CHP - The Business Case

An Introduction to Combined Heat and Power

CHP 100

UIC University of Illinois at Chicago

Acknowledgements

MIDWEST CHP APPLICATION CENTER

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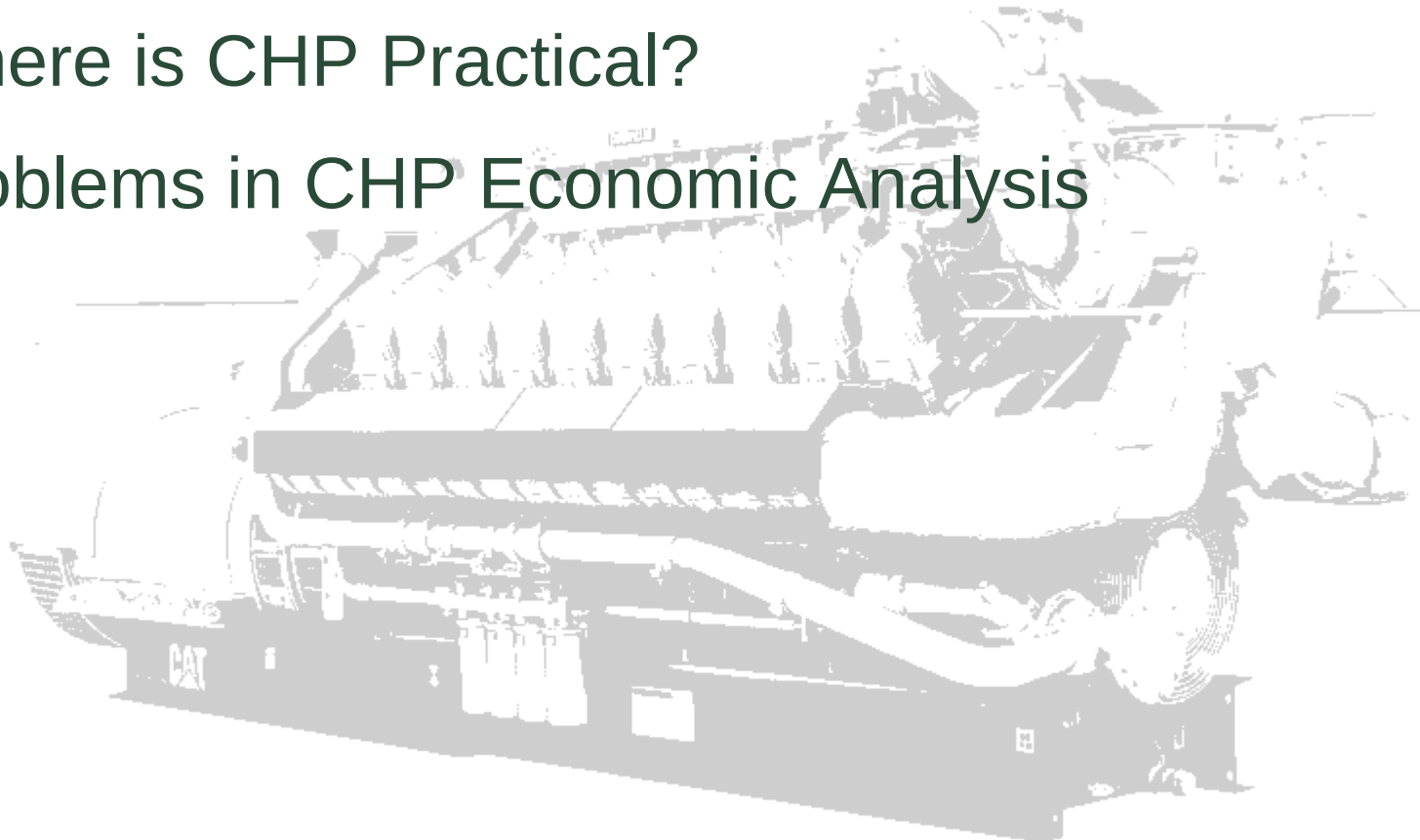
Overview

- When Does CHP Make Sense
- Where is CHP Practical?
- Problems in CHP Economic Analysis



When Does CHP Make $ense?

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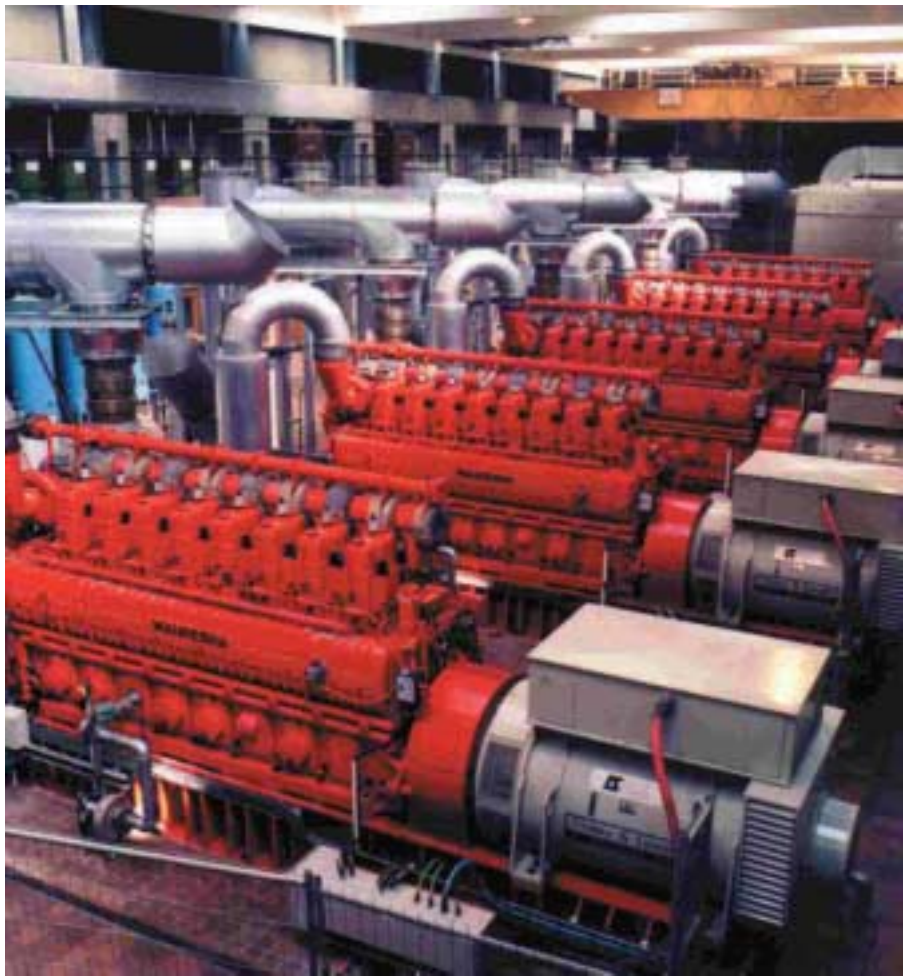


- High Thermal and Electric Loads that Occur Coincidentally
- Sufficient “Spark Spread”
- Long Operating Hours
- Central Heating and Cooling System
- Minimal Electric Distribution Connections
- Special Electrical, Cooling or Heating Needs

Picture Courtesy of Waukesha Engines Co.

When Does CHP Make $ense?

- Look Carefully at On Peak Power Rates
- CHP May Make Sense for On- Peak Operation
- Where Electric Back-Up is Desirable
  - Medical Facilities
  - Assisted Living Centers
  - Prisons
  - Mental Health
  - Locations that Need Existing Back-Up Systems Replaced
  - Security Location
  - Telecommunications and Server Facilities

Picture Courtesy of Waukesha Engines Co.

Where is CHP Practical?

- Knowing Facilities True Electric Price
- Three Questions in CHP Economics

Picture Courtesy of Caterpillar

Knowing Facilities True Electric Price

- Electric Prices are More than the Energy Charge
- Demand Charges Can be as Large or Larger Depending on the Facilities Load Profile

Picture Courtesy of Brownsville Electric Co.

Knowing Facilities True Electric Price

- Example:
  - What is the True Cost of On-Peak Electric Power for a Hospital Facility with a 75% On-Peak Load Factor on Comm Ed 6L
  - The Hospital Has a Peak Demand of 3 MW
  - Results in a Monthly On – Peak Energy Consumption of 330,000 kWh

True Electric Price – 6L - Summer

True Electric Costs			
Electric Energy Rate	*From Utility Bill*	$0.050	$/kWh
Electric Demand Rate	*From Utility Bill*	$16.41	$/kW
On Peak Electric Usage	*From Utility Bill*	330,000	kWh
Demand Usage	*From Utility Bill*	2,000	kW
Electric Charges	*From Utility Bill*	$16,573	
Demand Charges	*From Utility Bill*	$32,820	
Total Bill	*From Utility Bill*	$49,393	
Average Cost on Peak	*Total Bill/Electric Usage*	$0.150	$/kWh

True Electric Price – 6L - Winter

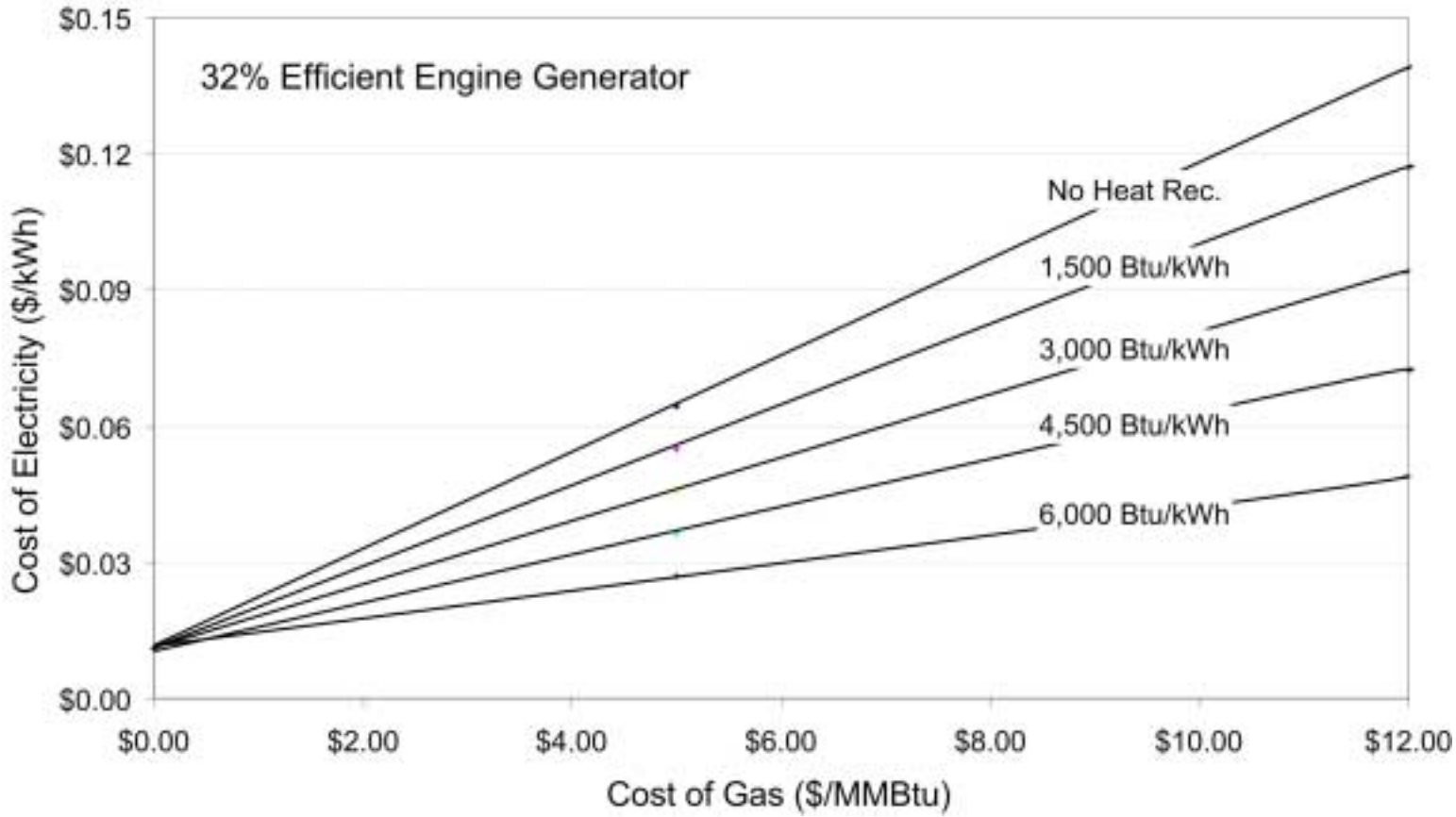
True Electric Costs			
Electric Energy Rate	*From Utility Bill*	$0.050	$/kWh
Electric Demand Rate	*From Utility Bill*	$12.85	$/kW
On Peak Electric Usage	*From Utility Bill*	330,000	kWh
Demand Usage	*From Utility Bill*	2,000	kW
Electric Charges	*From Utility Bill*	$16,573	
Demand Charges	*From Utility Bill*	$25,700	
Total Bill	*From Utility Bill*	$42,273	
Average Cost on Peak	*Total Bill/Electric Usage*	$0.128	$/kWh

Three Questions in CHP Economics

1. Is CHP Profitable: Can I Make a Profit on Each Hour of Operation?
2. Is the Profit Sufficient to Cover the First Cost and Provide a Sufficient Payback?
3. What is the Value of the "Other Benefits"

Question 1 - Profitability

- Shows NET Cost of Electric Generation From the CHP System AFTER Heat Recovery Displaces Boiler Load



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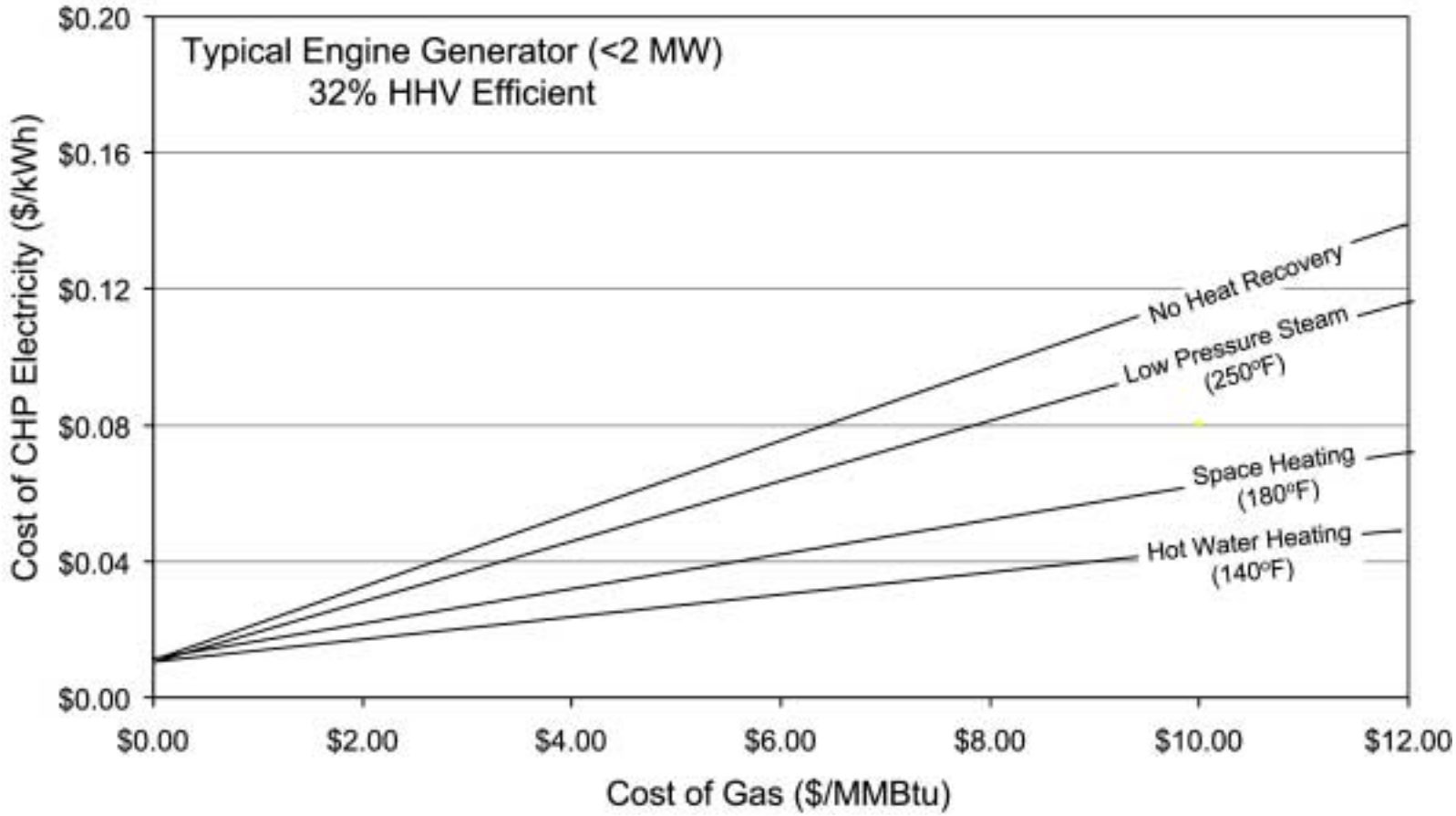
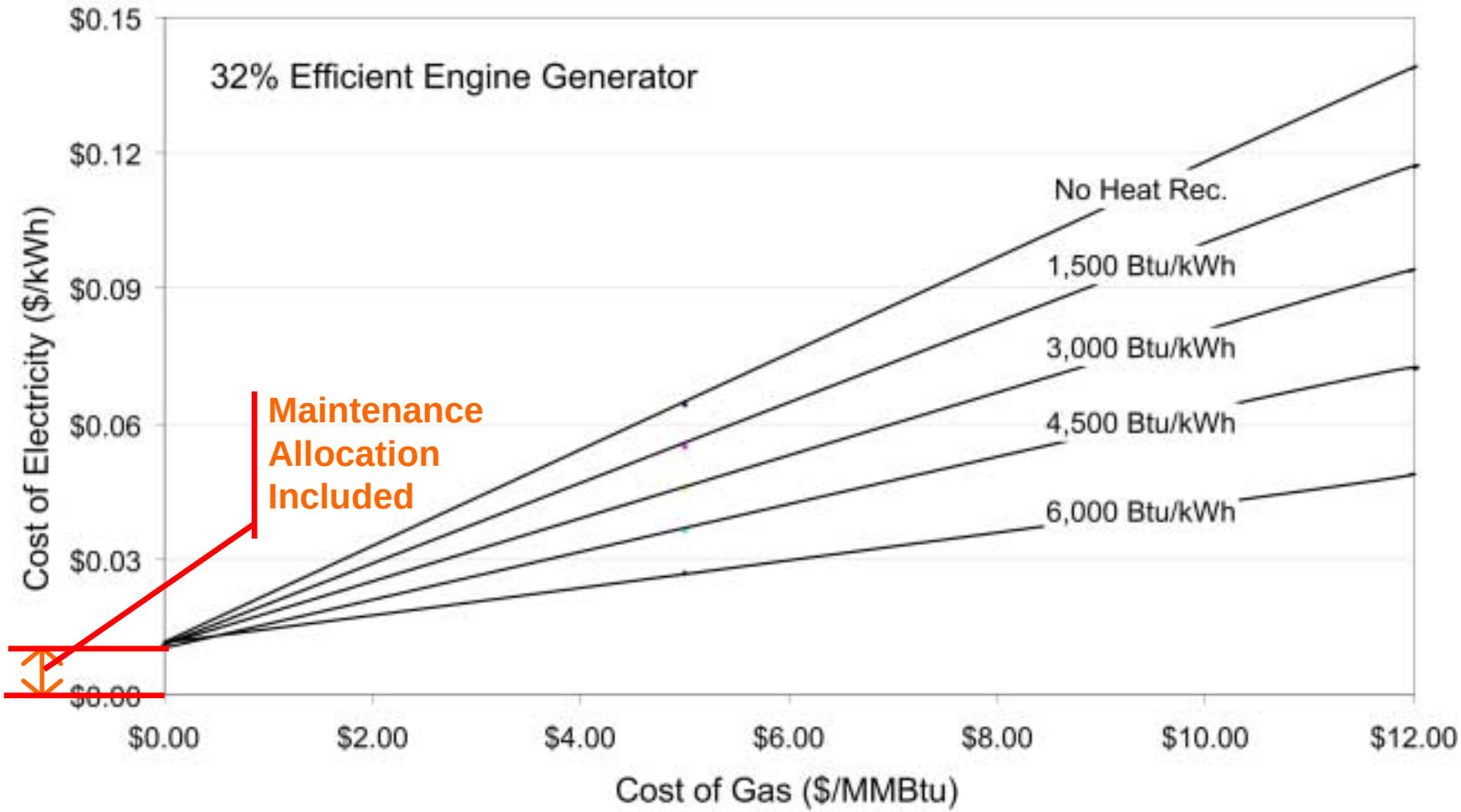


Values Includes Maintenance Allocation



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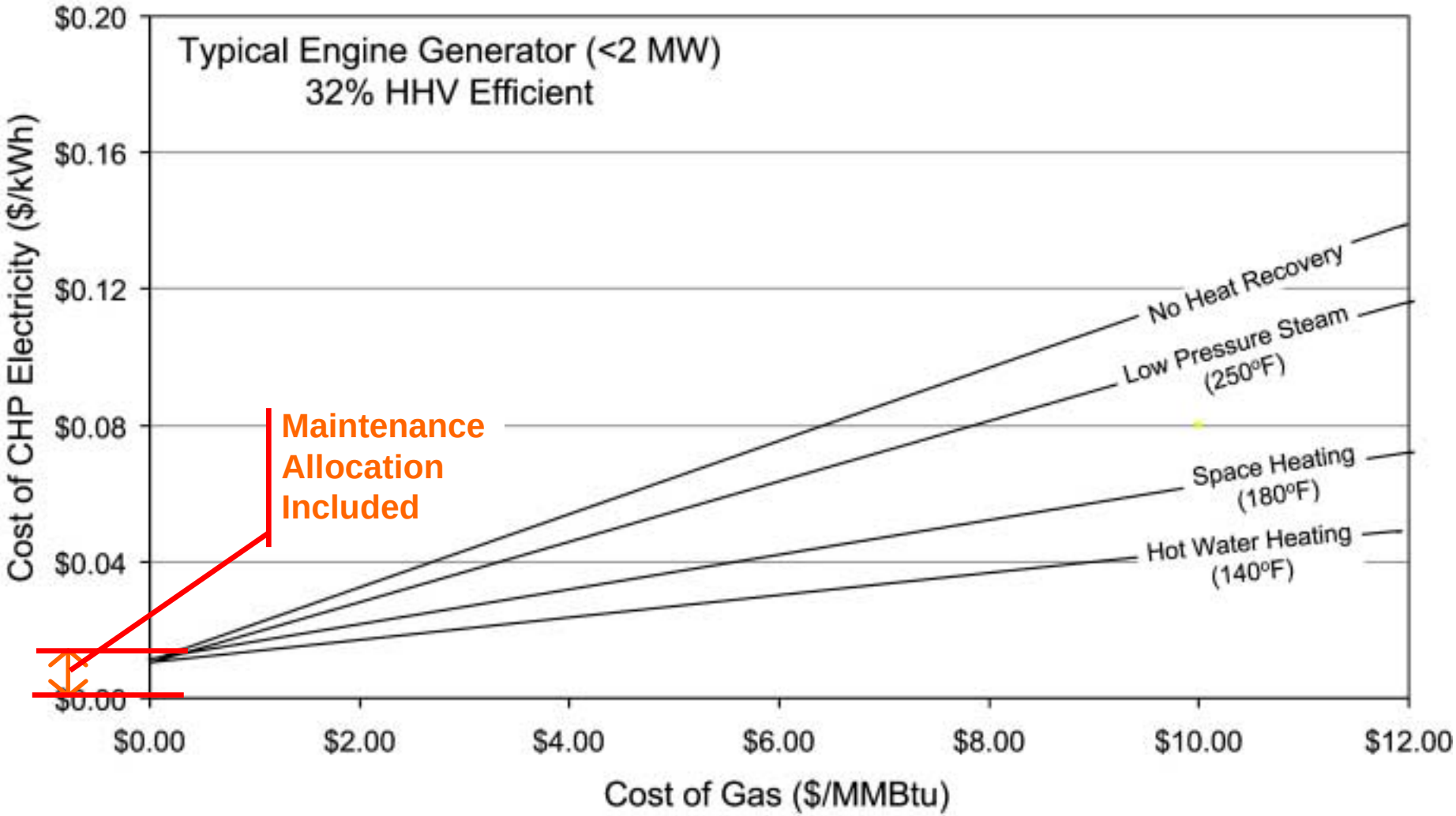
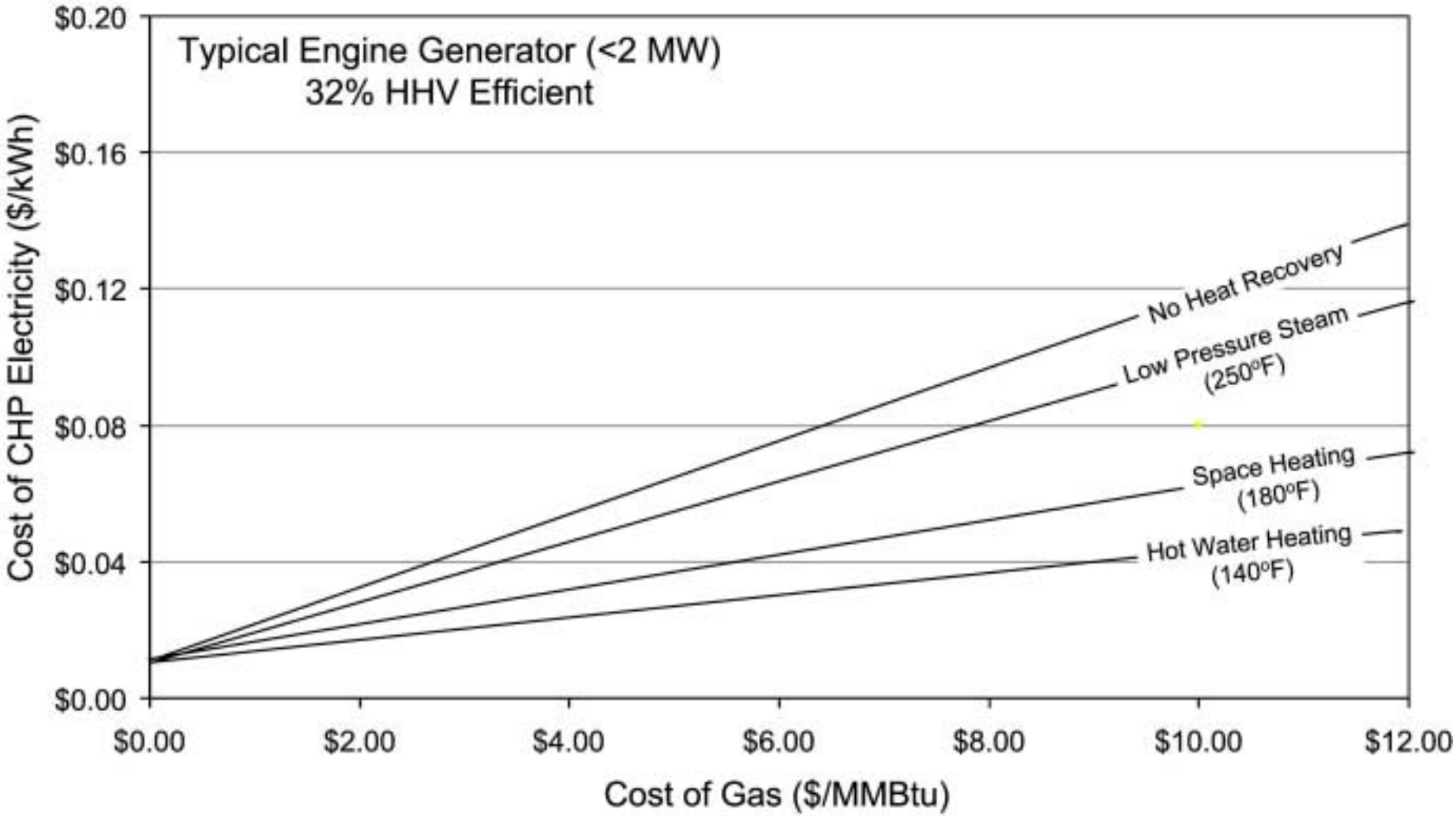
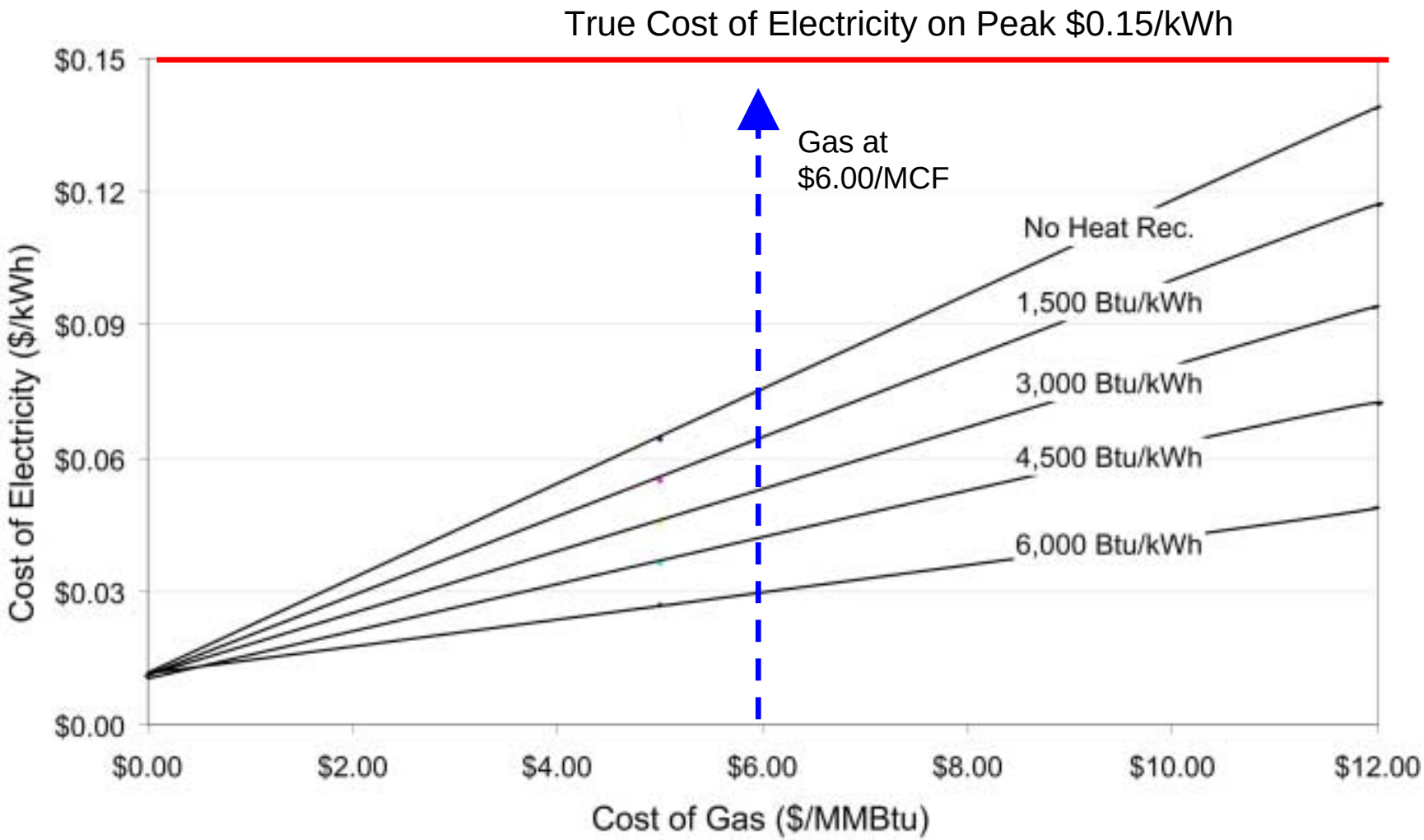


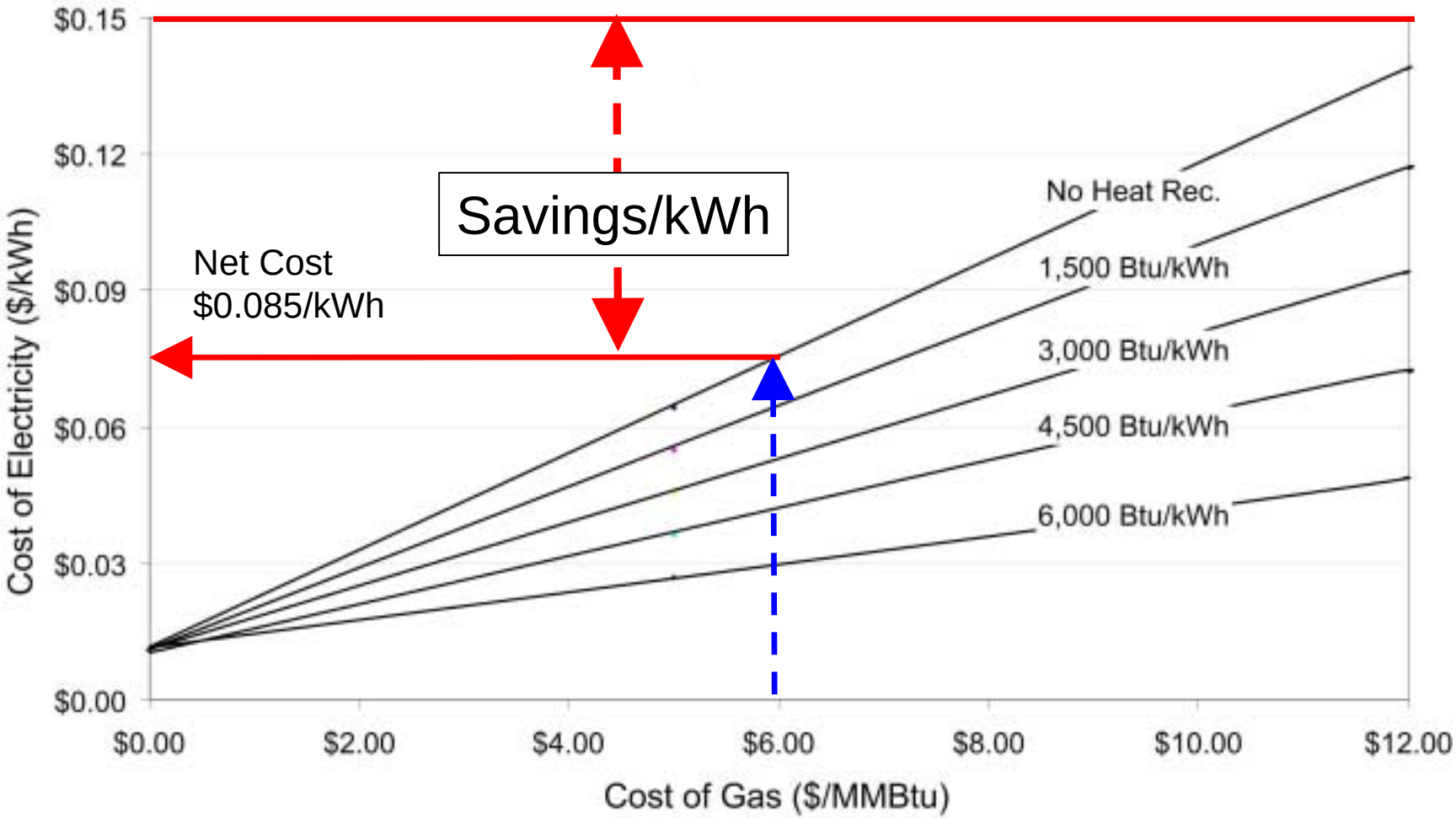
Approximate Heat Recovery Opportunities by Application



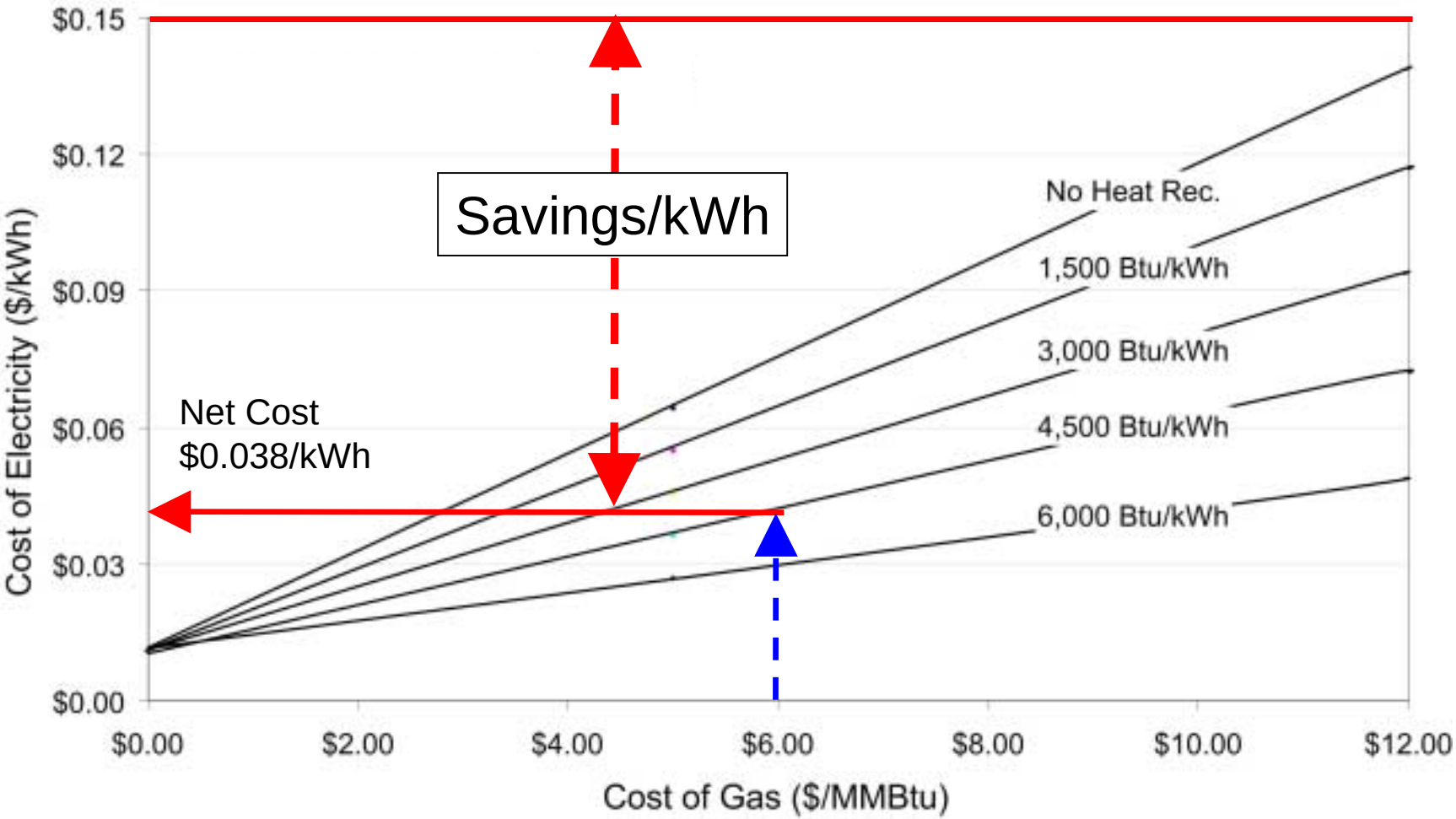
Putting in Current Gas and Electric Rates



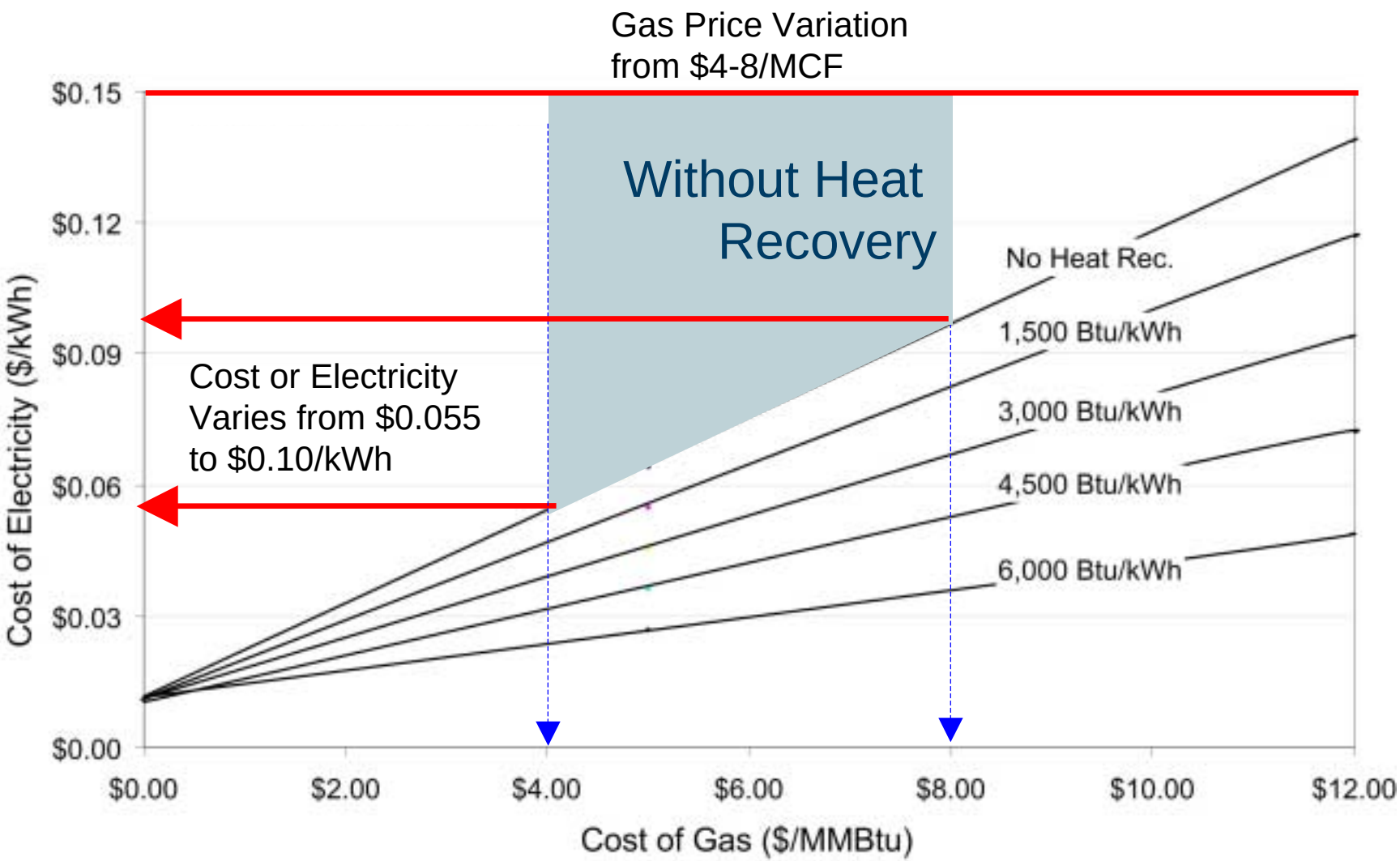
Without Heat Recovery



With Heat Recovery



What Happens When Gas Prices Vary



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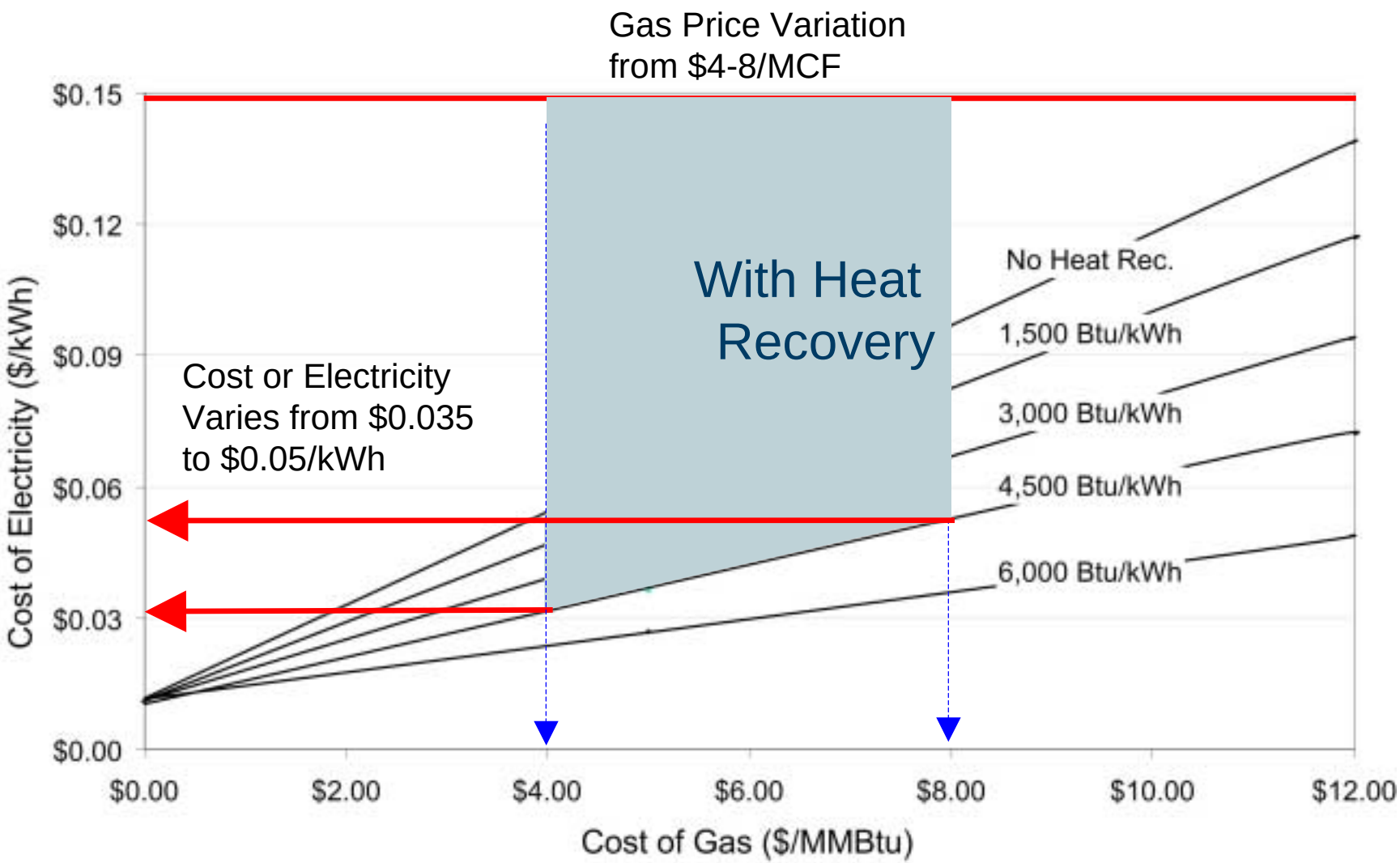


Gas Volatility

- Effect is Moderated by the Recovered Heat

Question 1 - Profitability

- Electric Generating Price Can Be Very Reasonable
- Heat Recovery LOWERS Volatility in Generating Cost
  - Recovered Heat Replaces Boiler Gas Fuel Which is Also Varying

Question 2: Is the Profit Sufficient?

Looks at Simplified Cases

- To Illustrate Important Principles
- Tend to Produce Low Paybacks
- Will Follow with Realistic Paybacks for the Northern Illinois Area

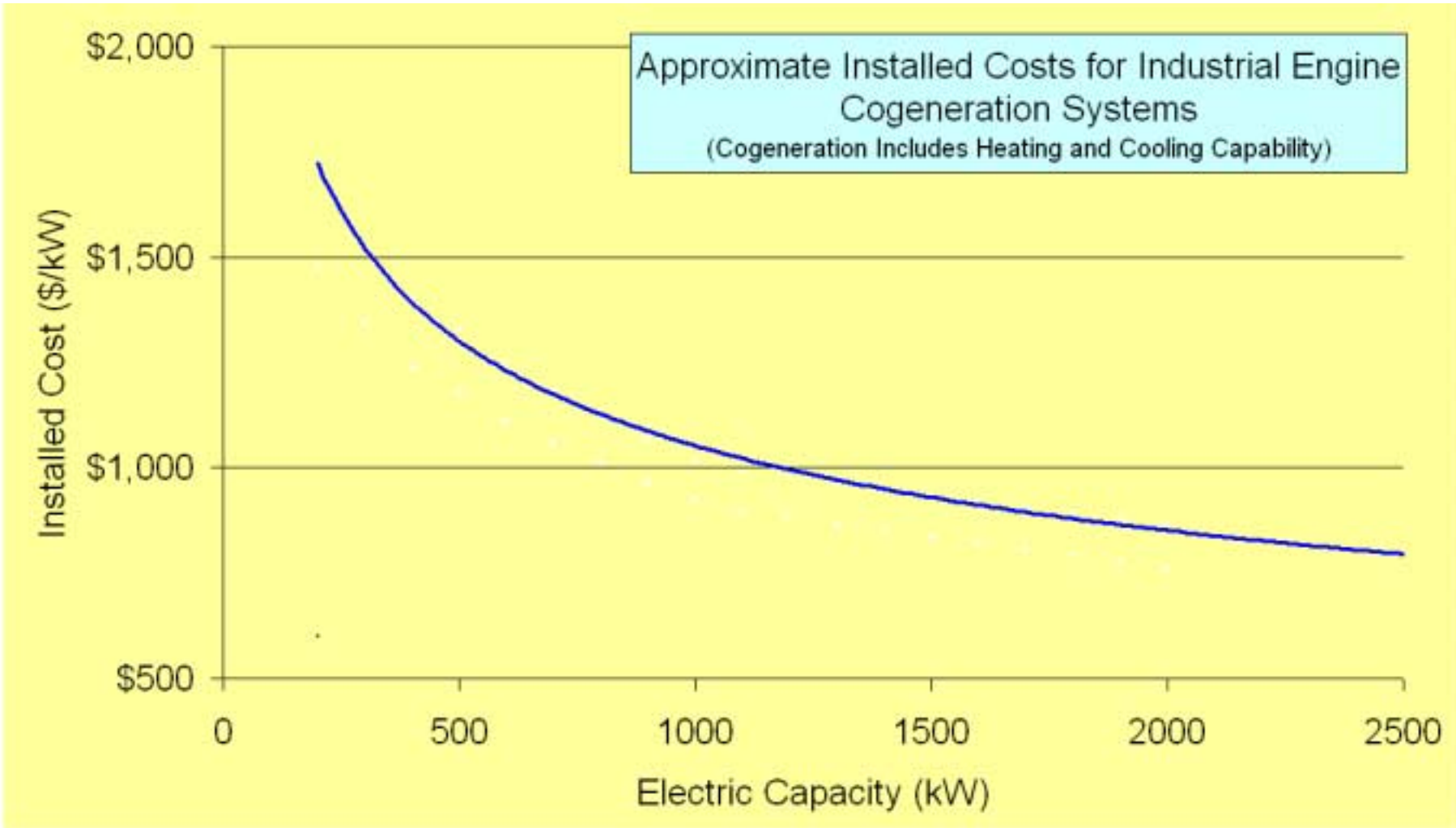
Simplified Case

- Use the 75% Load Factor Model (Hospital)
- Assume that 4,500 Btu/kW is Recoverable

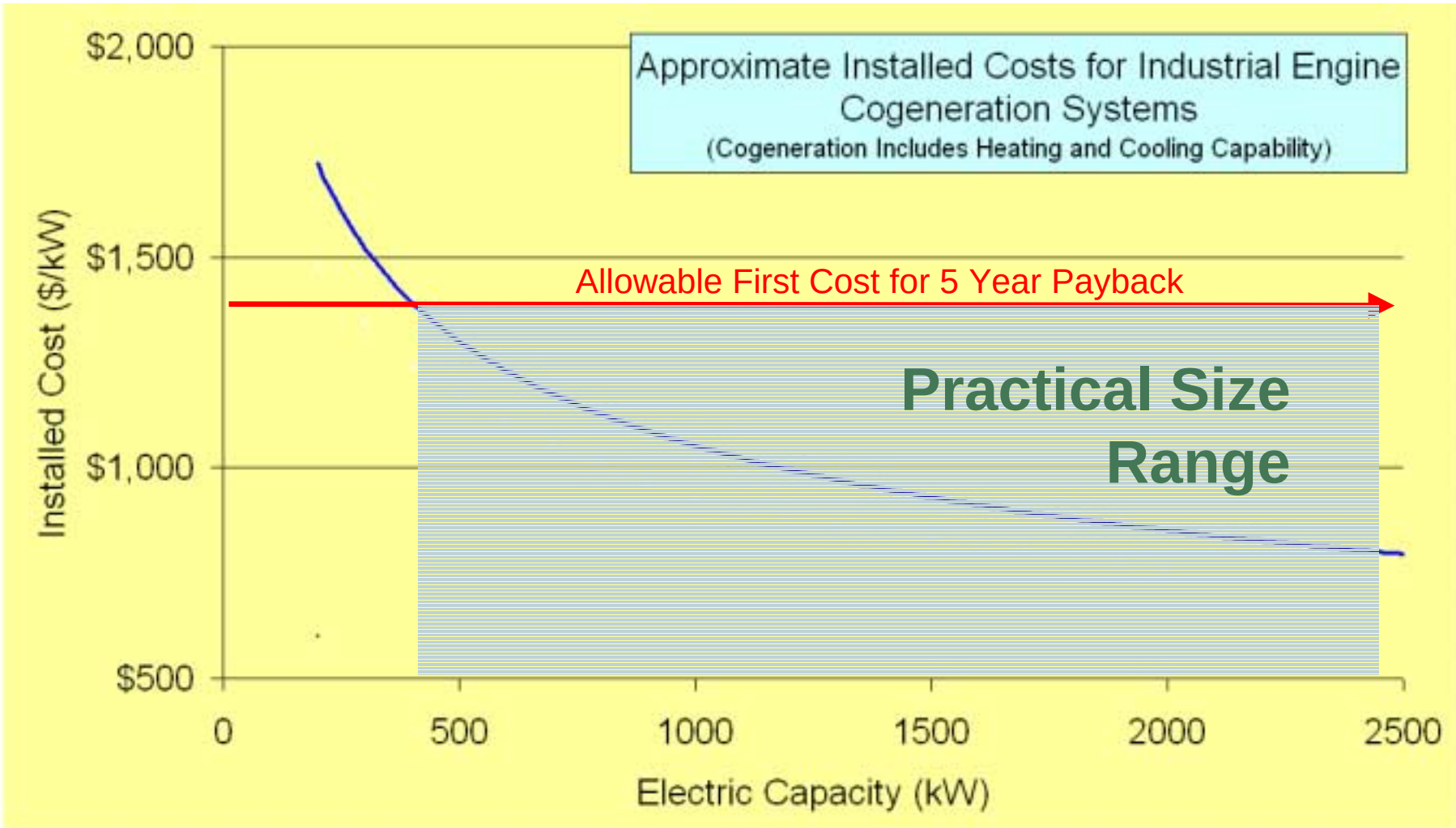
Full Load and 100% Heat Recovery

	Summer	Winter
On Peak Hours of Operation	715	2145
True Cost of Electricity	$0.15	$0.13
Cost of Gas	$6.00	$6.00
Cost of Generating Electricity	$0.04	$0.04
Cost Savings per kWh	$0.11	$0.09
Cost Savings per kW Capacity/Season	$80.08	$188.76
Total Savings per kW Capacity per Year	$268.84	
Max First Cost/kW for 5 Year Payback	$1,344.20	
Max First Cost/kW for 4 Year Payback	$1,075.36	

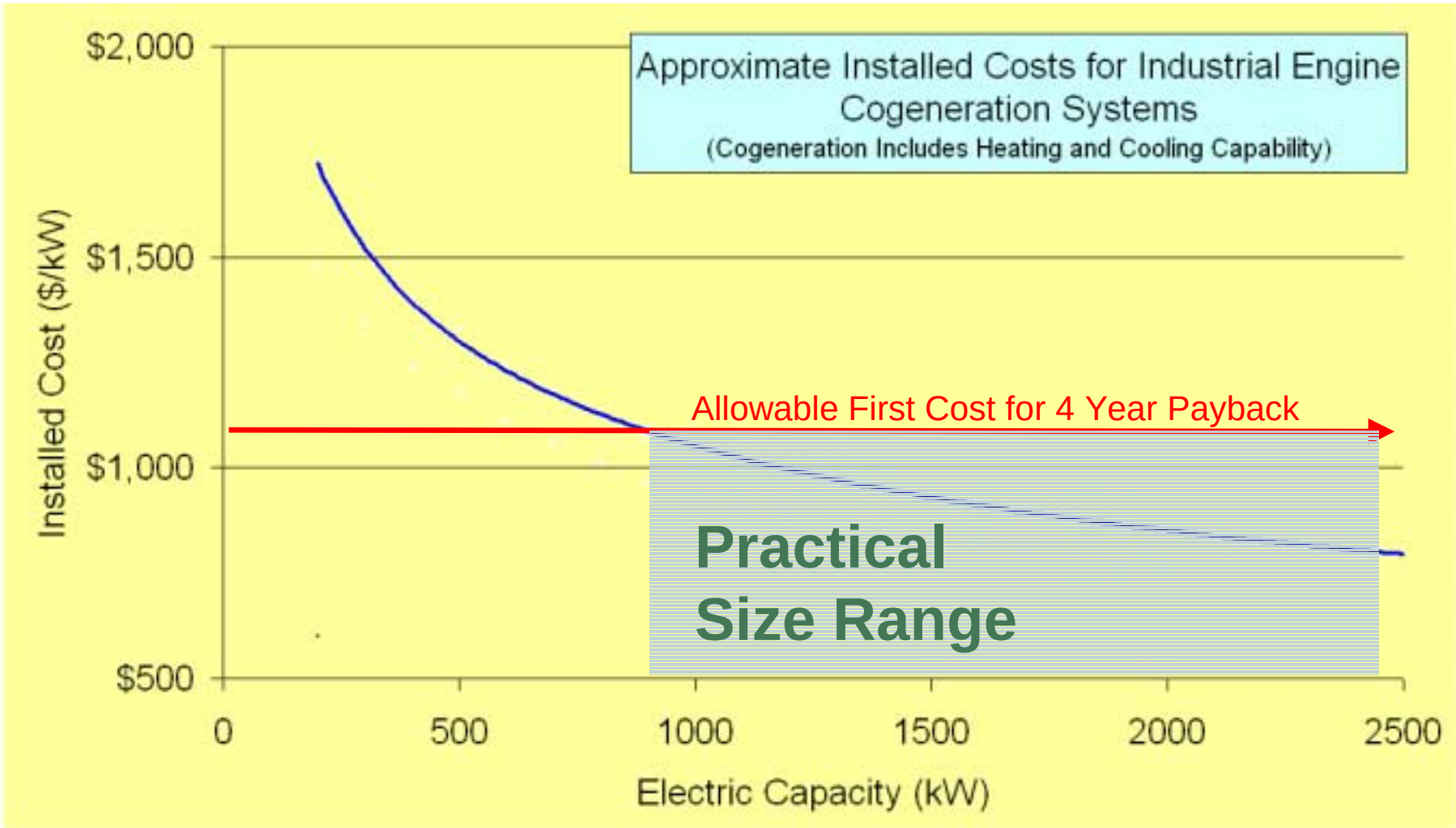
Larger Systems = Lower Cost/kW



Larger Systems = Shorter Payback



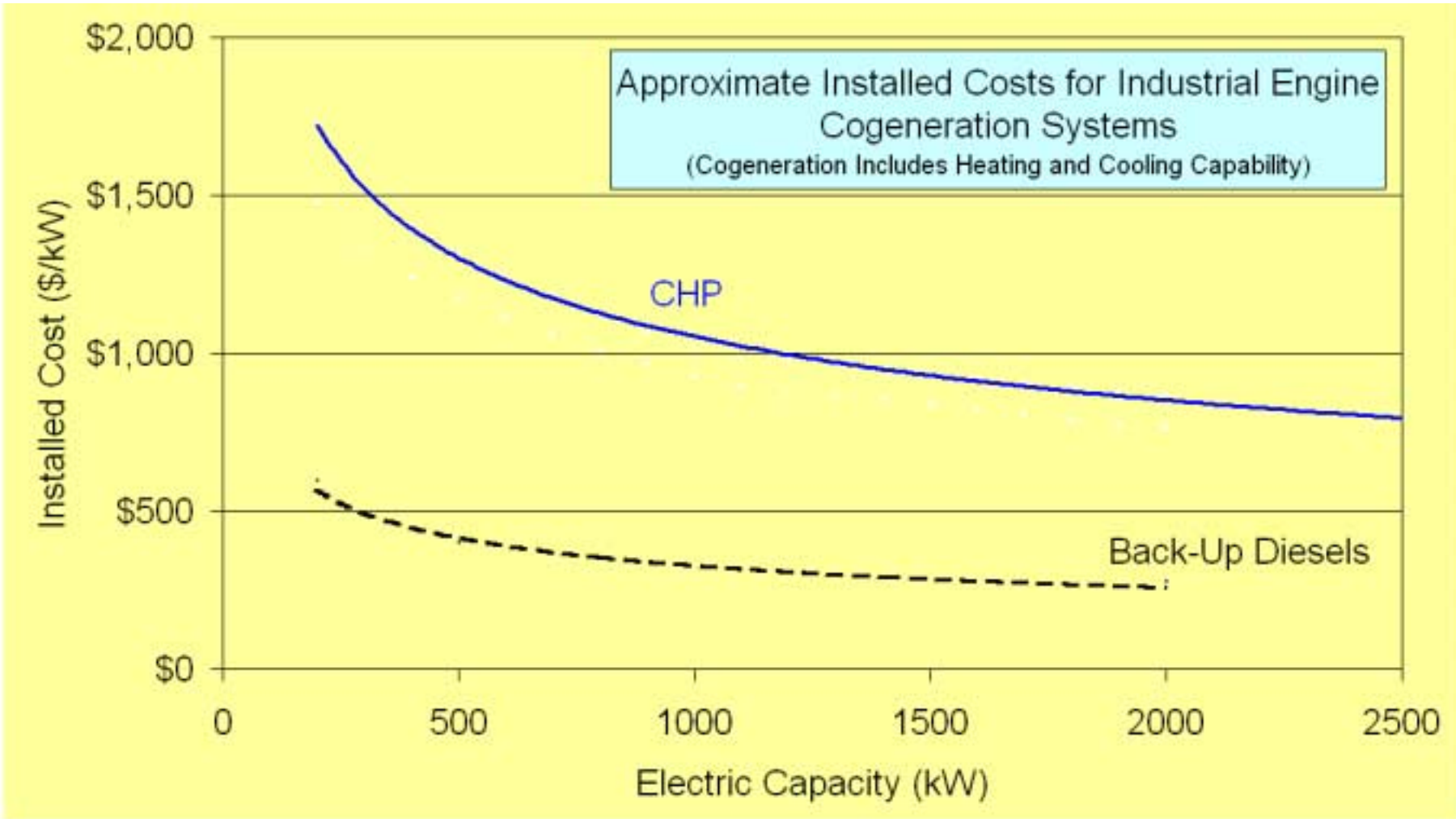
For a 4 Year Payback…



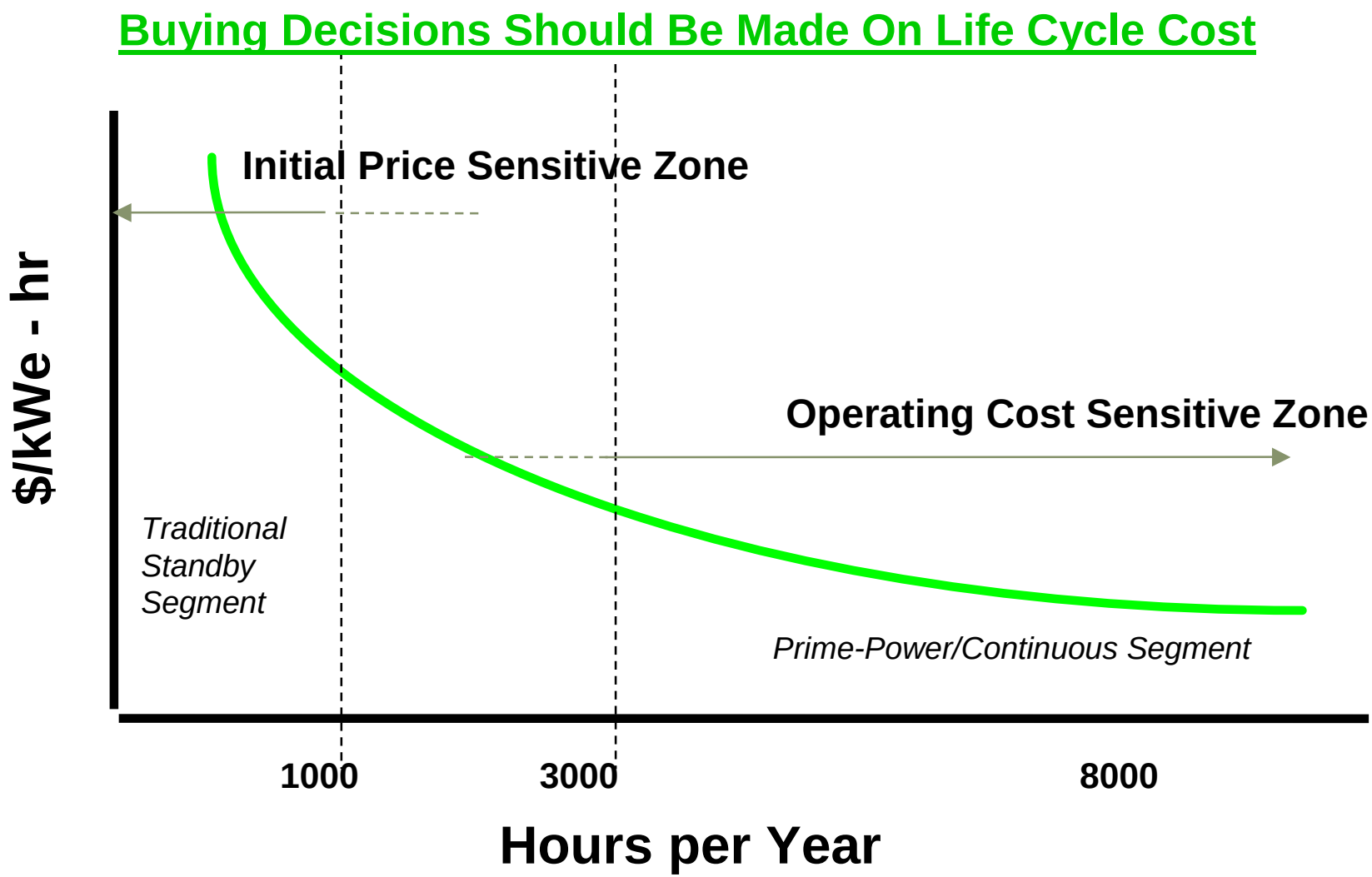
Question 2: Is the Profit Sufficient?

- Answer Depends on Customers Payback Horizon
- Answer Depends Heavily on the Plant Size
  - Larger Plants – Lower Payback
  - Why CHP is More Common on Larger Loads

Question 3: What is the Value of the"Other Benefits"



Standy Generators Vs. CHP



For a Client Who Desires Back-Up Capability

	Summer	Winter
On Peak Hours of Operation	715	2145
True Cost of Electricity	$0.15	$0.13
Cost of Gas	$6.00	$6.00
Cost of Generating Electricity	$0.038	$0.038
Cost Savings per kWh	$0.11	$0.09
Cost Savings per kW Capacity/Season	$80.08	$188.76
Total Savings per kW Capacity per Year	$268.84	
First Cost for 1500 kW Plant ($.kW)	$850.00	
Payback Period (Years)	3.16	
First Cost for 1500 kW Plant ($.kW)	$850.00	
Avoided Cost for 1500 kW of Back-Up	$300.00	
Net First Cost for CHP Function	$550.00	
Payback Period (Years)	2.05	

Question 3: What is the Value of the"Other Benefits"

Cogeneration Projects Usually Include Other Benefits That Can be Similarly Broken Out:

- Improved Power Quality
  - Avoided Cost – Power Conditioning Equipment
- New Heating Capacity
  - Avoided Cost – Replacing Old Boilers
- Centralized Power Feed – Single Account Billing
  - Avoided Cost – Overlapping Demand Charges

More Formal Economic Analysis

- Recoverable Heat Can Not All Be Productively Used
- More Detailed Economic Analysis is Essential
- Will Use a Simple Example;
  - Use the 75% Load Factor Model (Hospital)
  - Assume that 4,500 Btu/kW is Recoverable
  - Commonly Only 50% of the Recoverable Heat is Productively Used (Recovered)
    - Why? - Some Recoverable Heat is Produced When There is No Heat Load
  - 1500 kW Plant

Full Load and 100% Heat Recovery

	Summer	Winter
Plant Size	1500	
On Peak Hours of Operation	715	2145
MWh Generated	1072.5	3217.5
True Cost of Electricity	$0.15	$0.13
Avoided Electric Cost	$160,875	$482,625
Cost of Gas	$6.00	$6.00
Gas Consumed per Hour (32% HHV) MMBH	17.68	17.68
Gas Consumed MMBtu	12,640	37,919
Cost of Gas Consumed	-$75,838	-$227,514
Recoverable Heat Produced per Hour (MMBH)	6.75	6.75
Percent of Recoverable Heat Recovered	100%	100%
Total Heat Recovered (MMBtu)	4826	14479
Boiler Fuel Avoided by Recovering Heat (MMBtu)	6033	18098
Cost Savings for Boiler Fuel Avoided	$36,197	$108,591
Maintenance Allocation	-$11,798	-$35,393
Net Savings	$437,746	
First Cost for 1500 kW Plant	$1,275,000.00	
Payback Period (Years)	2.91	

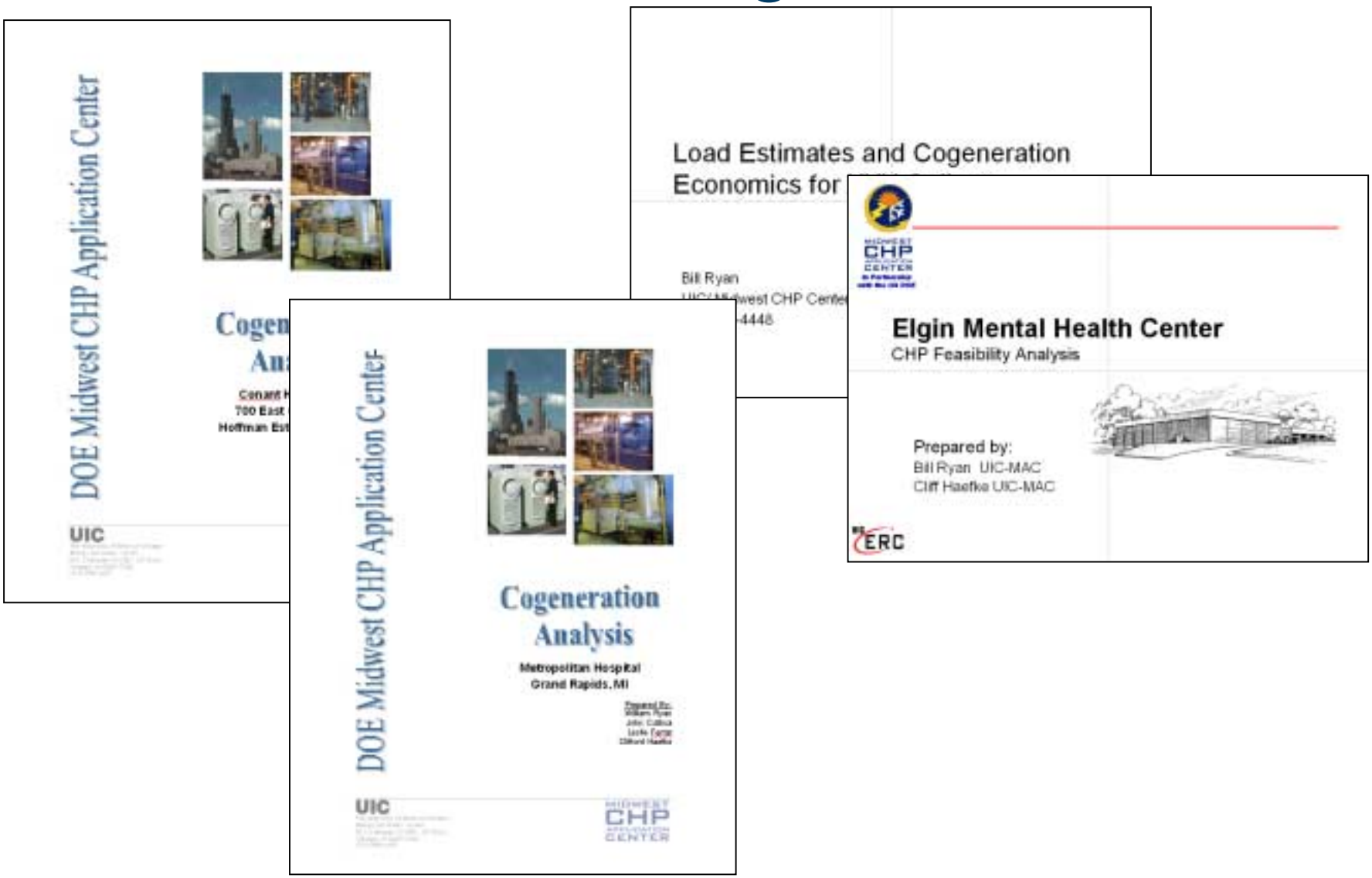
Full Load and 50% Heat Recovery

	Summer	Winter
Plant Size	1500	
On Peak Hours of Operation	715	2145
MWh Generated	1072.5	3217.5
True Cost of Electricity	$0.15	$0.13
Avoided Electric Cost	$160,875	$482,625
Cost of Gas	$6.00	$6.00
Gas Consumed per Hour (32% HHV) MMBH	17.68	17.68
Gas Consumed MMBtu	12,640	37,919
Cost of Gas Consumed	-$75,838	-$227,514
Recoverable Heat Produced per Hour (MMBH)	6.75	6.75
Percent of Recoverable Heat Recovered	50%	50%
Total Heat Recovered (MMBtu)	2413	7239
Boiler Fuel Avoided by Recovering Heat (MMBtu)	3016	9049
Cost Savings for Boiler Fuel Avoided	$18,098	$54,295
Maintenance Allocation	-$11,798	-$35,393
Net Savings	$365,352	
First Cost for 1500 kW Plant	$1,275,000.00	
Payback Period (Years)	3.49	

More Complete Realistic Economics

- Run CHP System Against Actual Plant Loads
  - System will Not Be Loaded at All Times
- Generally Seeing 4-6 Year Paybacks
  - Using a Far More Complete Hour by Hour Simulation Program
  - Against $5 - $6 Gas Prices
  - The 6L Rate
  - Commercial Systems in the 1-3 MW Range

Detailed CHP Modeling Services



Investment Level Economics

- Total Financial Pro Forma Analysis
  - Annual Cash Flow Plan
  - Rate of Return, Net Present Value
  - Sensitivity Analysis

Discount Rate	12%	Depreciation Period			15	Years											
Investment	270	Tax Rate			0%												
Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Savings		$80	$80	$80	$80	$80	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Before-Tax Cash Flow	-$270	$80	$80	$80	$80	$80	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Depreciation (Straight-line)		$18	$18	$18	$18	$18	$18	$18	$18	$18	$18	$18	$18	$18	$18	$18	$0
Taxable Income		$62	$62	$62	$62	$62	-$18	-$18	-$18	-$18	-$18	-$18	-$18	-$18	-$18	-$18	$0
Taxes @		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
After-Tax Cash Flow	-$270	$80	$80	$80	$80	$80	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Cumulative Cash Flows	-$270	-$190	-$110	-$30	$50	$130	$130	$130	$130	$130	$130	$130	$130	$130	$130	$130	$130
Present Value of Cash Flows	-$270	$71	$64	$57	$51	$45	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Cumulative PV Cash Flows	-$270	-$199	-$135	-$78	-$27	$18	$18	$18	$18	$18	$18	$18	$18	$18	$18	$18	$18
NPV	$18		IRR	15%													

All Dollar Values in Thousands

Problems in CHP Economic Analysis

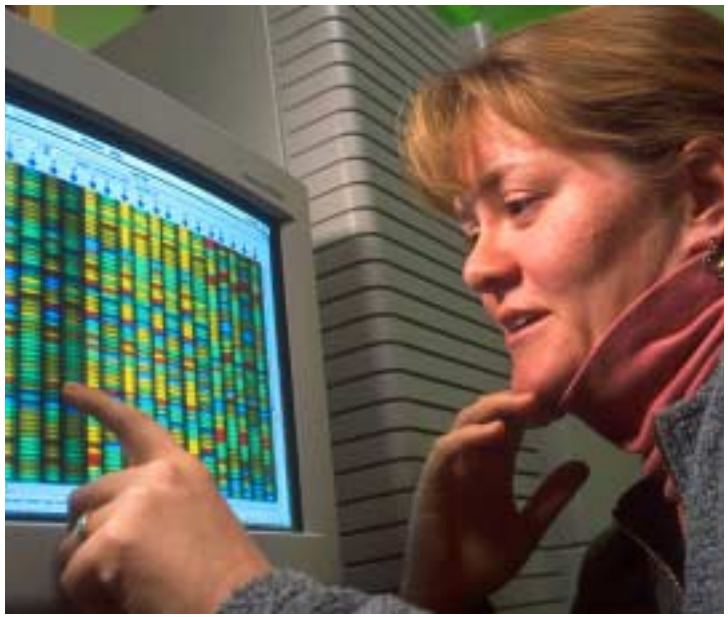
Problems in CHP Economic Analysis

- A List of Common Issues with CHP Economics
  - Washing Away the Saving
  - Over-Sizing the Plant
  - Poor Technology Choice for the Thermal Load
  - Averaging

Washing Away the Savings

- Economic Calculators and Spreadsheets are Always Based on an Assumption of How and When the System is to Be Run
- If the Wrong Operating Strategy is Chosen – Loseing Money During Some Operating Periods
  - Program May Not Show What is Happening
- Before Running Economics – Settle on the Most Profitable Possible Operating Strategy

Operating Strategy Examples



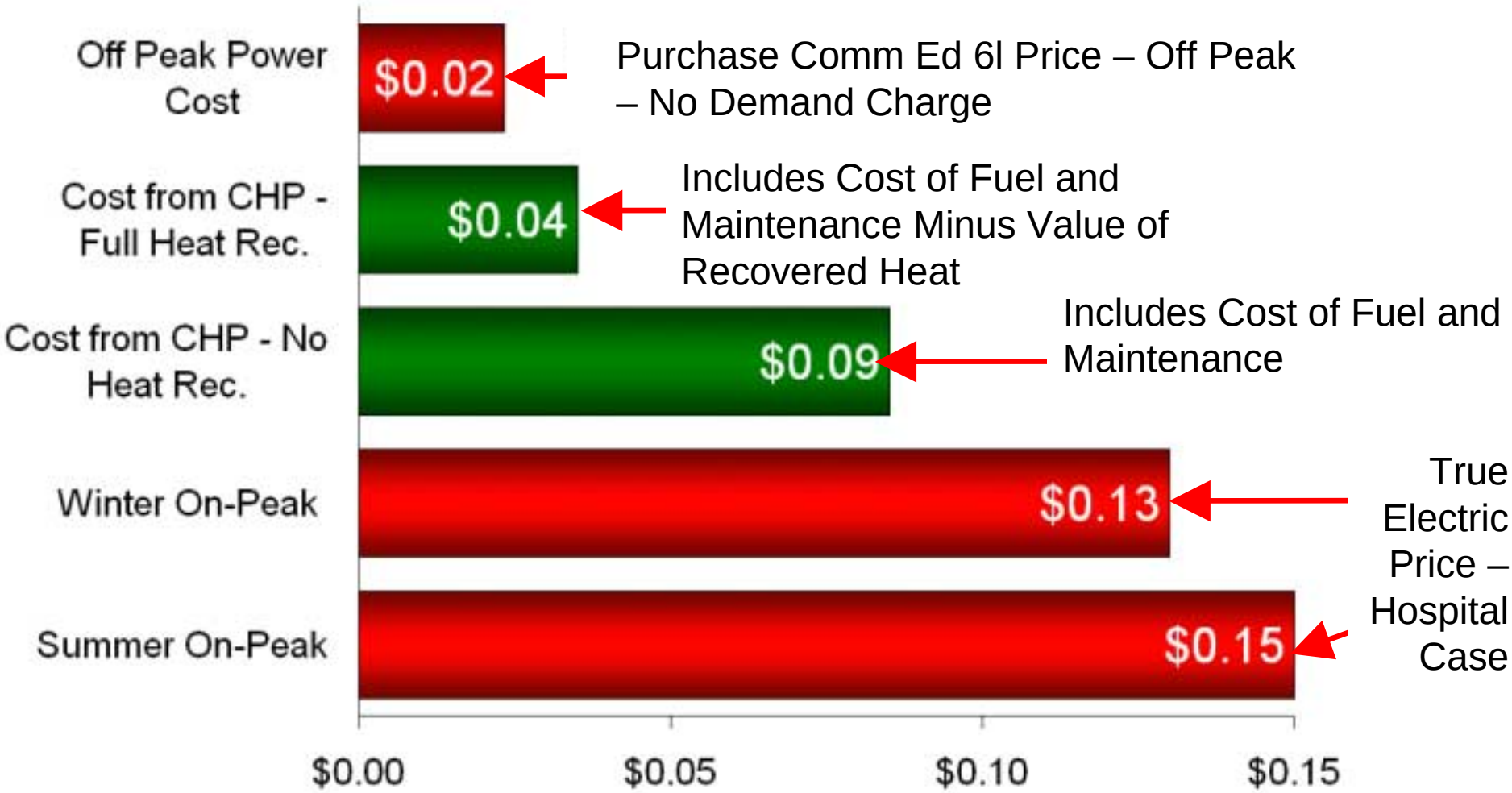
- Operate at All Times
- Operate On-Peak Only
- Operate to Meet the Electric Load
- Operate to Meet Thermal Load
- Operate to Shave Demand Charges

Any Number of Possibilities Exist

Look at the Cost of Power Gen Vs. Purchased Costs to Find the Right Strategy

Power Gen. Vs. Purchased Costs

Numbers from Previous Examples (Utility Prices in Red)



Power Gen. Vs. Purchased Costs

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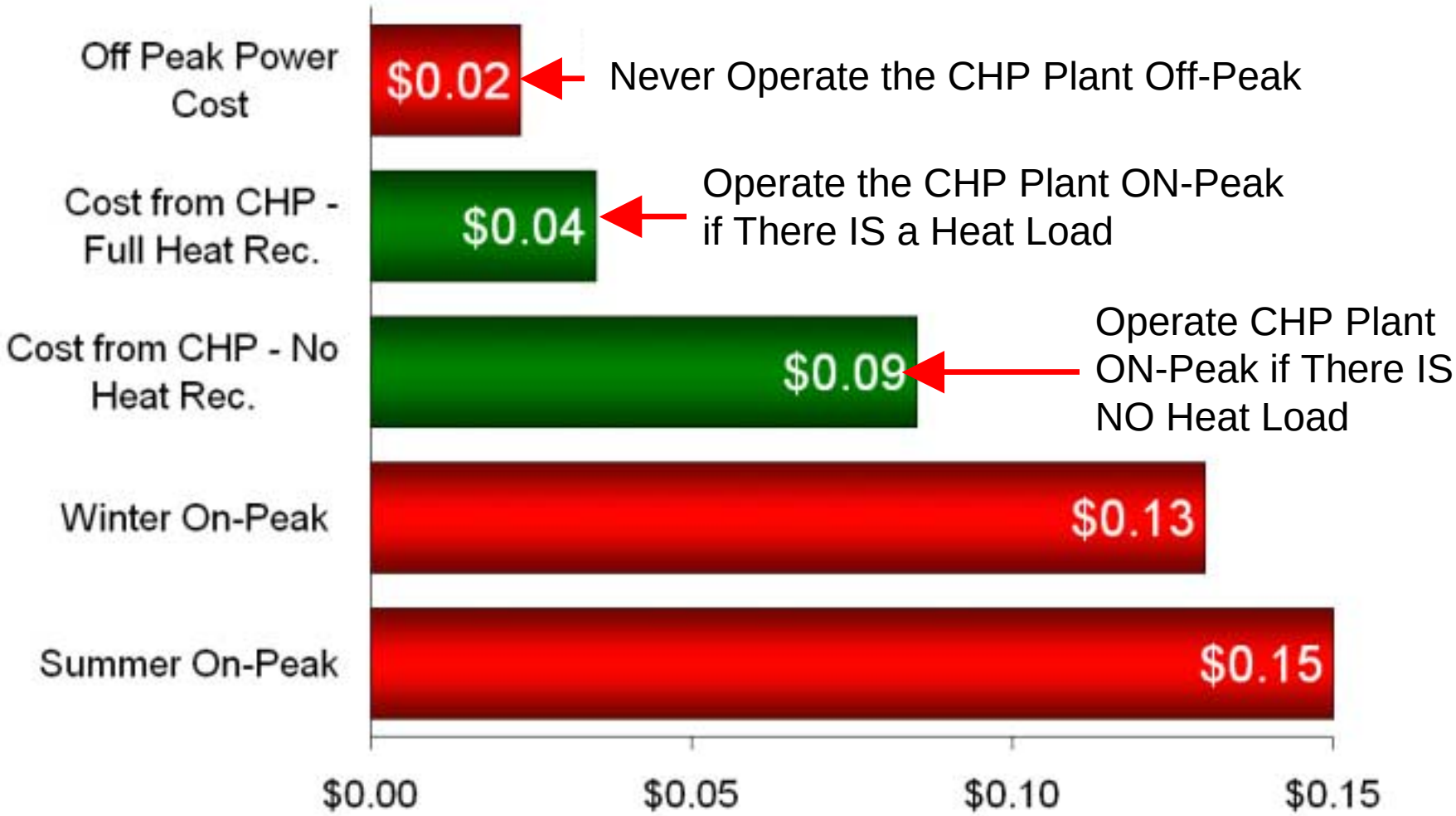


Washing Away the Savings

- Example Shown Demonstrates a Plant Should Operate only On-Peak
- Should Operate On-Peak if there is a Heat Load or Not

Washing Away the Savings

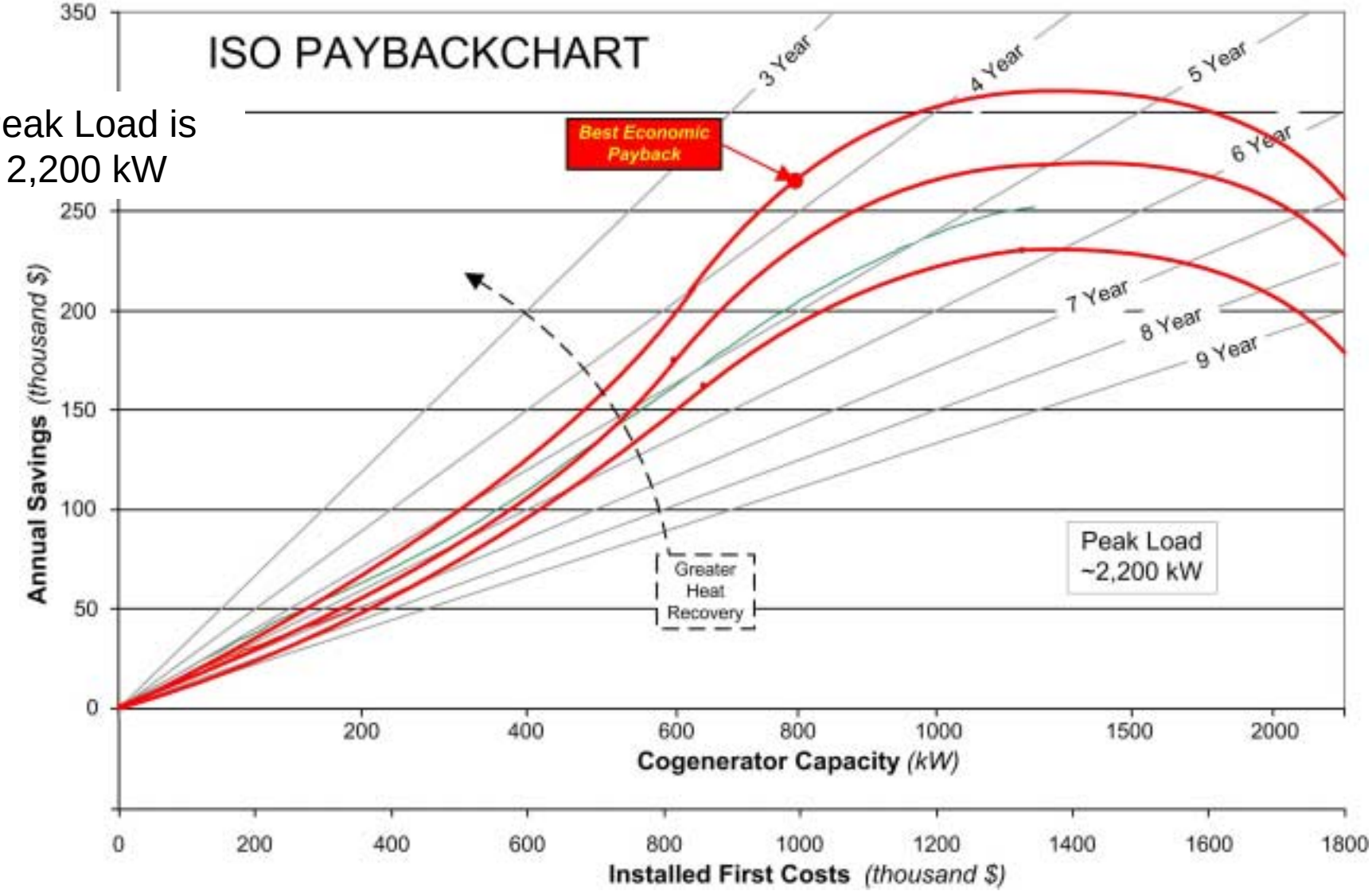
- Look to the Fuel and Maintenance Only Cost for Electric Generation to Decide WHICH Hours a CHP System Should Run
- If this is Buried in a Modeling Program – Money Losing Hours will Wash Away Savings from Money Making Hours.

Washing Away the Savings

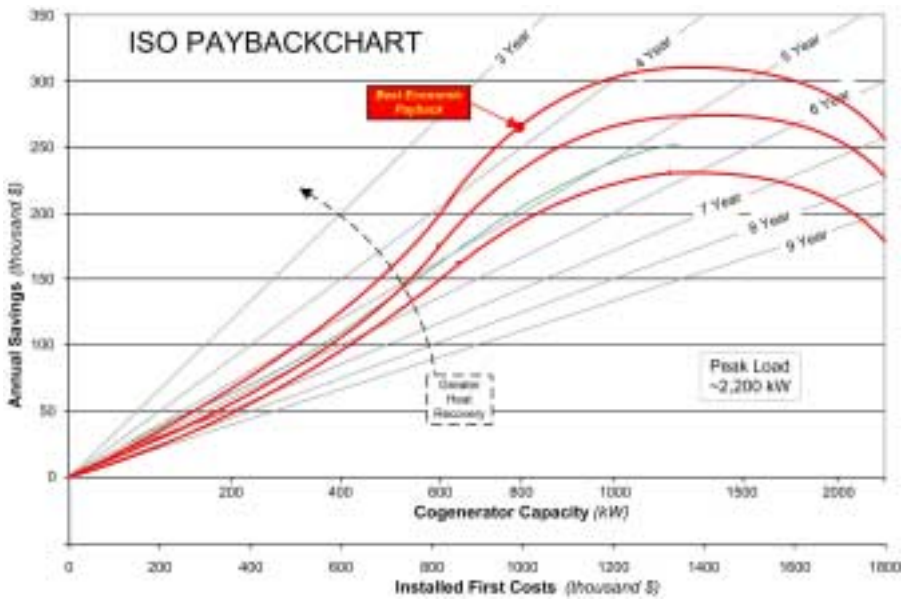
- These are MARGINAL Costs for CHP Electricity
  - Covers Fuel and Maintenance
- Use to Find the BEST Operating Scheme
- THEN (and ONLY Then) Do the Payback Analysis on the Required Investment

Over-Sizing the Plant

Peak Load is 2,200 kW



Over-Sizing the Plant



- Payback Depends VERY Heavily on How Large the System is Relative to the Load
  - Example Shows that CHP Payback Can Be <4 Years
  - BUT – if Sized to Carry Entire Load > 9 Years
- Why?? – More Money for Less Heavily Used Equipment

Another Way to Look at This

- For the 2,200 kW Building
- Install CHP Plant Consisting of 500 kW Generators
  - First Generator – Runs All the Time – Makes Savings All the Time
  - The Second & Third are Less Commonly Used
  - Fourth is Almost Never On – and Rarely Productive
- Yet All Have the SAME Purchase Price
- In General – CHP Plant Size Should be Between 40-60% of the Peak Load

Tech Choice for Thermal Load

Best Thermal Load for Engine Generators

- Hot Water
- Hydronic Space Heating
- Single Effect Absorption Chillers

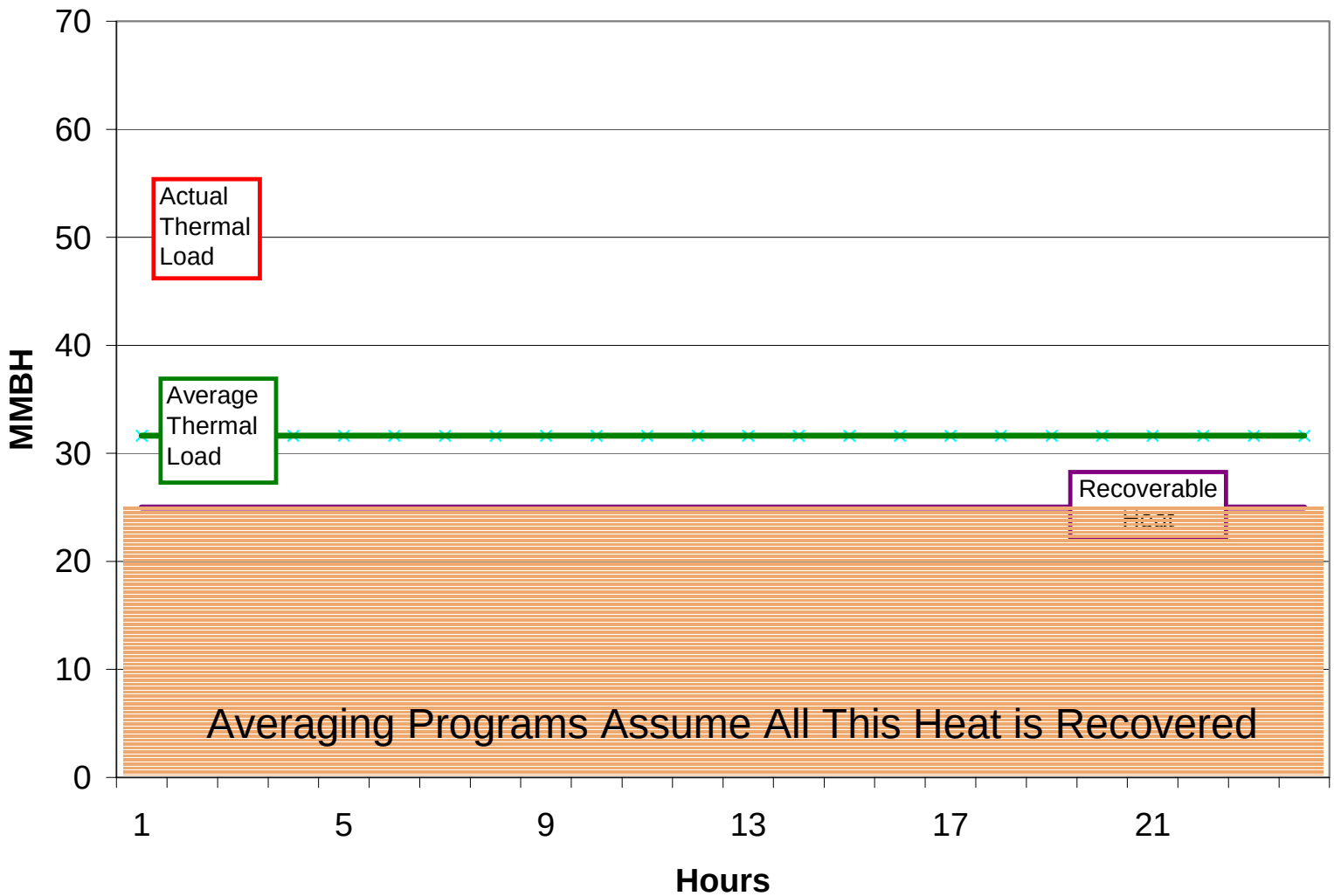
Best Thermal Load for Gas Turbines

- Any of the Above Under Engine Generators
- Steam to High Pressure
- Double Effect Absorption Chillers
- Steam Turbine Driven Chillers

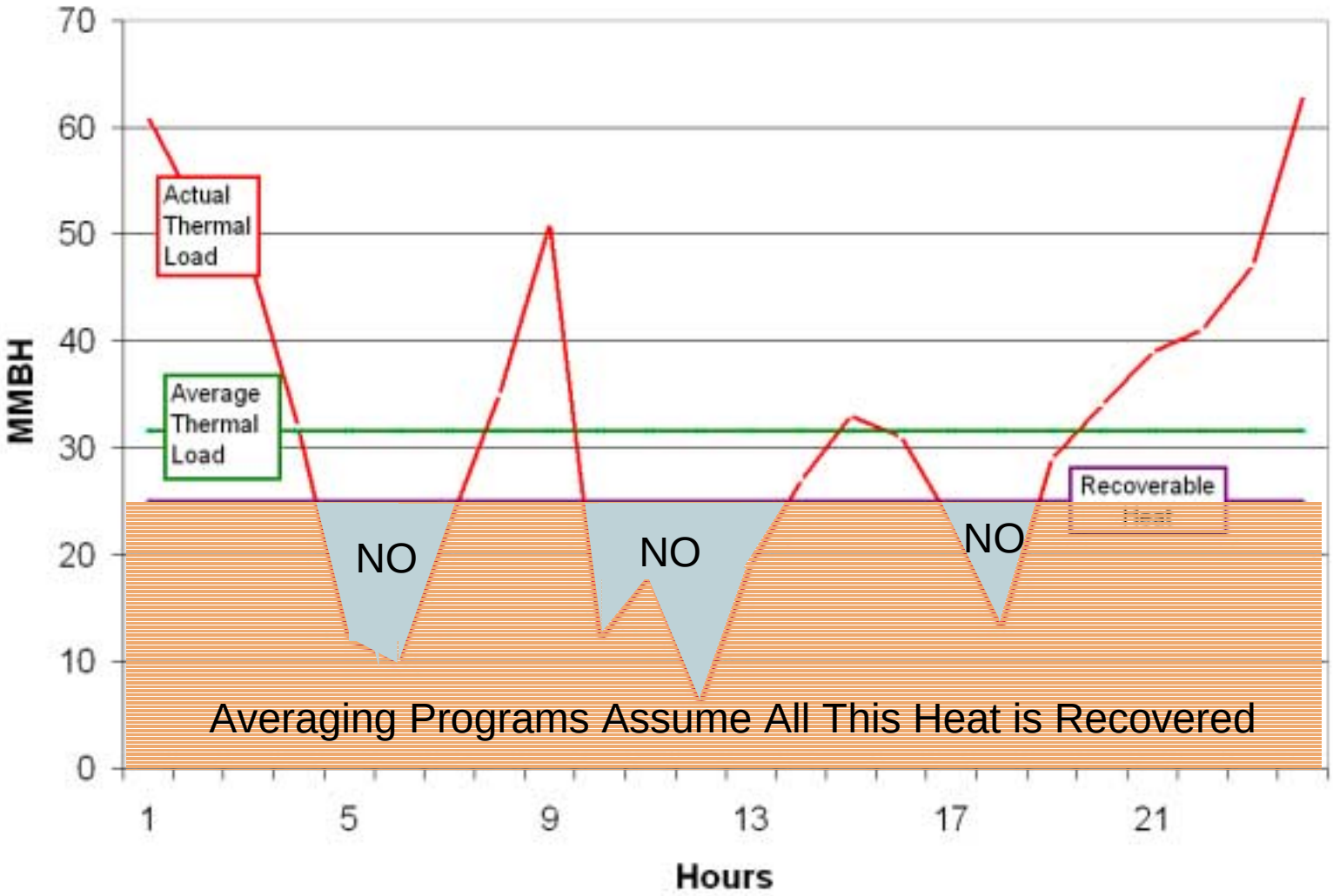
Averaging

- Dangerous - Tends to Overestimate Savings
- Programs that Predict Savings Based on Monthly Average Electric and Thermal Loads
- Example:
  - If the Recoverable Heat is Below the Monthly Average Heat Load – An Averaging Program will Assume All the Recoverable Heat is Actually Recovered

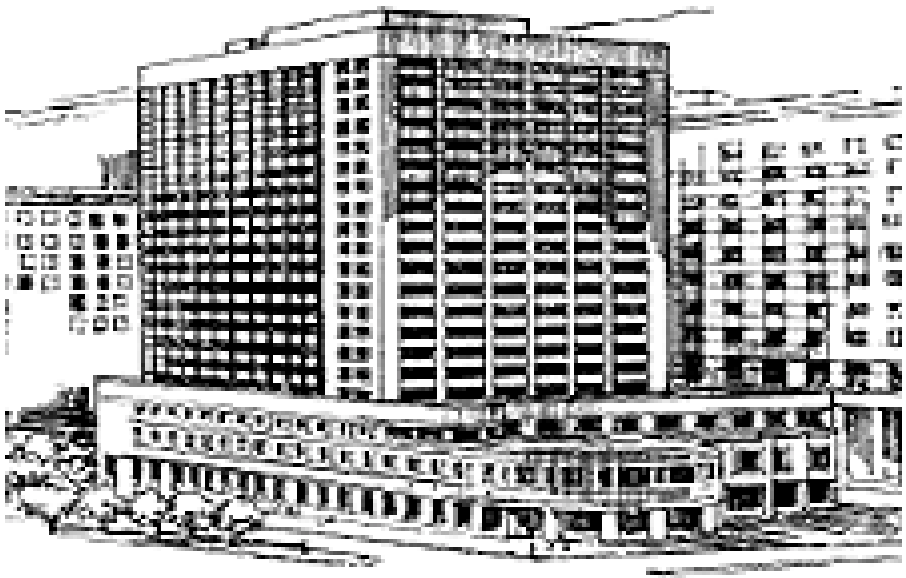
Buried in Averaging Programs



But is This True?



For the Best Paybacks



- Larger Loads
- Sizing System to Handle 40-60% of Max. Load
- Aggressive Heat Recovery

Summary

- Generally Seeing 4-6 Year Paybacks in the Chicago Area Against the 6L Rate
- Using Exact Hour-by-Hour Analysis that Can Model Electric and Thermal Needs in Detail

Summary Messages

- CHP Is Not Right For Every Application In Every Location
- Where CHP Makes Sense, It Can & Will:
  - Lower Energy Costs
  - Increase Reliability
  - Improve Power Quality
  - Provide Standby Power
  - Lower Emissions

Summary

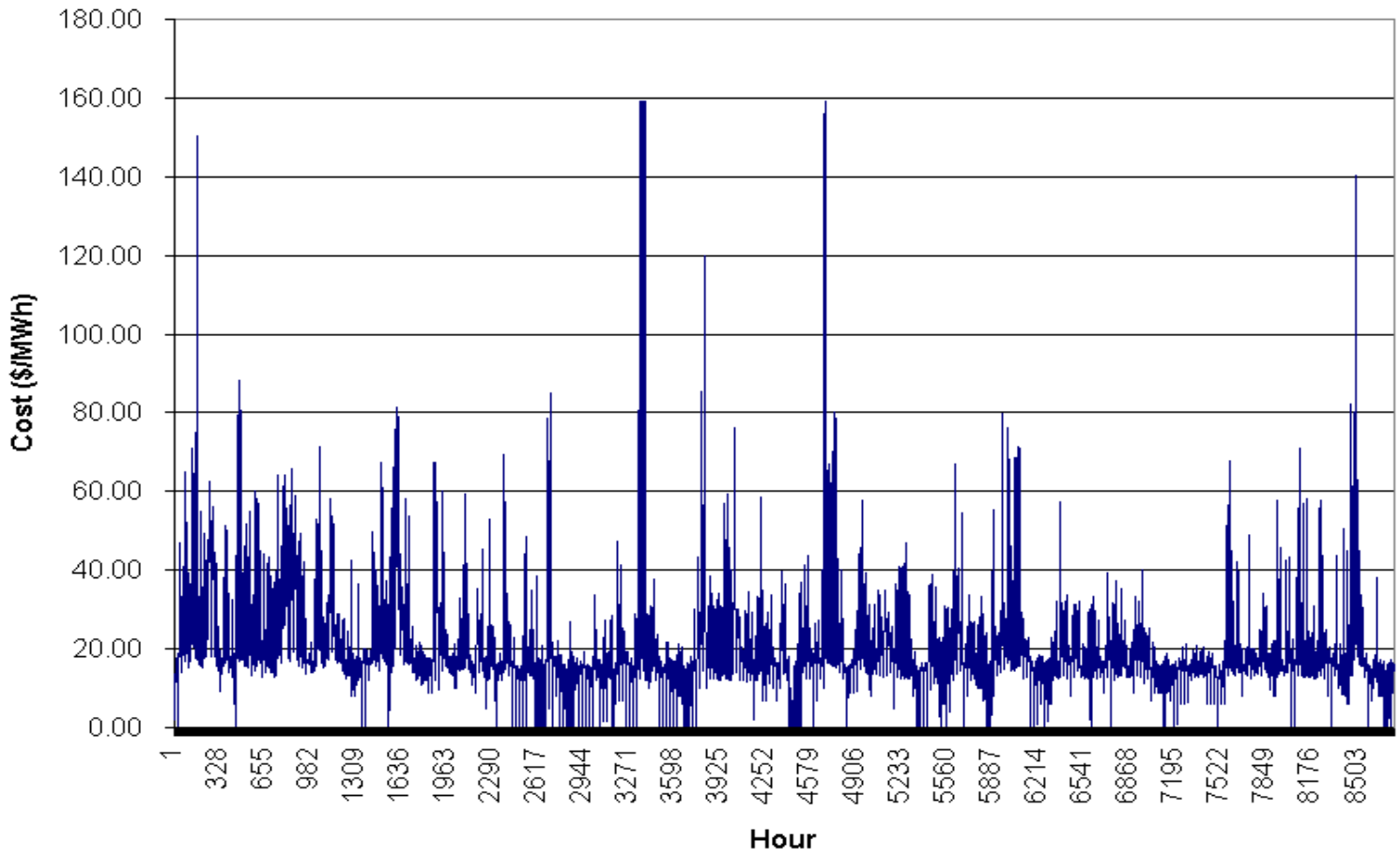
- Each Application Must Be Evaluated
  - Initial Screening: Rules Of Thumb / Averages
  - Capital Investment Analysis: Detail Analysis Provides Accurate Estimates of Savings / Cash Flows

Picture Courtesy of Turbophoto

Looking Forward

- Deregulation in 2007
- Comm Ed will be Supplying to PJM Power Exchange
- General Pattern in Deregulation to Date
  - Industrial Loads See Power Cost Decline
  - Commercial Loads See Power Costs Increase
  - Customers Who Can Shift Load and Have Flexibility Gain the Greatest Benefit
  - Having CHP Can Provide that Flexibility

Prices paid for electricity in a Deregulated Market...



Hourly PJM Rates

Questions?