



# **Impact of Combined Heat and Power on Energy Use and Carbon Emissions in the Dry Mill Ethanol Process**

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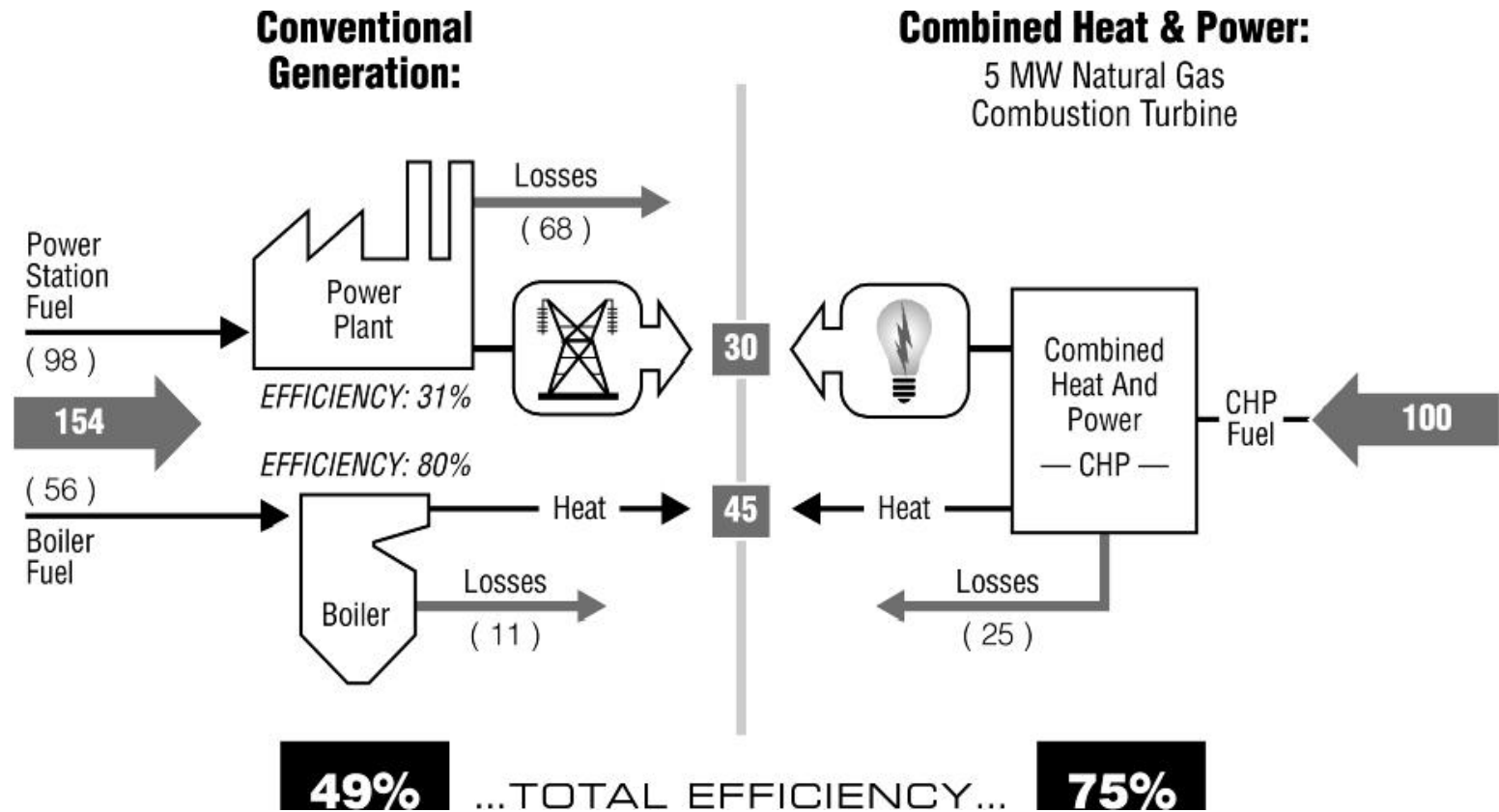
# What Is Combined Heat and Power?

- CHP – or cogeneration - is the generation of heat and power from the same fuel source.
  - Electricity primarily used on-site, but may be sold back to grid. Grid can serve as back-up or swing provider.
  - Thermal energy used for heating/cooling or process applications.
  - CHP uses wide variety of technologies and fuels.

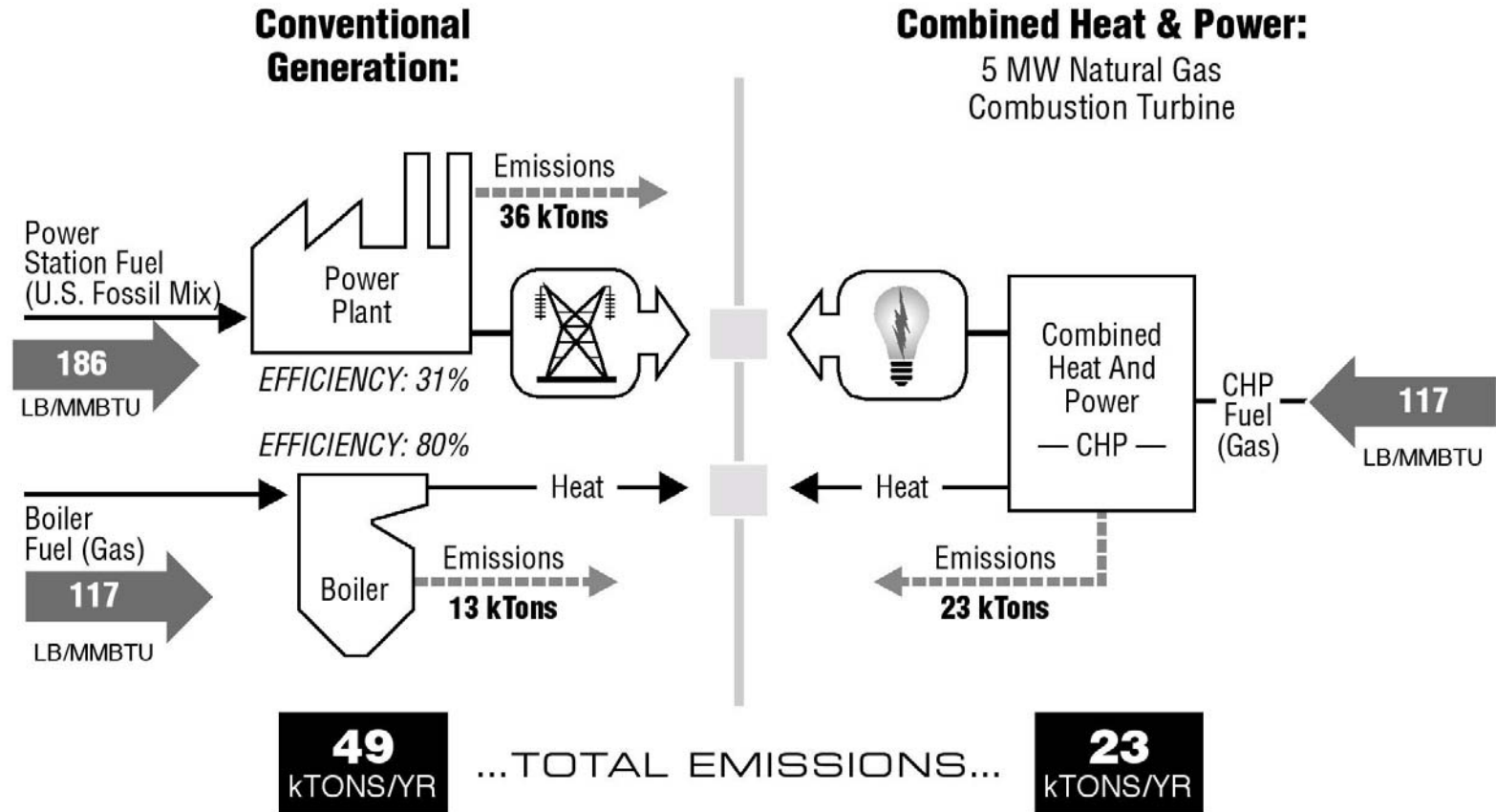
# What Are the Benefits of CHP?

- CHP is more efficient than separate generation of electricity and heat.
- Higher efficiency translates to lower operating cost, but requires capital investment.
- Higher efficiency reduces air emissions – lowers carbon footprint.
- CHP can provide increased reliability and power quality to the user.
- On-site electric generation reduces grid congestion and avoids distribution costs.

# Efficiency Benefits of CHP



# Environmental Benefits of CHP- CO2



# CHP Is an Excellent Fit for the Ethanol Industry

- Energy is the second largest cost of production for dry mill ethanol plants
- Electric and steam demands are large and coincident
  - Typical power demand is 2 to 10 MW
  - Typical steam use is 40,000 to 250,000 lb/hr
- Electric and steam profiles are relatively flat
- Operating hours are continuous
- Energy costs are rising

# What Can CHP Offer the Ethanol Plant?

- Increased energy efficiency of ethanol production
- Energy cost savings from 10 to 25 percent
- Reliable electricity and steam generated on site
- Hedge against unstable energy costs
- Improved competitiveness
- Reduced carbon footprint

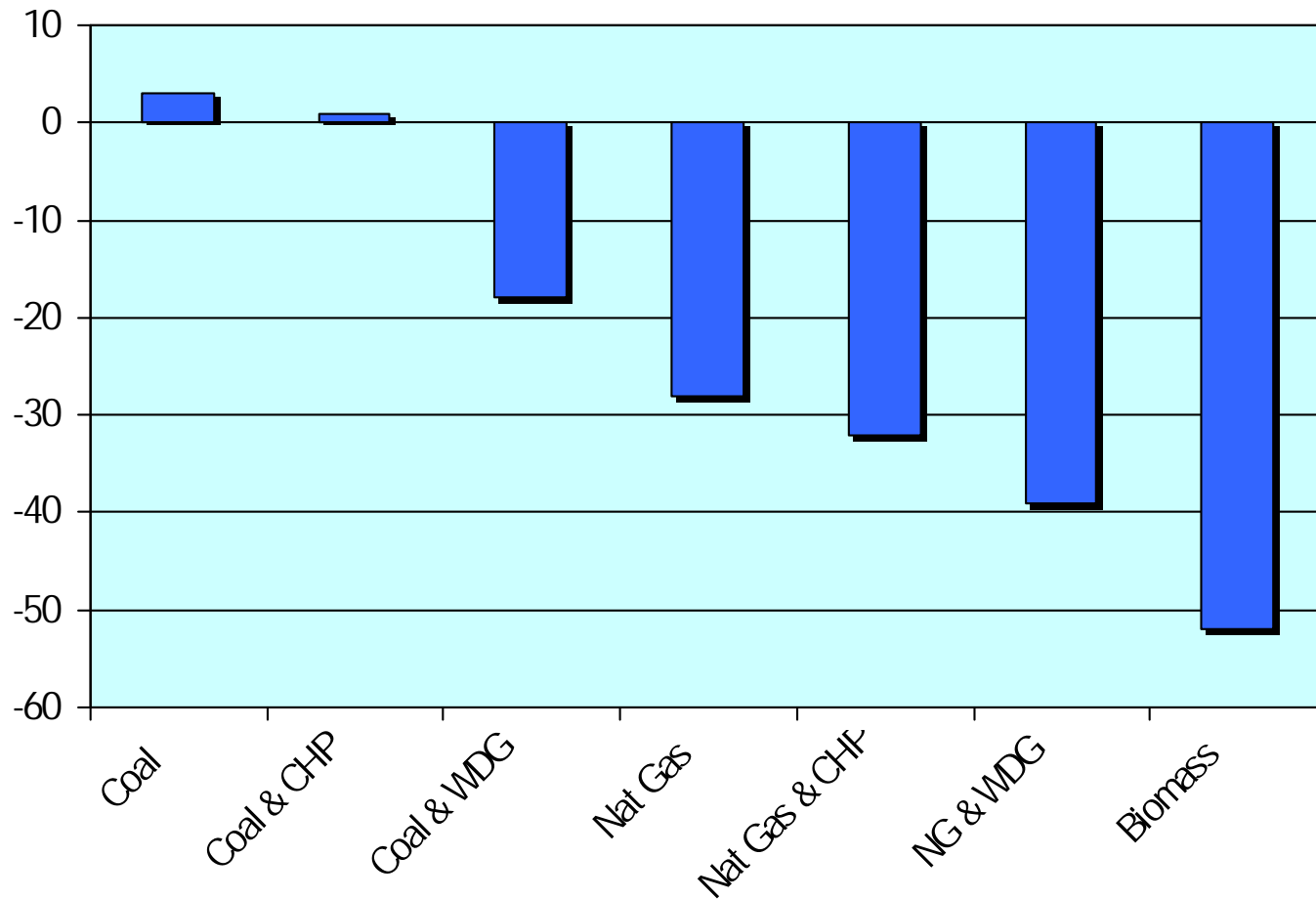
# CHP Options for Ethanol Plants

- Boiler/Steam Turbine CHP  
*Short payback, limited electric capacity*
- Gas Turbine CHP  
*If sized to electricity load, additional steam needed*
- Gas Turbine/Supplemental Fired CHP  
*Can be sized to meet both steam and electric loads*
- Biomass Fueled  
*Least-cost fuel but capital intensive; Tax credit for biomass electricity; Green electricity if sold*
- Integrated VOC destruction  
*Produce power with steam from thermal oxidizer, incorporate VOC destruction in turbine or boiler systems*

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*How Significant Is CHP in  
Reducing Overall Energy Use and  
Lowering the Carbon Footprint of the  
Dry Mill Ethanol Process?*

# Well to Wheels GHG Emissions Changes Relative to Gasoline (M. Wang, M. Wu, H. Huo, 2007)



# Dry Mill Baseline Assumptions

State of the Art *Operating Assumptions* for Dry Mill Ethanol

Operating Assumptions	Natural Gas	Coal/Biomass
Plant Capacity, MMgal/yr	50	50
Operating Hours	8600	8600
Boiler Type	Packaged	Fluidized Bed
DDGS	100%	100%
Dryer Type	Direct Fired	Steam
VOC Destruction	RTO	Boiler
Electricity Use, kWh/gal	0.75	0.90
Steam Use, lb/gal	17.1	31.4
Dryer Fuel, MMBtu/gal	10,500	NA
RTO Fuel, MMBtu/gal	330	NA

# Dry Mill Energy Consumption Baseline

State of the Art ***Energy Consumption*** for Dry Mill Ethanol

Energy Consumption	Natural Gas	Coal/Biomass
Plant Capacity, MMgal/yr	50	50
Operating Hours	8600	8600
Annual Electric Use, MWh	37,500	45,000
Average Electric Demand, MW	4.4	5.2
Total Plant Fuel Use, Btu/gal	32,300	40,300
Boiler Fuel Use, Btu/gal	21,500	40,300
Steam Use, lbs/hr	100,000	182,000
Annual Steam Use, MMlbs	860	1,570
Annual Boiler Fuel Use, MMBtu	1,075,000	2,015,000
Annual Drier Fuel Use, MMBtu	525,000	0

# CHP Options Evaluated

- Case 1: Natural Gas - Gas Turbine/Supplemental Fired CHP.  
*Electric output sized to plant demand*
- Case 2: Natural Gas – Gas Turbine with Power Export.  
*Thermal output sized to plant demand*
- Case 3: Natural Gas – Gas Turbine/Steam Turbine with Power Export.  
*Thermal output sized to plant demand, maximum power generation*
- Case 4/5: Coal/Biomass – High pressure boiler/steam turbine  
*Power output matched to plant demand*

# Comparison Assumptions

- Carbon emissions
  - Natural Gas = 117 lbs CO<sub>2</sub>/MMBtu
  - Coal = 220 lbs CO<sub>2</sub>/MMBtu
  - Biomass = 0 (carbon neutral)
- Central Station efficiency and carbon emissions (2004 eGRID)
  - U.S. Average Fossil Heat Rate = 10,215 Btu/kWh
  - U.S. Average Fossil Carbon Emissions = 1,867 lbs CO<sub>2</sub>/MWh
  - Average T&D Losses = 7%

# CHP *Plant* Energy Comparison – Natural Gas

Characteristics	Base Case no CHP	CHP Case 1 Gas Turbine w/Duct Firing	CHP Case 2 Gas Turbine w/Export	CHP Case 3 Combined Cycle w/Export
Plant Capacity, MMgal/yr	50	50	50	50
Average Electric Demand, MW	4.4	4.4	4.4	4.4
CHP Capacity, MW	0	4.0	20.6	27.5
CHP Availability, %	n/a	95%	95%	95%
Electric Generated, MWh	0	33,337	171,685	229,192
Electric Purchased, MWh	37,500	4,163	4,163	4,163
Electric Exported, MWh	0	0	138,348	195,855
Annual CHP Steam, MMBtu	0	834	834	834
Annual Boiler Steam, MMBtu	1,572	26	26	26
CHP Turbine Fuel Use, MMBtu	0	422,846	2,048,218	2,535,416
Duct Firing Fuel Use, MMBtu	0	718,533	0	0
Boiler Fuel Use, MMBtu	1,075,000	32,250	32,250	32,250
Dryer/TO Fuel Use, MMBtu	541,500	541,500	541,500	541,500
Total Plant Fuel Use, MMBtu	1,616,500	1,715,129	2,621,968	3,109,166
<b>Total Plant Fuel Use, Btu/Gal</b>	<b>32,330</b>	<b>34,303</b>	<b>52,434</b>	<b>62,183</b>

# CHP Net Energy Comparison – Natural Gas

Energy Consumption	Base Case no CHP	CHP Case 1 Gas Turbine - No Export	CHP Case 2 Gas Turbine w/Export	CHP Case 3 Combined Cycle w/Export
<i>Plant Fuel Use</i>				
Total Plant Fuel Use, MMBtu	1,616,500	1,715,129	2,621,968	3,109,166
<b>Total Plant Fuel Use, Btu/Gal</b>	<b>32,330</b>	<b>34,303</b>	<b>52,434</b>	<b>62,183</b>
<i>Central Station Fuel Use</i>				
Purchased Power – MMBtu	411,548	45,688	45,688	45,688
Export Power – MMBtu	0	0	(1,518,322)	(2,149,431)
Total Net Fuel Use, MMBtu	2,028,048	1,760,817	1,149,334	1,005,422
<b>Net Fuel Use, Btu/Gal</b>	<b>40,560</b>	<b>35,215</b>	<b>22,990</b>	<b>20,110</b>
Plant CO2 Emissions, Tons/yr	94,565	100,335	153,385	181,886
Central Station CO2 Emissions, Tons/yr	37,641	4,179	(124,970)	(182,830)
Net CO2 Emissions, Tons/yr	132,206	104,514	28,416	3,235
<b>Net CO2 Emissions, lb/Gal</b>	<b>5.29</b>	<b>4.18</b>	<b>1.14</b>	<b>0.13</b>

# CHP *Plant* Energy Comparison – Coal

Characteristics	Base Case no CHP	Case 4 CHP Case Boiler / Steam Turbine
Plant Capacity, MMgal/yr	50	50
Average Electric Demand, MW	5.2	5.2
CHP Capacity, MW	0	5.0
CHP Availability, %	n/a	95%
Electric Generated, MWh	0	40,812
Electric Purchased, MWh	45,000	4,188
Electric Exported, MWh	0	0
Annual Boiler Steam, MMBtu	1,572	1,755
Annual Process Steam, MMBtu	1,572	1,572
Boiler Fuel Use, MMBtu	2,015,026	2,250,313
Dryer/TO Fuel Use, MMBtu	0	0
Total Plant Fuel Use, MMBtu	2,015,026	2,250,313
<b>Total Plant Fuel Use, Btu/Gal</b>	<b>40,300</b>	<b>45,005</b>

# CHP Net Energy Comparison – Coal

Energy Consumption	Base Case no CHP	Case 4 CHP Case Boiler / Steam Turbine
<i>Plant Fuel Use</i>		
Total Plant Fuel Use, MMBtu	2,015,026	2,250,313
<b>Total Plant Fuel Use, Btu/Gal</b>	<b>40,300</b>	<b>45,005</b>
<i>Central Station Fuel Use</i>		
Purchased Power – MMBtu	493,858	45,962
Export Power – MMBtu/yr	0	0
Total Net Fuel Use, MMBtu	2,508,884	2,296,275
<b>Net Fuel Use, Btu/Gal</b>	<b>50,178</b>	<b>45,925</b>
Plant CO2 Emissions, Tons/yr	221,653	247,534
Central Station CO2 Emissions, Tons/yr	45,169	4,204
Net CO2 Emissions, Tons/yr	266,822	251,738
<b>Net CO2 Emissions, lb/Gal</b>	<b>10.67</b>	<b>10.07</b>

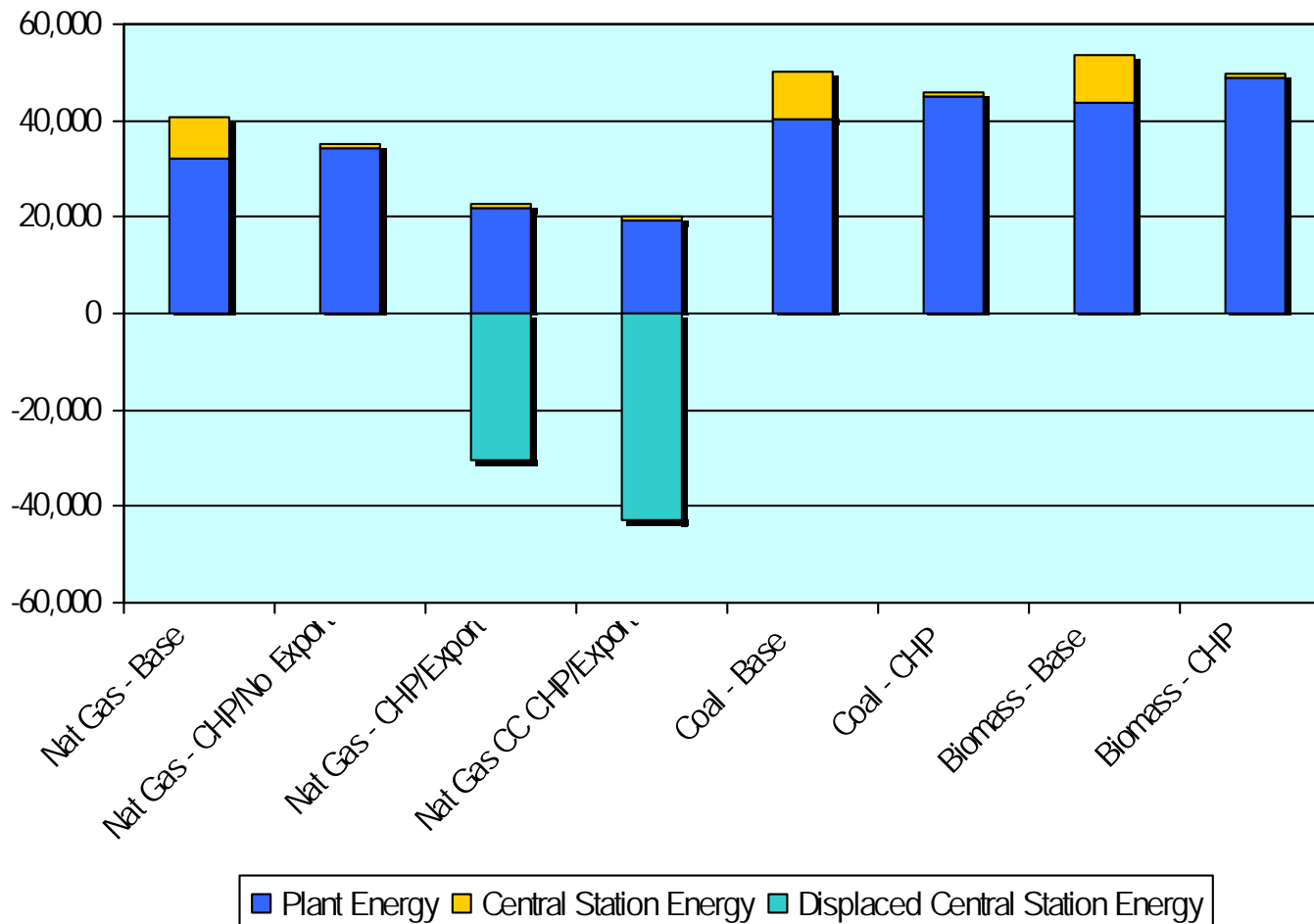
# CHP *Plant* Energy Comparison – Biomass

Characteristics	Base Case no CHP	Case 5 CHP Case Boiler / Steam Turbine
Plant Capacity, MMgal/yr	50	50
Average Electric Demand, MW	5.2	5.2
CHP Capacity, MW	0	5.0
CHP Availability, %	n/a	95%
Electric Generated, MWh	0	40,812
Electric Purchased, MWh	45,000	4,188
Electric Exported, MWh	0	0
Annual Boiler Steam, MMBtu	1,572	1,755
Annual Process Steam, MMBtu	1,572	1,572
Boiler Fuel Use, MMBtu	2,182,944	2,437,839
Dryer/TO Fuel Use, MMBtu	0	0
Total Plant Fuel Use, MMBtu	2,182,994	2,437,839
<b>Total Plant Fuel Use, Btu/Gal</b>	<b>43,660</b>	<b>48,760</b>

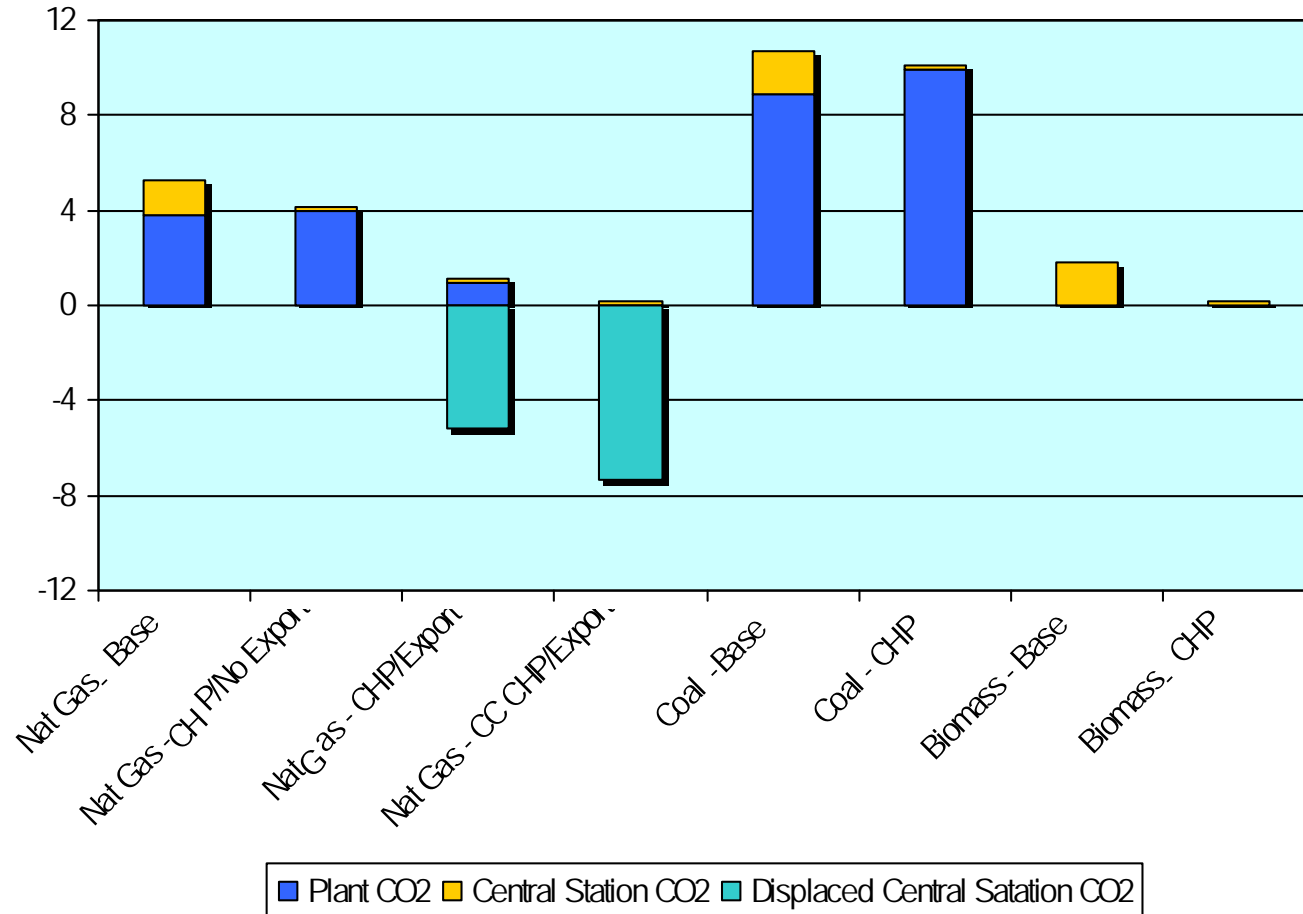
# CHP Net Energy Comparison – Biomass

Energy Consumption	Base Case no CHP	Case 5 CHP Case Boiler / Steam Turbine
<i>Plant Fuel Use</i>		
Total Plant Fuel Use, MMBtu	2,182,994	2,437,839
<b>Total Plant Fuel Use, Btu/Gal</b>	<b>43,660</b>	<b>48,760</b>
<i>Central Station Fuel Use</i>		
Purchased Power – MMBtu	493,858	45,962
Export Power – MMBtu	<u>0</u>	<u>0</u>
Total Net Fuel Use, MMBtu	2,676,852	289,801
<b>Net Fuel Use, Btu/Gal</b>	<b>53,540</b>	<b>49,675</b>
Plant CO2 Emissions, Tons/yr	0	0
Central Station CO2 Emissions, Tons/yr	<u>45,169</u>	<u>4,204</u>
Net CO2 Emissions, Tons/yr	45,169	4,204
<b>Net CO2 Emissions, lb/Gal</b>	<b>1.81</b>	<b>0.17</b>

# Dry Mill Energy Use, Btu/Gal Ethanol



# Dry Mill CO2 Emissions, lb/Gal Ethanol



# Bottom Line

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- Energy use and carbon footprint primarily driven by fuel choice and process configurations
- Once fuel is selected, CHP can reduce net energy use and reduce carbon footprint
  - Natural gas: CHP reduces net energy 13 to 50%; lowers carbon emissions 25 to 97%
  - Coal: CHP reduces net energy 9% and carbon emissions 6%
  - Biomass: CHP reduces net energy 7% and carbon emissions 90%

# The EPA CHP Partnership Can Help

- Goal: to reduce the environmental impact of power generation by increasing the deployment of highly efficient CHP projects
- Strategy: provide education/outreach, direct project assistance, and public recognition of the benefits of CHP
  - Targeted market efforts in ethanol CHP applications since 2003
- >200 Partners
  - Large energy users, CHP developers, utilities, equipment manufacturers, energy service companies, policy makers
  - Through 2006, CHP Partners installed 3,577 MW of CHP with Partnership assistance

# CHP Partnership at Work with Ethanol Facilities

- Level 1 Technical Feasibility Studies
- Permitting / Regulatory / Funding Advice
- ENERGY STAR CHP Awards
  - Recognize efficient CHP projects that reduce emissions:
    - Use 5 % less fuel than state-of-the-art comparable separate heat and power
- [www.epa.gov/chp](http://www.epa.gov/chp)

# Questions?

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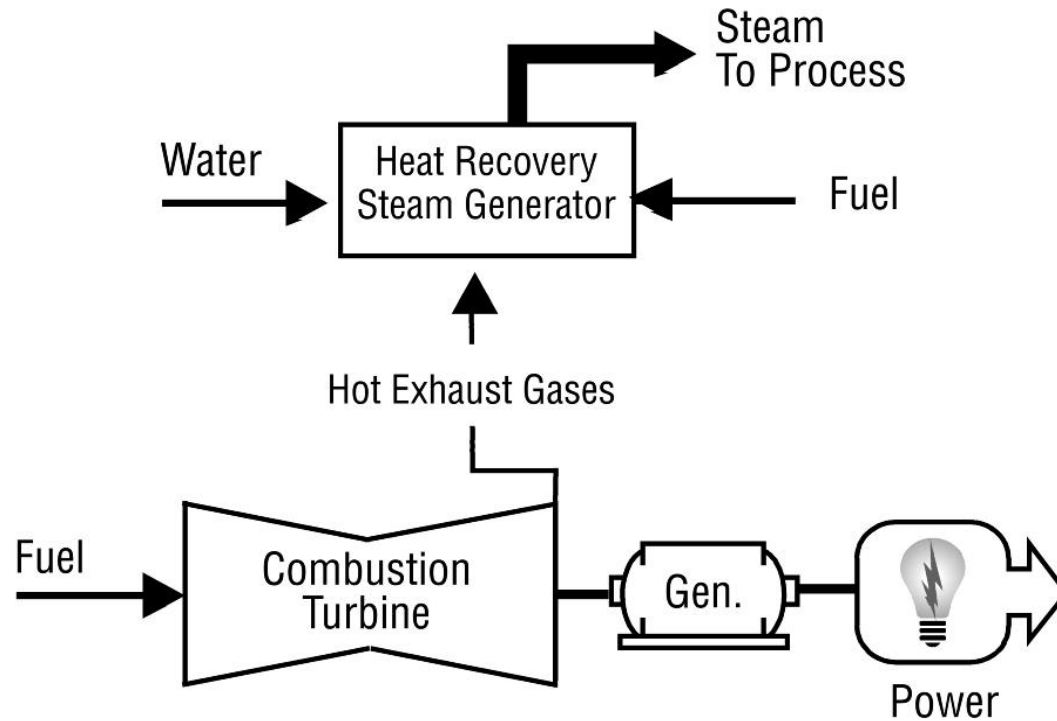
# Appendix

# Typical CHP System Cost and Performance

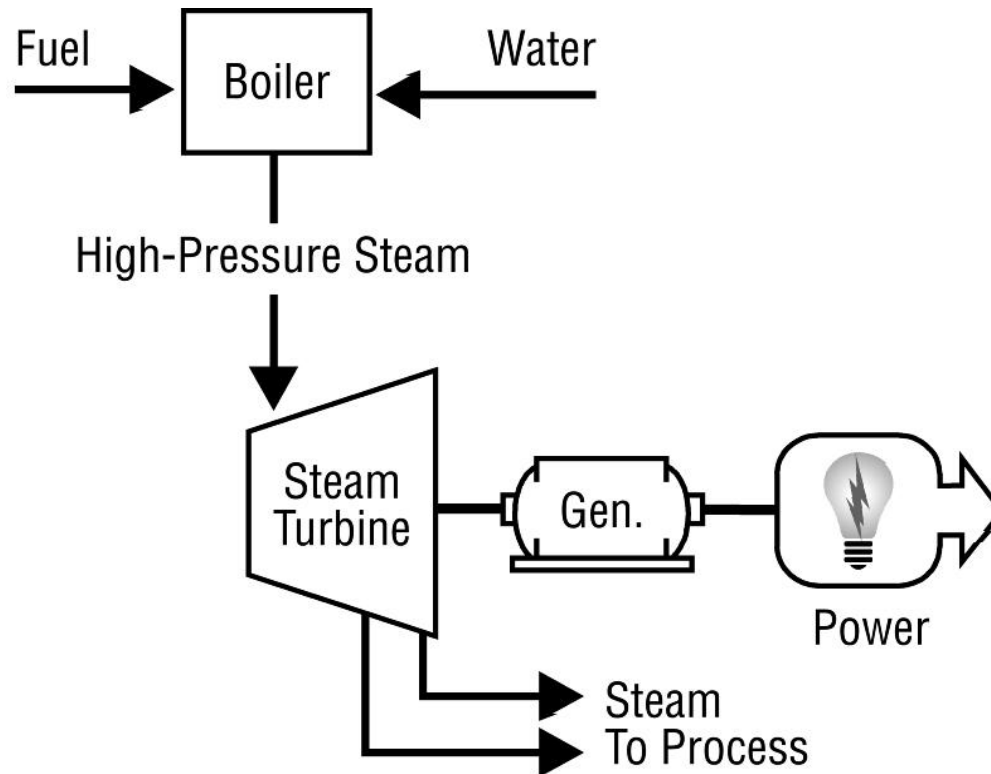
Characteristics	Gas Turbine	Gas Turbine w/Duct Firing	Boiler/Steam Turbine
Capacity, MW	1 - 15	1 - 15	0.5 - 5
Electrical Efficiency, % (HHV)	22 – 32	12 - 17	6 - 10
Steam Output, Btu/kWh	4,500 – 6,700	12,000 – 20,000	35,000 – 40,000
Overall Efficiency, % (HHV)	65 - 70	80 - 85	75 - 85
Power to Steam Ratio	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

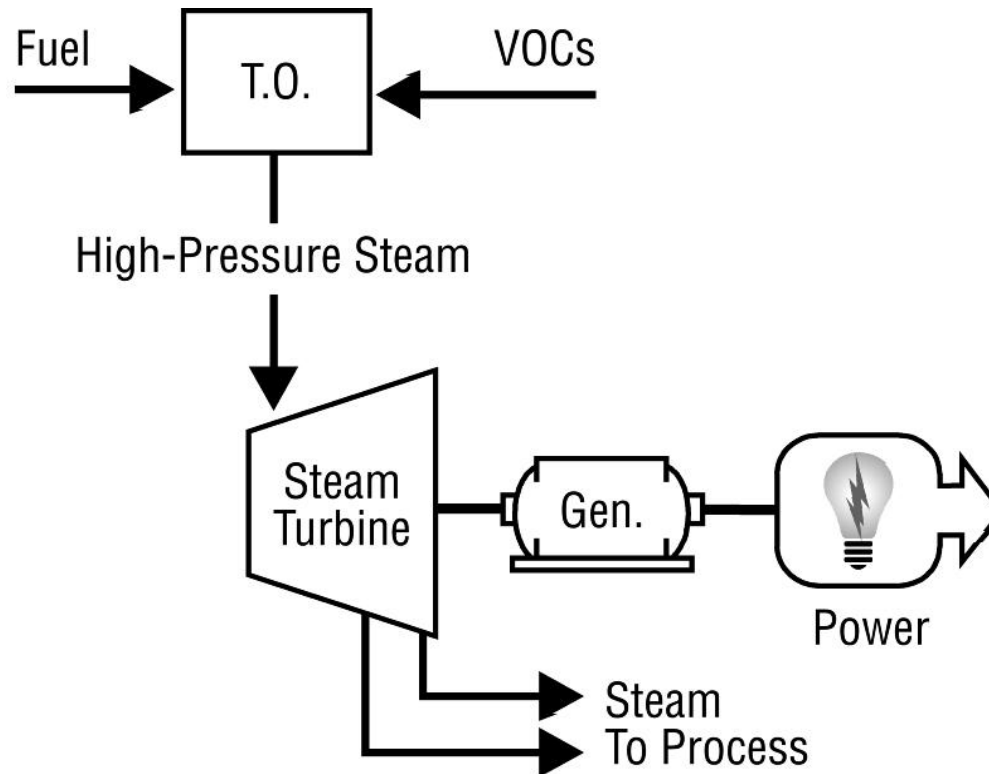
# Gas Turbine/Duct Firing CHP



# Boiler/Steam Turbine CHP



# Thermal Oxidizer/Steam Turbine CHP



# Gas Turbine/VOC Destruction CHP

