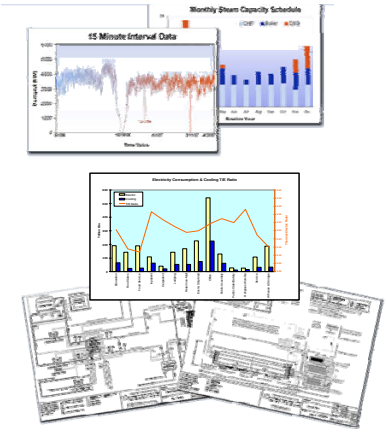
U.S. Department of Energy
Mid-Atlantic Clean Energy Application Center
Promoting CHP, District Energy, and Waste Heat Recovery

CHP, Waste Heat & District Energy

Module 5: CHP Economics in Pennsylvania

Module 5 Topics

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



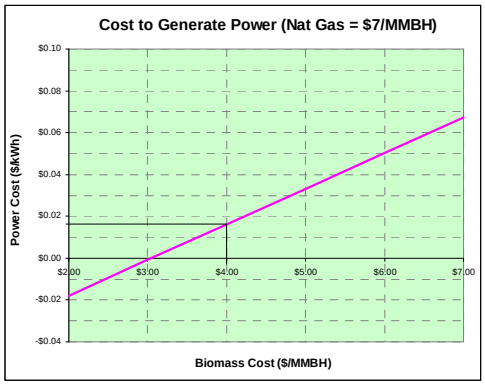
CHP Economics

- 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.

Solid Biomass CHP Economics

At a fuel cost of $4/MMBH a typical Biomass Power Plant will produce power at approx. 9.8 cents/kWh*

Offsetting $7/MMBH Natural Gas Heating, a Biomass CHP Plant produces power at an effective 1.6 cents/kWh*



* Includes maintenance

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%	

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	$0.70	/Therm	Heating	$8.75	/MMBH
Grid Electricity	$0.075	/kWh	Cooling	$3.75	/MMBH
NG Boiler Efficiency	80	%	CHP Costs		
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	Biomass	Nat Gas	
Fuel Cost[1]	$4.00	$7.00	$/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	$0.069	@ 1,000 Btu/CF
Maintenance per kWh	$0.0300	$0.0175	Excl HR Equip[2]
Total Cost per kWh	$0.098	$0.087	

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	Btu
Offset Value per kWh	$0.082	$0.031	@ 1,000 Btu/CF
Net Cost per kWh	$0.016	$0.059	Incl HR Equip

Simple Payback

At power costs of 7.5¢/kWh and 70¢/Therm gas, Biomass CHP simple payback without incentives is 7.1 years versus Natural Gas CHP at 14.6 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

CHP Costs	Biomass	Nat Gas	
Fuel Cost1	$4.00	$7.00	$/MMBH
Maintenance Cost	$0.0300	$0.0200	$kWh w/HR Equip

CHP Economics v's Gas Heating			
Savings per MW	$489,911	$137,148	
CapX per MW[1]	$3,500,000	$2,000,000	
Simple Payback	7.1	14.6	Years

Note 1: Biomass based on 2 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 70¢/Therm gas, Biomass CHP simple payback without incentives is 6.0 years versus Natural Gas CHP at 8.7 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 Cost1	$4.00	$7.00	$/MMBH
Maintenance Cost	$0.0300	$0.0200	$kWh w/HR Equip

CHP Economics v's Gas Heating			
Savings per MW	$583,533	$230,771	
CapX per MW[1]	$3,500,000	$2,000,000	
Simple Payback	6.0	8.7	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 Cost1	$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[1]	$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[1]	$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[2]
Total Cost per kWh	$0.098	$0.072	

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	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 15% decrease in gas cost to 60¢/Therm and 7.5¢/kWh electric, the Biomass CHP payback increases while the Nat Gas fired CHP payback decreases

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 Cost1	$4.00	$6.00	$/MMBH
Maintenance Cost	$0.0300	$0.0200	$kWh w/HR Equip

CHP Economics v's Gas Heating			
Savings per MW	$392,247	$182,943	
CapX per MW[1]	$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

Payback with Varying Gas Price

With 30% 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 Cost1	$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[1]	$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

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Thermal Load Factor

Reducing the Thermal Heat Utilization by 25%, more than doubles the 'Net' cost to produce power for the Biomass CHP plant while it only increases the Nat Gas net cost by 12%

Cost to Generate Power including Thermal Offset

CHP Costs	Biomass	Nat Gas	
Fuel Cost[1]	$4.00	$7.00	$/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	$0.069	@ 1,000 Btu/CF
Maintenance per kWh	$0.0300	$0.0175	Excl HR Equip[2]
Total Cost per kWh	$0.098	$0.087	

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	$0.082	$0.031
Net Cost per kWh	$0.016	$0.059

Gas Offset @ 75% Thermal Load Factor			
Existing Boiler Efficiency	80%	80%	
Nat Gas Offset per kWh	8,802	3,285	Btu
Offset Value per kWh	$0.062	$0.023	@ 1,000 Btu/CF
Net Cost per kWh	$0.037	$0.066	Incl HR Equip

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Thermal Load Factor

The same 25% reduction in Thermal Load Factor results in an increase of 55% in payback time for Biomass and 87% 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	$0.075	/kWh

CHP Costs	Biomass	Nat Gas	
Fuel Cost1	$4.00	$7.00	$/MMBH
Maintenance Cost	$0.0300	$0.0200	$kWh w/HR Equip

CHP Economics v's Gas Heating			
Savings per MW	$318,999	$73,363	
CapX per MW[1]	$3,500,000	$2,000,000	
Simple Payback	11.0	27.3	Years

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

CHP Economics v's Gas Heating			
Savings per MW	$489,911	$137,148	
CapX per MW[1]	$3,500,000	$2,000,000	
Simple Payback	7.1	14.6	Years

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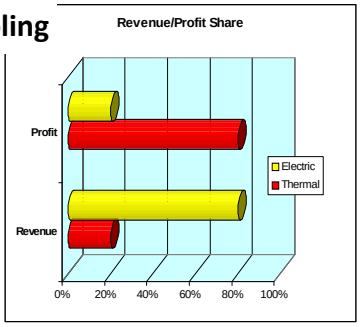
Conclusions

- **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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