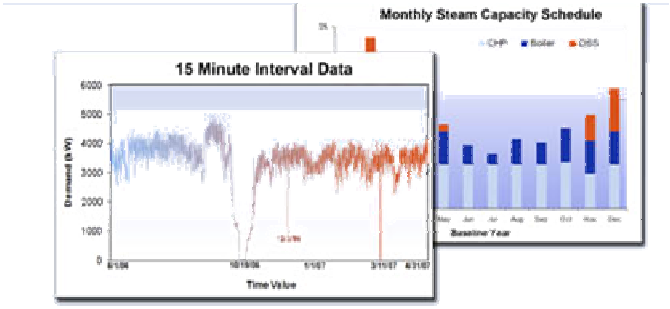
U.S. Department of Energy
Mid-Atlantic Clean Energy Application Center
Promoting CHP, District Energy, and Waste Heat Recovery

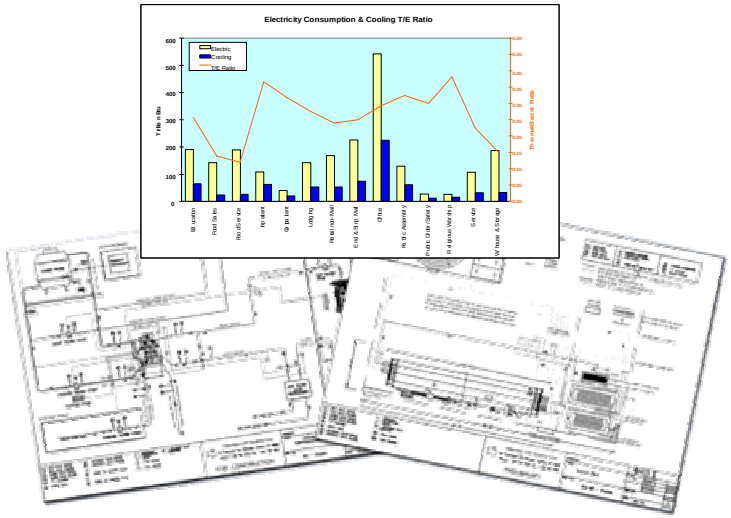
CHP, Waste Heat & District Energy

Module 5: CHP Economics in Pennsylvania

Module 5 Topics

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



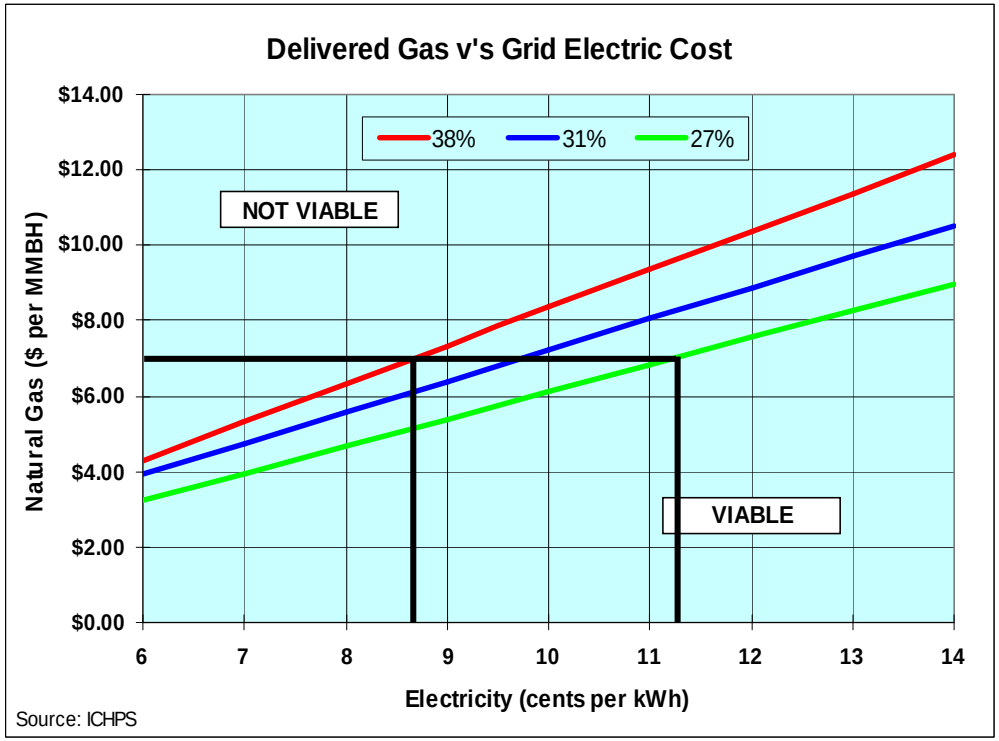


Cost to Generate Power

At a natural gas cost of $7/MMBH, on-site generators will produce power at between 8½ and 11½ cents/kWh*

With high thermal load factor, CHP produces power at an effective 6½ to 9 cents/kWh*

*** Includes maintenance**



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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		
Natural Gas	**$0.70**	/Therm	**Electricity**	**$29.29**	/MMBH
Grid Electricity	**$0.10**	/kWh	**Heating**	**$8.75**	/MMBH
Boiler Efficiency	**80**	%	**Cooling**	**$5.00**	/MMBH
Chiller Efficiency	**0.60**	kW/Ton	**CHP Costs**		
Generator Efficiency	**35**	%	**Fuel**	**$0.075**	/kWh
			Maintenance	**$0.025**	/kWh

Cost to Generate Power with Heat Use

Large IC Engine CHP:

- **Displacing Nat Gas Heating reduces cost to generate by 1/3.**
- **Displacing Electric Heating reduces cost to generate by 1/2.**

Cost to Generate Power including Thermal Offset				
CHP Costs				
Natural Gas Cost	$0.60	$0.70	$0.80	$/Therm
Maintenance Cost	$0.0200	$0.0200	$0.0200	$kWh
Engine				
Electric Efficiency (LHV)	38.0%	38.0%	38.0%	
Electric Efficiency (HHV)	34.5%	34.5%	34.5%	
Thermal Efficiency (HHV)	35.5%	35.5%	35.5%	
Cost to Generate Power Only				
Fuel Input (HHV) per kWh	9,883	9,883	9,883	Btu
Fuel Cost per kWh	$0.059	$0.069	$0.079	@ 1,000 Btu/CF
Maintenance per kWh	$0.0175	$0.0175	$0.0175	Excl HR Equipment
Total Cost per kWh	$0.077	$0.087	$0.097	
Gas Offset @ 100% Thermal Load Factor				
Boiler Efficiency	80%	80%	80%	
Nat Gas Offset per kWh	4,380	4,380	4,380	Btu
Offset Value per kWh	$0.026	$0.031	$0.035	@ 1,000 Btu/CF
Net Cost per kWh	$0.053	$0.059	$0.064	Incl HR Equipment
Electric Heat Offset @ 100% Thermal LF				
Heating Efficiency	99%	99%	99%	
Offset kW Output per kWh	1.04	1.04	1.04	
Total Cost per kWh	$0.039	$0.044	$0.049	Incl HR Equipment

Basic Economics

At power costs of 8¢/kWh and 70¢/Therm, CHP simple payback without incentives is 8.3 years versus electric heat and 11.2 years versus gas heat

CHP Economics				
2009 Average Rate	0.08	/kWh		
Electric Power Rate Increase	0%	Over 2009 Rates		
Future Power Cost	$0.080	$0.080	$0.080	/kWh
CHP Costs				
Natural Gas Cost	$0.60	$0.70	$0.80	$/Therm
Maintenance Cost	$0.020	$0.020	$0.020	$kWh
CHP Economics v's Gas Heating				
Savings per MW	$224,553	$178,758	$132,964	
CapX per MW	$2,000,000	$2,000,000	$2,000,000	
Simple Payback	8.9	11.2	15.0	Years
CHP Economics v's Electric Heating				
Savings per MW	$341,753	$301,372	$260,991	
CapX per MW	$2,500,000	$2,500,000	$2,500,000	
Simple Payback	7.3	8.3	9.6	Years
Electric Heating	$2.37	$/Therm Equivalent Cost		

Basic Economics

At 10¢/kWh and 70¢/Therm, CHP simple payback without incentives is 5.3 years versus electric heat and 5.8 years versus gas heat

CHP Economics				
2009 Average Rate	0.08	/kWh		
Electric Power Rate Increase	25%	Over 2009 Rates		
Future Power Cost	$0.100	$0.100	$0.100	/kWh
CHP Costs				
Natural Gas Cost	$0.60	$0.70	$0.80	$/Therm
Maintenance Cost	$0.020	$0.020	$0.020	$kWh
CHP Economics v's Gas Heating				
Savings per MW	$390,993	$345,198	$299,404	
CapX per MW	$2,000,000	$2,000,000	$2,000,000	
Simple Payback	5.1	5.8	6.7	Years
CHP Economics v's Electric Heating				
Savings per MW	$508,193	$467,812	$427,431	
CapX per MW	$2,500,000	$2,500,000	$2,500,000	
Simple Payback	4.9	5.3	5.8	Years
Electric Heating	$2.96	$/Therm Equivalent Cost		

2 MW w/ Steam & Hot Water

2 MW ICE w/Steam & Hot Water

Engine Selection:	ICE	
Net Power Output:	1,960	kW
Net Steam Output:	3,284	Lbs/hr
Net HW Output:	3,356	MBH
Electric Load Factor:	95%	
Thermal Load Factor:	96%	

Nat Gas Offset	$463,180	$2,088,224
Electric Offset	$1,625,044	
Maintenance	$406,261	$1,553,383
Gas Input	$1,147,122	
Addnl Labor	$0	
	Net Savings:	**$534,841**

Economic Analysis		Input	Variable Power Rate		Base Case	Variable Gas Rate	
Net Capital [1]	$	$3,453,975	$3,453,975	$3,453,975	$3,453,975	$3,453,975	$3,453,975
Grid Power	$/kWh	$0.100	**$0.075**	**$0.110**	$0.100	$0.100	$0.100
Boiler Gas	$/Dtherm	$7.00	$7.00	$7.00	$7.00	**$6.00**	**$8.00**
Annual Costs	$/yr	$1,553,383	$1,553,383	$1,553,383	$1,553,383	$1,389,508	$1,717,258
Annual Savings	$/yr	$2,088,224	$1,681,963	$2,250,729	$2,088,224	$2,022,056	$2,154,393
Net Savings	$/yr	**$534,841**	$128,580	$697,346	$534,841	$632,547	$437,135
Simple Payback	Years	6.5	26.9	5.0	6.5	5.5	7.9
10-Year Net [2]	$	$2,677,379	($1,979,947)	$4,540,310	$2,677,379	$3,797,469	$1,557,290

Notes: 1 Capital cost includes Federal 10% ITC

2 Includes 3% cost escalation per year for all utilities and engine maintenance

77% simple ROI over 10 years

2 MW w/ Steam & Chilled Water

2 MW ICE w/Steam & Cooling

Engine Selection:	ICE	
Net Power Output:	1,960	kW
Steam Output:	3,284	Lbs/hr
Cooling Output:	206	Tons/hr
Electric Load Factor:	95%	
Thermal Load Factor:	96%	

Nat Gas Offset	$242,544	$1,964,671
Electric Offset	$1,722,127	
Maintenance	$406,261	$1,553,383
Gas Input	$1,147,122	
Addnl Labor	$0	
	Net Savings:	**$411,288**

Economic Analysis		Input	Variable Power Rate		Base Case	Variable Gas Rate	
Net Capital	$	$3,784,725	$3,784,725	$3,784,725	$3,784,725	$3,784,725	$3,784,725
Grid Power	$/kWh	$0.100	$0.075	$0.110	$0.100	$0.100	$0.100
Boiler Gas	$/Dtherm	$7.00	$7.00	$7.00	$7.00	$0.00	$0.00
Annual Costs	$/yr	$1,553,383	$1,553,383	$1,553,383	$1,553,383	$1,389,508	$1,717,258
Annual Savings	$/yr	$1,964,671	$1,534,139	$2,136,884	$1,964,671	$1,930,022	$1,999,320
Net Savings	$/yr	**$411,288**	($19,244)	$583,501	$411,288	$540,514	$282,063
Simple Payback	Years	9.2	N/A	6.5	9.2	7.0	13.4
10-Year Net [1]	$	$930,233	($4,005,331)	$2,904,459	$930,233	$2,411,658	($551,192)

Notes:

1 Includes 3% cost escalation per year for all utilities and engine maintenance

2 Includes 3% cost escalation per year for all utilities and engine maintenance

2 MW ICE, 95% Electric LF, 100% Thermal LF

2 MW ICE w/Steam & Hot Water

Engine Selection:	ICE	
Net Power Output:	1,960	kW
Net Steam Output:	3,284	Lbs/hr
Net HW Output:	3,356	MBH
Electric Load Factor:	95%	
Thermal Load Factor:	100%	

Nat Gas Offset	$502,583	$2,127,627
Electric Offset	$1,625,044	
Maintenance	$406,261	$1,553,383
Gas Input	$1,147,122	
Addnl Labor	$0	
	Net Savings:	**$574,244**

Economic Analysis		Input	Variable Power Rate	Base Case	Variable Gas Rate
Net Capital [1]	$	$3,453,975		$3,453,975	
Grid Power	$/kWh	$0.100		$0.100	
Boiler Gas	$/Dtherm	$7.00		$7.00	
Annual Costs	$/yr	$1,553,383		$1,553,383	
Annual Savings	$/yr	$2,127,627		$2,127,627	
Net Savings	$/yr	**$574,244**		$574,244	
Simple Payback	Years	6.0		6.0	
10-Year Net [2]	$	$3,129,085		$3,129,085	

Notes: 1 Capital cost includes Federal 10% ITC

2 Includes 3% cost escalation per year for all utilities and engine maintenance

2 MW ICE, 95% Electric LF, 50% Thermal LF

2 MW ICE w/Steam & Hot Water

Engine Selection:	ICE	
Net Power Output:	1,960	kW
Net Steam Output:	3,284	Lbs/hr
Net HW Output:	3,356	MBH
Electric Load Factor:	95%	
Thermal Load Factor:	50%	

Nat Gas Offset	$162,082	$1,787,126
Electric Offset	$1,625,044	
Maintenance	$406,261	$1,553,383
Gas Input	$1,147,122	
Addnl Labor	$0	
	Net Savings:	**$233,743**

Economic Analysis		Input	Variable Power Rate	Base Case	Variable Gas Rate
Net Capital [1]	$	$3,453,975		$3,453,975	
Grid Power	$/kWh	$0.100		$0.100	
Boiler Gas	$/Dtherm	$7.00		$7.00	
Annual Costs	$/yr	$1,553,383		$1,553,383	
Annual Savings	$/yr	$1,787,126		$2,127,627	
Net Savings	$/yr	**$233,743**		$574,244	
Simple Payback	Years	14.8		6.0	
10-Year Net [2]	$	($774,376)		$3,129,085	

Notes: 1 Capital cost includes Federal 10% ITC

2 Includes 3% cost escalation per year for all utilities and engine maintenance

2 MW ICE, 95% Electric LF, 0% Thermal LF

2 MW ICE w/Steam & Hot Water

Engine Selection:	ICE	
Net Power Output:	1,960	kW
Net Steam Output:	3,284	Lbs/hr
Net HW Output:	#DIV/0!	MBH
Electric Load Factor:	95%	
Thermal Load Factor:	0%	

Nat Gas Offset	$0	$1,625,044
Electric Offset	$1,625,044	
Maintenance	$406,261	$1,553,383
Gas Input	$1,147,122	
Addnl Labor	$0	
	Net Savings:	**$71,661**

Economic Analysis		Input	Variable Power Rate	Base Case	Variable Gas Rate
Net Capital [1]	$	$3,453,975		$3,453,975	
Grid Power	$/kWh	$0.100		$0.100	
Boiler Gas	$/Dtherm	$7.00		$7.00	
Annual Costs	$/yr	$1,553,383		$1,553,383	
Annual Savings	$/yr	$1,625,044		$2,127,627	
Net Savings	$/yr	**$71,661**		$574,244	
Simple Payback	Years	48.2		6.0	
10-Year Net [2]	$	($2,632,465)		$3,129,085	

Notes: 1 Capital cost includes Federal 10% ITC

2 Includes 3% cost escalation per year for all utilities and engine maintenance

Emissions

- **Environmental Impact**
- **2 MW Recip Engine w/ Cooling & Heating**

This reduction is equal to removing the carbon that would be absorbed by 2,289 acres of forest

This reduction is equal to removing the carbon emissions of 1,835 cars

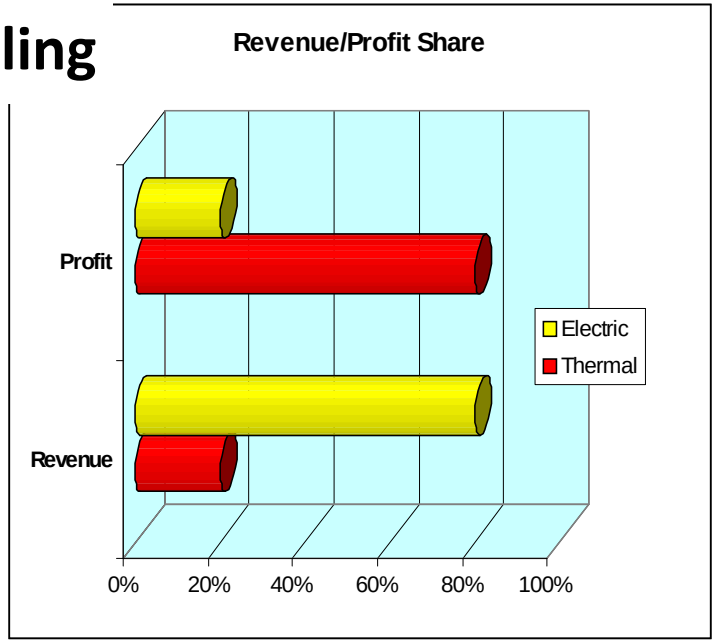
Annual Emissions Analysis					
	CHP System	Displaced Electricity Production	Displaced Thermal Production	Emissions/Fuel Reduction	Percent Reduction
NOx (tons/year)	1.72	22.82	2.01	23.11	93%
SO2 (tons/year)	0.05	112.36	0.01	112.32	100%
CO2 (tons/year)	9,116	17,875	2,350	11,109	55%
Carbon (metric tons/year)	2,254	4,420	581	2,747	55%
Fuel Consumption (MMBtu/year)	156,232	187,583	40,282	71,633	31%
Acres of Forest Equivalent				2,289	
Number of Cars Removed				1,835	

This CHP project will reduce emissions of Carbon Dioxide (CO2) by 11,109 tons per year

This is equal to 2,747 metric tons of carbon equivalent (MTCE) per year

Conclusions

- Electricity at 10 ¢/kWh
- Gas at $7.00 to $8.00 per Dtherm
- 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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