



# Basic CHP Evaluation

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**Midwest CHP Application Center (MAC)**

**[www.CHPCenterMW.org](http://www.CHPCenterMW.org)**

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*University of Illinois at Chicago  
Energy Resources Center*

# Five Levels of Development

1. **Screening Walk-Through and Basic CHP Evaluation**
2. **Detailed Financial Analysis**
3. **Concept Design**
4. **Engineering Plans**
5. **Build**

# Operational Considerations

- **Hours of Operation**
  - **How Many Hours is the Building Used/Occupied?**
  - **How Many Hours is it Desirable to Operate the Generator?**  
*(Electrical Load verses Demand)*
  - **Does the Local Electric Utility Have Peak Demand Periods?**
    - » **When Are They?**

# Operational Considerations

- **Thermal Coincidence** (*Thermal Capacity*)
  - **When Are Your Loads?**
  - **Does the Electrical Load Occur at the Same Time as the Thermal Load?**
    - » **Seasonal (Winter and Summer)**
    - » **Daily**
  - **Better Balance = Higher Efficiency = Better Payback**
    - » **What Can Be Done to Balance?**
      - **Winter Heating – Give Me!**
      - **Absorption Chillers**
      - **Desiccant Dehumidification**
      - **Energy Storage ????**

# Operational Considerations

- Sell Back Electricity?

- Will the System Meet the PURPA Minimum Qualifying Efficiency?

$$\text{QF Efficiency} = \frac{\text{Generator Power} + \frac{1}{2} \text{ Useful Thermal Energy}}{\text{Fuel Input (BTU/h in LHV)}}$$

$$\text{QF} > 42.5\% \text{ (or } 45\% \text{ if } < 15\% \text{ Thermal Recovery)}$$

- Is the Cost to Generate Greater than to Buy?
- Increases the Time Generator Operates, But is There a Corresponding Thermal Load?

# Component Considerations

- **Prime Movers**
  - **Engine Generator Sets**
    - » **Natural Gas**
    - » **Diesel**
  - **Turbines**
    - » **Gas**
    - » **Steam**
  - **Microturbines**
  - **Fuel Cells**
    - » **PAFC**

# Component Considerations

- **Chillers**
  - **Electric**
  - **Motor Driven**
  - **Absorption**
- **Desiccants**

# Fuels

## Heating Values:

**Higher Heating Value (HHV) = Total energy from combustion process.**

**Lower Heating Value (LHV) = Assumes heat of the water in the fuel cannot be recovered.**

*LHV is used for majority of calculations.*

	<u>Units</u>	<u>LHV</u>	<u>HHV</u>	<u>LHV/HHV</u>
Natural Gas	<i>BTU/CF</i>	950	1,050	0.905
#2 Fuel Oil	<i>BTU/Gallon</i>	130,000	138,300	0.940
#6 Fuel Oil	<i>BTU/Gallon</i>	143,000	150,500	0.950
Propane	<i>BTU/Gallon</i>	84,650	92,000	0.920
Sewage/Landfill	<i>BTU/CF</i>	350	380	0.921
Coal <i>Bituminous</i>	<i>BTU/lbm</i>	13,600	14,100	0.965



# Simple Payback

- **Shows Here and Now**

- **Based on Past Year of Costs Verses What They Would Have Been with CHP**
- **Annual Saving Based on Status Quo**
  - » **Deregulation?**
    - Gas
    - Electric
  - » **Current Operational Characterization?**
- **Power Reliability or Quality Issues?**
- **Power Security?**
- **Cost of Money?**

# Simple Payback

- **Gas Prices**
  - **Hedges Costs Because Recovered Heat Displaces Gas for Thermal Use**
- **Electric Deregulation**
  - **Likely Drive Peak Demand Costs ↑**
- **Peak Electric Costs Linked to Gas Costs**
  - **Central Generation Peaker Units Mostly Gas Fired**
  - **Central Generation \$s More Sensitive to Gas Price ↑ than CHP Because Lower Efficiencies**

# Simple Payback

- **Bottom Line**

**Come Out \$\$\$ Ahead**

- **Other Considerations**

- **Reliability**
- **Energy Conservation**
- **Environmental Benefits**

# Basic CHP Evaluation Tool

- **Enter Information**
  - Record Energy Use and Identify Facility
- **Create Baseline Profiles**
  - Determine Annual Energy Characteristics
    - » How Many Hours Was the Average Monthly Load Above a Base Point
  - Helps Size Equipment
- **CHP Recommendations and Choices**
  - Recommendations Based on Annual T/E Ratio and Load Profile
    - » Commercial / Institutional: Sized 40% – 60% of Peak Load
    - » Industrial: Sized on Load at 6000 Hours

# Basic CHP Evaluation Tool

- **Create CHP Profiles**
  - **Overview of Contribution from CHP**
- **Results ( $\pm 30\%$ )**
  - **Financial**
    - » **Estimated System Cost**
    - » **Annual Savings**
    - » **Simple Payback**
    - » **Cost per kWh to Generate**
  - **Engineering**
    - » **Electric and Thermal Energy Contributions**

# Enter General Information

Facility Name	Street Address	City	State	Zipcode
Prime Gen Co	1234 W. Main St	Anycity	MN	
Facility Type	SIC	Classification		
		Commercial		
Contact	Title	E-Mail Address	Phone Number	Fax Number

- **Company Information**

- Name
- Location
- Contact
- Type of Facility
  - » Commercial
  - » Institutional
  - » Industrial

# Enter Energy Use Information

	Electricity			Fuels			
	Energy	Peak Demand	Cost	Gas		Fuel Oil	#2
				Energy	Cost	Energy	Cost
<i>kWh</i>	<i>kW</i>	\$	<i>Therms</i>	\$	<i>Gallons</i>	\$	
Jan-01	1,061,658	1,787	\$54,806	89,551	\$43,940		
Feb-01	961,300	1,783	\$51,674	76,663	\$37,128		
Mar-01	1,076,400	1,988	\$57,739	73,200	\$35,919		
Apr-01	1,184,300	1,915	\$57,302	52,176	\$25,603		
May-01	1,074,067	2,170	\$63,035	41,784	\$20,319		
Jun-01	1,225,800	2,261	\$93,634	44,113	\$20,965		
Jul-01	1,309,200	2,362	\$98,890	48,092	\$23,385		
Aug-01	1,308,100	2,372	\$100,645	51,536	\$25,072		
Sep-01	1,193,000	2,173	\$90,270	38,213	\$18,584		
Oct-01	1,144,100	2,069	\$60,259	44,146	\$21,669		
Nov-01	1,054,900	2,036	\$56,555	56,680	\$27,817		
Dec-01	1,061,600	1,801	\$54,653	82,297	\$40,431		

- **Electric**

- Energy (*kWh*)
- Demand (*kW*)
- Monthly \$\$

- **Gas**

- Energy (*Therms*)
- Monthly \$\$

- **Fuel Oil**

- Quantity Used (*Gallons*)
- Monthly \$\$

# Assess & Enter Operating Hours

Estimated Hours of Operation	Electric Generators	Absorption Chillers
	3,200 Hours/Year	846 Hours/Year

## Assess Operating Hours

### – Commercial/Institutional

#### » Building Occupancy

- 9 Hours/Day ~ 2400 Hours/Year
- Peak Demand ~ 3200 Hours/Year

#### » Absorption Chillers

- 3 Months ~ 850 Hours/Year  
*During Peak Summer Demand*

### – Industrial

- » 2 Shifts ~ 4200 Hours/Year
- » 3 Shifts ~ 6300 Hours/Year
- » Continuous = 8760 Hours/Year



# Enter Miscellaneous Information

<b>Sell Back Desired</b>	<b>Yes</b>		
Electric Sell Back Price:	<b>1.500</b>	¢/kWh	
Cogen Initial Fuel Cost:	<b>3.50</b>	\$/MMBTU	
W/O Cogen Fuel Cost:	<b>4.00</b>	\$/MMBTU	
Existing Boiler Efficiency:	<b>80</b>	%	
Standby Demand Charge:	<b>\$3.25</b>	\$/kw/month	

## Indicate:

- **Desire to Sell Back**
- **Electric Sell Back Price**
- **Cogen Initial Fuel Cost**
- **W/O Cogen Fuel Cost**
- **Existing Boiler Efficiency**
- **Standby Demand Charge**

# Enter Data

## Step 1: Enter Site Data

Facility Name	Street Address	City	State	Zipcode
Nowhere Inc.	1234 W. Main St	Anycity	IL	
Facility Type	SIC	Classification		
		Institutional		
Contact	Title	E-Mail Address	Phone Number	Fax Number

	Electricity			Fuels			
	Energy	Peak Demand	Cost	Gas		Fuel Oil	#2
				Energy	Cost	Energy	Cost
	kWh	kW	\$	Therms	\$	Gallons	\$
Jan-01	1,061,658	1,787	\$54,806	89,551	\$43,940		
Feb-01	961,300	1,783	\$51,674	75,663	\$37,428		
Mar-01	1,078,400	1,988	\$57,739	73,200	\$35,919		
Apr-01	1,184,300	1,915	\$57,302	52,176	\$25,603		
May-01	1,074,067	2,170	\$63,835	41,704	\$20,319		
Jun-01	1,225,800	2,261	\$93,634	44,113	\$20,365		
Jul-01	1,309,200	2,362	\$98,890	48,892	\$23,385		
Aug-01	1,308,100	2,372	\$100,645	51,536	\$25,072		
Sep-01	1,193,000	2,173	\$90,270	38,213	\$18,584		
Oct-01	1,144,100	2,069	\$60,259	44,146	\$21,669		
Nov-01	1,054,900	2,036	\$56,555	56,680	\$27,817		
Dec-01	1,061,600	1,801	\$54,653	82,297	\$40,431		

Sell Back Desired	No
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Electric Sell Back Price:	1.500 ¢/kWh
Supplemental Elect. Cost:	3.206 ¢/kWh
Cogen Initial Fuel Cost:	3.50 \$/MMBTU
W/O Cogen Fuel Cost:	4.00 \$/MMBTU
Existing Boiler Efficiency:	70 %
Standby Demand Charge:	\$3.25 \$/kw/month

Estimated Hours of Operation	Electric Generators	Absorption Chillers
	6,300 Hours/Year	846 Hours/Year

Enter Information in Yellow Fields!



**Example: 500,000 ft<sup>2</sup> Hospital in MN**

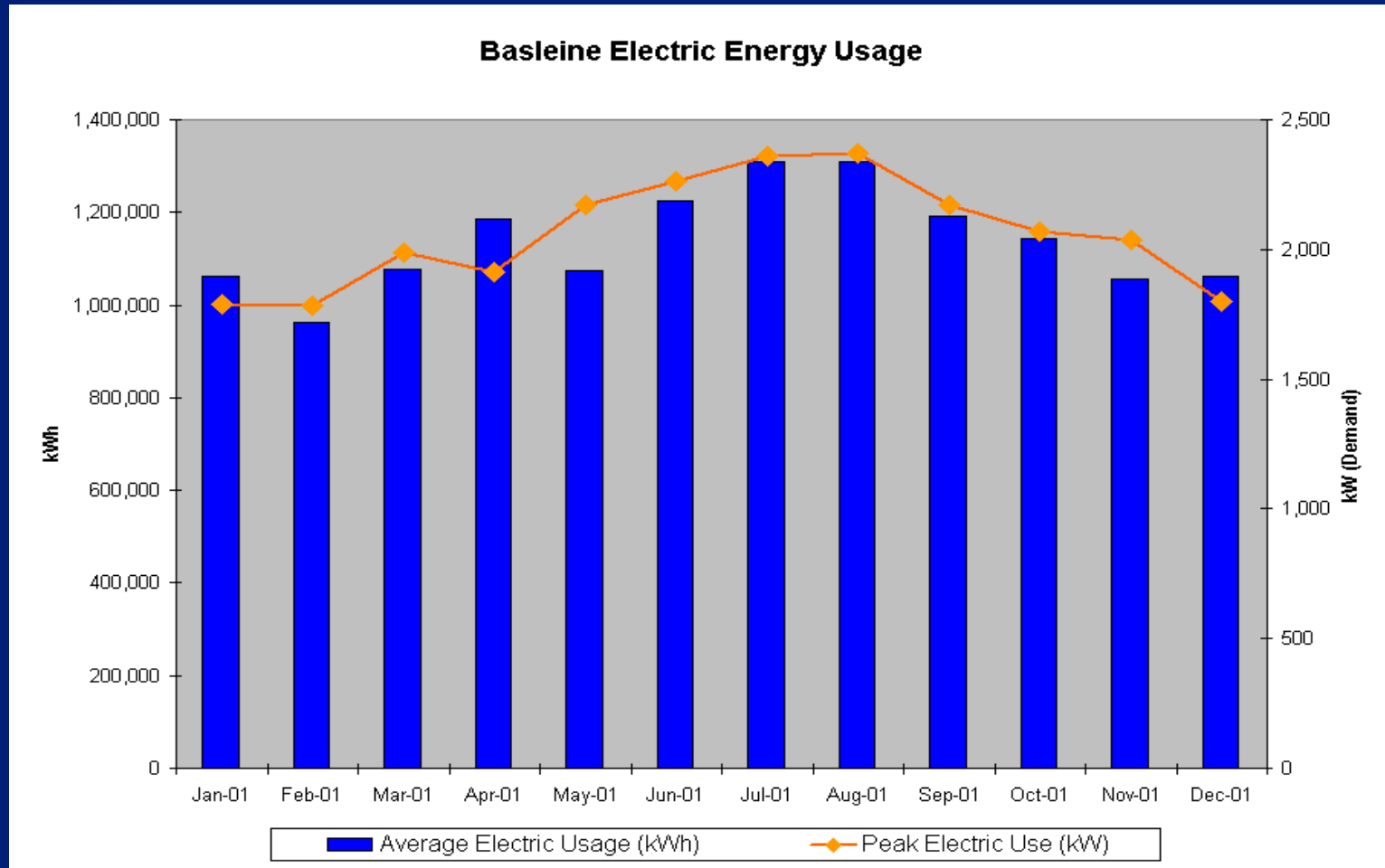


# Create Baseline Electric Profile

		Electric				kWe @		Hours > System
		Energy	Peak	Average	Cumulative	16,425	Hours	Capacity
Month	Hour/Month	kWh	kW	kW	Hours	1,427		8,760
			2,372	1,760	0			
Jul-01	744	1,309,200	2,362	1,760	372			
Aug-01	744	1,308,100	2,372	1,758	1,116			
Jun-01	720	1,225,800	2,261	1,703	1,848			
Sep-01	720	1,193,000	2,173	1,657	2,568			
Apr-01	720	1,184,300	1,915	1,645	3,288			
Oct-01	744	1,144,100	2,069	1,538	4,020			
Nov-01	720	1,054,900	2,036	1,465	4,752			
Mar-01	744	1,078,400	1,988	1,449	5,484			
May-01	744	1,074,067	2,170	1,444	6,228			
Feb-01	672	961,300	1,783	1,431	6,936			
Jan-01	744	1,061,658	1,787	1,427	7,644			
Dec-01	744	1,061,600	1,801	1,427	8,388			
				1,427	8,760			
<b>Total</b>	8,760	13,656,425						

**Step 2: Click Here to Create Baseline Electric Load Profile**

# Baseline Results

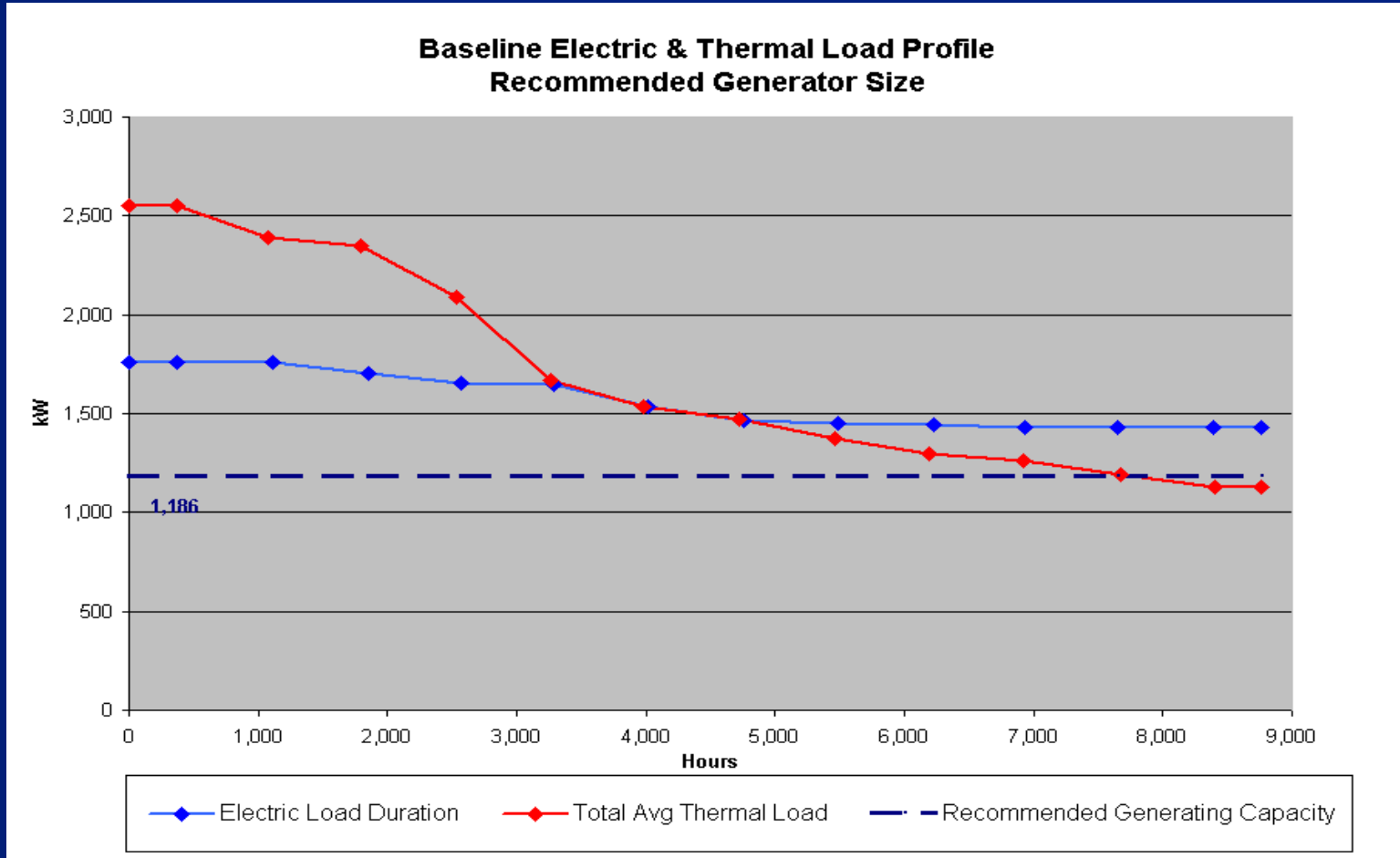


# Create Baseline Thermal Profile

		Total Thermal Use			Hours > System Capacity
Month	Hour/Month	Average Demand <i>BTU/h</i>	Average Demand <i>kWt</i>	Cumulative <i>Hours</i>	
		6,481,786,667	2,553	0	8,760
Jan-01	744	6,481,786,667	2,553	372	
Feb-01	672	5,476,560,000	2,388	1,080	
Dec-01	744	5,956,735,238	2,346	1,788	
Mar-01	744	5,298,285,714	2,087	2,532	
Nov-01	720	4,102,552,381	1,670	3,264	
Apr-01	720	3,776,548,571	1,537	3,984	
Aug-01	744	3,730,224,762	1,469	4,716	
Jul-01	744	3,480,944,762	1,371	5,460	
Jun-01	720	3,192,940,952	1,299	6,192	
Oct-01	744	3,195,329,524	1,258	6,924	
May-01	744	3,024,365,714	1,191	7,668	
Sep-01	720	2,765,893,333	1,126	8,400	
		2,765,893,333	1,126	8,760	
<b>Total</b>	8,760	50,482,167,619			

Step 3: Click Here to Create Baseline Thermal Load Profile

# Baseline Results



# CHP Recommendations and Choices

## Step 4: Enter CHP Equipment Data

Thermal-to-Electric Ratio = 1.08

Recommended Prime Mover(s)	
Gas Engine	Recommended
Microturbine	
Gas Turbine (Simple Cycle)	Recommended
Phosphoric Acid Fuel Cells	

Select Prime Mover	Gas Turbine (Simple)
Recommended Generation	1,186 kWe
Chose Size (per Unit)	600 kWe
Chose Number of Units	2 Unit(s)
Total Selected Capacity	1,200 kWe
Electric Efficiency	27 %
Gross Heat Rate Exhaust (LHV)	9,225 BTU/kWe
Recoverable Heat Rate (LHV)	4,613 BTU/kWe
O&M Costs	\$0.0090 \$/kWh/yr
Electric Use	0.0000 kWe/kWh

Select Absorption Chiller	Yes
Chose Size (per Unit)	326 RT
Thermal Input	5,535 MBTU/hr
O&M Costs	\$30 \$/RT/yr
Electric Use	0.0300 kWe/RT
Electric Displaced	0.6000 kWe/RT

Select Desiccant	No
Chose Size (per Unit)	SCFM
Chose Number of Units	Unit(s)
Total Selected Capacity	0 SCFM
Thermal Input	0 BTU/hr
O&M Costs	\$0 \$/SCFM/yr
Electric Use	0.0000 kWe/SCFM

Costs		Estimated*	Known
Generator	\$1,015 per kWe	\$1,218,000	
Heat Recovery Unit*		Included	
Absorption Chiller	\$550 per RT	\$179,074	
Desiccant	NONE per SCFM	\$0	
Installation*		Included	
Other			
<b>Total</b>		<b>\$1,397,074</b>	

\* Estimated Costs includes heat recovery unit and installation costs.

Electric Use		
Estimated*	Known	Total kWh/Year
0.0	kWe	0 kWh
<b>Included</b>	kWe	0 kWh
9.8	kWe	9,377 kWh
0.0	kWe	0 kWh
	kWe	0 kWh
<b>9.8</b>	<b>kWe</b>	<b>9,377 kWh</b>

Total Electric Displaced by Non-Electric Chillers	
195 kWe	165,269 kWh



# Create CHP Electrical Profile

		Electric				kWe @		Hours > System
		Energy	Peak	Average	Cumulative	3,200	Hours	Capacity
Month	Hour/Month	kWh	kW	kW	Hours	1,471		8,760
				1,657	0			
Sep-01	720	1,193,000	2,173	1,657	360			
Apr-01	720	1,184,300	1,915	1,645	1,080			
Jun-01	720	1,110,067	1,577	1,542	1,800			
Oct-01	744	1,144,100	2,069	1,538	2,532			
Nov-01	720	1,054,900	2,036	1,465	3,264			
Mar-01	744	1,078,400	1,988	1,449	3,996			
Jul-01	744	1,077,734	1,678	1,449	4,740			
Aug-01	744	1,076,634	1,688	1,447	5,484			
May-01	744	1,074,067	2,170	1,444	6,228			
Feb-01	672	961,300	1,783	1,431	6,936			
Jan-01	744	1,061,658	1,787	1,427	7,644			
Dec-01	744	1,061,600	1,801	1,427	8,388			
				1,427	8,760			
<b>Total</b>	8,760	13,656,425						

**Step 5: Click Here to Create CHP Electric Load Profile**

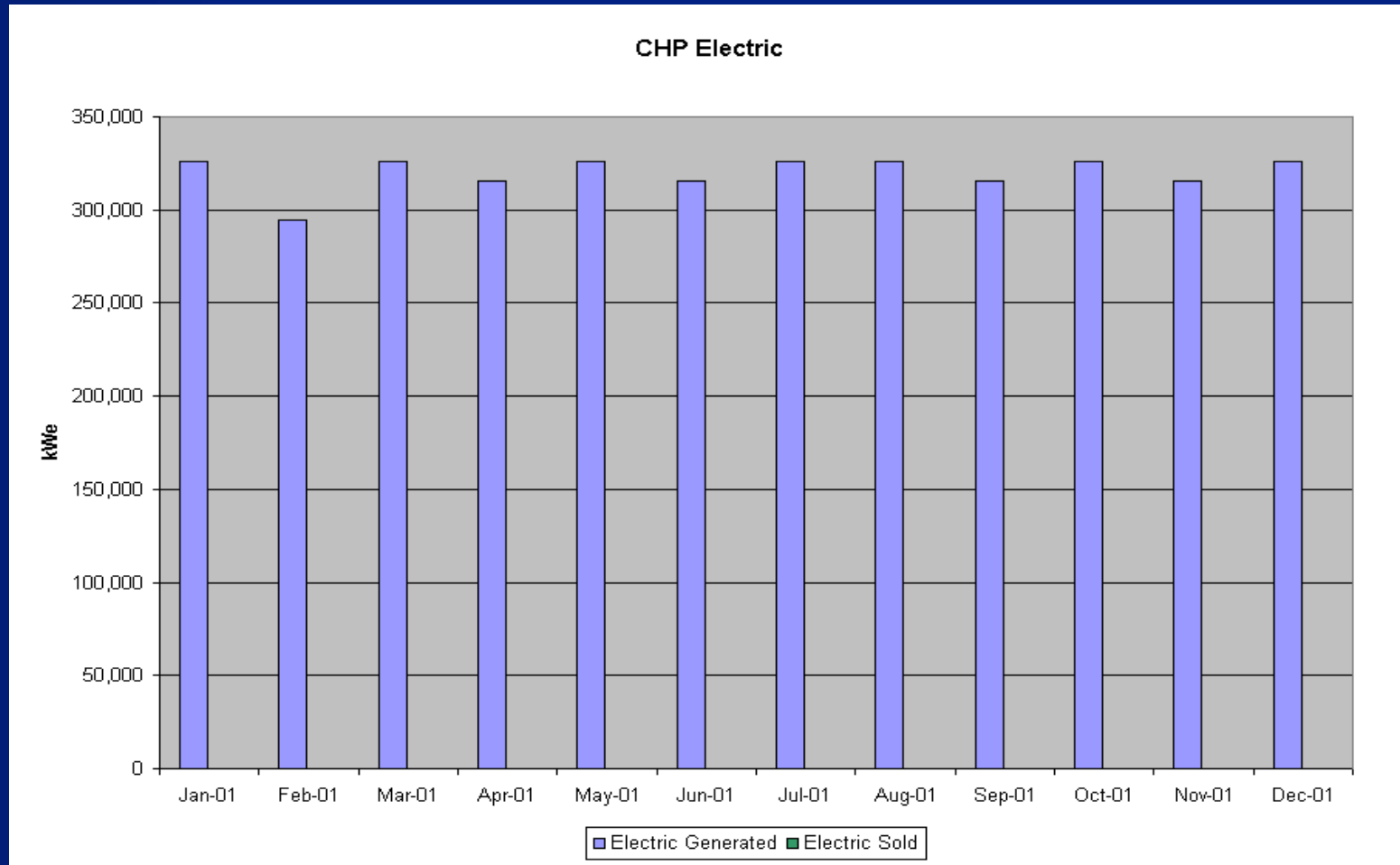


# Create CHP Generation Profile

		Electric Generation Electricity (Estimated)			Electric Generation Thermal (Estimated)				
		Generated Energy	Average Power	Electric Sold	Energy	Average Output	Cumulative		
Month	Hour/Month	kWhe	kWe	kWhe	kWh	kWh	Hours	<b>Electric Capacity Factor</b>	
								73.1%	With Sell Back
Jan-01	744	326,137	438		440,786	592	372		
Feb-01	672	294,575	438		398,129	592	1,080		
Mar-01	744	326,137	438		440,786	592	1,788		
Apr-01	720	315,616	438		426,567	592	2,520		
May-01	744	326,137	438		440,786	592	3,252		
Jun-01	720	315,616	438		426,567	592	3,984	<b>PURPA</b>	
Jul-01	744	326,137	438		440,786	592	4,716	(Assuming Gas or Liquid Fuel Fired)	
Aug-01	744	326,137	438		440,786	592	5,460	Efficiency	52.0 %
Sep-01	720	315,616	438		426,567	592	6,192	Qualified Facility	Yes
Nov-01	720	315,616	438		426,567	592	6,912	Sell Back	0 kWh
Dec-01	744	326,137	438		440,786	592	7,644	Sell Back Desired	Yes
Oct-01	744	326,137	438		440,786	592	8,388		
			438			592	8,760		
<b>Total</b>	8,760	3,840,000			5,189,894	592			
<b>Average</b>	730	320,000	438		432,491	592			

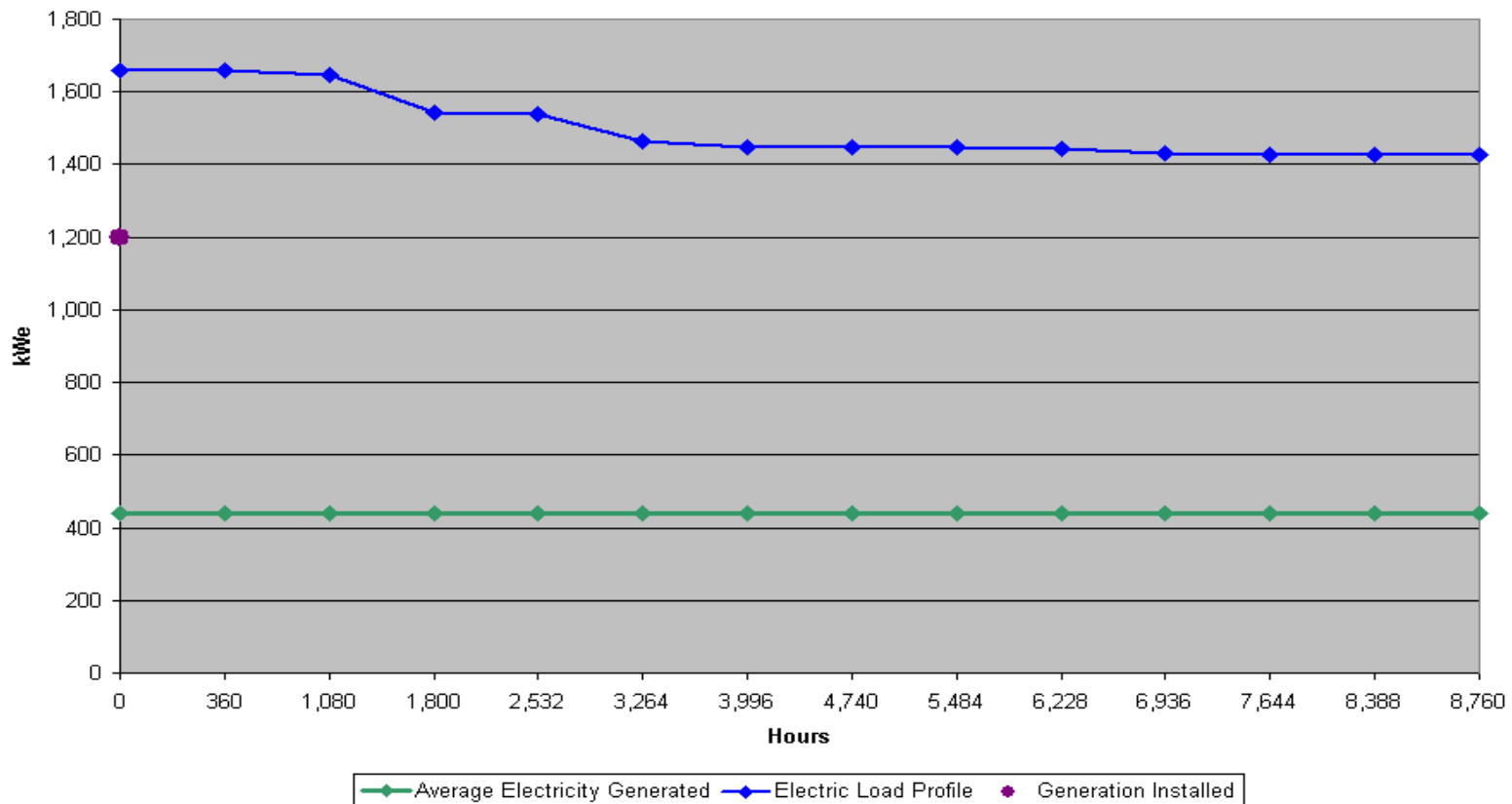
Step 6: Click Here to Create CHP Electric and Thermal Generation

# CHP Electric Generation



# CHP Electric Load to Generation

Comparison of Generation to CHP Electric Load



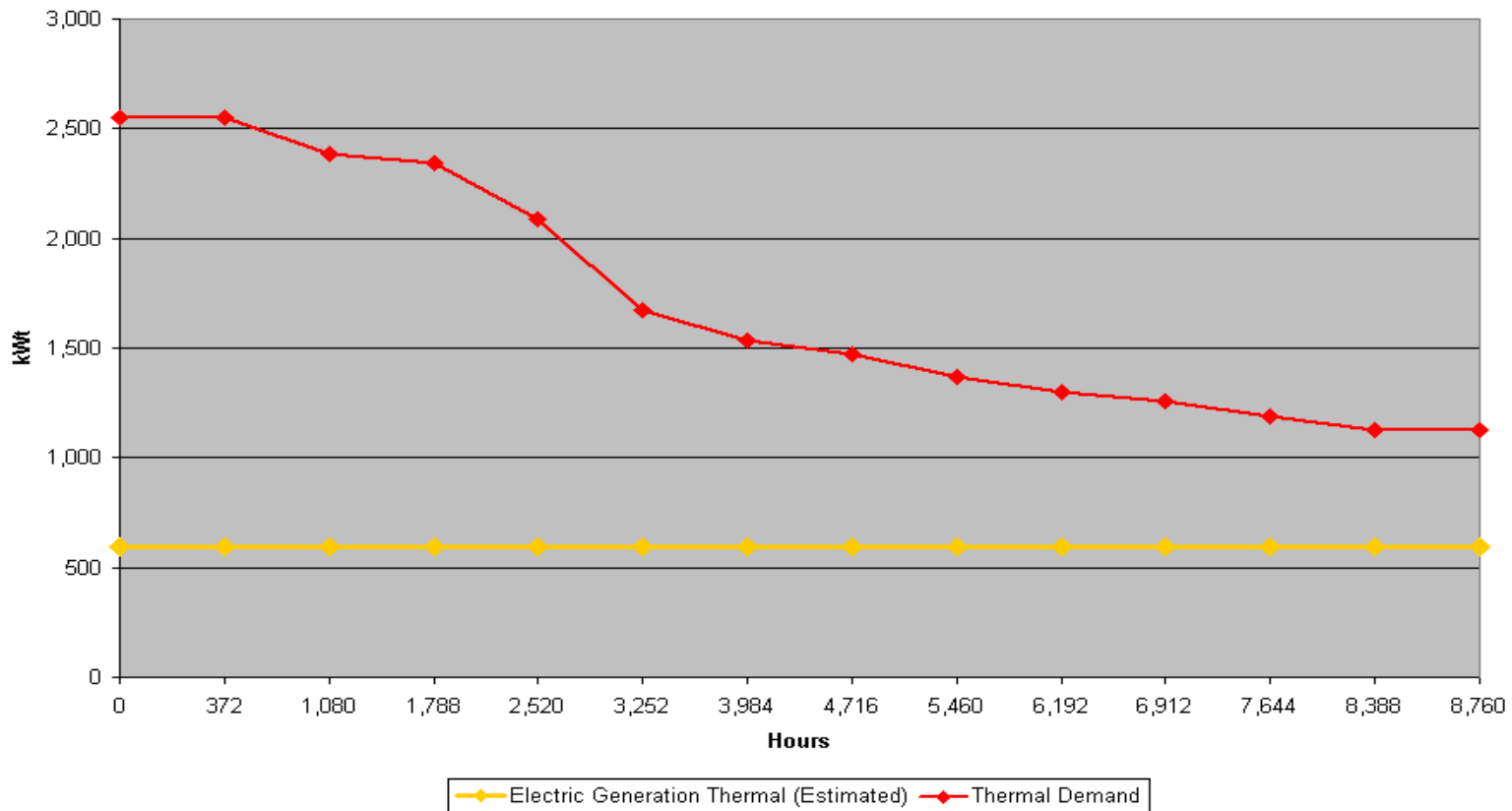
# Create CHP Thermal Profile

		Total Thermal Use			
		Including TAT Load	Average Demand	Cumulative	Hours > System Capacity
Month	Hour/Month	<i>BTU/h</i>	<i>kWt</i>	<i>Hours</i>	8,760
		6,481,786,667	1,899,258	0	
Jan-01	744	6,481,786,667	2,553	372	Thermal Capacity Factor
Feb-01	672	5,476,560,000	2,388	1,080	100%
Dec-01	744	5,956,735,238	2,346	1,788	
Mar-01	744	5,298,285,714	2,087	2,532	
Nov-01	720	4,102,552,381	1,670	3,264	
Apr-01	720	3,776,548,571	1,537	3,984	
Aug-01	744	3,735,759,784	1,471	4,716	
Jul-01	744	3,486,479,784	1,373	5,460	
Jun-01	720	3,198,475,975	1,302	6,192	
Oct-01	744	3,195,329,524	1,258	6,924	
May-01	744	3,024,365,714	1,191	7,668	
Sep-01	720	2,765,893,333	1,126	8,400	
		2,765,893,333	1,126	8,760	
<b>Total</b>	8,760	50,498,772,686			

Step 7: Click Here to Create CHP Thermal Load Profile

# CHP Thermal Results

Thermal Demand vs CHP Generation Thermal



# CHP Results

SITE			RESULTS		
Prime Gen Co 1234 W. Main St Anycity MN					
ASSUMPTIONS			CHP RESULTS		
Average Electric Cost	6.147	¢/kWh	<b>Prime Mover</b>		
Initial Electric Sell Back	1.500	¢/kWh	Total ECP Cost	\$1,397	\$(1000)
Supplemental Elect Cost	6.147	¢/kWh	Prime Mover	Gas Turbine (Simple Cycle)	
Cogen Initial Fuel Cost	3.50	\$/MMBTU	Parasitic Load	9.8 kW	
W/O Cogen Fuel Cost	4.00	\$/MMBTU	Total Generation Capacity	1,200 kW	
Existing Boiler Efficiency	80.0	%	Electrical Output	3,840 MWh	
Standby Demand Charge	\$3.25	\$/kw/month	Absorption Chiller Credit	165 MWh	
Standby Capacity Required	600	kW	Net Total Generation Effect	4,005 MWh	
O&M Charge	\$9,802	\$/yr	Eleelectric Capacity Factor	73 %	
Annual Electric Load	13,656	MWh	Gross Heat Rate (LHV)	12,640 BTU/kWh	
Annual Heat Load	50,482	MMBTU	Recoverable Heat	4,813 BTU/kWh	
<b>PURPA</b> (Assuming Gas or Liquid Fuel Fired)			<b>Thermal Loads</b>		
Efficiency	52.0	%	TAT Thermal Loads (June, July, August)		
Qualified Facility	Yes		Absorption Chiller	4,883	MMBTU
Sell Back	0	kWh	Desiccant	0	MMBTU
Sell Back Desired	Yes		Total Thermal Load with TAT	55,165	MMBTU
			Thermal Capacity Factor	100 %	
			Thermal Energy Output		
			From Generator	1,771	MMBTU
			From Auxiliary Boiler	48,711	MMBTU
<b>FINANCIAL RESULTS</b>			<b>Fuel Requirements:</b>		
<b>COSTS WITHOUT COGENERATION \$(1000)</b>			For Generator (HHV)	53,647	MMBTU
Electricity Costs		\$839	For Auxiliary Boiler (HHV)	67,298	MMBTU
Thermal Energy Costs		\$341			
	<b>TOTAL</b>	\$1,180			
<b>COSTS WITH COGENERATION \$(1000)</b>					
Supplemental Electric Purchase		\$593			
Fuel		\$423			
Electricity Sold		\$0			
O&M		\$10			
Standby Charges		\$23			
	<b>TOTAL</b>	\$1,050			
	<b>SAVINGS</b>	<b>\$131</b>			
	<b>SIMPLE PAYBACK</b>	<b>10.70 Years</b>			
			<b>Generation Costs</b>	<b>4.89</b>	<b>¢/kWh</b>



# CHP Results

- **Idea of Type and General Size of Equipment**
- **± 30% Assessment of Cost**
  - **Better with Better Numbers**
    - » **Equipment Costs and Sizing**
    - » **Operational Considerations**
- **Simple Payback**
- **Viability**
- **Next Steps?**

# Next Steps

- **Identified Potential Show Stoppers**
  - Too Costly or Poor Payback
  - Engineering Limitations
  - Regulatory Restrictions
- **Considered Possible Locations**
  - Inside/Outside
  - New Building
- **Look for Load Balancing Possibilities**
  - Operating Hour Changes
  - Energy Storage



# Five Levels of Development

- ✓ 1. **Screening Walk-Through and Basic CHP Evaluation**
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