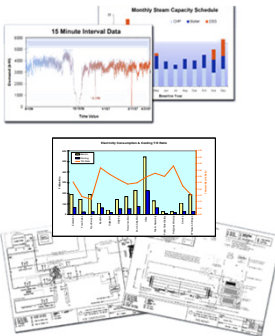



**CHP & Woody Biomass**

**CHP Economics in West Virginia**

### Topics

- Cost of Generating Power
- Basic Economics
- Thermal Economics
- Conclusions

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### CHP Economics

For CHP to provide a positive economic proposition it must generate sufficient operational savings to pay down the investment cost within an acceptable period that is less than the life cycle of the equipment.

Operational savings are based on the cost of fuel and maintenance compared to grid power and boiler fuel.

Capital grants, output based payments, emissions or efficiency credits, investment tax credits or other financial incentives can be used to improve the economics.

Additional credits due to capital cost offsets, increased power reliability, 'green' marketing, etc. can enhance the basic economic proposition.



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### Solid Biomass versus Natural Gas CHP

Solid biomass uses lower cost fuel but has higher total plant maintenance requirements

Solid biomass electric efficiency is lower than Natural Gas generation but it's thermal efficiency is higher

Biomass CHP plant capital costs are higher

	Biomass	Nat Gas	
Fuel Cost	\$4.00	\$6.00	\$/MMBH
Maintenance Cost	\$0.0300	\$0.0200	\$/kWh w/HR Equip
Electric Efficiency (LHV)	22.0%	38.0%	
Electric Efficiency (HHV)	20.0%	34.5%	
Thermal Efficiency (HHV)	55.0%	35.5%	



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## CHP System Output Energy Values

Of the various energy streams produced by a CHP plant, the highest value output is electric power, next in value is heating and cooling is lowest value output based on typical utility costs and generator, boiler and chiller efficiencies.

Input Values		Offset Values	
Biomass	\$4.00 /MMBH	Electricity	\$21.97 /MMBH
Natural Gas	\$0.60 /Therm	Heating	\$7.50 /MMBH
Grid Electricity	\$0.075 /kWh	Cooling	\$3.75 /MMBH
NG Boiler Efficiency	80 %	<b>Biomass CHP Costs</b>	
Elec Chiller Efficiency	0.60 kW/Ton	Fuel	\$0.068 /kWh
Generator Efficiency	20 % HHV	Maintenance	\$0.030 /kWh

## Cost to Generate Power with Heat Use

**Biomass & NG CHP:**

**Biomass CHP has a much higher Thermal/Electric Ratio than Nat Gas CHP**

**Cost to generate power only is higher for Biomass but effective cost with heat recovery is lower.**

Cost to Generate Power including Thermal Offset			
CHP Costs	Fuel Cost <sup>1</sup>	Biomass \$4.00	Nat Gas \$6.00 \$/MMBH
	Maintenance Cost	\$0.0300	\$0.0200 \$/kWh w /HR Equip
<b>Engine</b>			
	Electric Efficiency (LHV)	22.0%	38.0%
	Electric Efficiency (HHV)	20.0%	34.5%
	Thermal Efficiency (HHV)	55.0%	35.5%
<b>Cost to Generate Power Only</b>			
	Fuel Input (HHV) per kWh	17,070	9,883 Btu
	Fuel Cost per kWh	\$0.068	\$0.059 @ 1,000 Btu/CF
	Maintenance per kWh	\$0.0300	\$0.0175 Excl HR Equip <sup>2</sup>
	<b>Total Cost per kWh</b>	<b>\$0.098</b>	<b>\$0.077</b>
<small>Note 1: Biomass Fuel - Green Wood Chips at \$50/Ton, 12 GJ/Ton</small>			
<small>Note 2: Heat Recovery Equipment relevant to Nat Gas case only</small>			
<b>Gas Offset @ 100% Thermal Load Factor</b>			
	Existing Boiler Efficiency	80%	80%
	Nat Gas Offset per kWh	11,736	4,380 Btu
	Offset Value per kWh	\$0.070	\$0.026 @ 1,000 Btu/CF
	<b>Net Cost per kWh</b>	<b>\$0.028</b>	<b>\$0.053 Incl HR Equip</b>

## Simple Payback

**At power costs of 7.5¢/kWh and 60¢/Therm gas, Biomass CHP simple payback without incentives is 8.9 years versus Natural Gas CHP at 10.9 years**

CHP Economics			
2009 Average Rate	0.075	/kWh	
Electric Power Rate Increase	0%	Over 2009 Rates	
Future Power Cost	\$0.075	\$0.075	/kWh
<b>CHP Costs</b>			
	Biomass	Nat Gas	
Fuel Cost <sup>1</sup>	\$4.00	\$6.00	\$/MMBH
Maintenance Cost	\$0.0300	\$0.0200	\$/kWh w /HR Equip
<b>CHP Economics v's Gas Heating</b>			
Savings per MW	\$392,247	\$182,943	
CapX per MW <sup>1</sup>	\$3,500,000	\$2,000,000	
Simple Payback	8.9	10.9 Years	

Note 1: Biomass based on 2 MW Fluidized Bed Reactor with Back Pressure Steam Turbine

## Simple Payback – Larger Systems

**As system size grows, capital costs (CapX) decrease. For a 20 MW installation, the payback for Biomass and CHP is reduced by 30% and 25% respectively.**

CHP Economics			
2009 Average Rate	0.075	/kWh	
Electric Power Rate Increase	0%	Over 2009 Rates	
Future Power Cost	\$0.075	\$0.075	/kWh
<b>CHP Costs</b>			
	Biomass	Nat Gas	
Fuel Cost <sup>1</sup>	\$4.00	\$6.00	\$/MMBH
Maintenance Cost	\$0.0300	\$0.0200	\$/kWh w /HR Equip
<b>CHP Economics v's Gas Heating</b>			
Savings per MW	\$392,247	\$182,943	
CapX per MW <sup>1</sup>	\$2,500,000	\$1,500,000	
Simple Payback	6.4	8.2 Years	

Note 1: Biomass based on 20 MW Fluidized Bed Reactor with Back Pressure Steam Turbine

### Payback with Varying Electric Price

With 15% increase in power rate to **8.6¢/kWh** and **60¢/Therm gas**, Biomass CHP simple payback without incentives and Natural Gas CHP are equal at **7.2 years**

CHP Economics			
2009 Average Rate	0.075	/kWh	
Electric Power Rate Increase	15%	Over 2009 Rates	
Future Power Cost	\$0.086	\$0.086 /kWh	

CHP Costs	Biomass	Nat Gas	
Fuel Cost <sup>1</sup>	\$4.00	\$6.00	\$/MMBH
Maintenance Cost	\$0.0300	\$0.0200	\$/kWh w/HR Equip

CHP Economics v's Gas Heating			
Savings per MW	\$485,870	\$276,565	
CapX per MW <sup>1</sup>	\$3,500,000	\$2,000,000	
Simple Payback	7.2	7.2	Years

Note 1: Biomass based on 2 MW Fluidized Bed Reactor with Back Pressure Steam Turbine

### Payback with Varying Electric Price

With 33% increase in power rate to **10¢/kWh** and **70¢/Therm gas**, Biomass CHP and Natural Gas CHP simple paybacks without incentives are similar at **under 6 years**

CHP Economics			
2009 Average Rate	0.075	/kWh	
Electric Power Rate Increase	33%	Over 2009 Rates	
Future Power Cost	\$0.100	\$0.100 /kWh	

CHP Costs	Biomass	Nat Gas	
Fuel Cost <sup>1</sup>	\$4.00	\$7.00	\$/MMBH
Maintenance Cost	\$0.0300	\$0.0200	\$/kWh w/HR Equip

CHP Economics v's Gas Heating			
Savings per MW	\$695,880	\$343,118	
CapX per MW <sup>1</sup>	\$3,500,000	\$2,000,000	
Simple Payback	5.0	5.8	Years

Note 1: Biomass based on 2 MW Fluidized Bed Reactor with Back Pressure Steam Turbine

### Variable Gas Rate

As natural gas price is reduced, thermal offset value decreases resulting in a higher 'net' cost to generate power from Biomass

Effect is less evident for Nat Gas fired CHP which has a lower T/E Ratio

#### Cost to Generate Power including Thermal Offset

CHP Costs	Biomass	Nat Gas	
Fuel Cost <sup>1</sup>	\$4.00	\$5.50	\$/MMBH
Maintenance Cost	\$0.0300	\$0.0200	\$/kWh w/HR Equip

Engine			
Electric Efficiency (LHV)	22.0%	38.0%	
Electric Efficiency (HHV)	20.0%	34.5%	
Thermal Efficiency (HHV)	55.0%	35.5%	

Cost to Generate Power Only			
Fuel Input (HHV) per kWh	17,070	9,883	Btu
Fuel Cost per kWh	\$0.068	\$0.054	@ 1,000 Btu/CF
Maintenance per kWh	\$0.0300	\$0.0175	Excl HR Equip <sup>2</sup>
Total Cost per kWh	\$0.098	\$0.072	

Note 1: Biomass Fuel = Green Wood Chips at \$50/T on, 12 GJ/Ton

Note 2: Heat Recovery Equipment relevant to Nat Gas case only

Gas Offset @ 100% Thermal Load Factor			
Existing Boiler Efficiency	80%	80%	
Nat Gas Offset per kWh	11,736	4,380	Btu
Offset Value per kWh	\$0.065	\$0.024	@ 1,000 Btu/CF
Net Cost per kWh	\$0.034	\$0.050	Incl HR Equip

### Payback with Varying Gas Price

With 17% decrease in gas cost to **50¢/Therm** and **7.5¢/kWh electric**, the Biomass CHP cost savings are still better but the payback is now higher than the Nat Gas fired CHP payback

CHP Economics			
2009 Average Rate	0.075	/kWh	
Electric Power Rate Increase	0%	Over 2009 Rates	
Future Power Cost	\$0.075	\$0.075 /kWh	

CHP Costs	Biomass	Nat Gas	
Fuel Cost <sup>1</sup>	\$4.00	\$5.00	\$/MMBH
Maintenance Cost	\$0.0300	\$0.0200	\$/kWh w/HR Equip

CHP Economics v's Gas Heating			
Savings per MW	\$294,583	\$228,737	
CapX per MW <sup>1</sup>	\$3,500,000	\$2,000,000	
Simple Payback	11.9	8.7	Years

Note 1: Biomass based on 2 MW Fluidized Bed Reactor with Back Pressure Steam Turbine

## Thermal Load Factor

Reducing the Thermal Heat Utilization by 25%, increases the 'Net' cost to produce power for the Biomass CHP plant by 60% while it only increases the Nat Gas net cost by 13%

### Cost to Generate Power including Thermal Offset

CHP Costs	Biomass		Nat Gas	
	Fuel Cost <sup>1</sup>	\$4.00	\$6.00	\$/MMBh
Maintenance Cost	\$0.0300	\$0.0200	\$/kWh w /HR Equip	
<b>Engine</b>				
Electric Efficiency (LHV)	22.0%	38.0%		
Electric Efficiency (HHV)	20.0%	34.5%		
Thermal Efficiency (HHV)	55.0%	35.5%		
<b>Cost to Generate Power Only</b>				
Fuel Input (HHV) per kWh	17,070	9,883	Btu	
Fuel Cost per kWh	\$0.068	\$0.059	@ 1,000 Btu/CF	
Maintenance per kWh	\$0.0300	\$0.0175	Excl HR Equip <sup>2</sup>	
Total Cost per kWh	\$0.098	\$0.077		

Note 1: Biomass Fuel - Green Wood Chips at \$50/Ton, 12 GJ/Ton  
 Note 2: Heat Recovery Equipment relevant to Nat Gas case only

Gas Offset @ 100% Thermal Load Factor		
Existing Boiler Efficiency	80%	80%
Nat Gas Offset per kWh	11,736	4,380
Offset Value per kWh	\$0.070	\$0.026
Net Cost per kWh	\$0.028	\$0.053

Gas Offset @ 75% Thermal Load Factor		
Existing Boiler Efficiency	80%	80%
Nat Gas Offset per kWh	8,802	3,285
Offset Value per kWh	\$0.053	\$0.020
Net Cost per kWh	\$0.045	\$0.060

## Thermal Load Factor

The same 25% reduction in Thermal Load Factor results in an increase of 60% in payback time for Biomass and 43% for Nat Gas CHP

### CHP Economics

2009 Average Rate	0.075	/kWh
Electric Power Rate Increase	0%	Over 2009 Rates
Future Power Cost	\$0.075	\$/kWh

CHP Costs	Biomass	Nat Gas
Fuel Cost <sup>1</sup>	\$4.00	\$6.00
Maintenance Cost	\$0.0300	\$0.0200
	\$/kWh w /HR Equip	

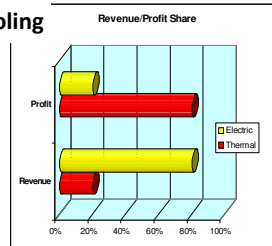
CHP Economics v's Gas Heating		
Savings per MW	\$245,751	\$128,270
CapX per MW <sup>1</sup>	\$3,500,000	\$2,000,000
Simple Payback	14.2	15.6
	Years	

CHP Economics v's Gas Heating		
Savings per MW	\$392,247	\$182,943
CapX per MW <sup>1</sup>	\$3,500,000	\$2,000,000
Simple Payback	8.9	10.9
	Years	

Note 1: Biomass based on 2 MW Fluidized Bed Reactor with Back Pressure Steam Turbine

## Conclusions

- Electricity at 7 ½ ¢/kWh or higher
- Thermal offset value is very important to Biomass CHP
- Offsetting electric heat improves economics
- Offsetting heating is better than cooling
- High thermal load factor required
  - Essentially the electric output covers the cost of operation and the thermal revenue represents the annual cost savings/capital cost recovery.



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