

CHP Site Selection Considerations

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Outline

How can small (<1,000 kW) CHP sites be selected (screened) and successfully implemented?

- **Market Drivers**
- **Favorable Site Characteristics**
- **Collection and Analysis of Site Data**
- **Selection of DG Equipment**
- **Matching Heat Recovery Devices to DG**
- **Examples**
- **Financing Strategies**
- **Summary**

CHP Market Drivers

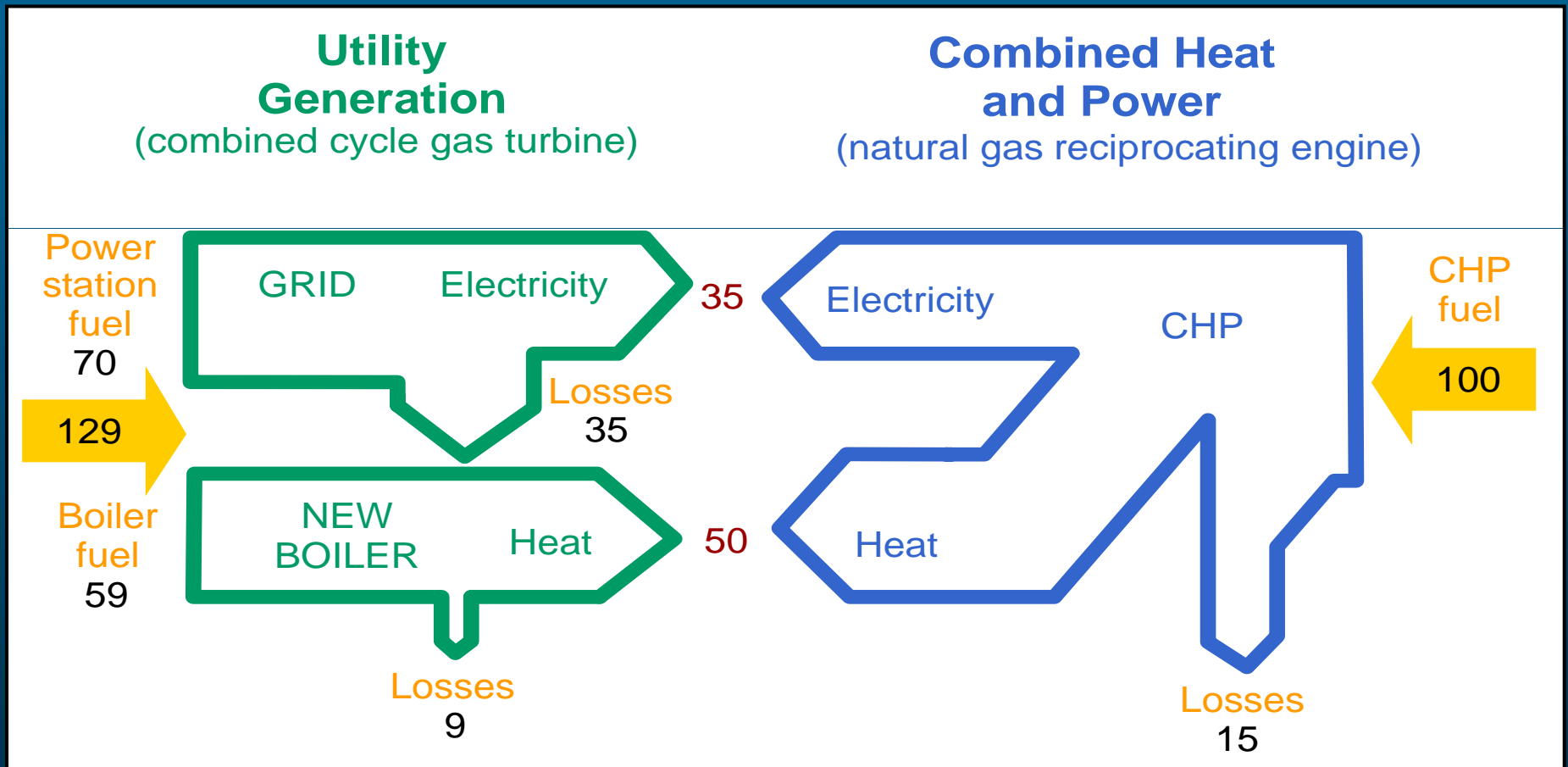
- **Energy Suppliers (Utilities)**

- Deregulation – new business opportunities to make money
- Increased demand for electricity
- Aging infrastructure
- Energy security

- **Energy Users (Customers)**

- Interest in increasing efficiency and lowering energy costs
- Need for high power quality and reliability
- Demand for energy choice
- Demand for “green energy”

State-of-the-Art Central Generation vs. CHP



Source: Compiled from EPRI, DOE, and EI data

Trends that Favor CHP

- **Ideal sites for CHP will have:**
 - Large average electric load (i.e., economics typically improve with increasing electric load)
 - Ratio of average electric load to peak load > 0.7
 - Central or district heating and/or cooling system in place OR a need for process heat
 - Spark spread $> \$12/\text{MMBtu}$
 - High annual operating hours ($>6,000$)
 - Thermal demand closely matches electric load

Source: Analysis of CHP Potential at Federal Sites, Feb. 2002, DOE-FEMP

Data Collection and Analysis

- **Collection and analysis of site data may be expensive and time consuming**
 - Electric and thermal demand – peak and average
 - Electric and thermal load shape
 - Fuel availability
 - Space availability
 - Emissions regulations
 - Permitting requirements
 - Electrical and interconnection issues
- **Simple tools and calculators are needed**

Optimization

- **Load following strategy?**

- Electrical, heating, and cooling load profiles rarely coincide
- Thermal-load following may improve application economics, especially when the excess electric power can be sold to the grid at a good price
- Electric-load following permits peak-shaving
- Must consider load-following capabilities of DG and heat recovery equipment

Optimization (Cont.)

- **Stand-alone or grid-parallel?**
 - Stand-alone systems offer independence from the grid, but may be susceptible to reliability problems
 - Grid-parallel systems permit efficient operation and control in combination with the grid, but may be subject to expensive stand-by charges

Selection of DG Equipment

- **DG equipment may be sized and selected based on electric or thermal demand requirements**
- **Several factors vary between DG technologies, including:**
 - Fuel options
 - Type of thermal output (steam, hot water, etc.)
 - Noise and vibration
 - Emissions
 - Efficiency
 - Cost

DG Technical Comparison

Technology	Size (kW)	Electrical Eff. (%)	Exhaust Temp (° F)
Reciprocating Engines	< 7,000	25-45	200-1,200
Combustion Turbines	500-200,000	20-45	500-1,000
Mini / Microturbines	< 400	25-30	400-650
PAFC	200	36-42	150-250
PEMFC	< 250	30-40	120-220
MCFC	250-2,000	45-55	700-800
SOFC	1-50,000	45-55	1,400-1,800

DG Installed Cost Comparison

MATURE TECHNOLOGIES	
Reciprocating Engine – Diesel	\$550-1,000/kW
Reciprocating Engine – Dual Fuel	\$800-1,200/kW
Reciprocating Engine – Natural Gas	\$600-1,100/kW
Combustion Turbine	\$700-1,400/kW
EMERGING TECHNOLOGIES	
Mini / Microturbines	\$700-1,500/kW
PAFC	\$4,200/kW *
PEMFC	< \$10,000/kW
MCFC	< \$10,000/kW
SOFC	< \$10,000/kW

* *Uninstalled*

From DG to CHP

- **“Plug-and-play” or “off-the-shelf” heat recovery technologies can be matched and integrated with DG equipment**
- **Type and temperature of the heat source will determine appropriate heat recovery technologies and applications**

Matching DG with “Plug and Play” Heat Recovery Technologies

	Hot Water	Space Heating	Low Pressure Steam	High Pressure Steam	Single-stage Absorption Chiller	Two-stage Absorption Chiller	Dry Air
ICE Exhaust	✓	✓	✓	✓	✓	✓	✓
ICE Jacket Lube	✓	✓	✗	✗	✓	✗	✓
Combustion Turbine	✓	✓	✓	✓	✓	✓	✓
Recuperated Microturbine	✓	✓	✓	✓	✓	✗	✓
PAFC	✓	✓	✓	✗	✓	✗	✓
PEMFC	✓	✓	✗	✗	✓	✗	✗
MCFC/SOFC	✓	✓	✓	✓	✓	✓	✓

✓ = Applicable Technology

✓ = Marginal Technology

✗ = Inappropriate Technology

Example 1: Hypothetical Microturbine-CHP Scenario

- **Analyze cooling options for three cases:**
 - 18 RT of cooling required
 - 36 RT of cooling required
 - 54 RT of cooling required
- **Options:**
 - Buy electricity from the grid to power an electric chiller
 - Install a combination of microturbines, heat exchangers, and absorption chillers

Capital Cost Assumptions

Item	Cost
75-kW Microturbine	\$60,000
Heat Exchanger	\$12,630
Chiller, 18 RT	\$28,080
Chiller, 36 RT	\$46,400
Chiller, 54 RT	\$64,800
Electric Chiller, 18 RT	\$18,900

O&M Cost Assumptions

O&M Component	Cost
Natural Gas	\$4.69/MMBtu
Microturbine Power *	0.94 ¢/kWh
Microturbine Maintenance	0.50 ¢/kWh
Heat Exchanger and Chiller Maintenance	0.167 ¢/kWh
Electric Chiller Maintenance	0.16 ¢/kWh
Grid Power	7.85 ¢/kWh
Electric Chiller Power Consumption	1.17 kWh/RT

** Only that power which drives the downstream chilling components*

Performance and Financial Assumptions

Factor	Value
Microturbine Efficiency	26.6%
Heat Exchanger Efficiency	66.5%
Chiller Efficiency	57.1%
Capacity Factor	50%
Amortization Period	10 years
Interest Rate	15%
Inflation Rate	3%/year

Analysis Results – Power Only

Grid Power (¢/kWh)	7.85	7.85	7.85
Power From Microturbine (¢/kWh)	(1 MT Unit) 9.92	(2 MT Units) 9.43	(3 MT Units) 9.14
Net Microturbine Value (¢/kWh)	-2.07	-1.58	-1.29

Analysis Results – Cooling Only

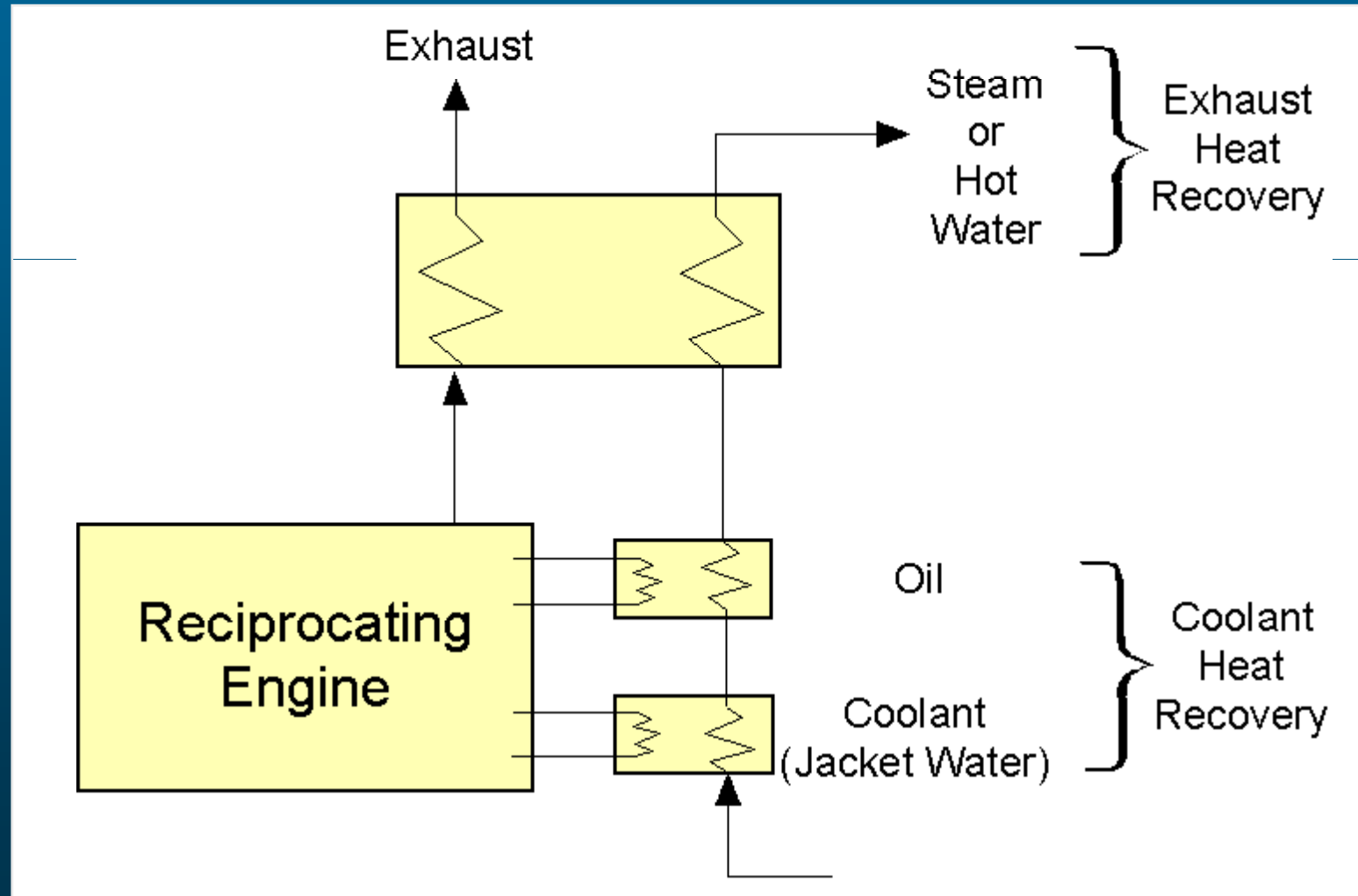
	Cooling Capacity		
	18 RT	36 RT	54 RT
Total Cost of Cooling from Electric Chiller (¢/kWh)	10.53	10.28	10.24
Total Cost of Cooling from Microturbine * (¢/kWh)	(1 MT Unit) 13.45	(2 MT Units) 12.90	(3 MT Units) 12.44
Net Microturbine Value (¢/kWh)	-2.92	-2.62	-2.20

* Includes the capital, O&M, and power generation cost components of the downstream cooling equipment (3.53¢, 3.47¢, and 3.30¢ respectively) PLUS 9.92¢, 9.43¢, and 9.14¢, respectively, for Microturbine heat (and power) generation.

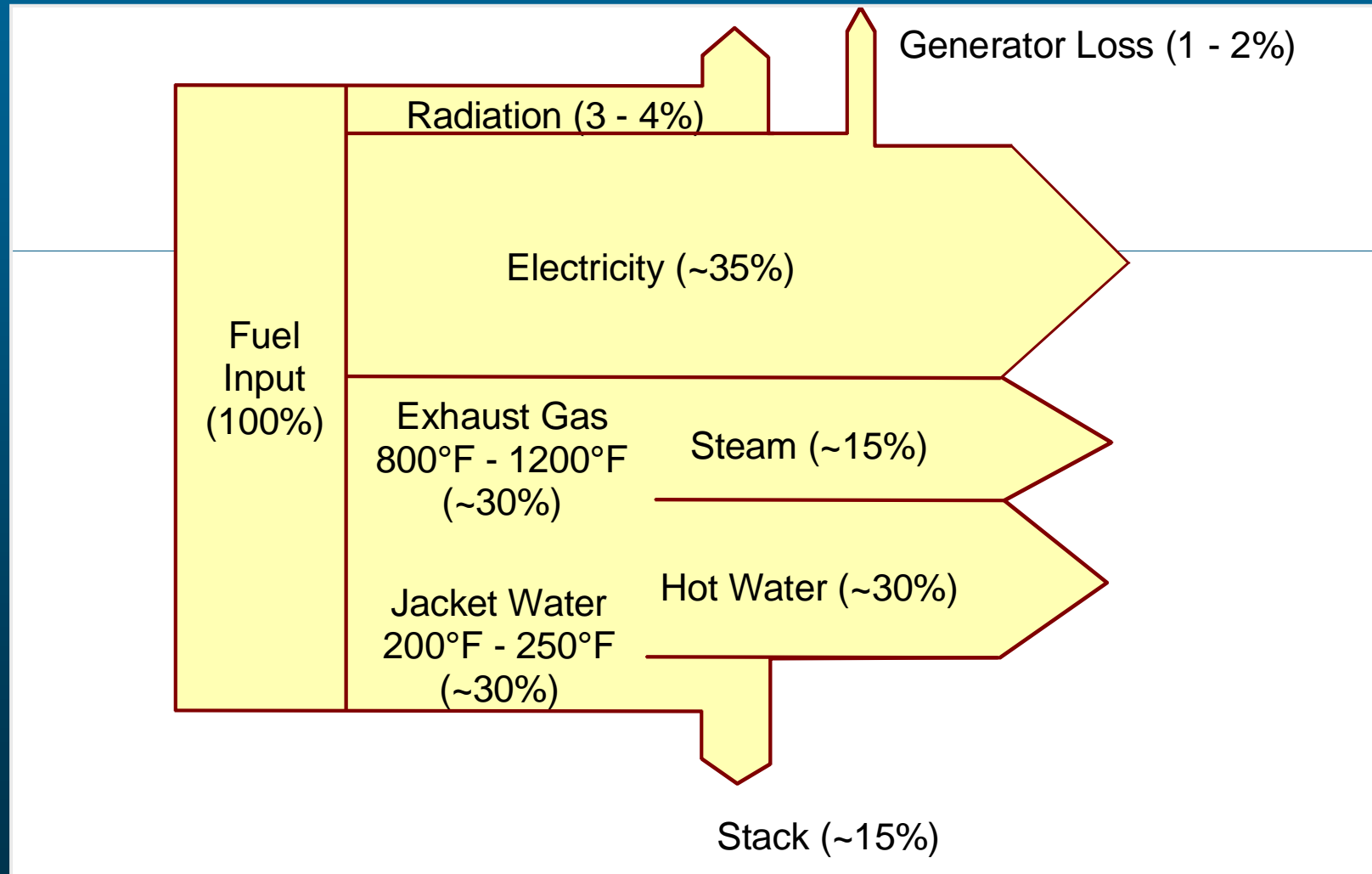
Analysis Results – CHP

	Cooling Capacity		
	18 RT	36 RT	54 RT
Electric Cooling + Grid Power (¢/kWh)	18.38	18.13	18.09
Microturbine Cooling + Microturbine Power (¢/kWh)	(1 MT Unit) 13.45	(2 MT Units) 12.90	(3 MT Units) 12.44
Net Microturbine Value (¢/kWh)	4.93	5.23	5.65

Example 2: Heat Recovery from a Reciprocating Engine



Heat Balance for a Reciprocating Engine



Reciprocating Engine Economics (simplified hypothetical example)

- **Base Case Parameters**

- Configuration: Base load thermal and electric (simultaneous demand)
- Electric Production: 750 kW
- Engine Efficiency: 34% (LHV)
- Usage: 6,570 hrs/yr (75%)

- **Heat Recovery (CHP) Options**

- Coolant Water
- Exhaust
- Both Coolant and Exhaust

Reciprocating Engine (Cont.)

- **Base Case Cost Factors**

- Natural Gas: \$6/MMBtu
- Reciprocating Engine (installed): \$800/kW
- Heat Recovery Hardware (installed):
 - Coolant \$160/kW (20%)
 - Exhaust \$160/kW (20%)
- Maintenance
 - Engine 1.0 ¢/kWh
 - Coolant Heat Exchanger 0.1 ¢/kWh
 - Exhaust Heat Exchanger 0.1 ¢/kWh

Reciprocating Engine (Cont.)

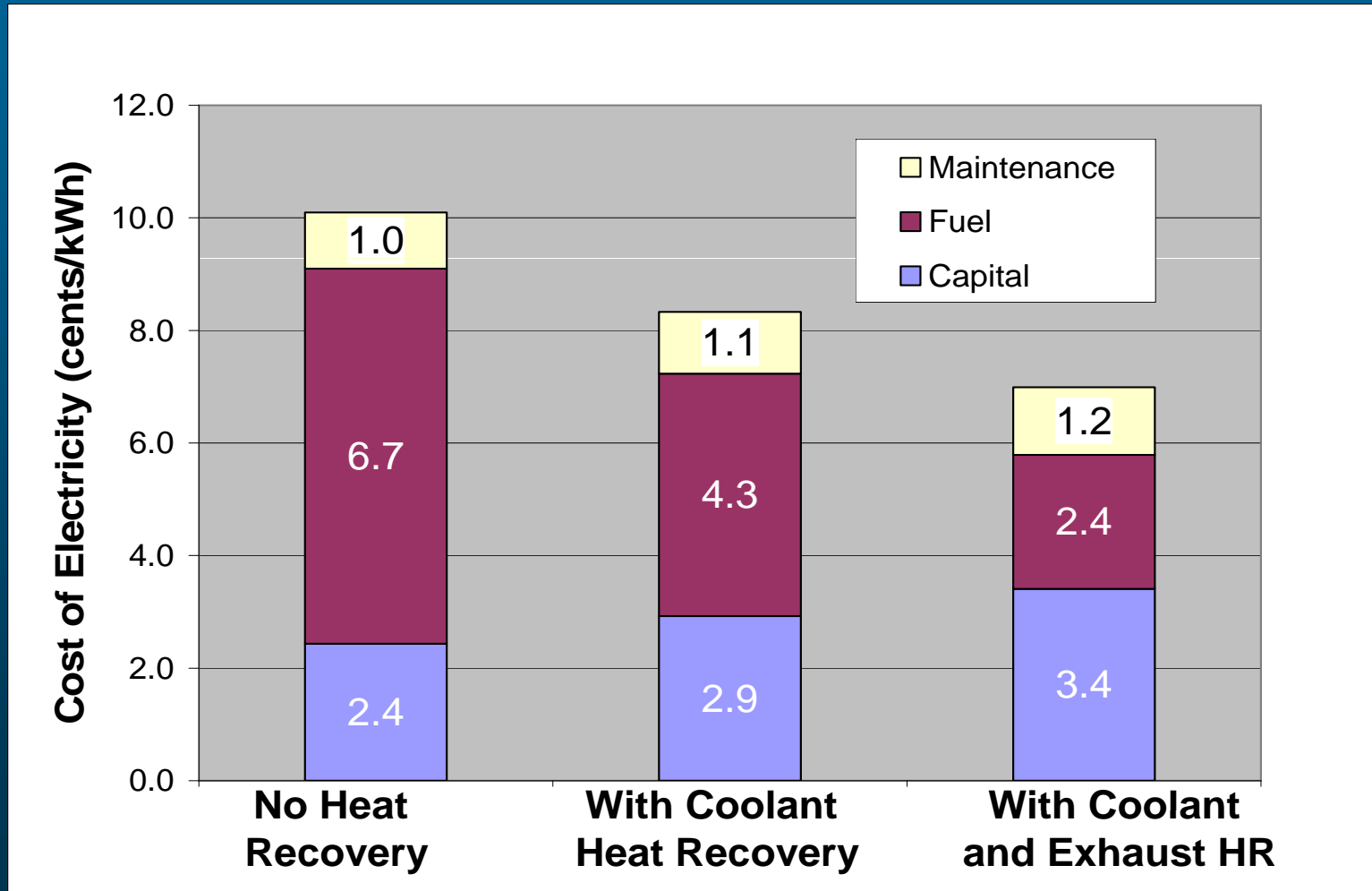
- **Fuel Cost for CHP**

- Based on Fuel Chargeable to Power (FCP) method
- Displaced energy generated at 80% efficiency (e.g., CHP system offsets energy consumed by onsite boiler)

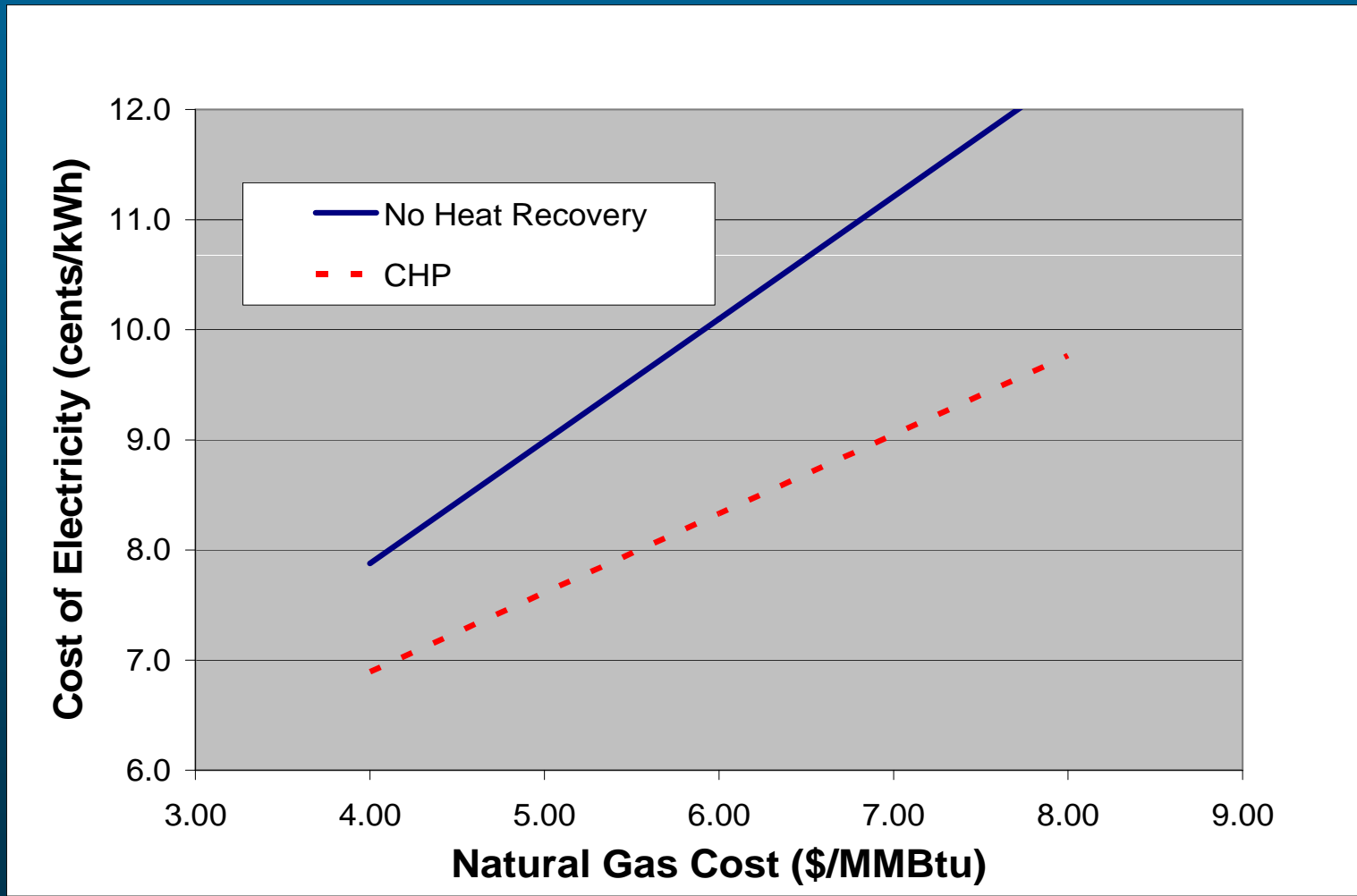
- **Capital Recovery**

- 5 year time frame

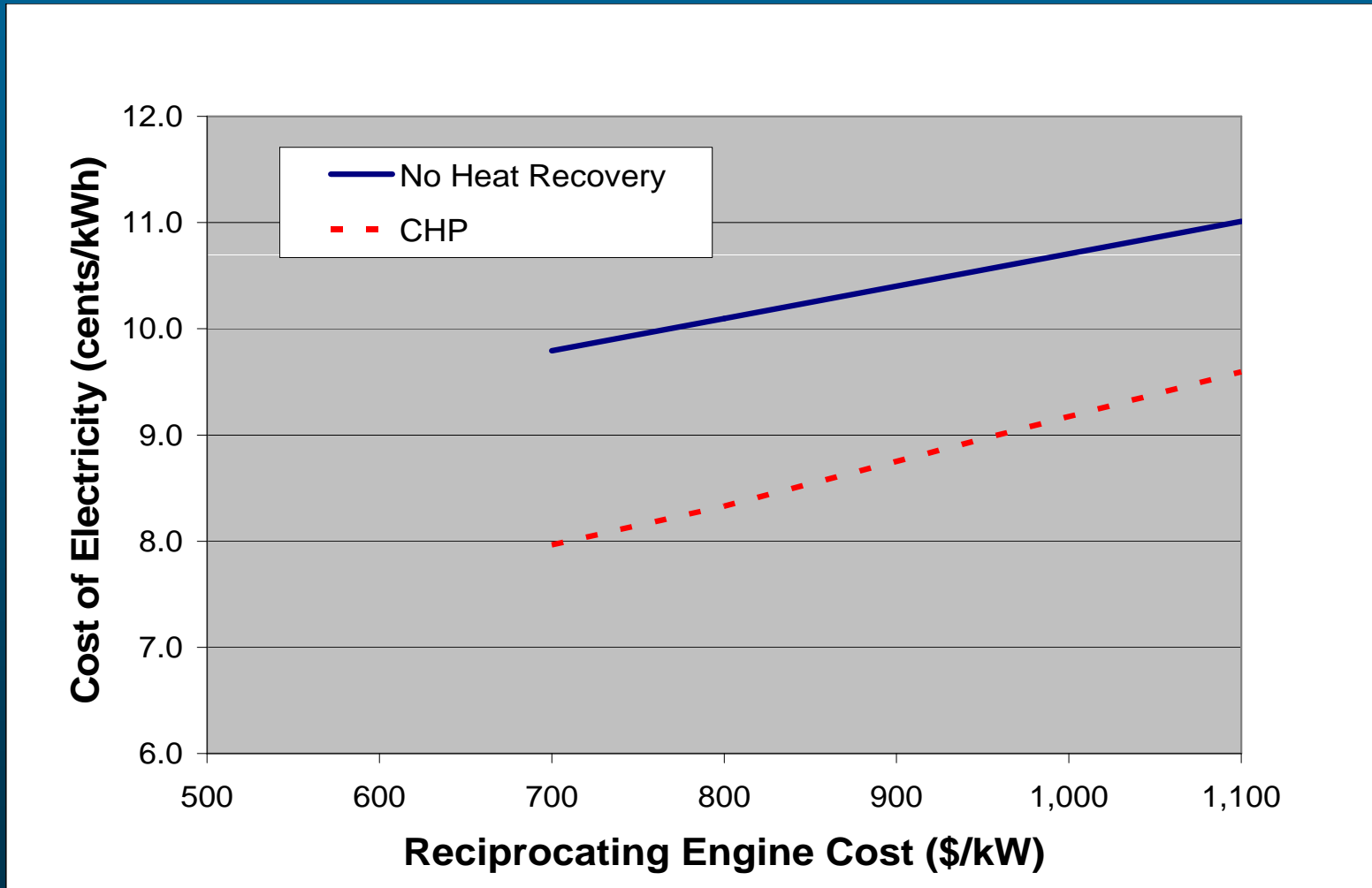
Cost of Electricity Comparison



Fuel Cost Sensitivity



Capital Cost Sensitivity



CHP Financing Strategies

- **Several ownership options to consider**
 - Who owns the CHP system?
 - Is it purchased or leased?
 - Who handles financing?
 - Who handles servicing?
- **Electricity contract specifics**
 - Net metering permitted?
 - Buy back rates?

Summary and Conclusions

- **Evaluation of CHP options is site-specific and cannot be generalized**
- **A significant amount of data collection and analysis is required in order to optimize CHP design**
- **Off-the-shelf heat recovery devices can make otherwise unattractive DG projects (i.e., power-only) economical**

Thank You

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