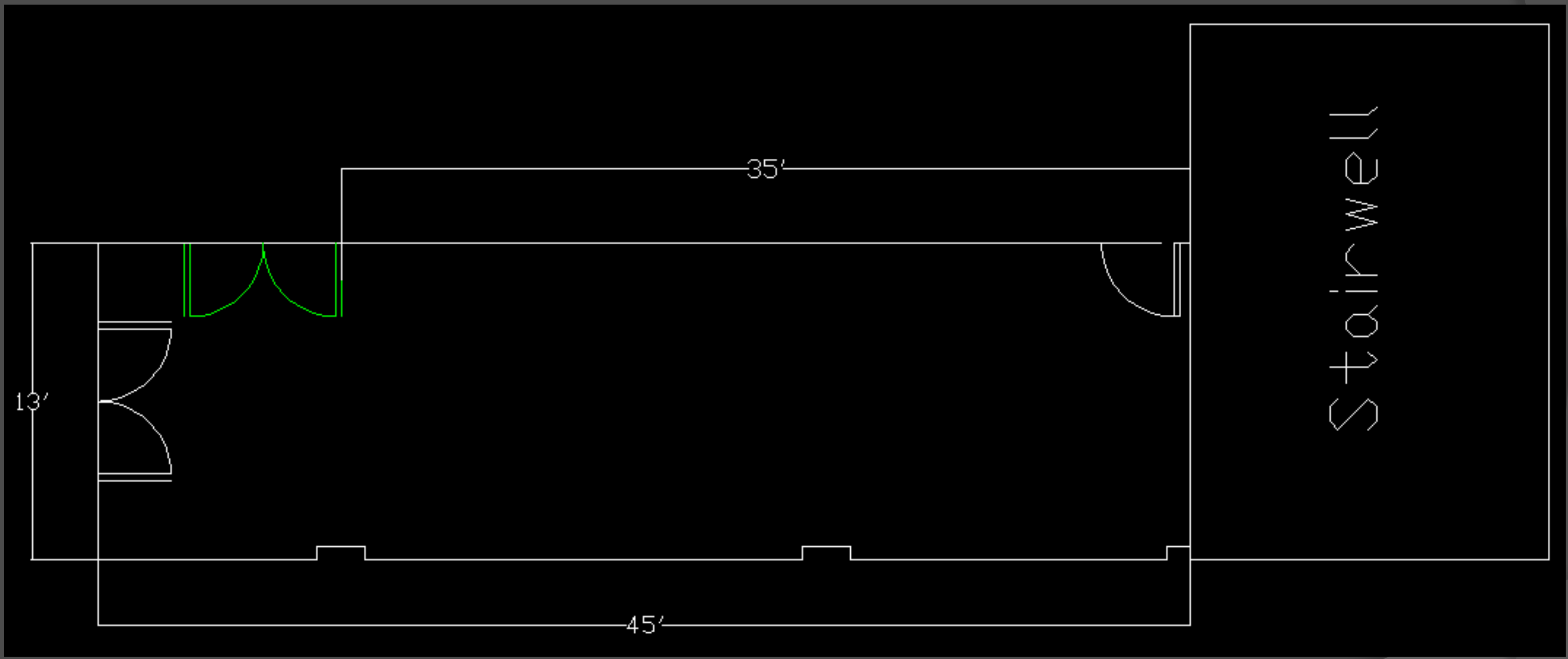
Purpose of the Envelope

- Security
  - Located in a secure location, however, many have access
  - Various activities could damage the servers
- HVAC
  - Isolate a small area- easier to keep cool
    - Increased efficiency



MECH 137B
TRAINING ROOM 137
THERAPY ROOM 137A
WOMEN'S LOCKER ROOM 136
WOMEN'S LOCKER ROOM 135
WOMEN'S LOCKER ROOM 134
MEN'S LOCKER ROOM 133
MEN'S LOCKER ROOM 132
WOMEN 131
MECH 130
C
D
E
F
139
138
ELEV.
128A
MEN 142
ELEC. 140
CUST. 143
CONCESS 144
STOR 144A
STOR 112
WOMEN 146
CUST 145
CALVIN
CALVIN
ARENA FLOOR 100
STOR 128
CUST 127
101
101A
FITNESS 110
MECH 110A
121
122
WOMEN'S LOCKER ROOM 123
MEN'S LOCKER ROOM 124
MEN 125
MECH 126
STOR 114
STORAGE 113
STOR 112

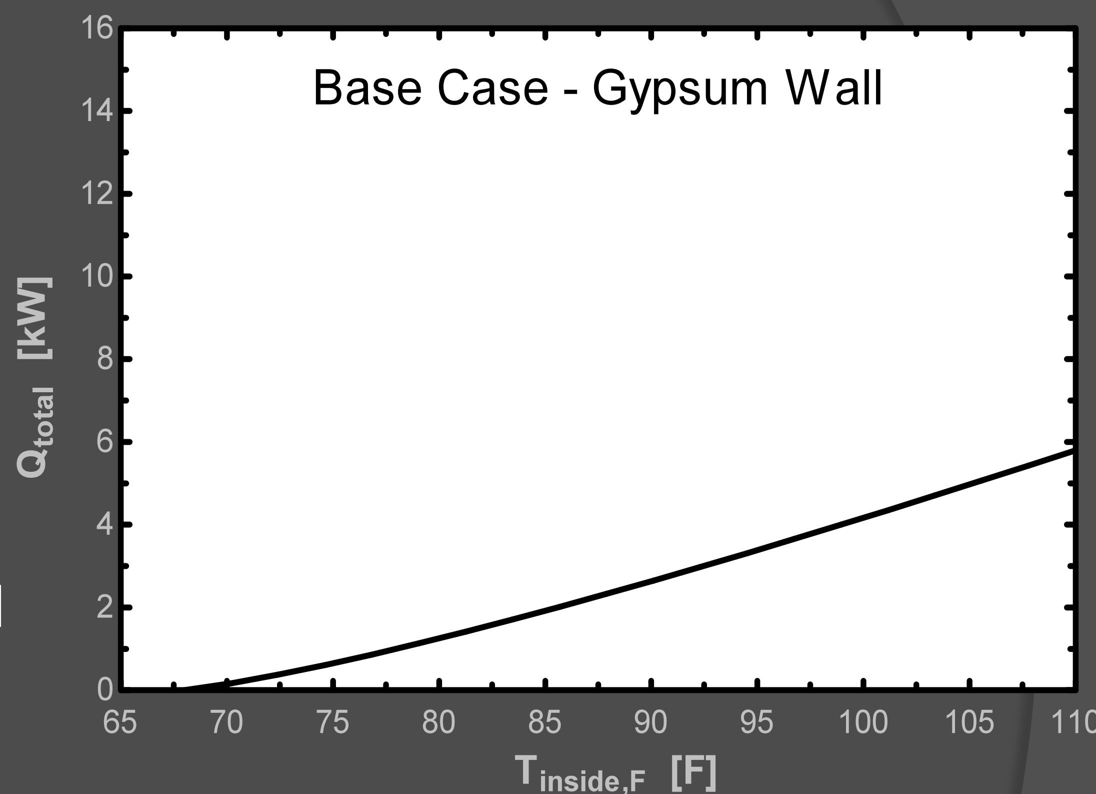
Proposed Layout



Proposed Layout

Base Case

- Metal Studs with Gypsum board wall
  - Calculated heat transfer considering natural convection and conduction
- Efficiency
  - Heat transfer is most important



$T_{inside,F}$ = 90 [F]

$T_{outside,F}$ = 68 [F]

$Total_{costs}$ = 2065 [$]

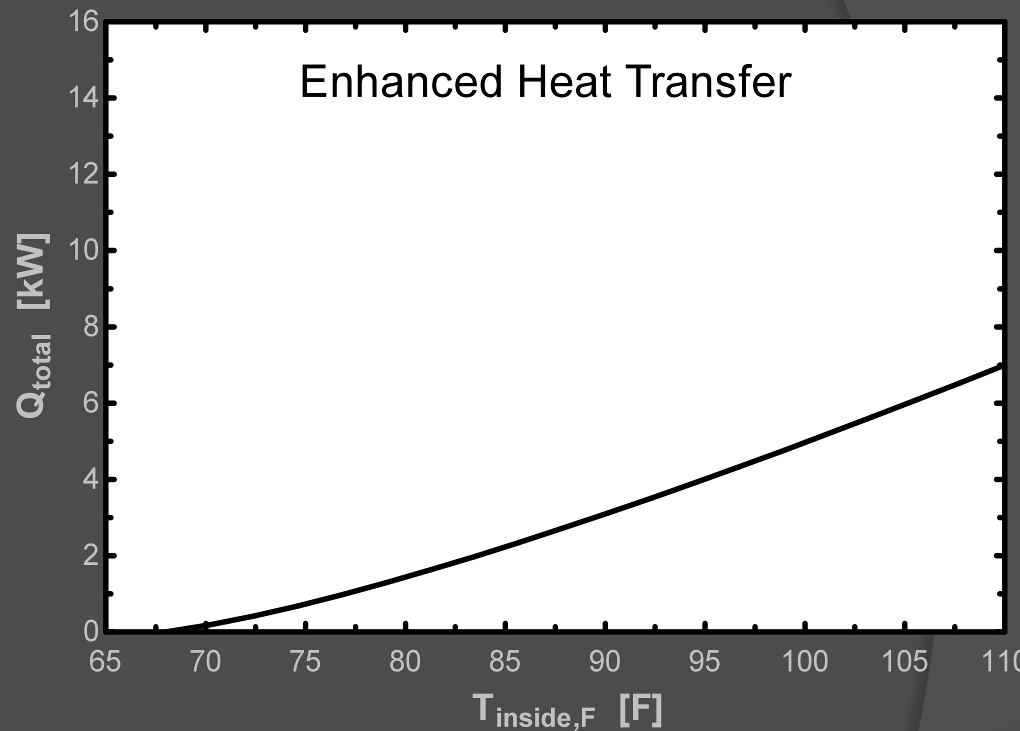
Q_{total} = 2.632 [kW]

Alternative Designs

- Originally wanted to improve heat transfer out of room under normal operating conditions
  - Could not modify existing walls without compromising integrity
  - Expense
  - Small ΔT during normal conditions
- Improving response of envelope to HVAC performance

Alternative designs

- Corrugated Metal Wall
  - Advantages
    - Significantly improves the rate of heat transfer from gypsum wall
  - Disadvantages
    - Transfers heating load to current HVAC system



$T_{outside,F}$ = 68 [F]

$T_{inside,F}$ = 90 [F]

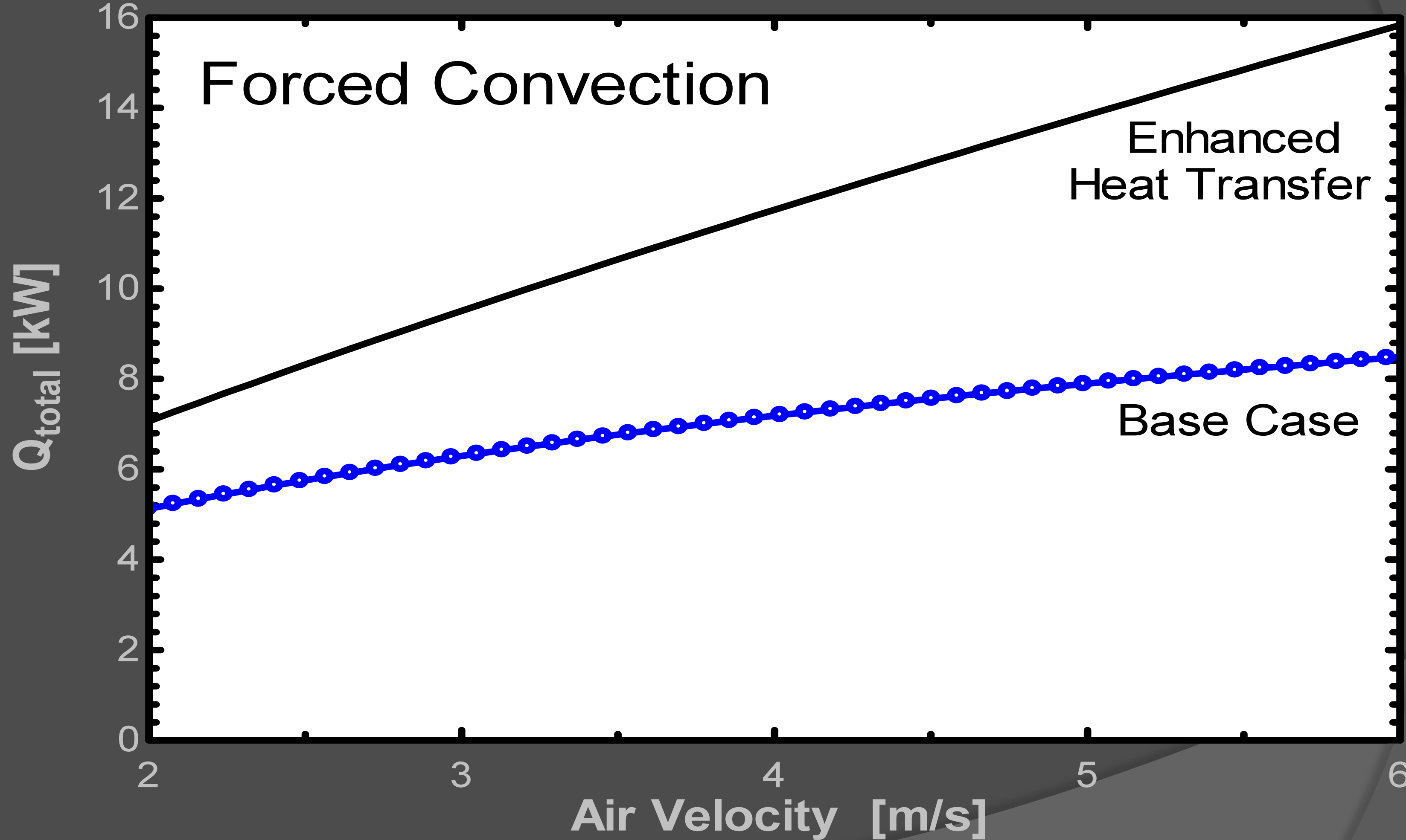
$Total_{costs}$ = 3158 [$]

Q_{total} = 3.093 [kW]

Alternative designs

- Primary Resistance to Heat Transfer is due to Convection
- Use fans to force air over the interior walls during poor HVAC performance
  - Increase difference between aluminum and Gypsum walls

Alternative designs



Envelope Recommendation

	Base Case (USD)	Aluminum Walls (USD)
Installed Costs	2065	3158

- Includes
  - Studs
  - Drywall/Aluminum
  - Doors
  - Misc (Tape, screws, etc)
  - Labor
- Recommendation: Aluminum Walls
  - No CERF Option

Power Supply Team

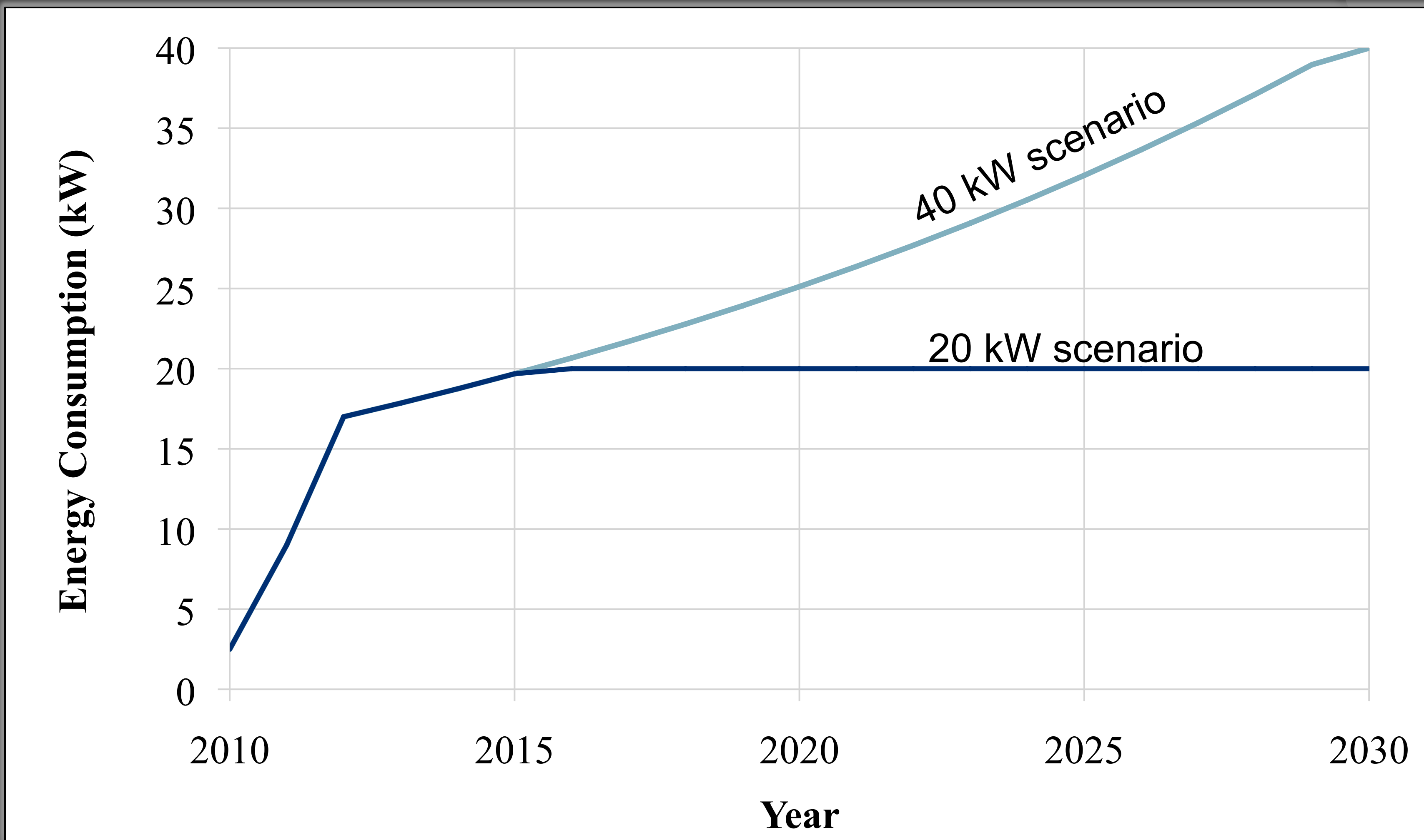
Introduction

- Uninterruptable Power Supply (UPS)
  - Online system is a series of batteries in between the servers and the grid
  - A large, stable energy storage system designed for a short, high power release in the case of grid failure.
  - Regulates power quality and eliminates surges and dips.

Introduction

- Design Goal
  - 30% efficiency increase over existing data center
- Existing data center is a Liebert AP346 (32 kW)
- Base case for new data center is Eaton Blade UPS
- CERF may be used to fund efficiency improvements
- Two power consumption models

Energy Usage Scenario

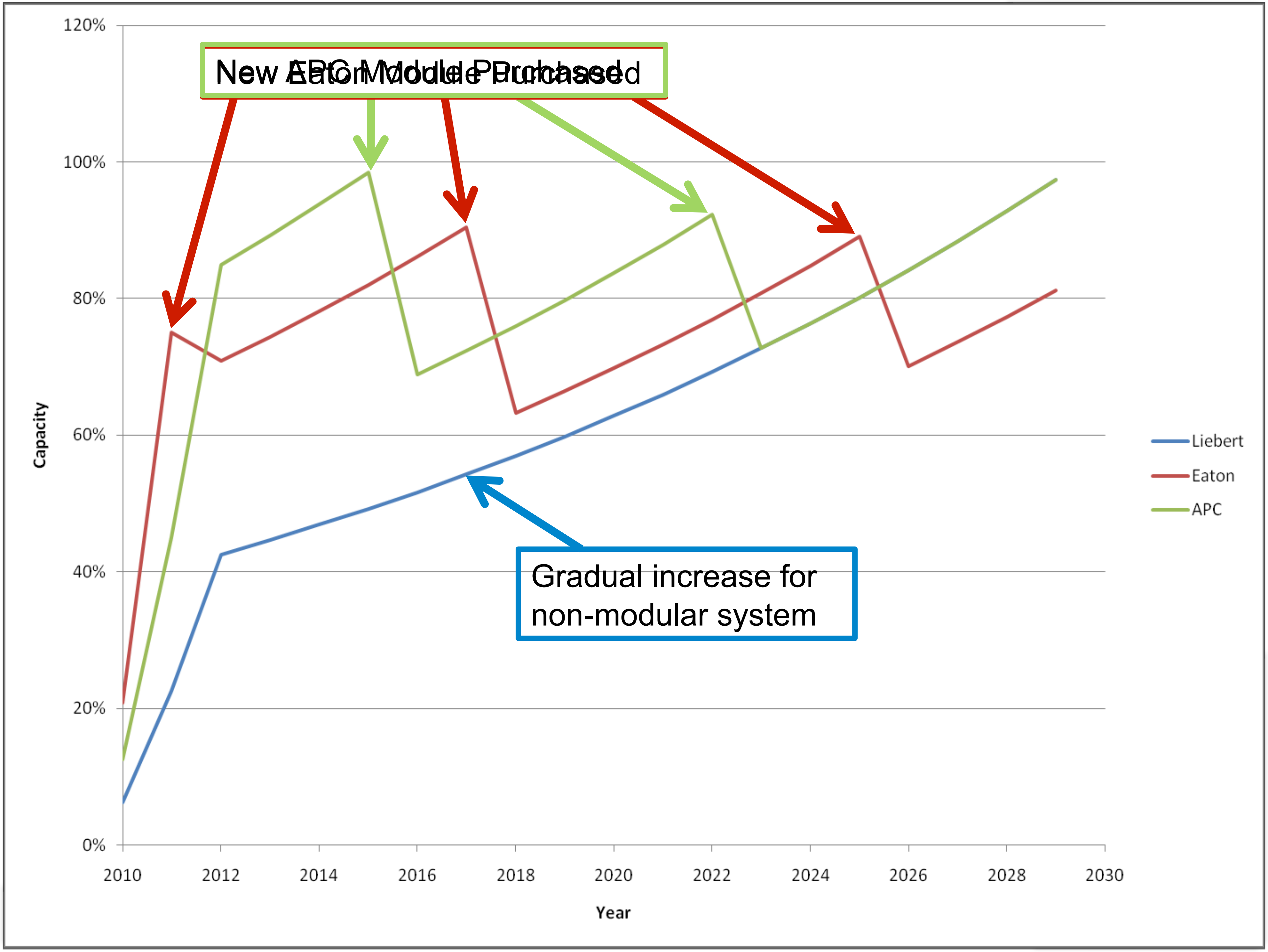


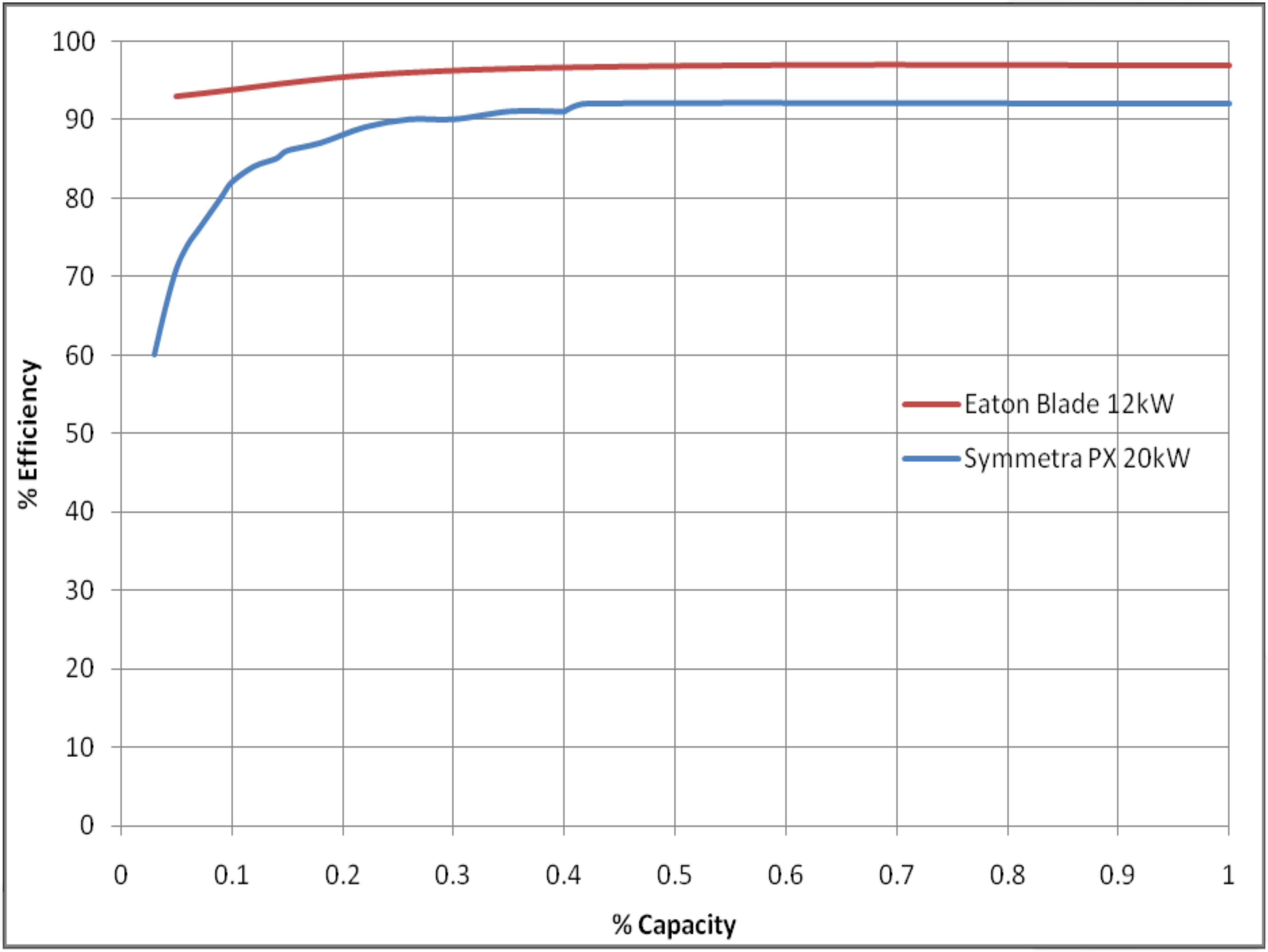
Alternative Computing Options

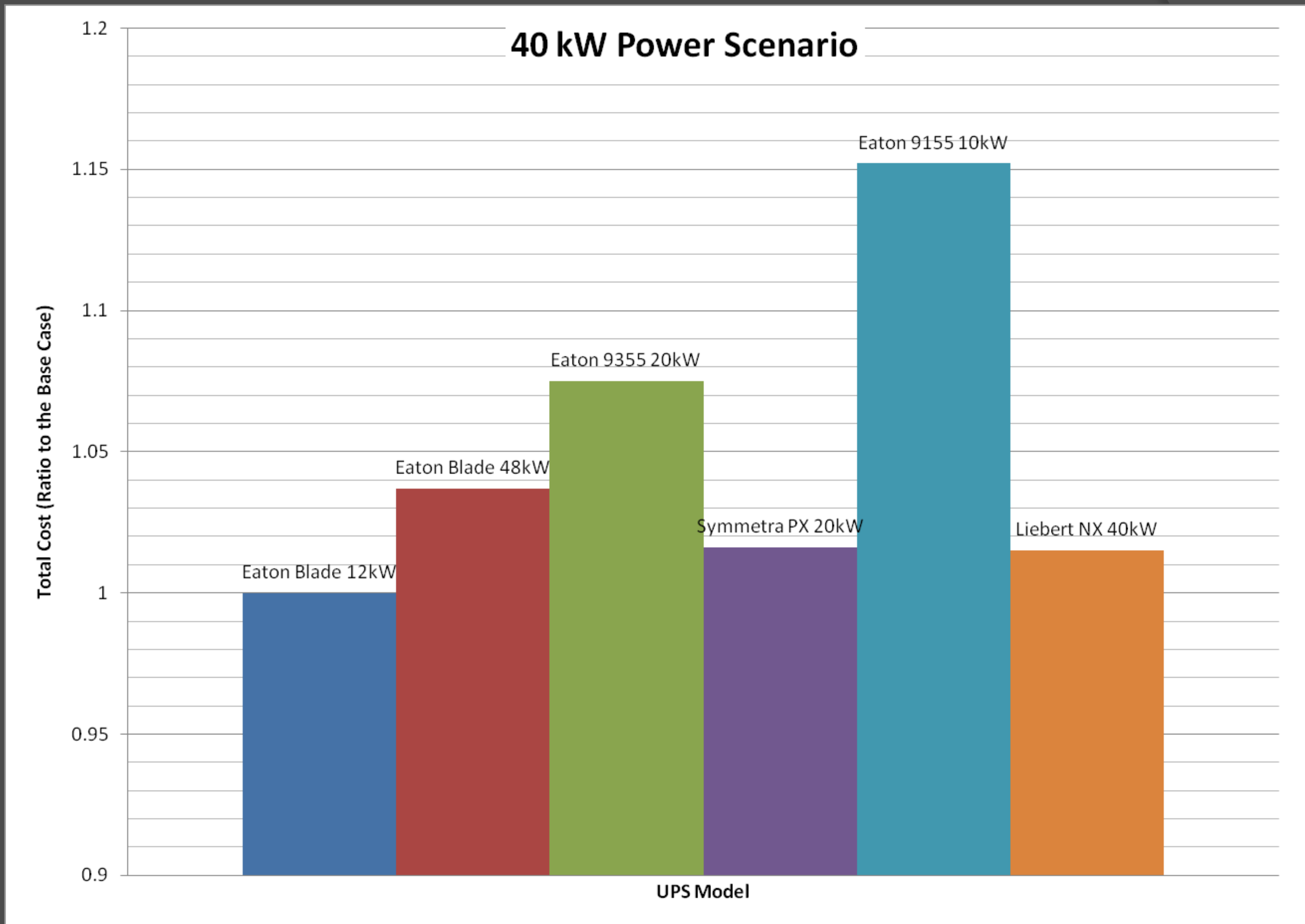
- Third party servers
  - Lower Capital Costs
  - Scalability
  - Bandwidth Restrictions
  - Security Issues
- Virtual Desktops
  - New Server Room Required

Work Accomplished

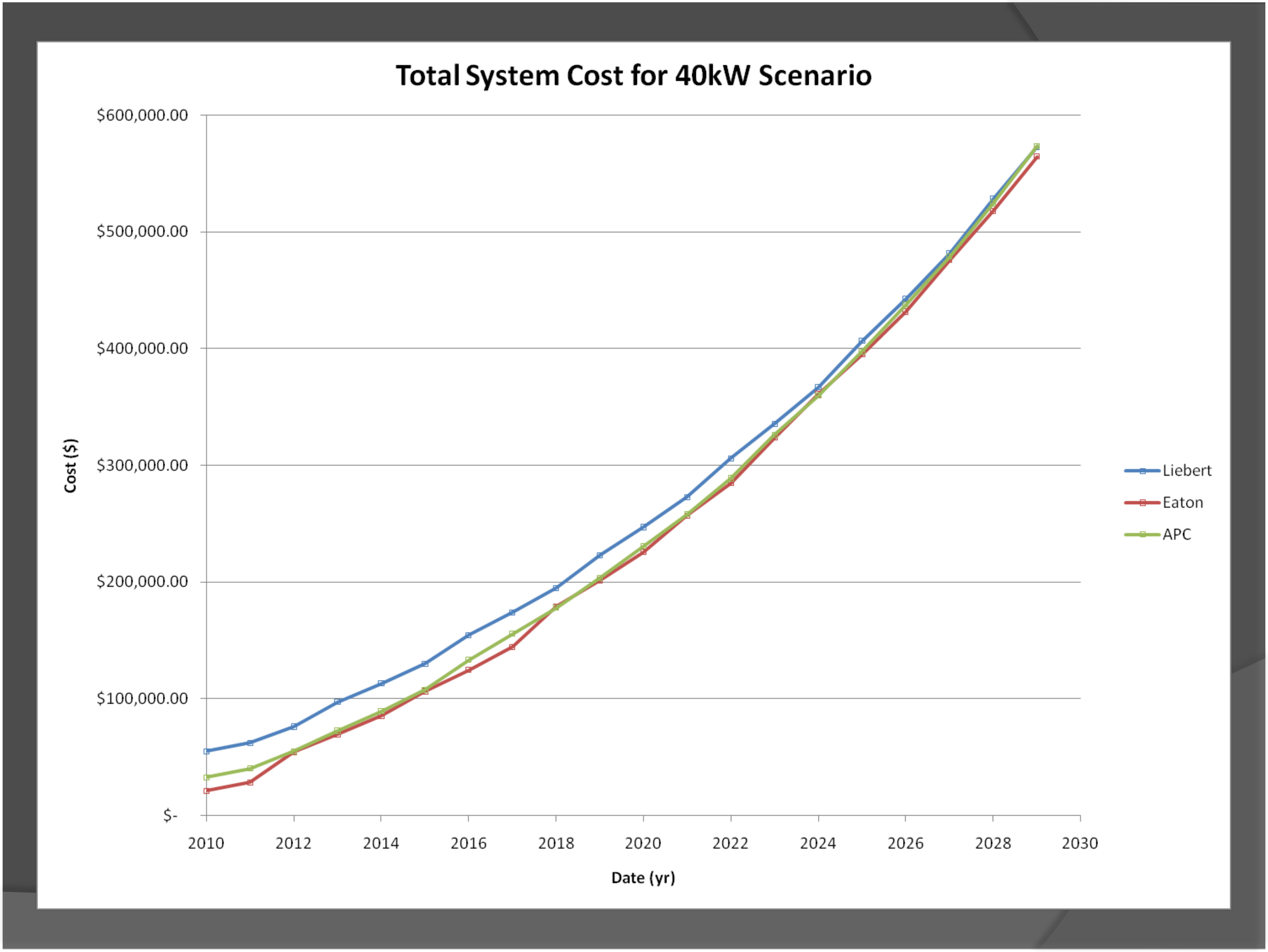
- Design Options Spreadsheet
  - Analyzes each option (including base case) for cost
  - Finds present value of Purchased Equipment Cost (PEC) and Operations and Maintenance (OM) costs
  - Includes electricity costs
    - Scaled by efficiency at each capacity level
    - Approximately 10x the PEC and OM
  - Compares each option on cost (including environmental)


New APC Module Purchased
New Eaton Module Purchased
Gradual increase for non-modular system
120%
100%
80%
60%
40%
20%
0%
Capacity
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028
2030
Year
Liebert
Eaton
APC


100
90
80
70
60
50
40
30
20
10
0
% Efficiency
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
% Capacity
Eaton Blade 12kW
Symmetra PX 20kW



40 kW Power Scenario
Total Cost (Ratio to the Base Case)
1.2
1.15
1.1
1.05
1
0.95
0.9
Eaton Blade 12kW
Eaton Blade 48kW
Eaton 9355 20kW
Symmetra PX 20kW
Eaton 9155 10kW
Liebert NX 40kW
UPS Model


Total System Cost for 40kW Scenario
$600,000.00
$500,000.00
$400,000.00
$300,000.00
$200,000.00
$100,000.00
$-
Cost ($)
2010
2012
2014
2016
2018
2020
2022
2024
2026
2028
2030
Date (yr)
Liebert
Eaton
APC

Additional Considerations

- NETBOTZ integration
  - None of the UPS options are able to directly integrate with the Instrumentation Team's selected system
- Heat generation is insignificant
  - 8% decrease in heat generation from the current data center
- All UPS require 1 rack space (7ft^2)
- 3-Phase power input
  - Will be provided without complications

Conclusion

- The Eaton Blade was initially selected by CIT as the base case
- This system has been confirmed by the Power Team as the best UPS option based on financial and environmental sustainability
- No CERF recommendations can be made

Conclusion

- Current data center UPS operates at 89% efficiency
- Selected UPS operates at 97% efficiency
- The only efficiency increase for the UPS can come from equipment upgrades
- Total lifetime costs are very close for all options
  - ENGR 333 selected based on energy
  - CIT selected based on cost

HVAC Team

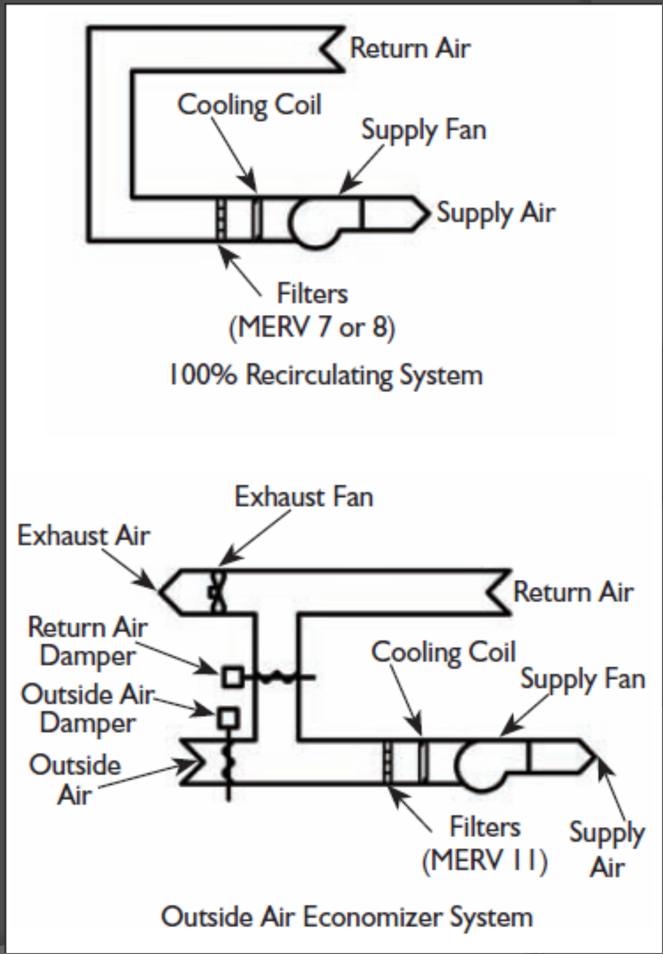
Base Case

- Liebert air cooled unit (20kW unit)
- Capital Cost: $28,731
  - Liebert Unit
  - Condenser
  - Materials
  - Installation
- Year Six: 2nd 20kW model purchased (according to 40kW scenario)

Design Option 1 - Economizer

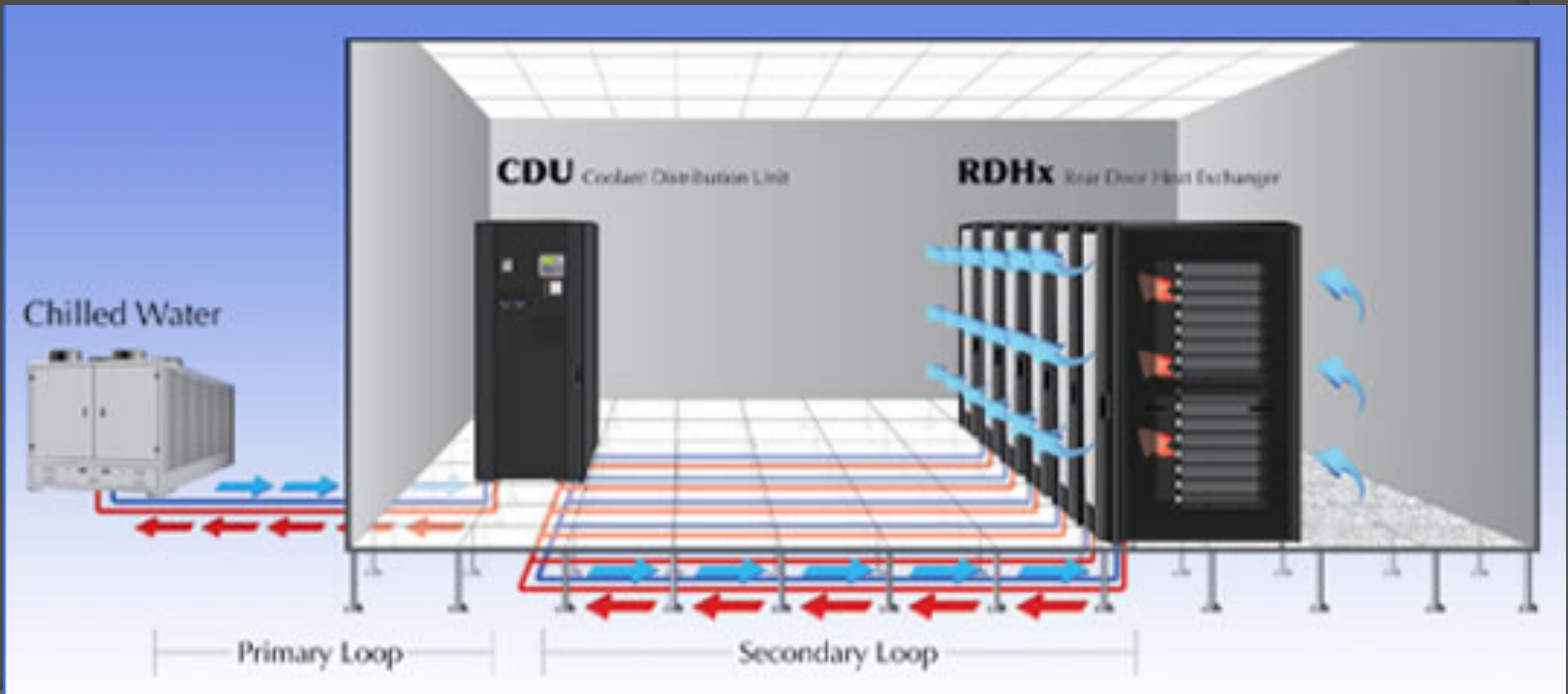
- Uses Cool, Dry Outside Air
- ⬇ Cooling Load
- ⬆ Humidity Load

- Added to Base Case System (Liebert air cooled unit)



Design Option 2 - Coolcentric

- Uses water to cool room, no fans
- Inlet water temp of 45F

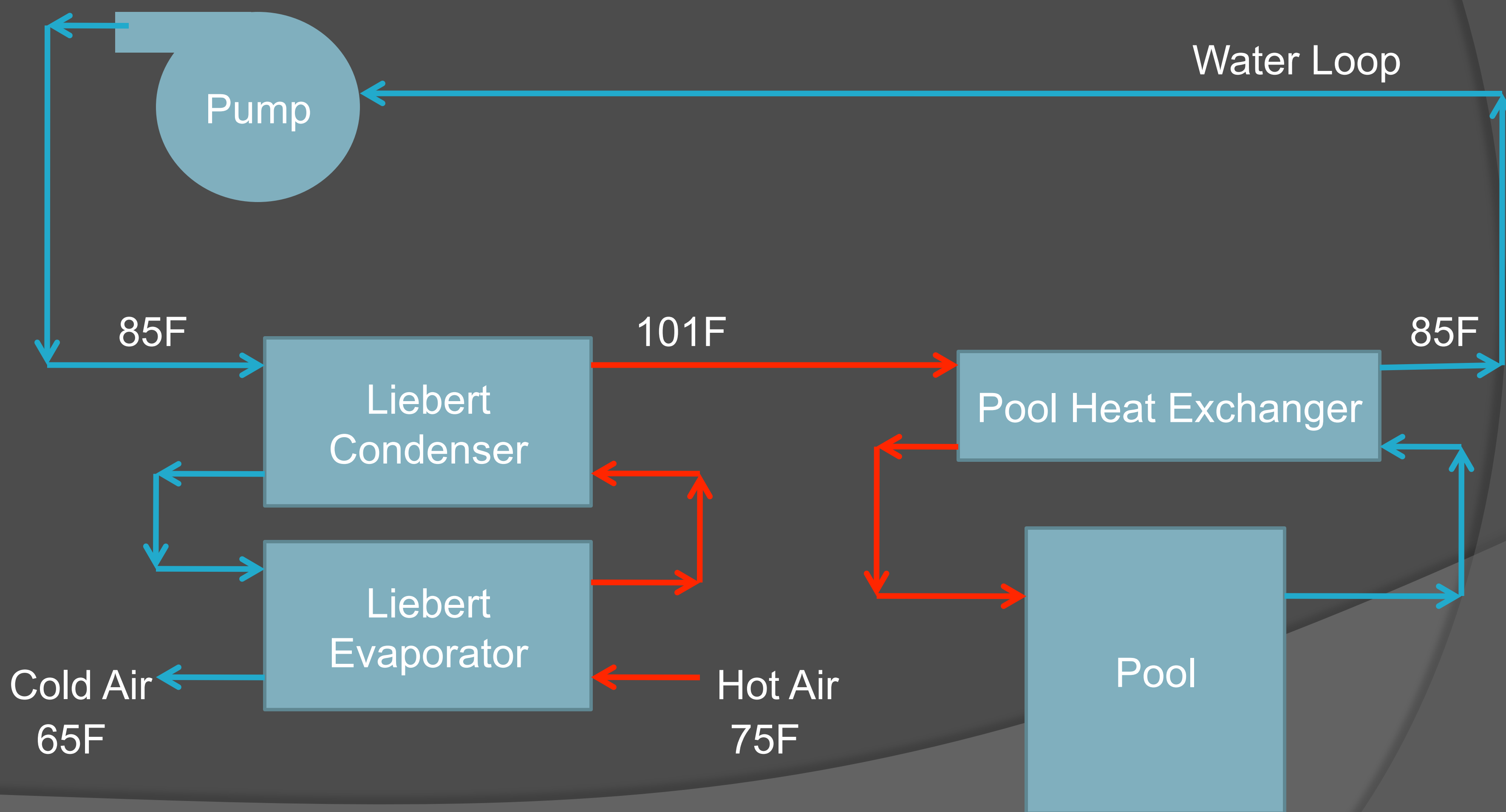


Design Option 3 – Pool Loop

- Liebert water cooled system
- Heat exchanger with pool
- All heat from data center into pool

Design Option 3 – Pool Loop

- System Diagram



Design Selection Considerations

- Criteria:
  - Energy Savings
  - Cost Savings
- Economizer
  - Slight energy and cost savings
- Coolcentric
  - Unable to connect to pool loop because of temperature requirements
- Pool Loop
  - Significant energy and cost savings

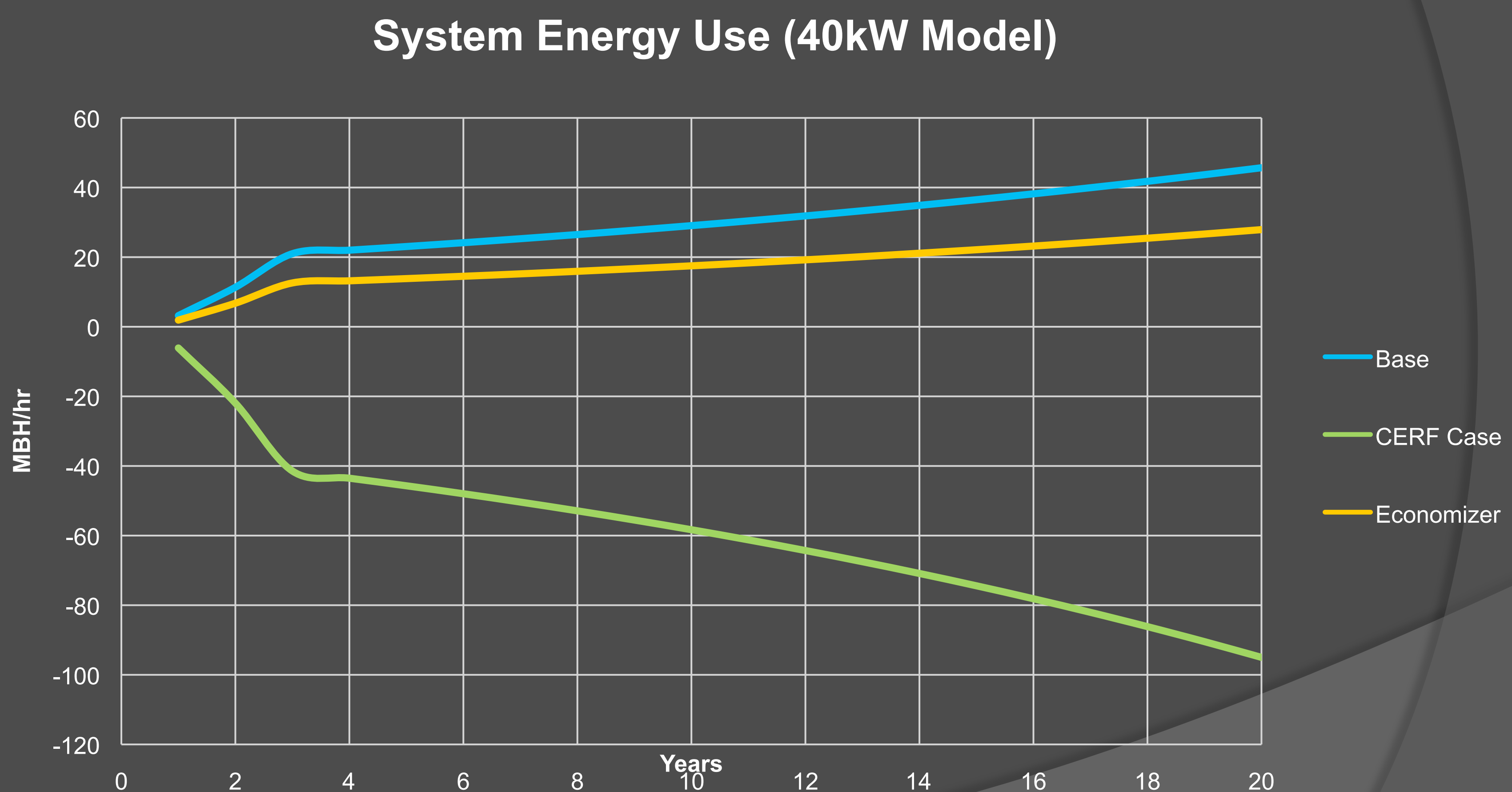
CERF Option

- Final CERF Selection: Pool Loop
  - Energy
    - Results in greatest overall energy savings
    - All data center heat → pool
  - Cost
    - Similar capital investment to base case
    - Greatest long term savings

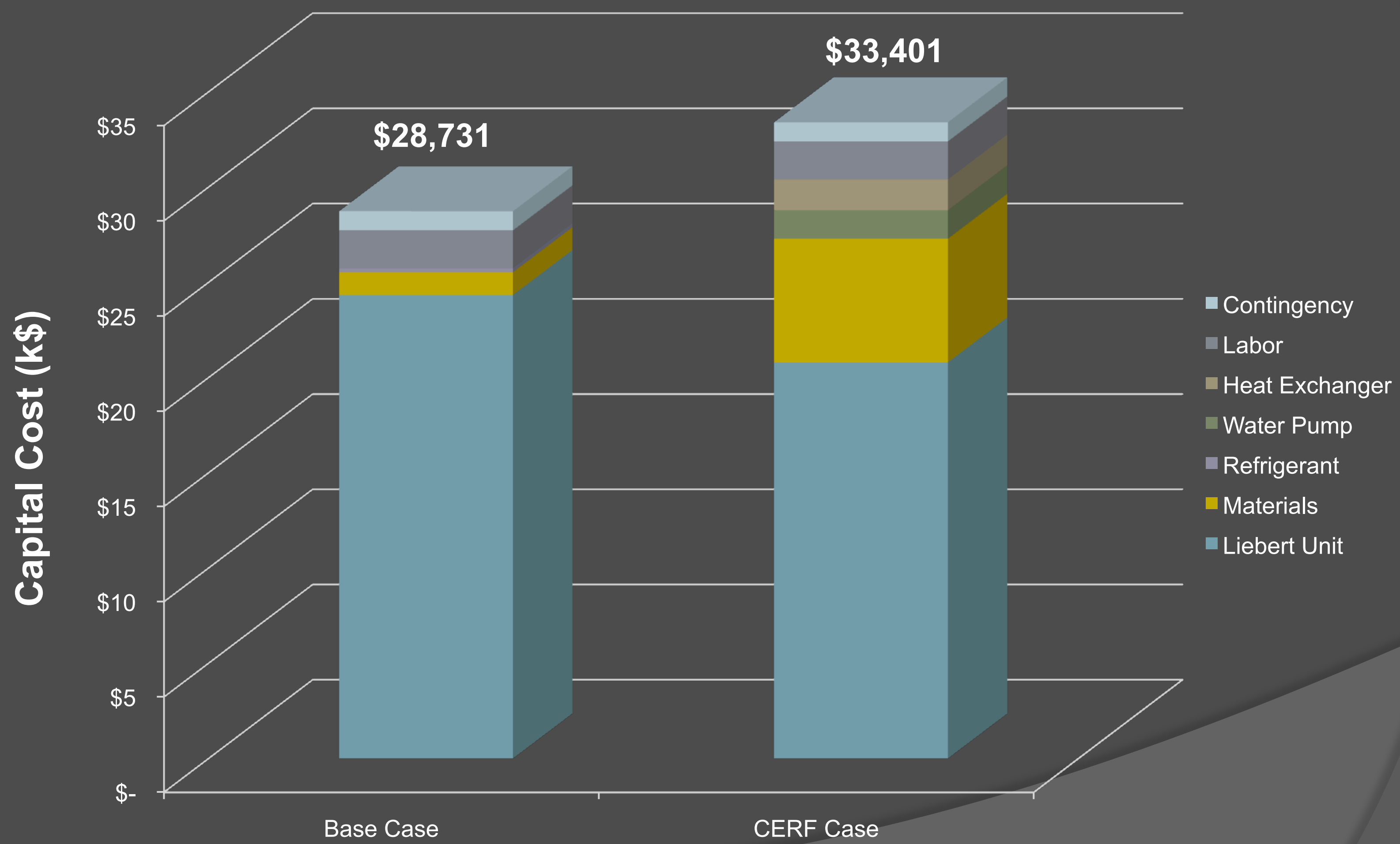
CERF Design – Pool Loop

- Assumptions
  - Liebert unit modeled as operating at 100%
  - Inlet air 75F
  - Outlet air 65F
  - Pool is operating year round at 81F
- Capital Cost: $33,401
  - Liebert unit
  - Heat Exchanger
  - Water Pump
  - Installation
  - Materials

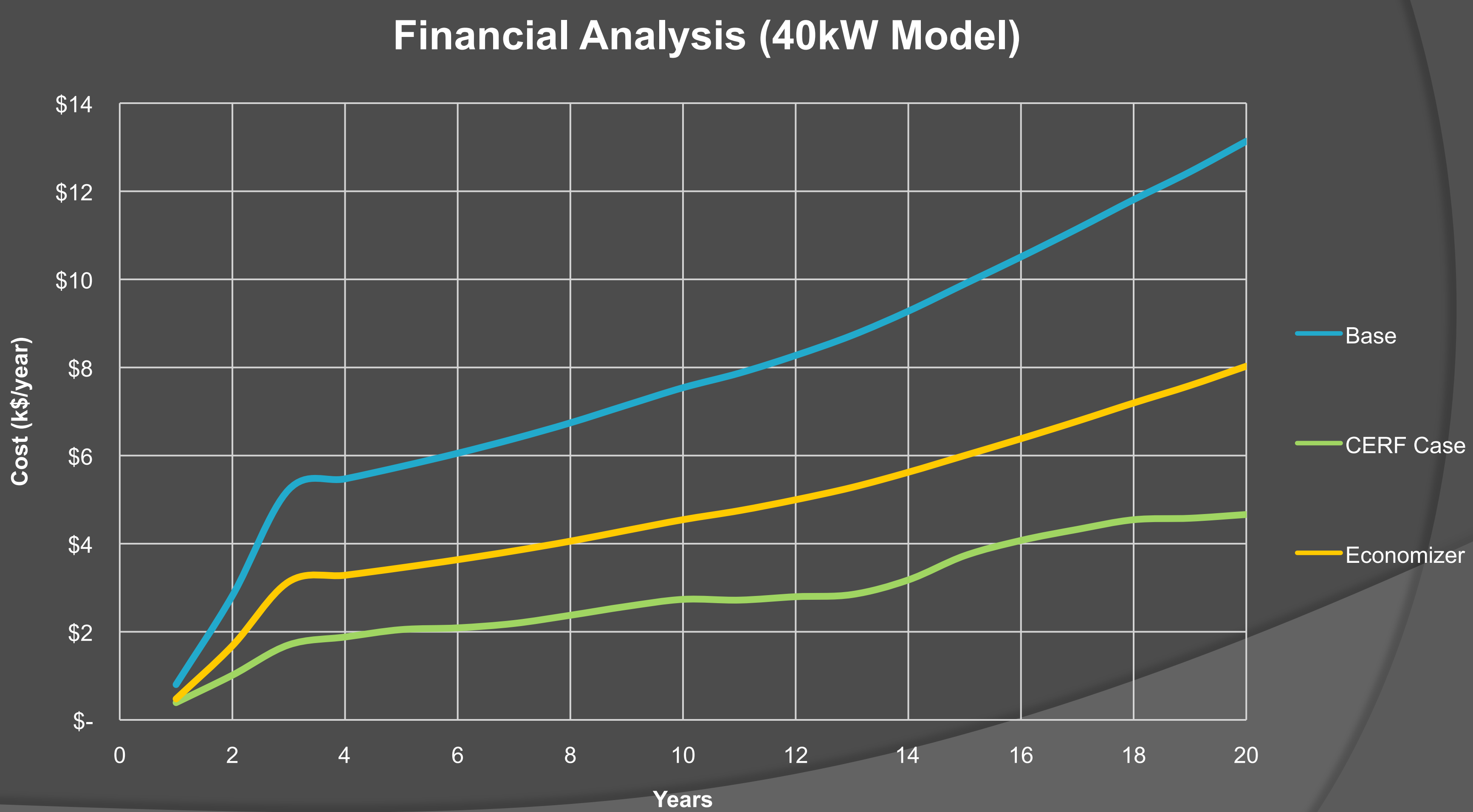
CERF Design – Energy Use



CERF Design – Capital Cost



CERF Design – Annual Cost



Instrumentation Team

Goals

- Monitor power, temperature, and humidity for CIT
- Monitor energy savings for Calvin Energy Recovery Fund(CERF)
- Retain “alert” functionality for CIT

Instrumentation: Current Case

- System Requirements:
  - Monitor temperature in the room
  - Monitor humidity of the room
  - Alert CIT when problems arise
- System Components:
  - NetBotz 310
  - NetBotz 320

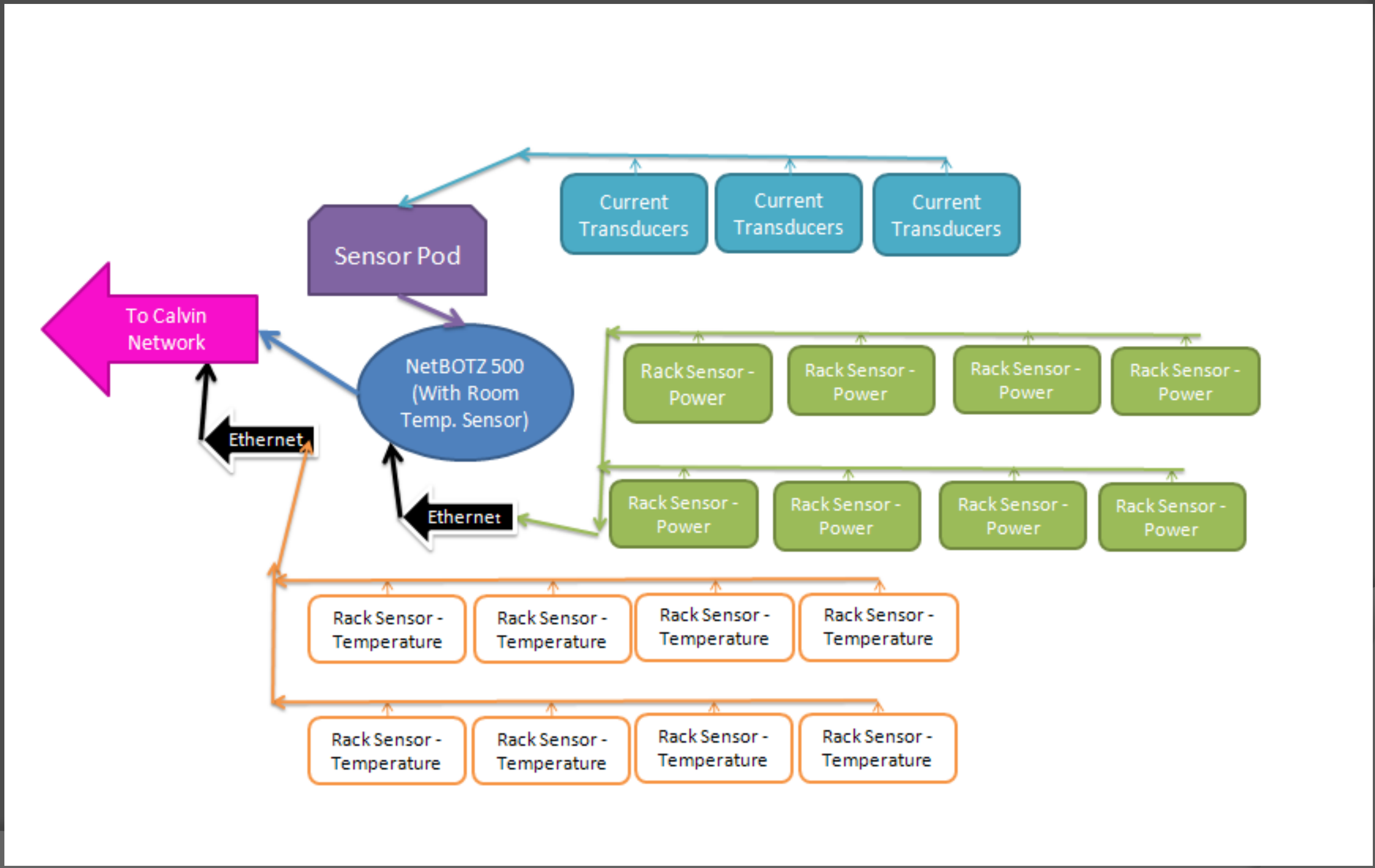
Instrumentation: Base Case

- New System Requirements (from CIT):
  - Monitor temperature in the room and at each rack
  - Monitor humidity of the room
  - Monitor power usage at each cabinet and UPS
  - Alert CIT when problems arise
  - Compatible with Statseeker

- System Components:
  - NetBotz 500
  - Metered Rack PDU
  - Sensor Pod
  - Current Transducers

Instrumentation: Base Case

Stream of information through system:



Instrumentation: Base Case

Component	Unit Cost	Qty.	Cost	
RACK				
Metered Rack PDU	$0.00	8	$0.00	With Cabinets
Temperature Sensor	$0.00	8	$0.00	With HVAC
GENERAL				
Netbotz 500	$2,177.99	1	$2,177.99	
ROOM				
4-20mA Sensor Pod	$379.99	1	$379.99	
Current Transducer	$97.08	3	$291.24	
	Initial Cost:		$2,849.22	

Annual Maintenance Cost:	$285

Instrumentation: CERF Design

- Instrumentation required to track energy savings of the system
- Additional instrumentation system components selected:
  - One ultrasonic flow meter
  - Two platinum Resistance Temperature Detectors (RTD) temperature probes
  - LabVIEW instrumentation hardware
  - LabVIEW software (already available on select computers on Calvin's campus)

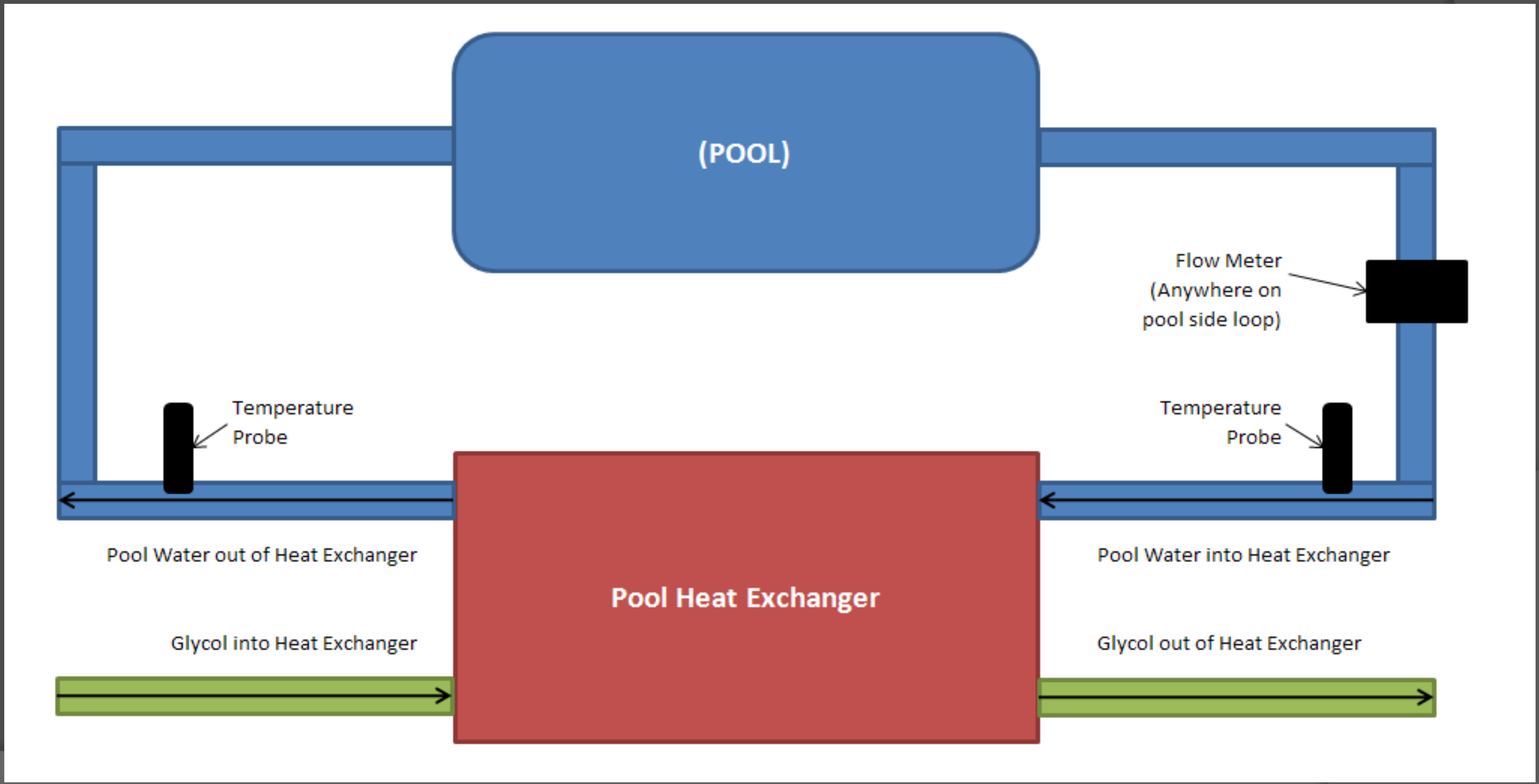
Instrumentation: CERF Design

Component	Unit Cost	Qty.	Cost	
RACK				
Metered Rack PDU	$0.00	8	$0.00	
Temperature Sensor	$0.00	8	$0.00	
GENERAL				
Netbotz 500	$2,177.99	1	$2,177.99	
LabVIEW Brain - cFP-2200	$1,559.00	1	$1,559.00	Incremental CERF Cost
LabVIEW Module NI-cFP-AI-110	$529.00	1	$529.00	Incremental CERF Cost
LabVIEW Module NI cFP-RTD-122	$529.00	1	$529.00	Incremental CERF Cost
LabVIEW Connector Block cFP-CB-1	$169.00	2	$338.00	Incremental CERF Cost
LabVIEW Back Plane cFP-BP-8	$799.00	1	$799.00	Incremental CERF Cost
Power Input - 778586-90 PS-4	$249.00	1	$249.00	Incremental CERF Cost
ROOM				
4-20mA Sensor Pod	$379.99	1	$379.99	
Current Transducer	$97.08	3	$291.24	
Pool				
Platinum RTD	$63.00	2	$126.00	Incremental CERF Cost
Ultrasonic Flow Meter	$1,708.00	1	$1,708.00	Incremental CERF Cost
	Initial Cost:		$8,686.22	

Annual Maintenance Cost:	$869

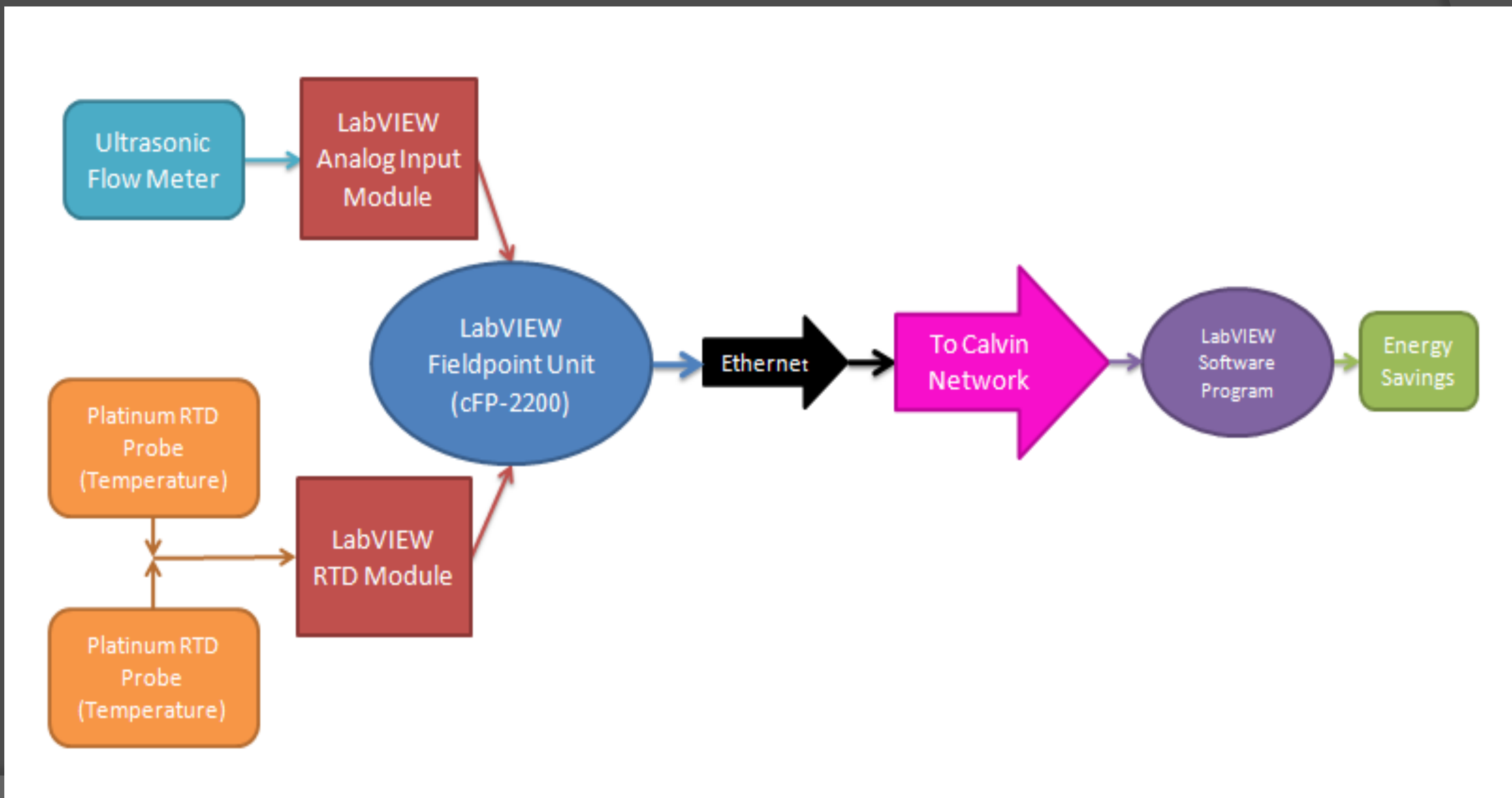
Instrumentation: CERF Design

Approximate Placement of Sensors:



Instrumentation: CERF Design

Stream of information through LabVIEW system:



Instrumentation: CERF Design

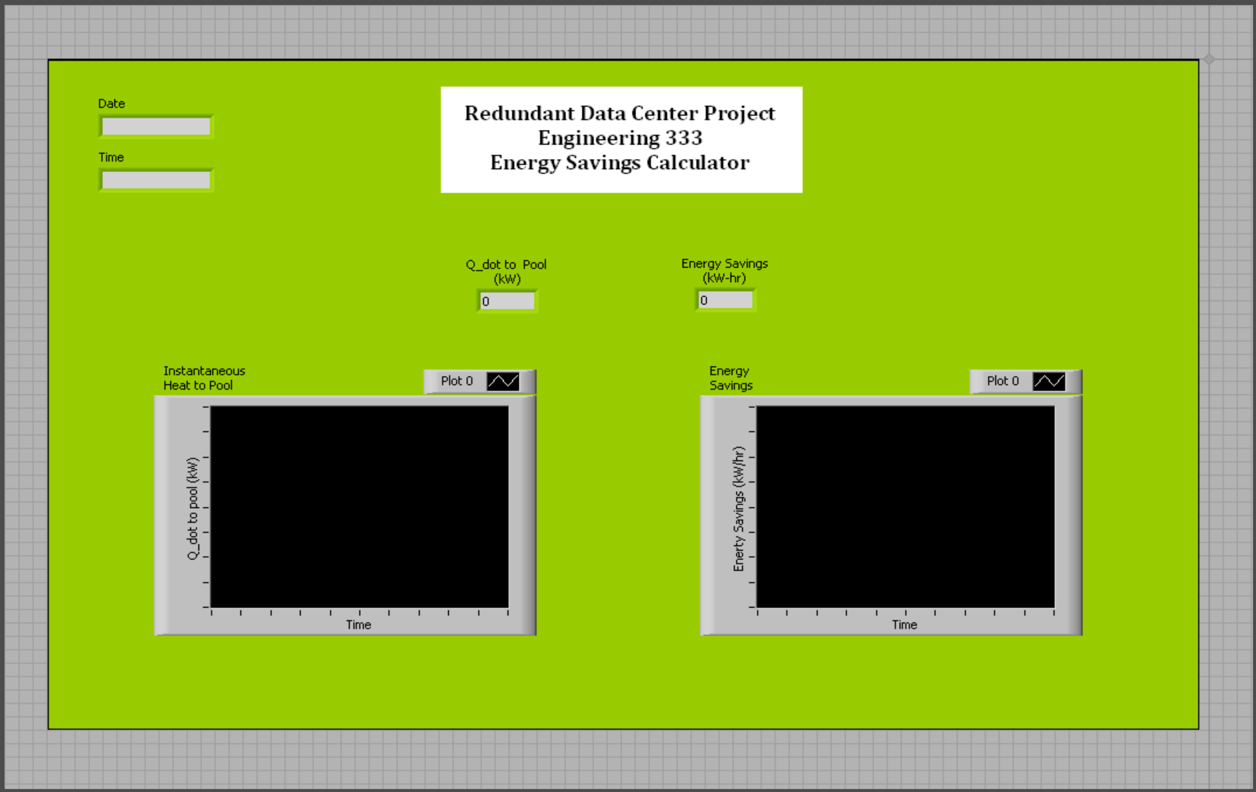
- Dummy LabVIEW code
  - Reads in temperature and flow measurements
  - Calculates cumulative energy savings (kW-hr) from start of program

$$\dot{Q} = \dot{m} C_p (T_{out} - T_{in})$$

$$E = \int \dot{Q} \, dt$$

  - Writes hourly data to excel files saved daily
  - Includes instructions for setting up with actual system inputs

LabVIEW Program:



Date	Time	Flow Rate	Pool Water Temperature Out of HXer	Pool Water Temperature Into HXer	Q_dot to Pool	Energy Savings	Energy Savings	Natural Gas Price	Monetary Savings	Error
[mm/dd/yyyy]	[hh:mm:ss]	[gpm]	[K]	[K]	[kW]	[kW-hr]	[Btu]	[$/million Btu]	[$]	
4/27/2010	15:28:53	10	313.15	293.15	52.826	15.412	52602.76	7.8	0.41	0

Conclusion

- Two Systems
  - NetBotz to monitor temperature, Power, and humidity for CIT
  - LabVIEW to monitor energy savings for CERF
- Instrumentation system not more efficient
  - Monitors much more than existing data room
  - Inefficiency absorbed by other groups

Team Money

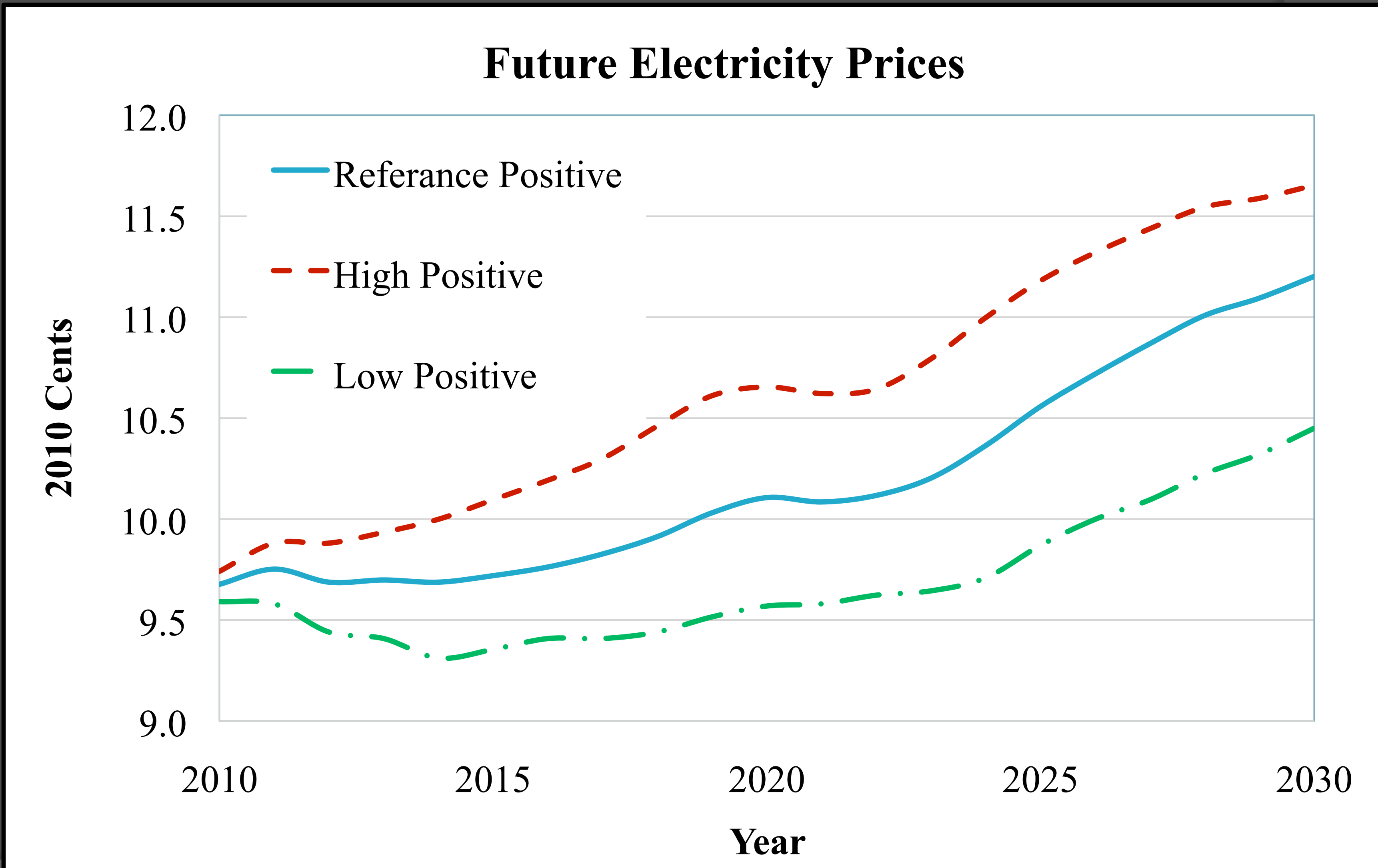
Outline

- Base Case Analysis
- CERF Case Analysis
- Cost Comparison and Savings
- Efficiency Results
- Final Recommendations

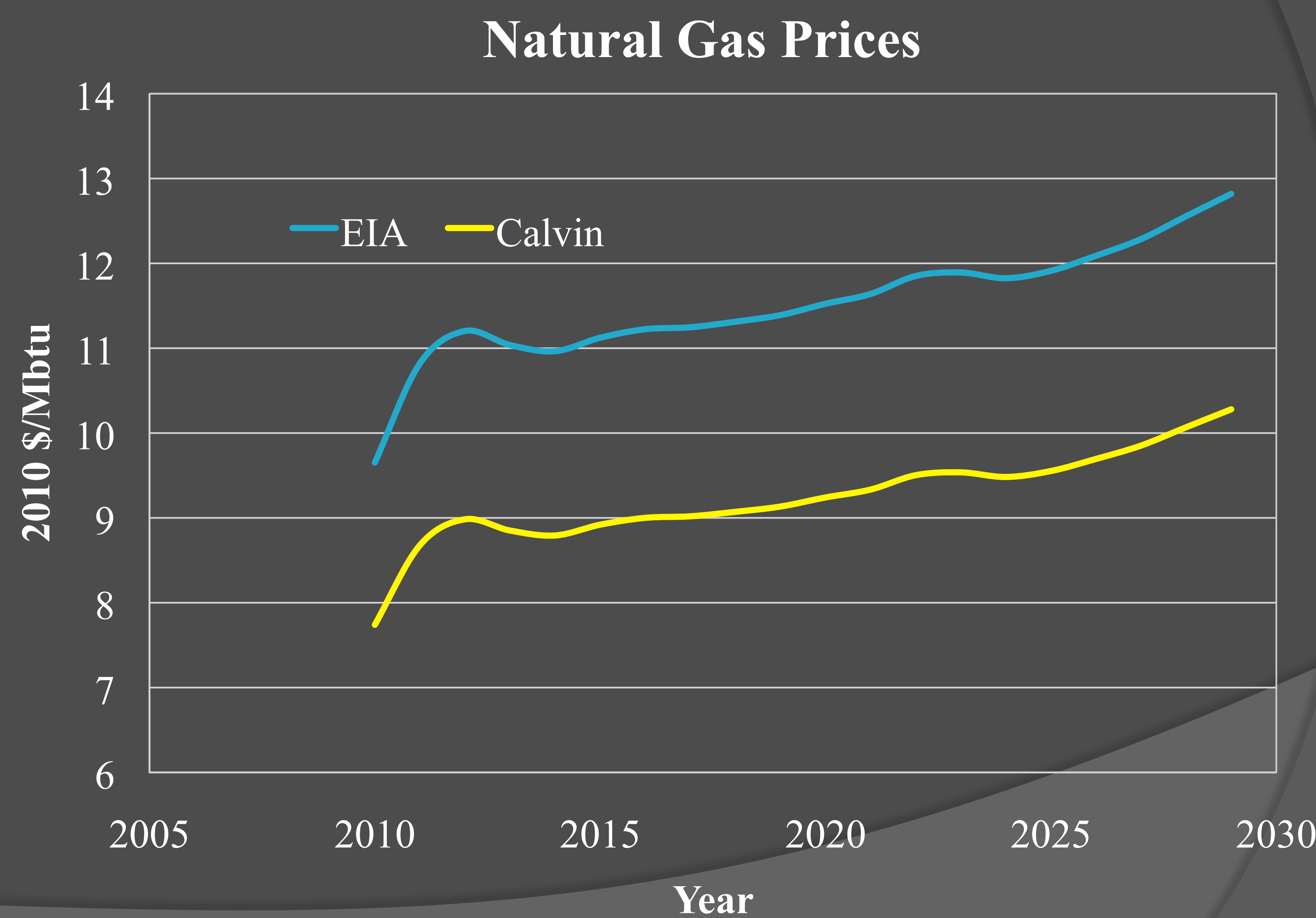
Case Analysis

- Cash flow in three streams
  - Capital cost
  - Recurring cost
  - Energy cost
- Methodology
  - Electricity price varies in future
  - Economy varies in future

Energy Forecast



Energy Forecast



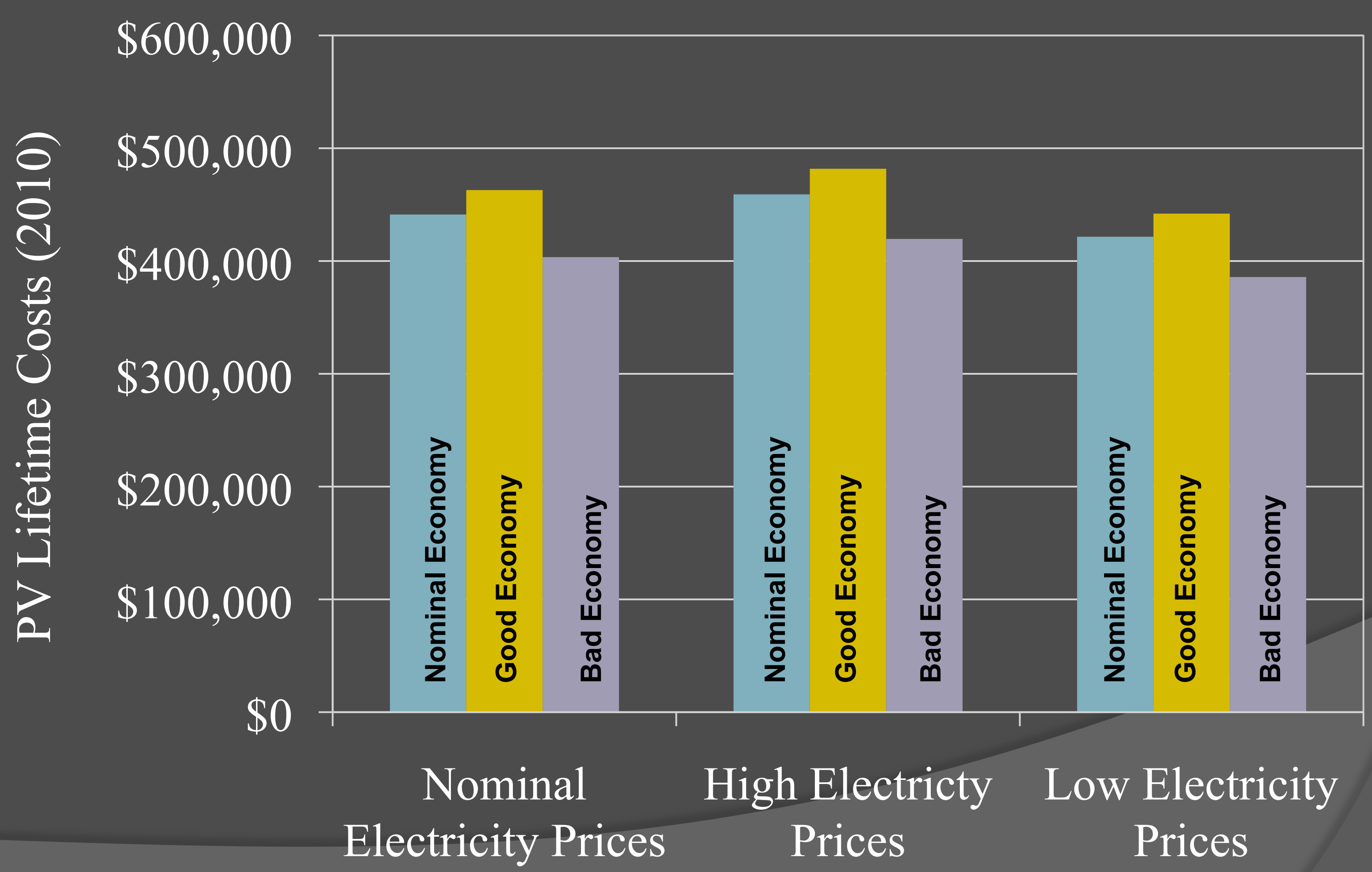
Economic Climate

Interest Rate		Inflation	
Nominal	6.0%	Nominal	4%
Good Economy	4.0%	Good Economy	2.5%
Poor Economy	10.0%	Poor Economy	7%

Envelope Capital

Envelope (Lifespan 20 yrs.)			
Base Case		Recommendation	
Gypsum Wall	$600	Aluminum Wall	$1,693
1 Door	$155	3 Doors	$465
Labor	$1,000	Labor	$1,000
$1,755		**$3,158**	

Power – 40 kW



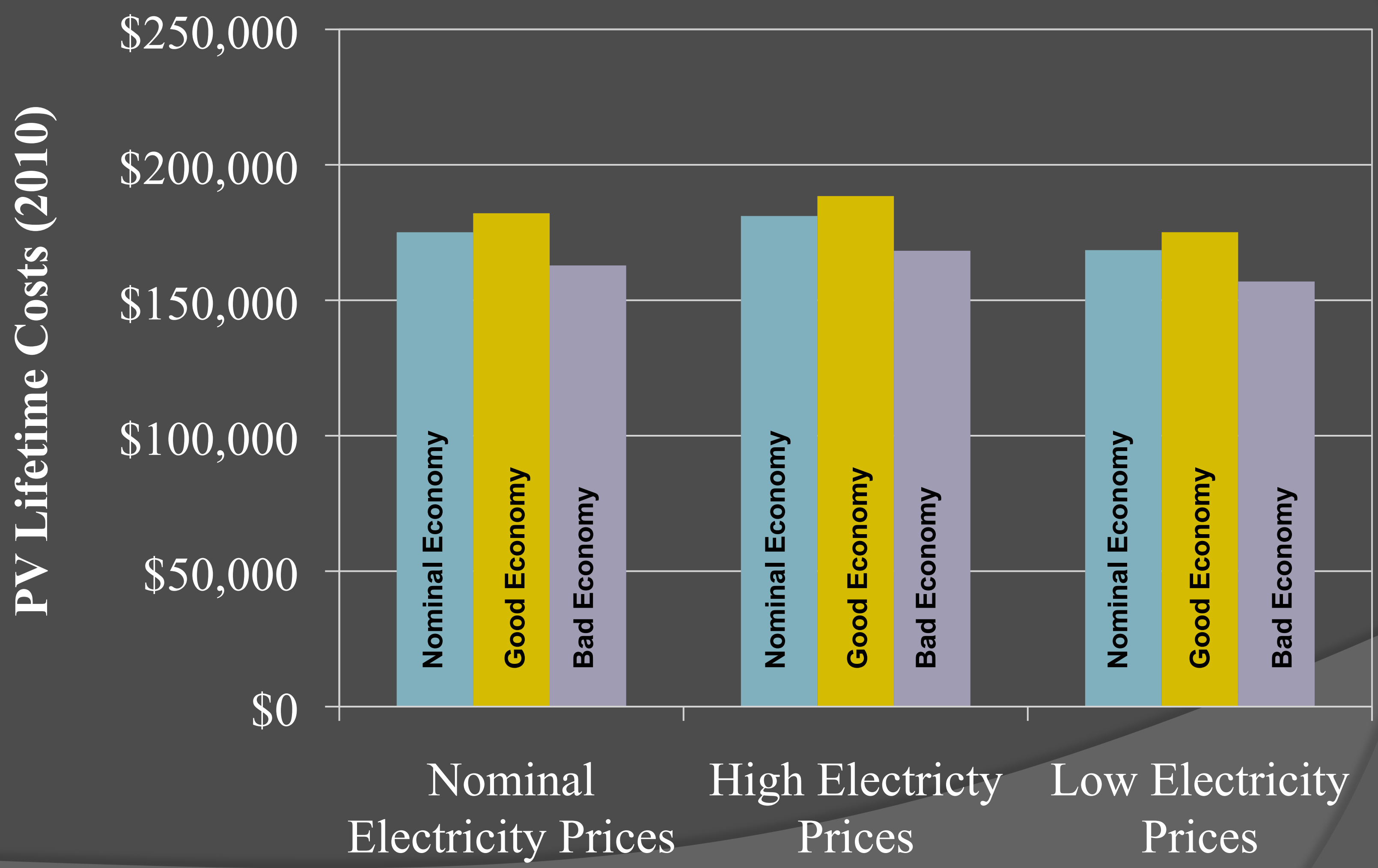
PV Lifetime Costs (2010)
$600,000
$500,000
$400,000
$300,000
$200,000
$100,000
$0
Nominal Economy
Good Economy
Bad Economy
Nominal Electricity Prices
High Electricty Prices
Low Electricity Prices

HVAC Capital

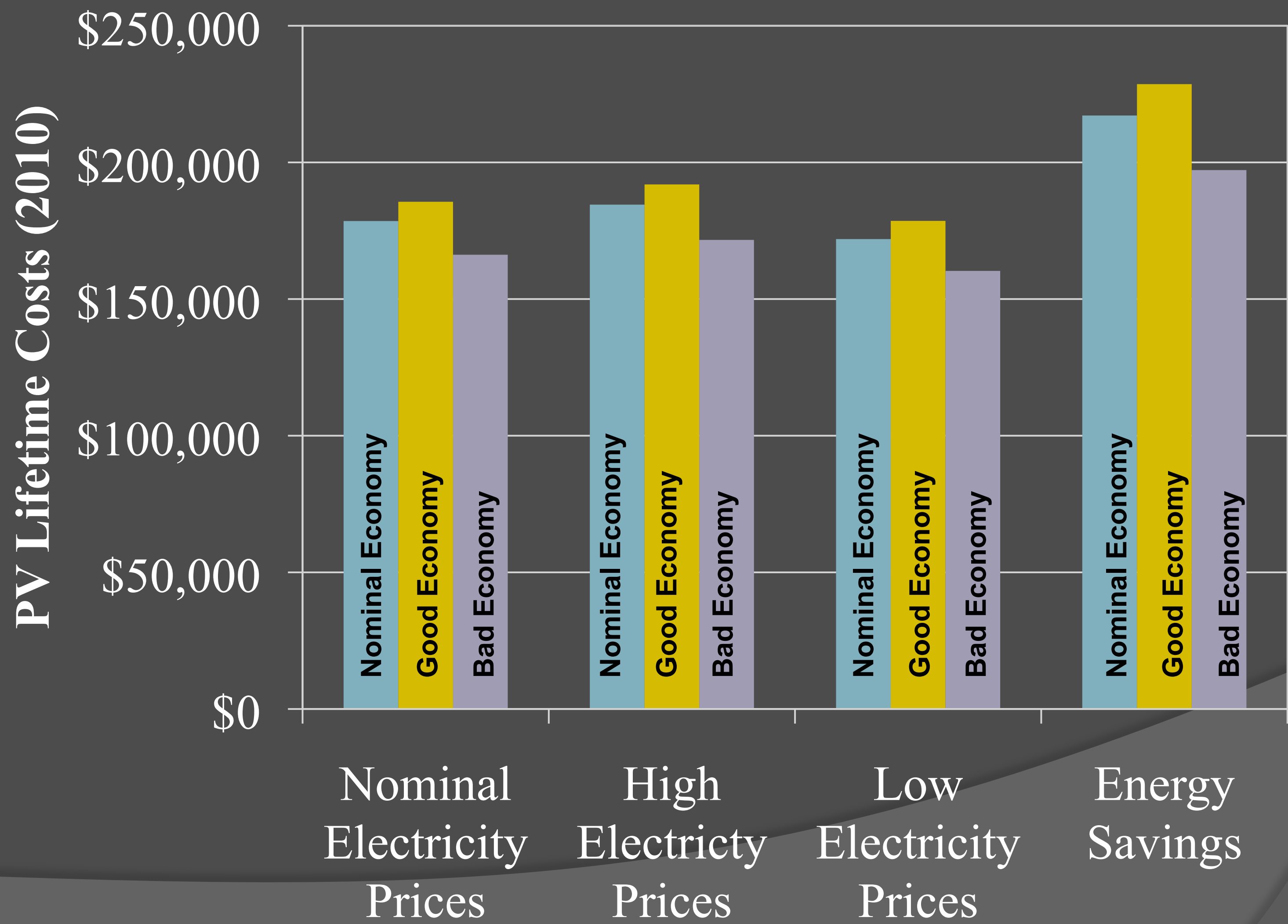
HVAC (Lifespan 20 yrs.)			
Base Case		CERF Case	
20 kW Liebert Unit + Condenser	$24,331	20 kW Liebert Unit - Water Cooled	$20,791
Materials	$1,200	Water pump	$1,500
Refrigerant	$200	Heat exchanger for pool	$1,610
Labor	$2,000	Materials	$6,500
Contingency	$1,000	Labor	$2,000
		Contingency	$1,000
$28,731		**$33,401**	

Cost Difference: **$4,670**

Base Case: HVAC – 40 kW



CERF Case: HVAC – 40 kW

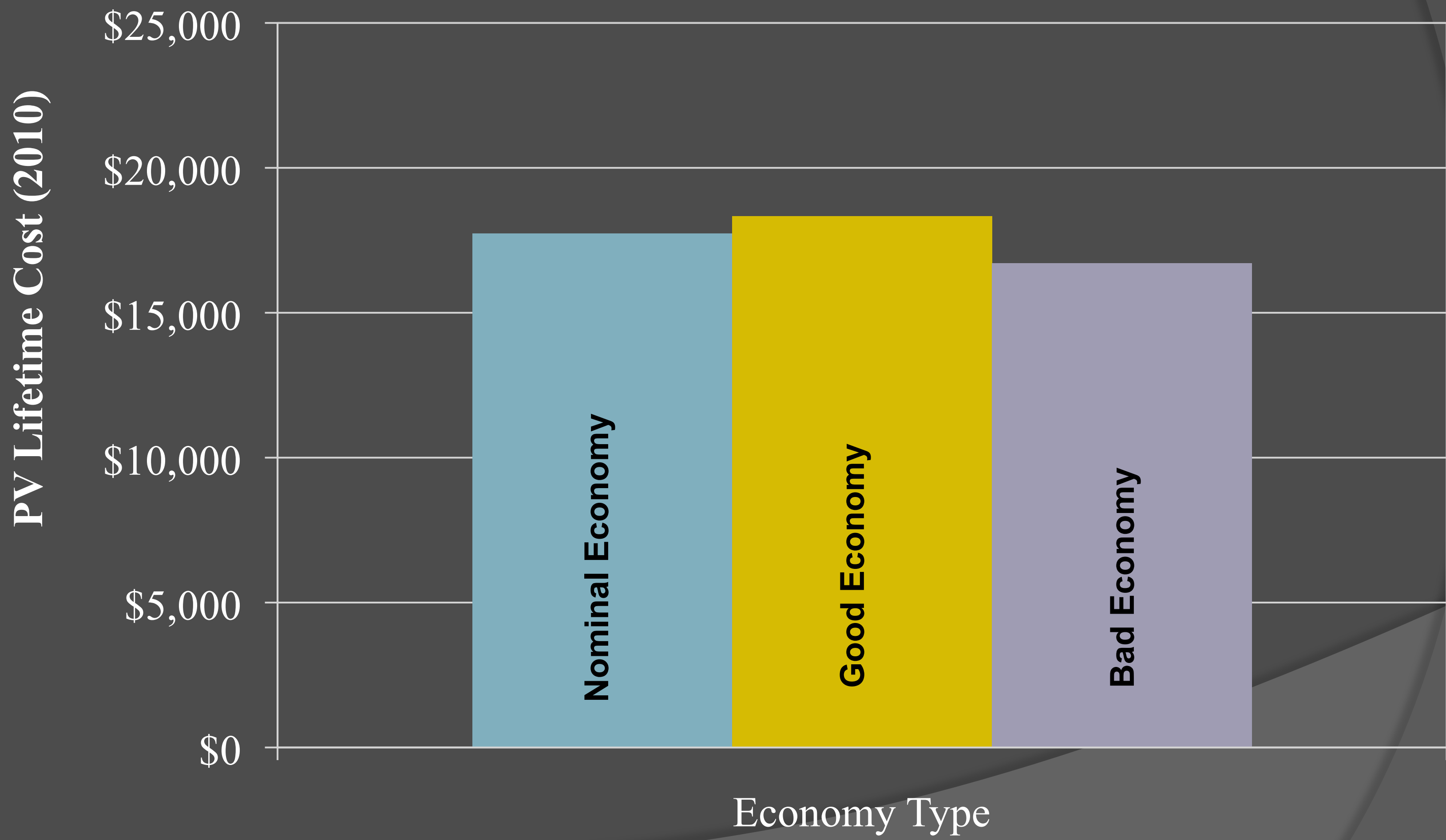


Instrumentation Capital

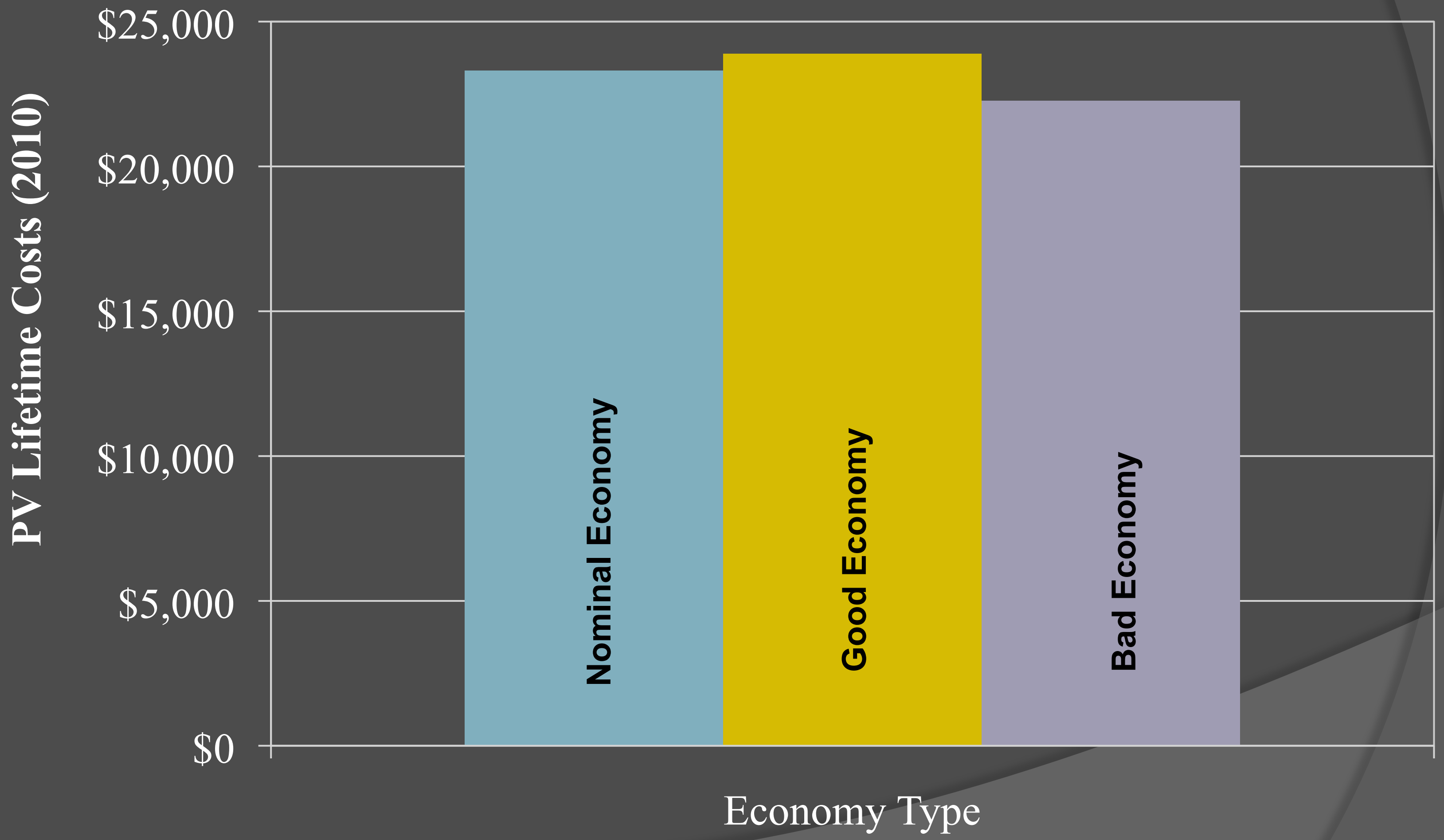
Instrumentation (Lifespan: 30 yrs)			
Base Case		CERF Case	
NetBotz Sensor Pod 120	$336	Netbotz 500	$2,178
NetBotz Temperature Sensor	$640	LabVIEW Brain - cFP-2200	$1,559
Netbotz 500	$2,178	LabVIEW Module AI-110	$529
4-20mA Sensor Pod	$380	LabVIEW Module RTD-122	$529
Current Transducer	$97	LabVIEW Connector Block	$338
Labor	$100	LabVIEW Back Plane	$799
Contingency (10%)	$373	Power Input	$249
		4-20mA Sensor Pod	$380
		Current Transducer	$291
		Platinum RTD	$126
		Ultrasonic Flow Meter	$1,708
		Labor	$300
		Contingency (10%)	$899
$4,104		**$9,885**	

Cost Difference: **$5,781**

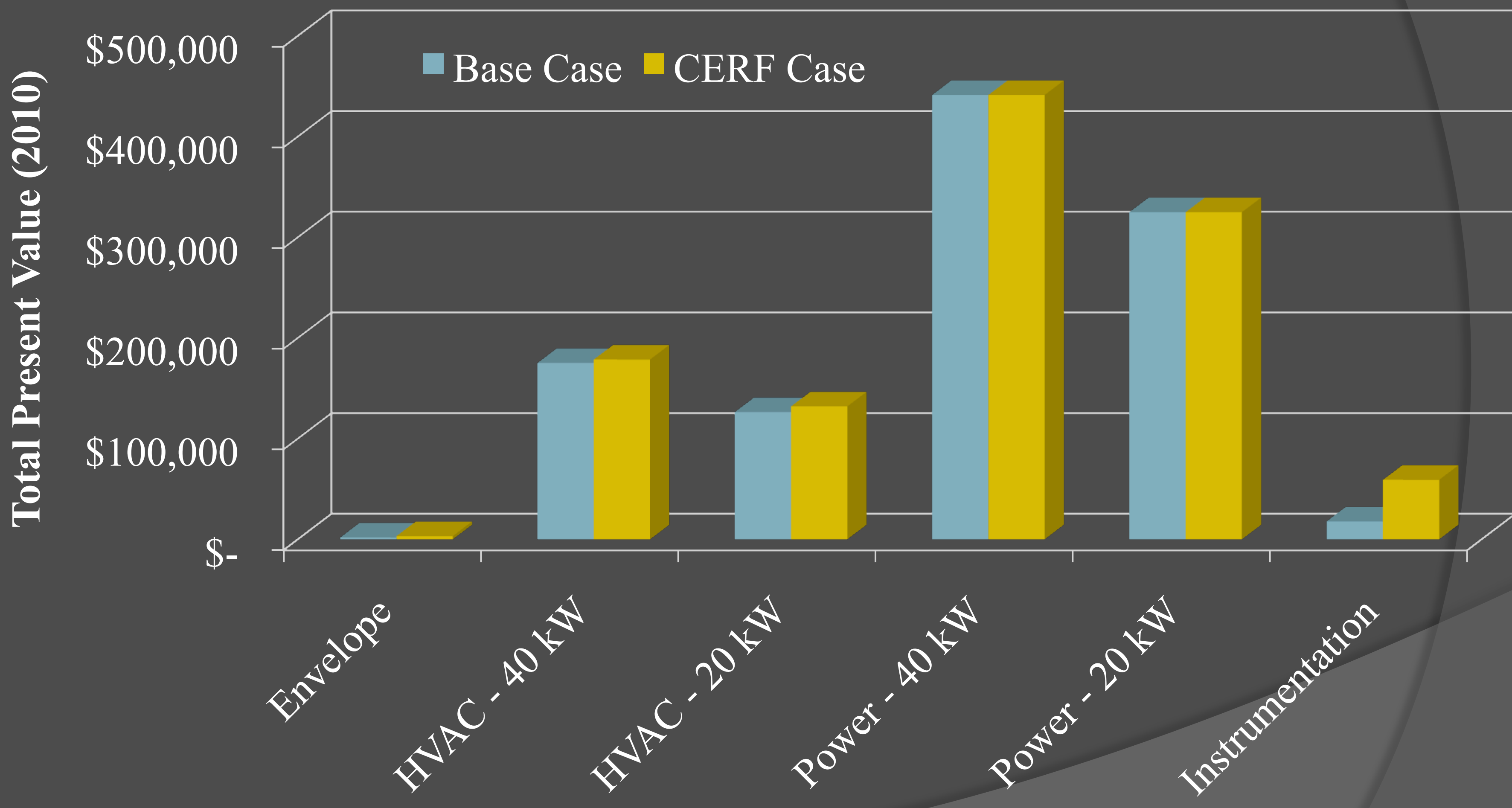
Base Case: Instrumentation



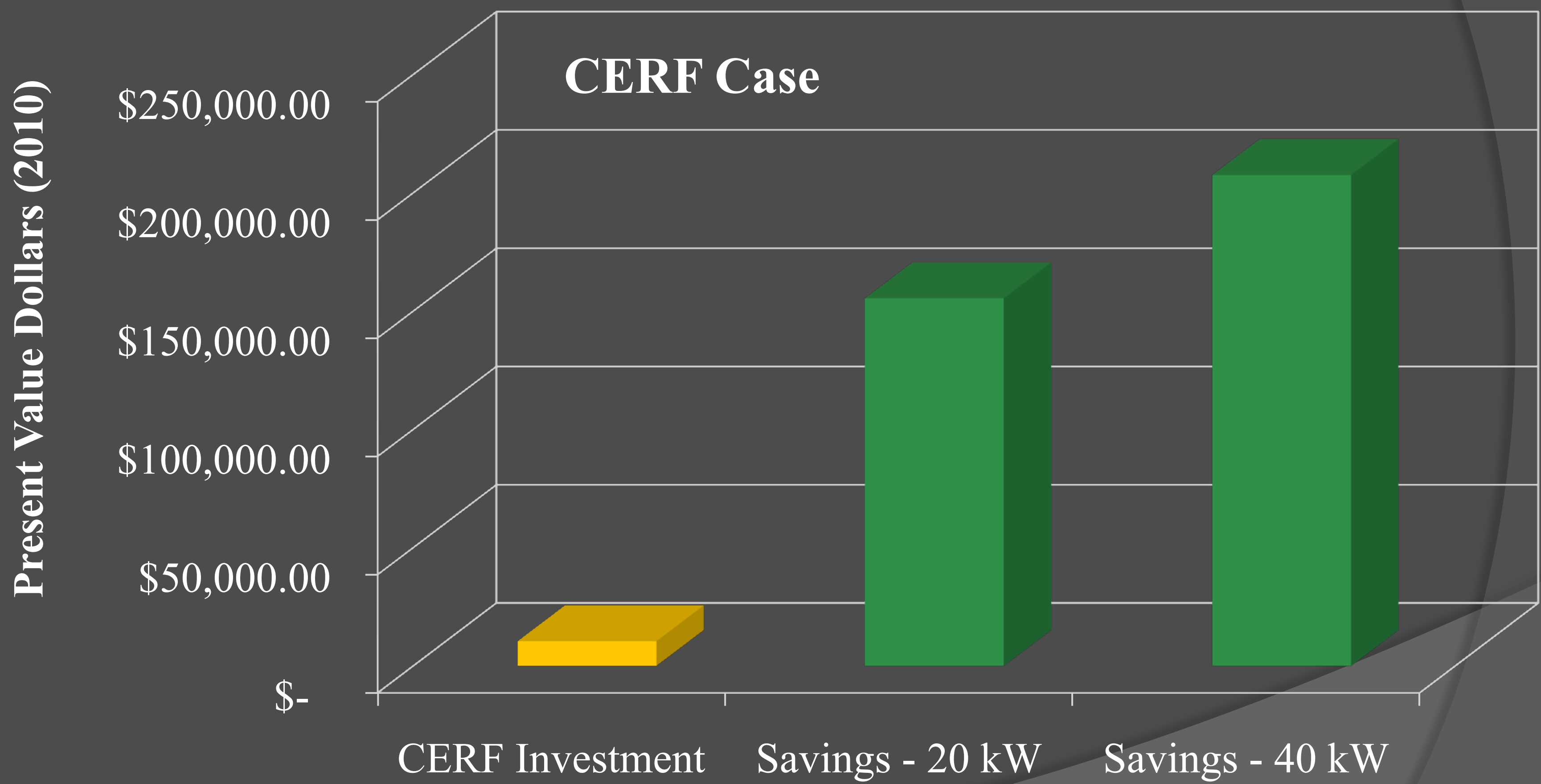
CERF Case: Instrumentation



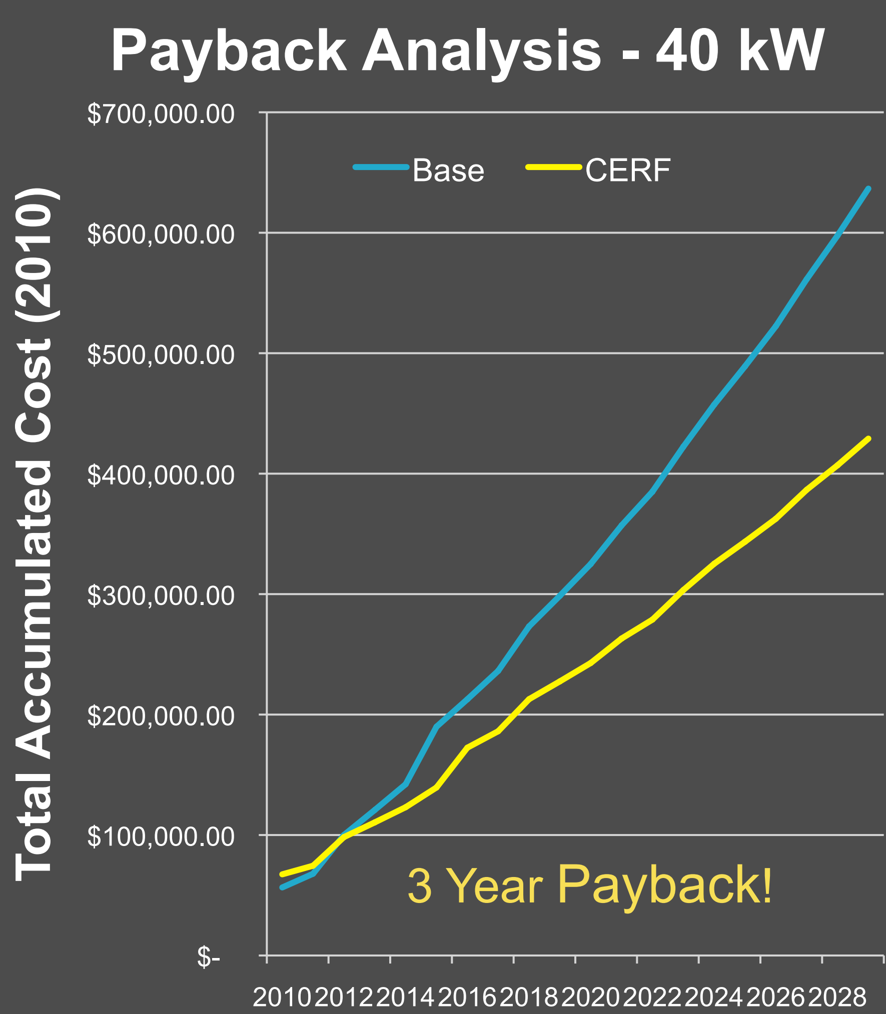
Cost Comparison

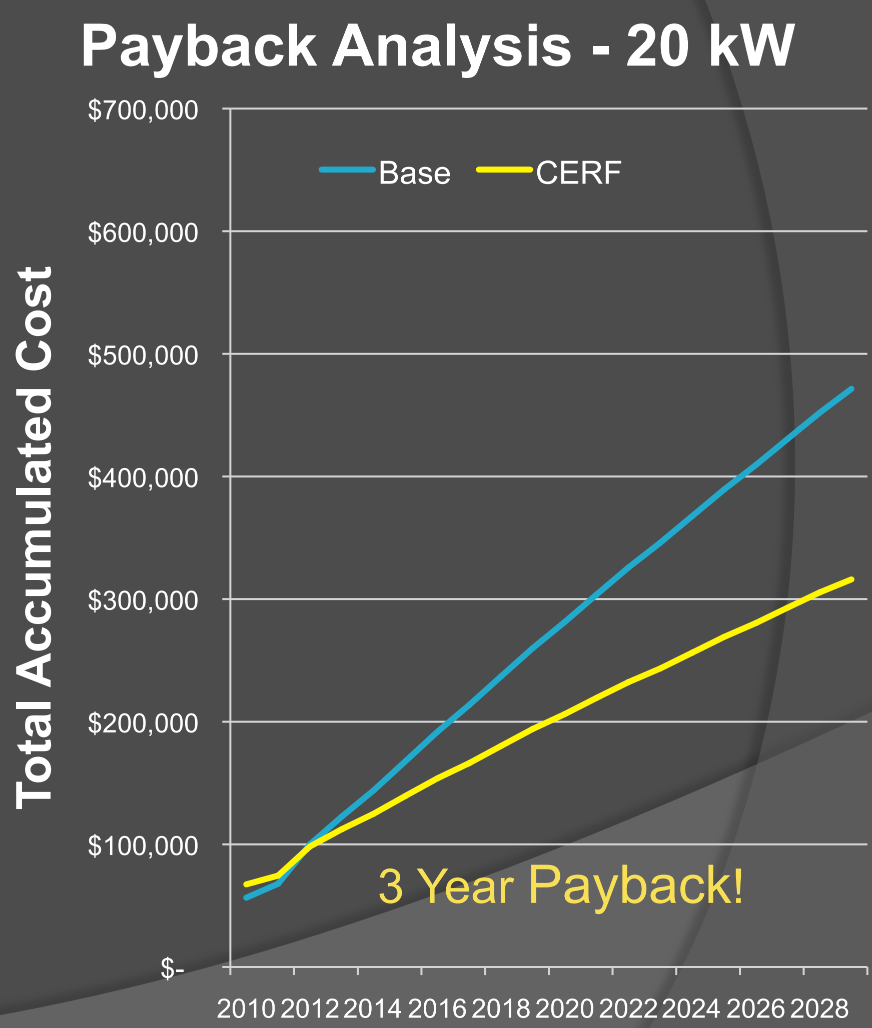


Investment & Savings over 20 Years

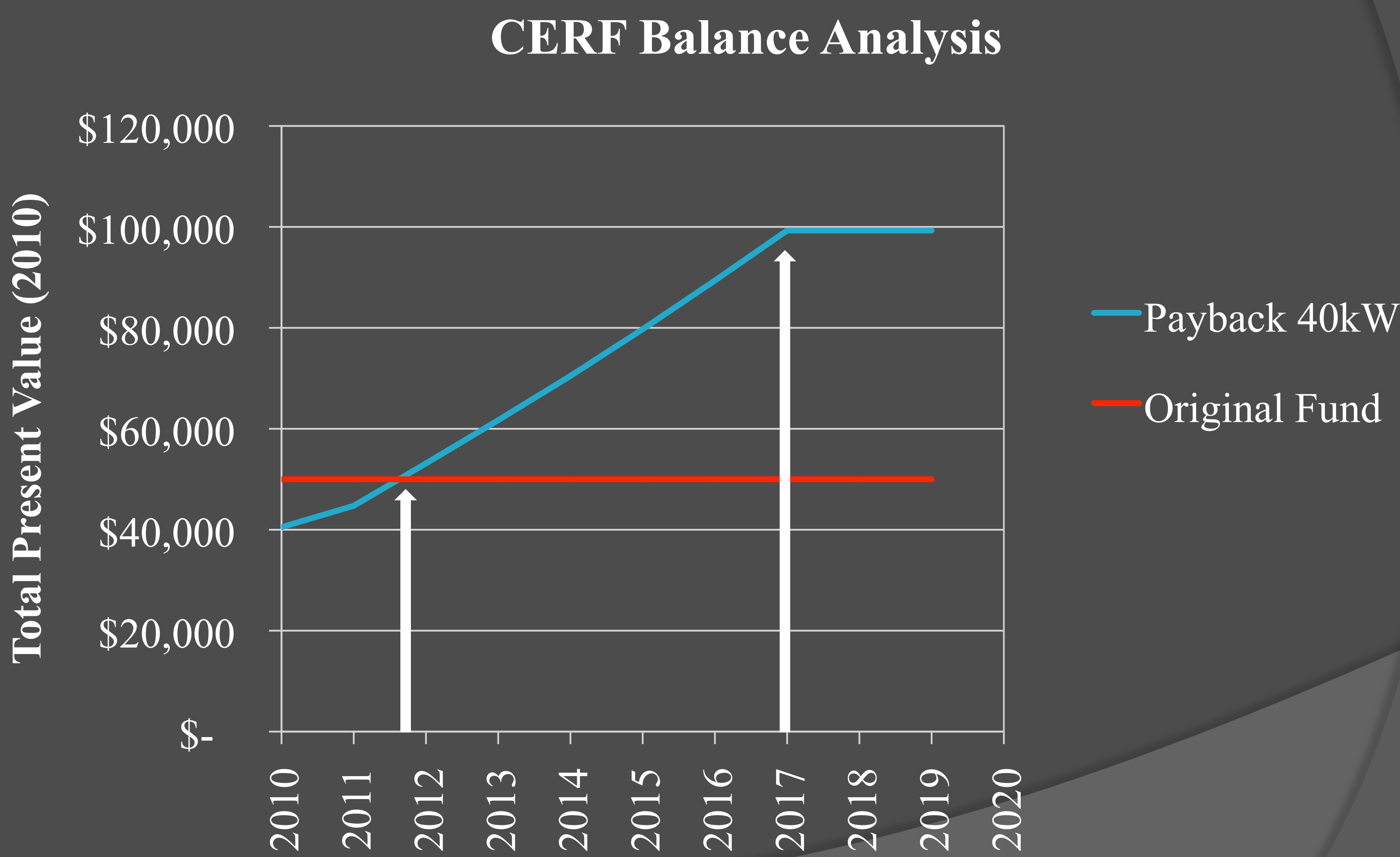


Final Recommendation Analysis



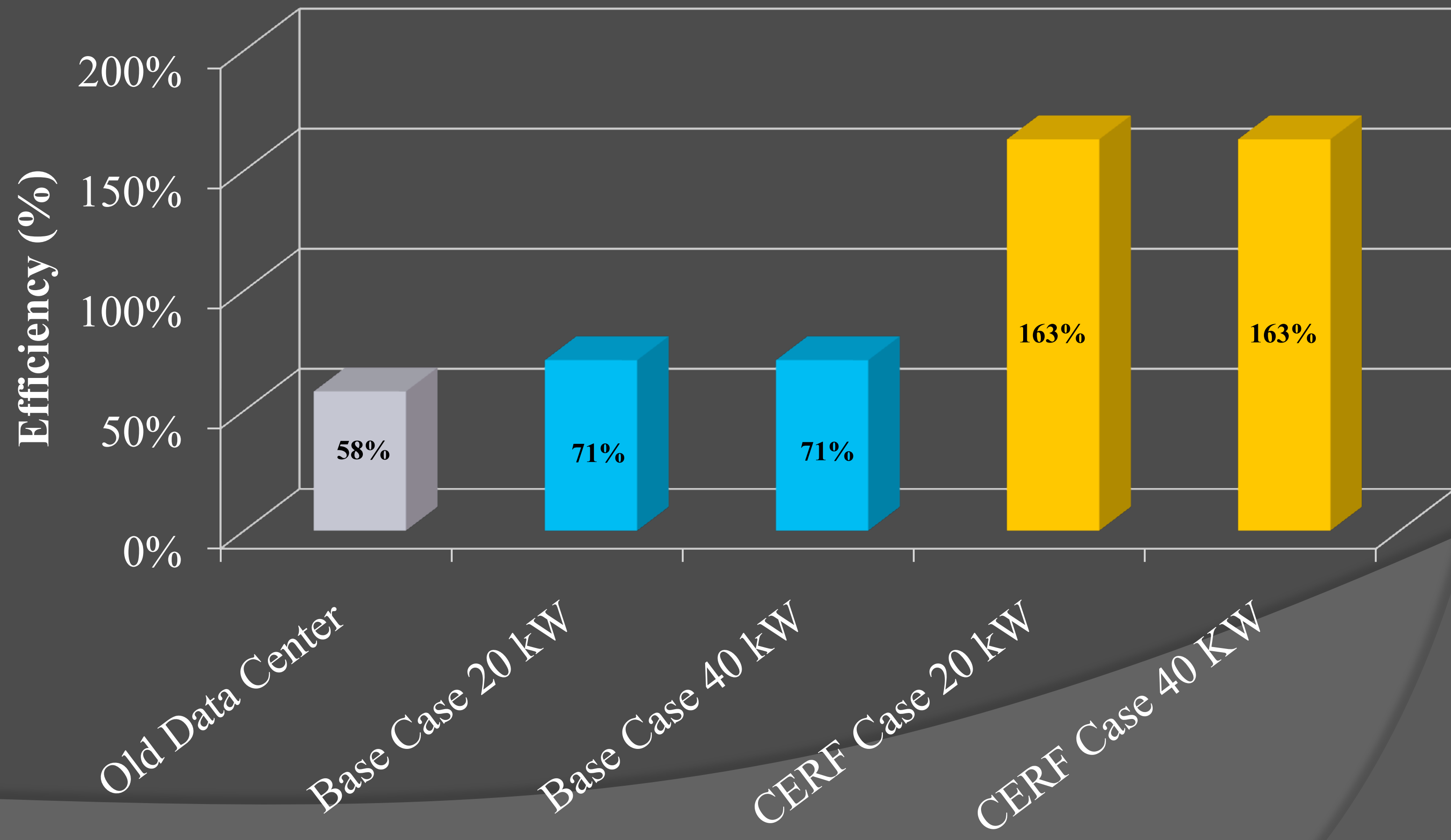


CERF Analysis



Efficiency Results

$$\frac{\textit{Energy to Server + Energy to Pool}}{\textit{Energy to Server + Energy to UPS + Energy to HVAC}}$$



Accounting Systems

- Why use CERF if the design shows it is beneficial for Calvin to adopt efficient design regardless of CERF?

  "Accounting systems change behavior"

- CERF provides entity for focused effort and an avenue for showing results.

Final Recommendation

- Financial analysis shows the CERF option is a viable CERF project
- Recommendation
  - Water cooled Liebert unit
  - Pool heat exchanger
  - Heat exchanger instrumentation for energy savings auditing

Acknowledgements

- Henry De Vries – Vice President, Information Services & Administration and Finance
- Robert Myers – Director, Administrative Technology and Services
- Sam Anema - Senior Systems Engineer
- Jeff Greenfield - Senior Systems Engineer
- Professor Heun – Engr. 333 Professor
- Paul Pennock – Physical Plant

Questions?

Thank you!