CHP in the Ethanol Industry: The Business Case

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Overview

- Why CHP for Ethanol
- What are the viable CHP options
- What are the critical cost and performance parameters
- Illustrative economics
- Critical factors

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Why CHP Is a Good Fit for Ethanol

- Energy is the second largest cost of production for dry mill ethanol plants
- Electric and steam demands are large and coincident
- Electric and steam profiles are relatively flat
- Operating hours are continuous – 24/7

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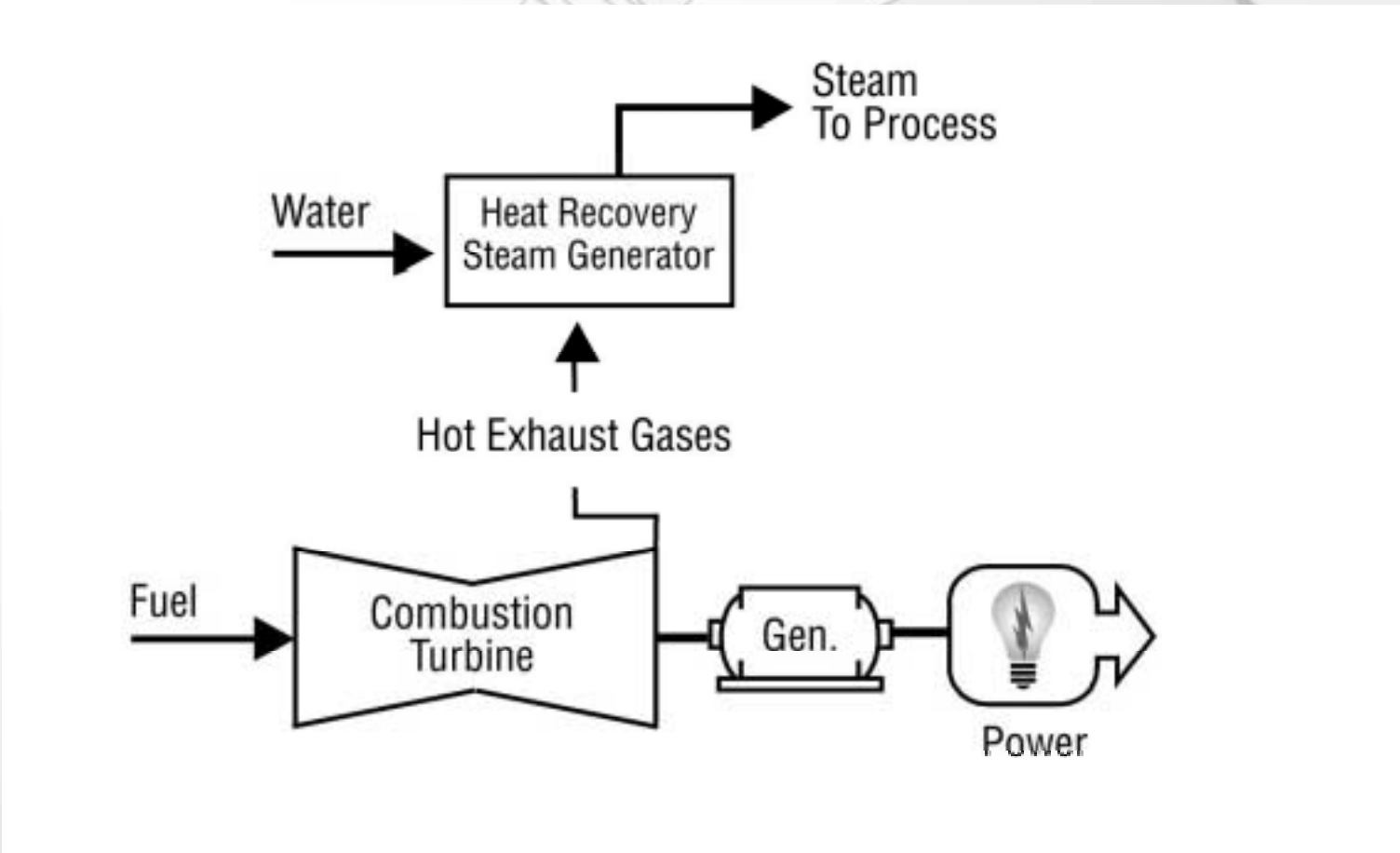
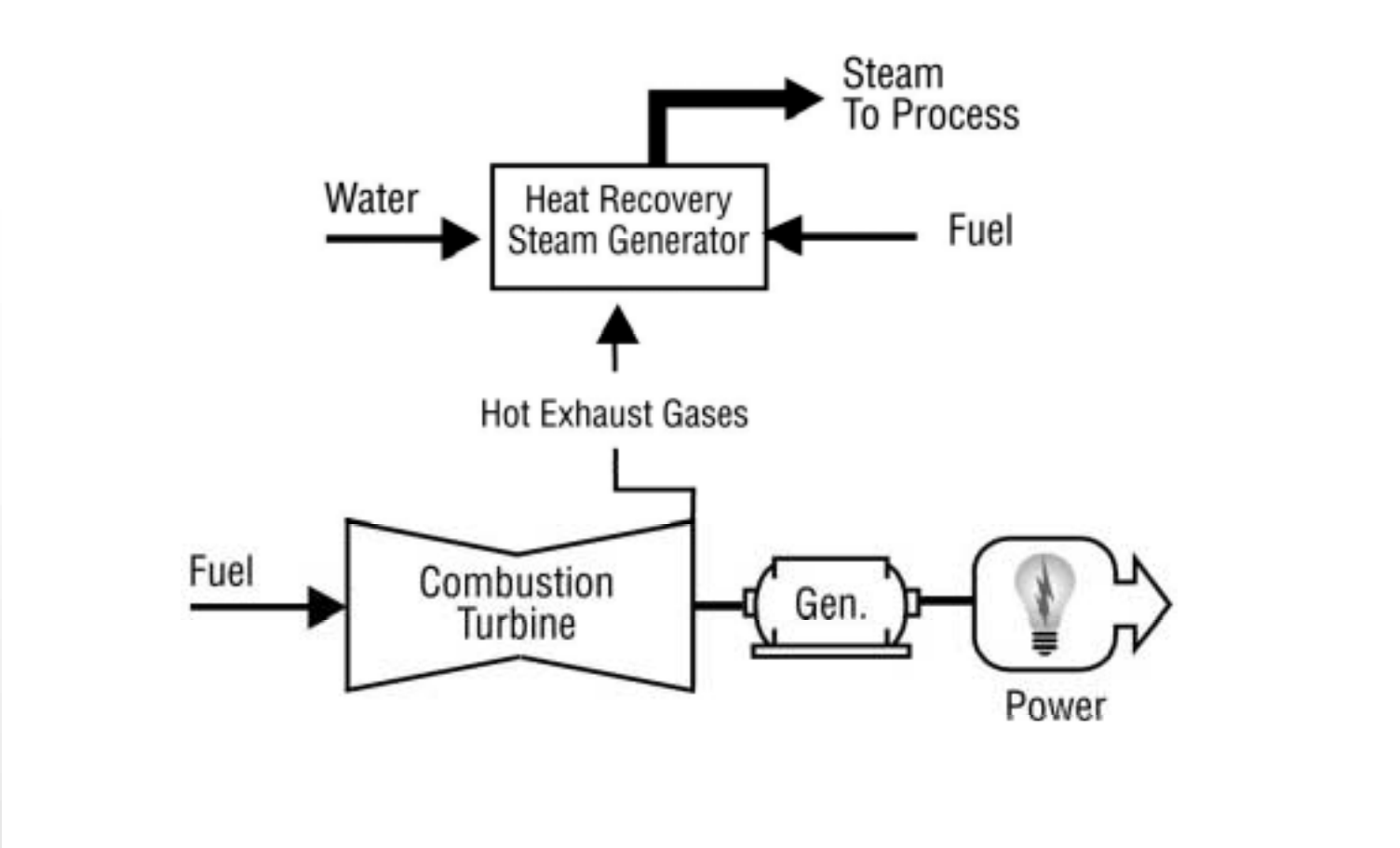
Ethanol Energy Demand

Plant Capacities, mmgal/yr	15 - 50
Electricity Demand, kWh/gal	0.9 – 2.0
Steam Demand, lbs/gal	19 - 22
Boiler Fuel, Btu/gal	24,000 – 27,500
DDGS Drier Fuel, Btu/gal	13,000
Power to Steam Ratio	0.16 – 0.32

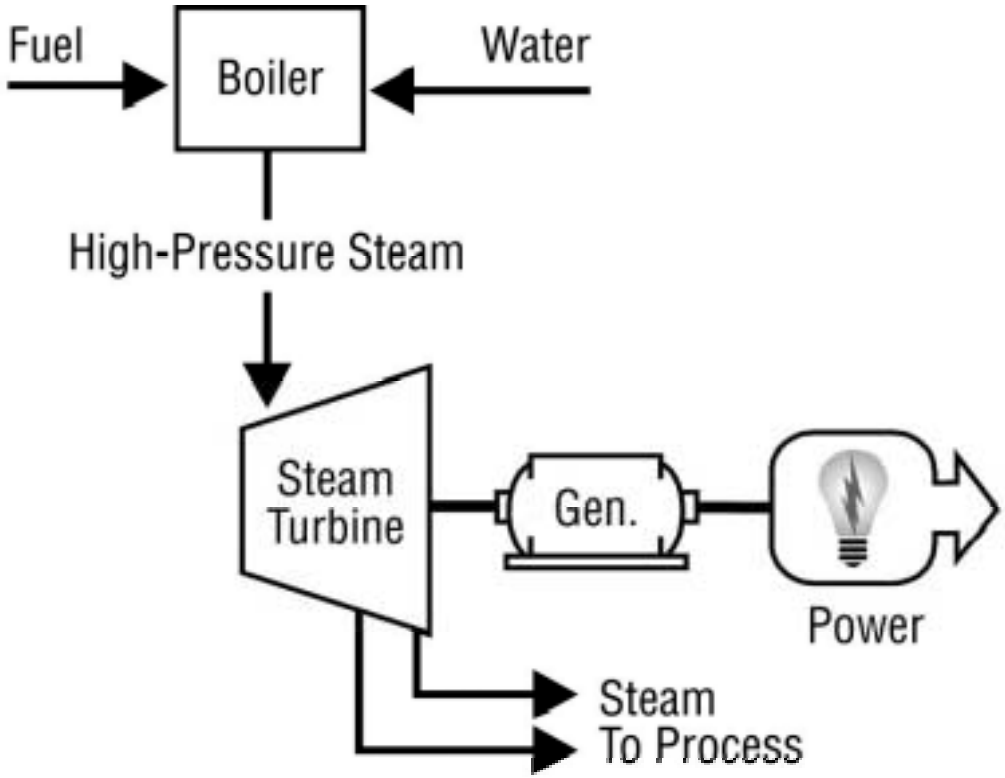
Gas Turbine CHP



Gas Turbine/Supplemental Firing CHP



Boiler/Steam Turbine CHP



CHP System Cost and Performance

	Gas Turbine	Gas Turbine w/Duct Firing	Boiler/Steam Turbine
Capacity, MW	1 - 15	1 - 15	0.5 - 5
Electrical Efficiency, % (HHV)	22 – 32	12 - 17	6 - 10
Steam Output, Btu/kWh	4,500 – 6,700	12,000 – 20,000	35,000 – 40,000
Overall Efficiency, % (HHV)	65 - 70	80 - 85	75 - 85
Power to Steam Ratio	0.4 – 0.6	0.17 – 0.27	0.08 – 0.12
Installed Costs, $/kW	1,800 - 900	2,000 – 1,000	350 – 900*
Non-fuel O&M Costs, $/kWh	0.006 – 0.01	0.006 – 0.01	<0.004

* Incremental costs of steam turbine generator and supporting systems only

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The Value Equation

- Reduced purchased electricity costs
+ Increased fuel costs
+ Increased O&M costs
+ Increased capital expenditure
- Displaced capital?
- Reliability, other operational savings?

- Overall Savings

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Simple Payback Analysis

- Payback = Capital Cost/Operating Savings
- Generic, first cut analysis
- Parametric calculation of payback as a function of fuel and electricity prices.
- Useful to identify sites for more complete assessment.

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Simple Payback Analysis

- Assume new construction or expansion of existing facility
- Compare operating costs of CHP system with conventional plant design
- Natural gas CHP compared to conventional natural gas boilers/purchased electricity
- Coal CHP compared to coal boiler/purchased electricity

Plant Operating Assumptions

Plant Capacity, mmgal/yr	50
Operating Hours	8760
Electric Use, kWh/gal	0.96
Annual Electric Use, MWh	48,180
Baseload Electric Demand, MW	5.5
Steam Use, lb/gal	19.3
Steam Use, lbs/hr	110,000
Annual Steam Use, mmlbs	963,600
Boiler Fuel Use, Btu/lb	24,125
Annual Boiler Fuel Use, mmBtu	1,206,300
Annual Drier Fuel Use, mmBtu	605,000
Electric Costs, $/kWh	0.07
Gas Costs, $/mmBtu	6.00

Gas Turbine CHP System Assumptions

	Gas Turbine	Gas Turbine w/Duct Firing
Capacity, MW	5.2	5.2
Run Hours	8500	8500
Gas Turbine Fuel, mmBtu/hr	67.2	67.2
Duct Burner Fuel, mmBtu/hr	0	49.8
Steam Output, lb/hr	28,600	76,600
Power to Steam Ratio	0.62	0.23
O&M Costs, $/kWh	0.008	0.008
Capital Costs		
Turbine Genset, $/kW	415	415
HRSG, $/kW	100	200
Interconnect, $/kW	60	60
Misc Equipment, $kW	80	80
Engineering, installation, etc, $/kW	390	450
Total Installed Cost, $/kW	1,045	1,205

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Gas Turbine CHP – Energy Results

	W/O CHP	W/ CHP
Purchased Electricity, MWh	48,180	3,980
Generated Electricity, MWh	0	44,200
Boiler Steam, mmlbs	963.3	723.1
Boiler Fuel, mmBtu	1,204,500	903,893
CHP Steam, mmlbs	0	240.5
CHP Fuel, mmBtu	0	557,460
Total Fuel, mmBtu	1,204,500	1,461,353

Gas Turbine CHP – Financial Results

	W/O CHP	W/ CHP
Purchased Electricity, 1000 $	3,372.6	278.6
Boiler Fuel, 1000 $	7,227.0	5,423.4
CHP Fuel, 1000 $	0	3,344.8
Energy Costs, 1000 $*	*10,599.6*	*9,046.8*
O&M Costs, 1000 $	0	353.6
Standby Charges, 1000 $ ($3/kW)	0	187.2
Total Operating Costs, 1000 $	*10,599.6*	*9,587.5*

* Does not include DDGS drier fuel

Operating Savings = $1,012,100

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Gas Turbine CHP – Payback

Capital Costs = $5,434,000 Payback = 5.4 yrs

Capital Costs = $4,980,000 Payback = 4.9 yrs

CHP System	$5,434,000
- Boiler credit	$ 450,000
	$4,984,000

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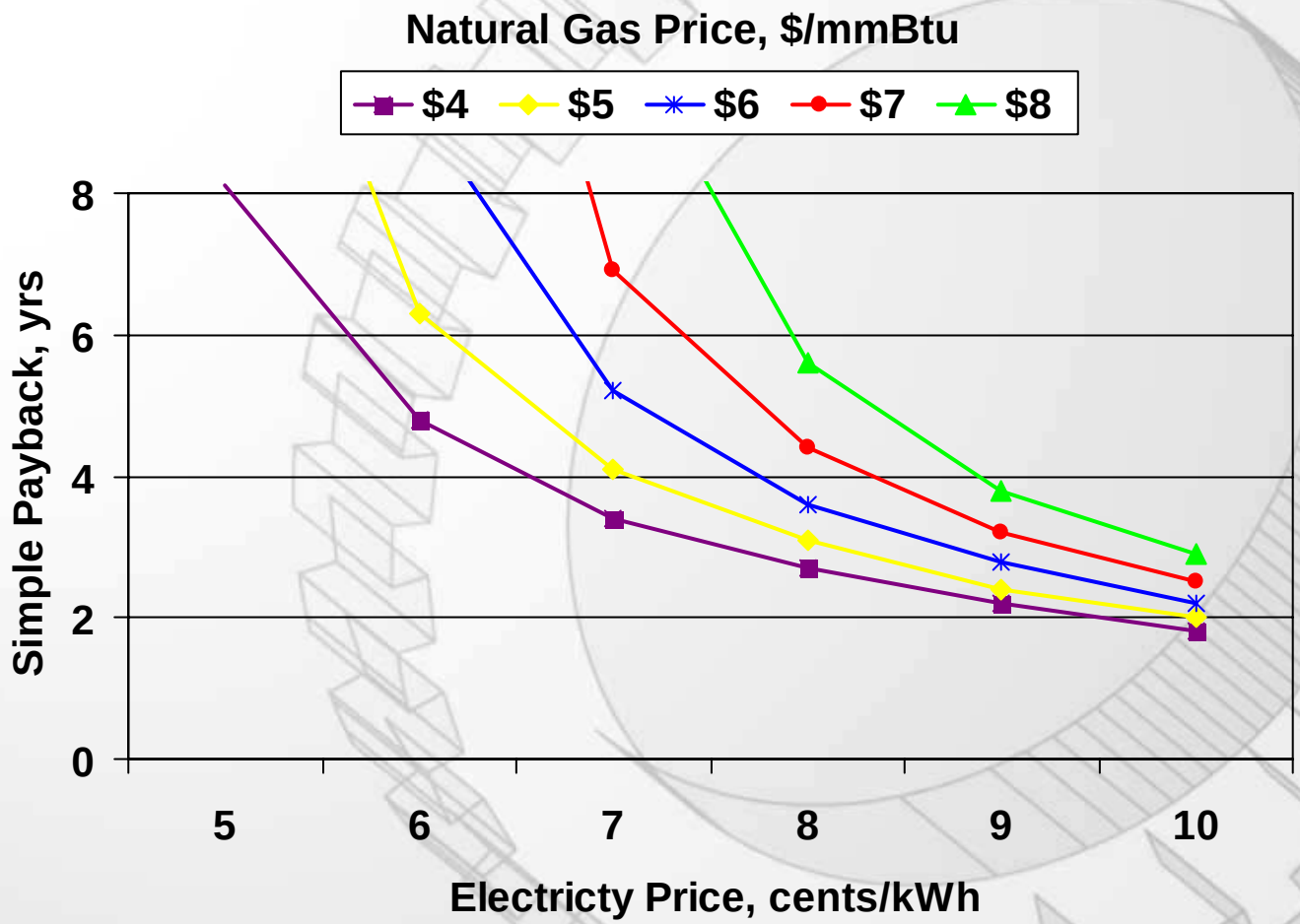
Sensitivity to Electricity and Natural Gas Prices - Gas Turbine CHP



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Gas Turbine CHP w/Duct Burner – Energy Results

	W/O CHP	W/ CHP
Purchased Electricity, MWh	48,180	3,980
Generated Electricity, MWh	0	44,200
Boiler Steam, mmlbs	963.3	318.3
Boiler Fuel, mmBtu	1,204,500	397,866
CHP Steam, mmlbs	0	645.3
CHP Fuel, mmBtu	0	986,275
Total Fuel, mmBtu	1,204,500	1,384,141

Gas Turbine CHP w/Duct Burner – Financial Results

	W/O CHP	W/ CHP
Purchased Electricity, 1000 $	3,372.6	278.6
Boiler Fuel, 1000 $	7,227.0	2,387.2
CHP Fuel, 1000 $	0	5,917.7
Energy Costs, 1000 $*	*10,599.6*	*8,583.5*
O&M Costs, 1000 $	0	353.6
Standby Charges, 1000 $ ($3/kW)	0	187.2
Total Operating Costs, 1000 $	*10,599.6*	*9,124.2*

* Does not include DDGS drier fuel

Operating Savings = $1,475,400

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Gas Turbine CHP w/Duct Burner – Payback

Capital Costs = $6,266,000 Payback = 4.2 yrs

Capital Costs = $5,366,000 Payback = 3.6 yrs

CHP System	$6,266,000
- Boiler credit	$ 900,000
	$5,366,000

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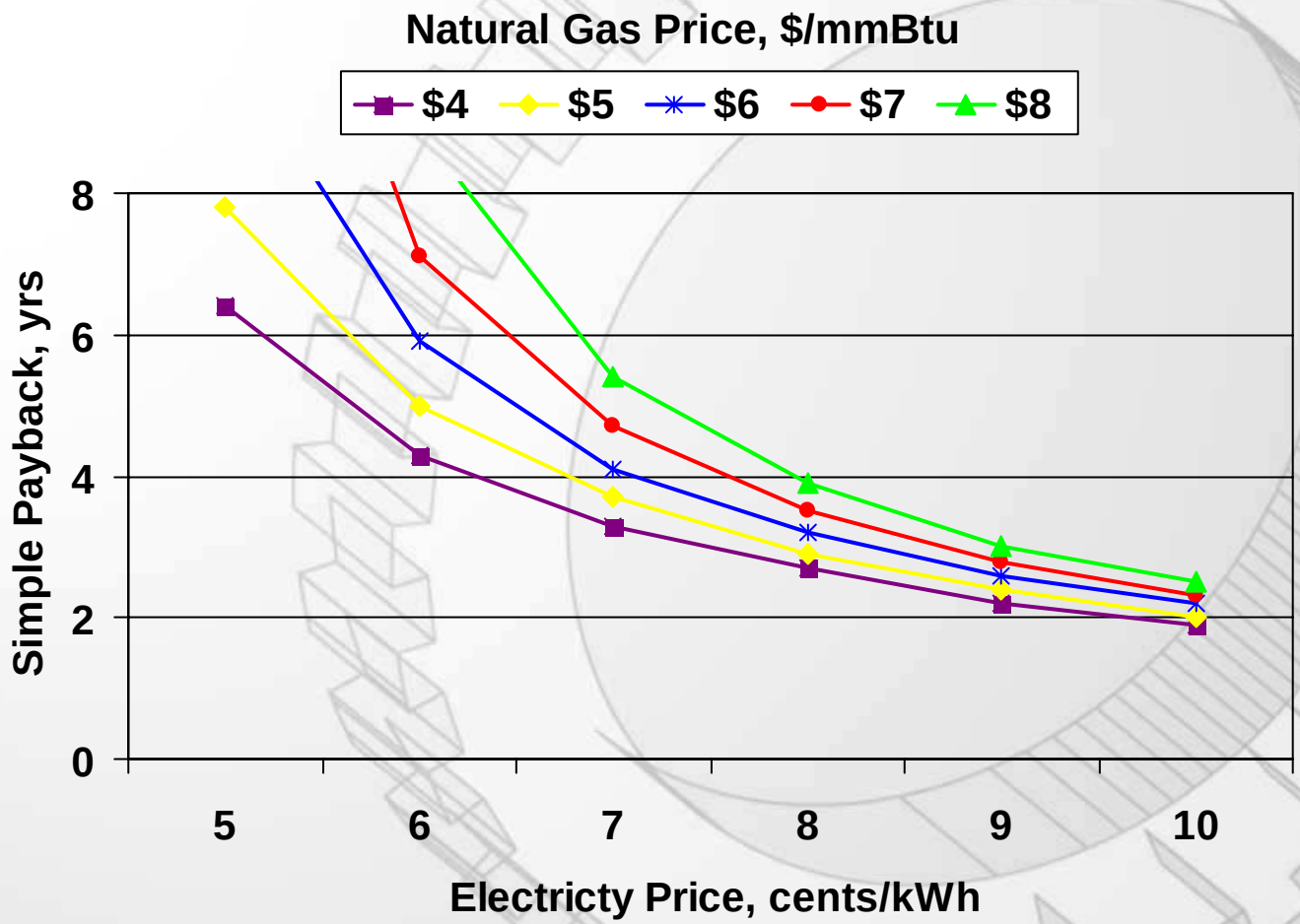
Sensitivity to Electricity and Natural Gas Prices - Gas Turbine CHP w/Duct Firing



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Boiler/Steam Turbine CHP System Assumptions

	Gas Turbine
Capacity, MW	3.0
Run Hours	8760
Boiler Fuel, mmBtu/hr	151.3
Steam Output, lb/hr	110,000
Overall Efficiency, % (HHV)	79
Power to Steam Ratio	0.08
O&M Costs, $/kWh	0.004
Incremental Capital Costs	
Steam Turbine Genset, $/kW	400
Incremental Boiler Costs, $/kW	325
Total Incremental Cost, $/kW	725
Coal Price, $/mmBtu	1.50

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Coal Boiler/Steam Turbine CHP – Energy Results

	W/O CHP	W/ CHP
Purchased Electricity, MWh	48,180	22,680
Generated Electricity, MWh	0	25,500
Boiler Steam, mmlbs	963.3	963.3
Boiler Fuel, mmBtu	1,204,500	1,325,000

Coal Boiler/Steam Turbine CHP– Financial Results

	W/O CHP	W/ CHP
Purchased Electricity, 1000 $	3,372.6	1,587.6
Boiler Fuel, 1000 $	1,806.8	1,989.6
Energy Costs, 1000 $*	*5,179.4*	*3,577.2*
O&M Costs, 1000 $	0	102.0
Standby Charges, 1000 $ ($3/kW)	0	108.0
Total Operating Costs, 1000 $	*5,179.4*	*3,787.2*

* Does not include DDGS drier fuel

Operating Savings = $1,392,200

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Coal Boiler/Steam Turbine CHP– Payback

Incremental Capital Costs = $2,175,000

Steam Turbine	$1,200,000
Incremental Boiler	$ 975,000

Payback = 1.6 yrs

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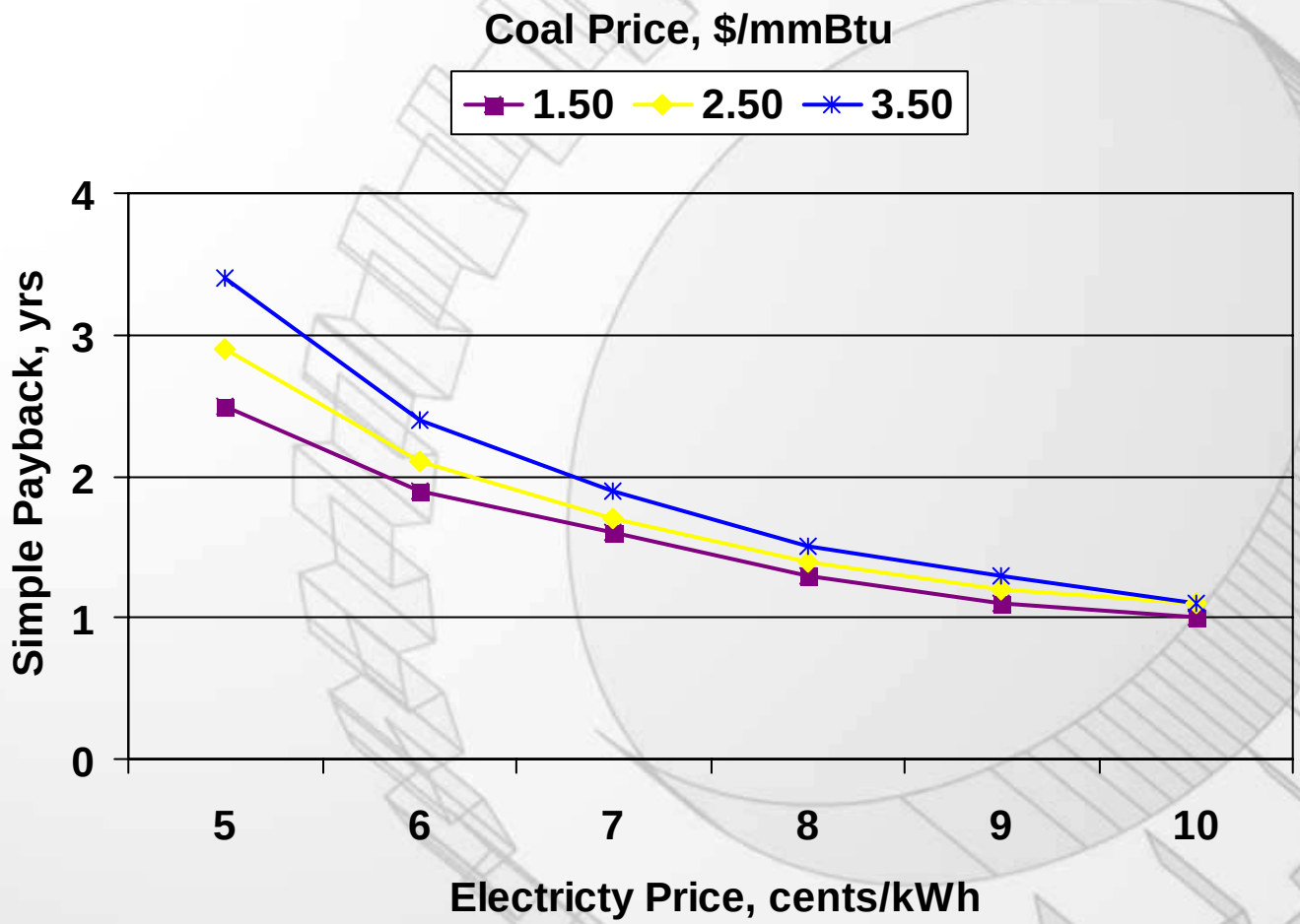
Sensitivity to Electricity and Coal Prices - Boiler/Steam Turbine CHP



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Critical Issues Affecting CHP Economics

- Reasonable projections of fuel and retail electricity prices are key
- Understanding and accounting for specific electric rate structures is critical
  - Demand rate
  - Standby tariffs
- Site requirements will impact capital costs
  - Space and access
  - Permitting
  - Interconnection

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Critical Issues Affecting CHP Economics (continued)

- In general, CHP system should be sized to supply within-the-fence energy needs
  - Difficult to sell excess power
  - However, explore opportunities to partner with utility
- Increased thermal utilization improves economics
  - Increasing thermal output displaces less efficient boiler output
- Consider the entire range of potential savings
  - Credits for displaced boiler capacity
  - Are there operating savings from increased reliability?

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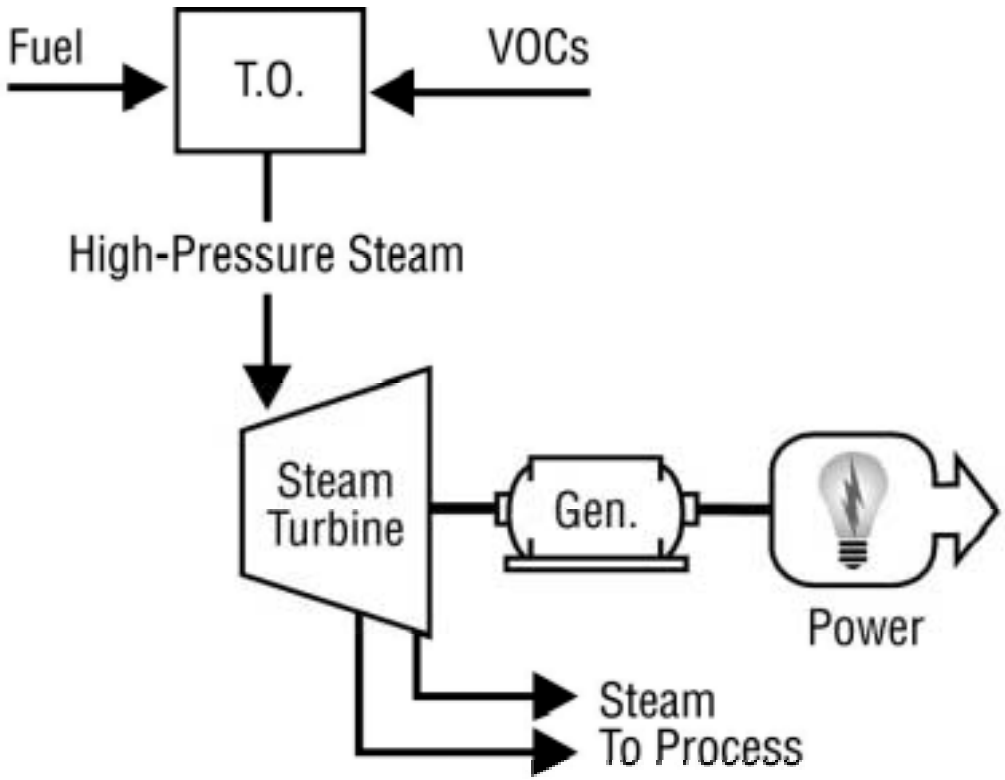
Thermal Oxidizer/Steam Turbine CHP



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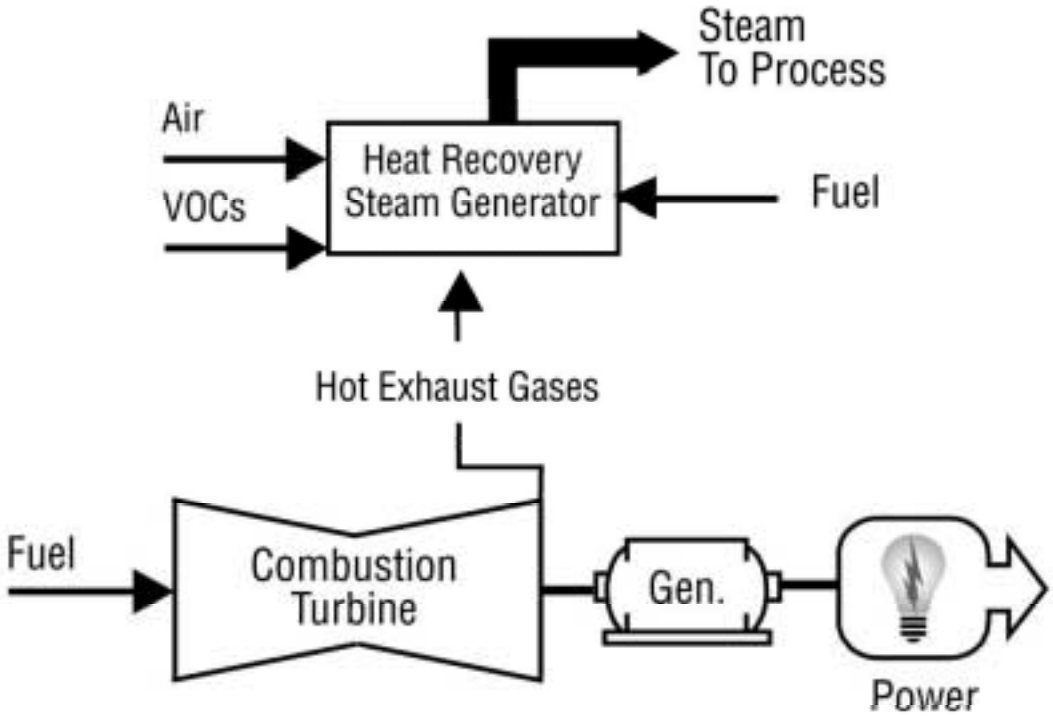
Gas Turbine/VOC Destruction CHP



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