The EPA CHP Partnership: Waste Heat to Power

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ICF International

Heat Is Power Annual Meeting

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ICF has been a Technical Support Contractor to the EPA CHP Partnership since 2001

- Market analysis
- Policy analysis
- Technical assistance
- Tools and outreach materials

EPA & Combined Heat and Power

- The EPA CHP Partnership (CHPP) is a **voluntary program** that seeks to reduce the environmental impact of power generation by promoting the use of **highly efficient CHP.**
- Through 2011, **CHPP industry partners** worked on more than 550 CHP projects representing more than 5,300 MW of new installed capacity.
- The CHPP offers services and tools for Partners to assist with CHP project development, overcome regulatory barriers, transform markets ripe for CHP, and provide crucial public recognition.

Overview of CHPP Tools and Resources

- Three types
  - General education and outreach
  - Technical assistance for candidate sites
  - Public recognition
- All tools and resources available for free
  - Education and outreach materials available to everyone
  - Technical assistance available to Partners
  - Partners nominate award candidates
- All Partnership tools and resources available on CHPP website:

  www.epa.gov/chp

Current Policy Support

- Output-based standards
  - How to incorporate CHP output credits
- Methodology to estimate energy and CO2 savings
- State portfolio standards
  - How to incorporate CHP in RPS, EERS and APS
- SIP Guidance
  - How to incorporate CHP as part of EE/RE in state implementation plans

Tools and Resources

- Direct Project Assistance (case-by-case basis)
  - (e.g. level 1 feasibility analyses, air permitting guidance, funding incentive research)
- ENERGY STAR CHP Award

  http://epa.gov/chp/public-recognition/awards.html
- Facilitate peer-to-peer networking
- Publications and Resources
  - Fact sheets, white papers, technical resource documents, market analyses http://epa.gov/chp/publications/index.html
- CHP Partnership Help Line:
  - (703)373-8108 or chp@epa.gov

Most Popular Resources

- Funding and Incentive Database (http://epa.gov/chp/funding/funding.html)
  - Presents information about federal and state CHP financial incentives and regulations that encourage CHP or biomass project development. Incentives include, but are not limited to, grants, loans, state tax exemptions, standardized interconnection rules, net metering rules, and output-based regulations. [html format]
- CHP Project Development Handbook (http://epa.gov/chp/project-development/index.html)
  - Presents tips and proven strategies for successful CHP project development. [.pdf format]

Most Popular Resources

- CHP Emissions Calculator (http://epa.gov/chp/basic/calculator.html)
  - Allows a user to calculate and compare the CO2, SO2, and NOx emissions from a CHP system to those of a separate heat and power system. The calculator also presents estimated CO2 emissions reductions in terms metric tons of carbon equivalent and emissions from passenger vehicles. [.xls format]
- Catalog of CHP Technologies (http://epa.gov/chp/basic/catalog.html)
  - Provides an overview of how combined heat and power (CHP) systems function and key concepts. It also presents useful estimates about the cost and performance characteristics of different types of CHP prime movers. [.pdf format]

CHP Emissions Calculator - Input

Introduction: Emissions Calculator Documentation: Emissions Calculator

1. CHP: Type of System

Combustion Turbine Submit

2. CHP: Electricity Generating Capacity (per unit)

Normal size range for this technology is 1,000 to 40,000 kW

5,000 kW Submit

3. CHP: How Many Identical Units (i.e., engines) Does This System Have?

1 Submi

4. CHP: How Many Hours per Year Does the CHP System Operate?

I will enter a value

As a number of hours per year: 7,500

OR As a percentage: 0% Submit

5. CHP: Does the System Provide Heating or Cooling or Both?

Heating Only

If Heating and Cooling: How many of the 7,500 hours are in cooling mode?

As a number of hours per year: -

as a percentage of the 7,500 hours? 0% Submit

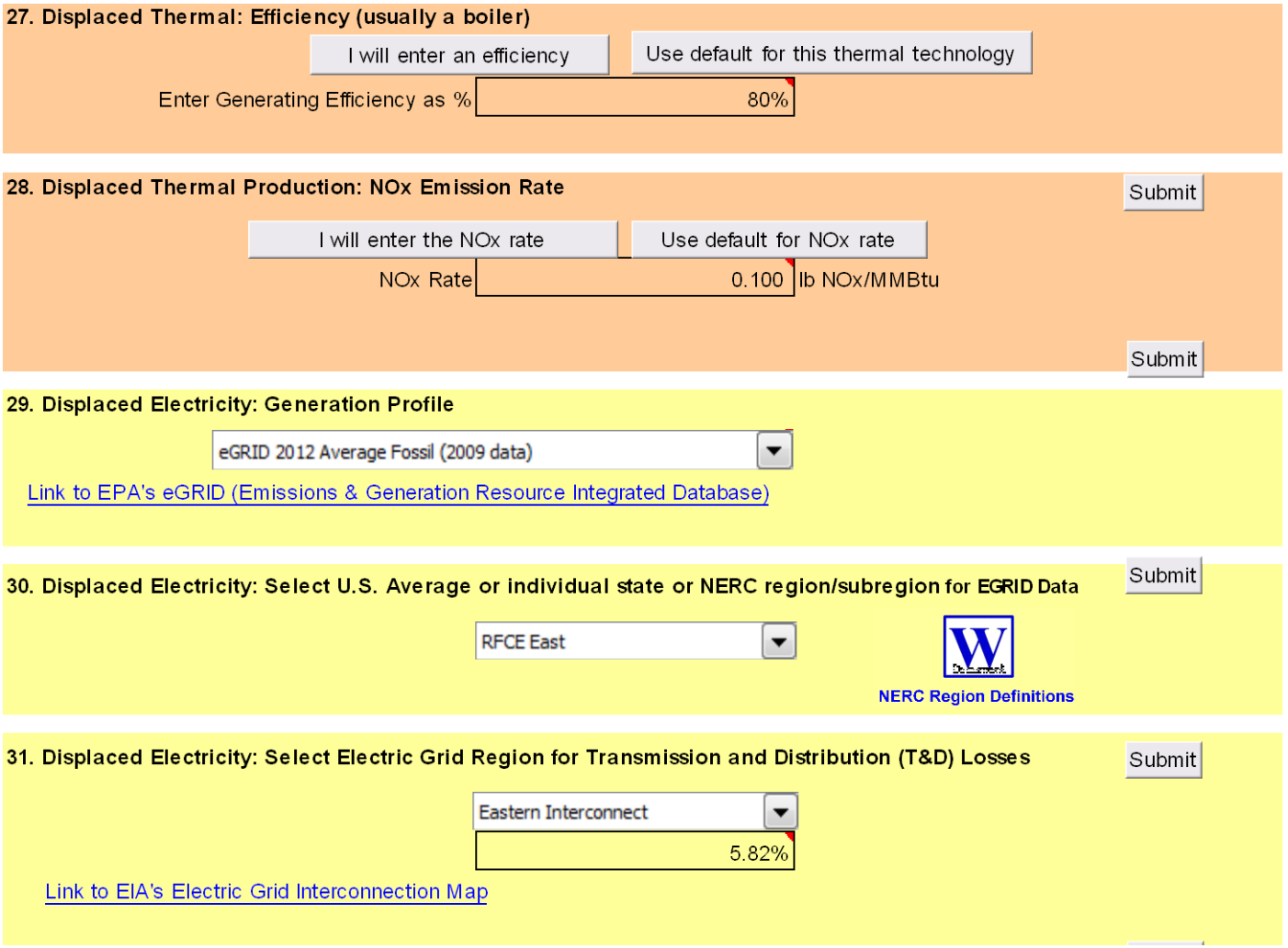
If Heating and Cooling: Does the System Provide Simultaneous Heating and Cooling?

No

6. CHP: Fuel

Fuel Type: Natural Gas View Biomass and Coal Fuel Characteristics Submit

CHP Emissions Calculator - Input



CHP Emissions Calculator - Output

CHP Results

The results generated by the CHP Emissions Calculator are intended for eductional and outreach purposes only; it is not designed for use in developing emission inventories or preparing air permit applications.

The results of this analysis have not been reviewed or endorsed by the EPA CHP Partnership.

Annual Emissions Analysis					
	CHP System	Displaced Electricity Production	Displaced Thermal Production	Emissions/Fuel Reduction	Percent Reduction
NO_x (tons/year)	20.35	27.80	12.90	20.35	50%
SO_2 (tons/year)	0.13	167.11	0.08	167.05	100%
CO_2 (tons/year)	25,885	33,601	15,078	22,794	47%
CH_4 (tons/year)	0.488	0.965	0.284	0.761	61%
N_2O (tons/year)	0.049	0.538	0.028	0.517	91%
Total GHGs (CO_2e tons/year)	25,910	33,788	15,093	22,970	47%
Carbon (metric tons/year)	6,400	8,308	3,728	5,636	47%
Fuel Consumption (MMBtu/year)	442,855	380,909	257,964	196,018	31%
Number of Cars Removed				3,991	

This CHP project will reduce emissions of Greenhouse Gases (CO2e) by 22,970 tons per year

This is equal to 5,636 metric tons of carbon equivalent (MTCE) per year

This reduction is equal to removing the carbon emissions of 3,991 cars

CHP Emissions Calculator - Output

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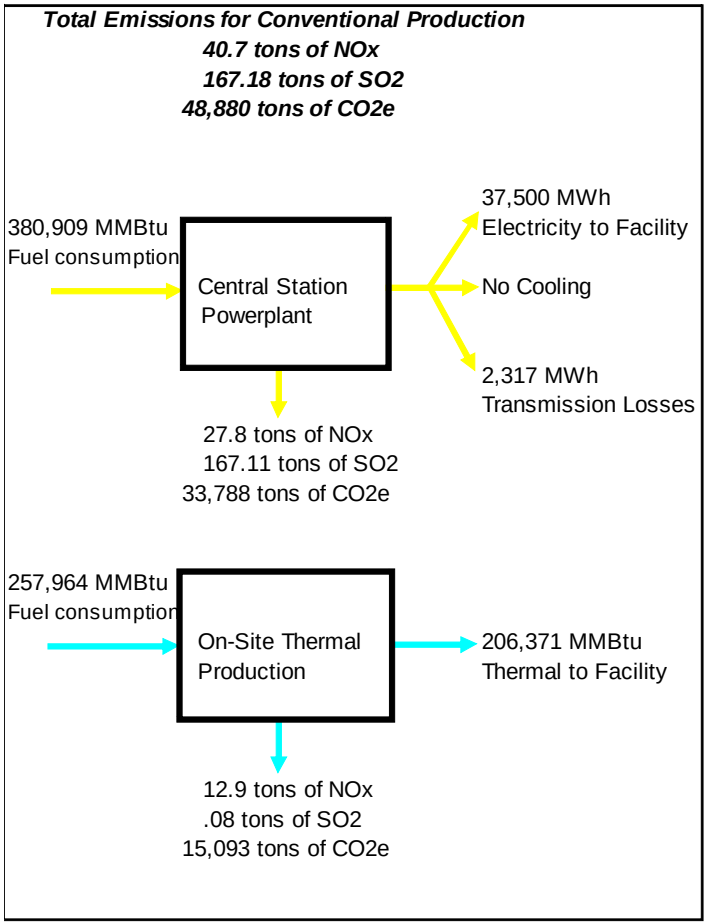
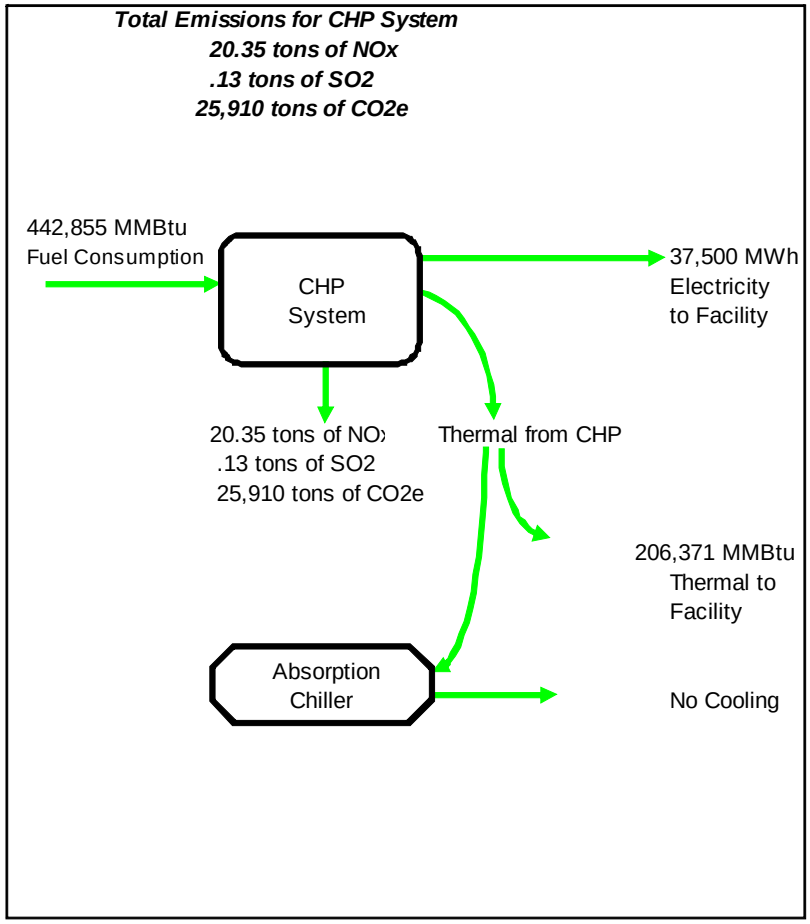
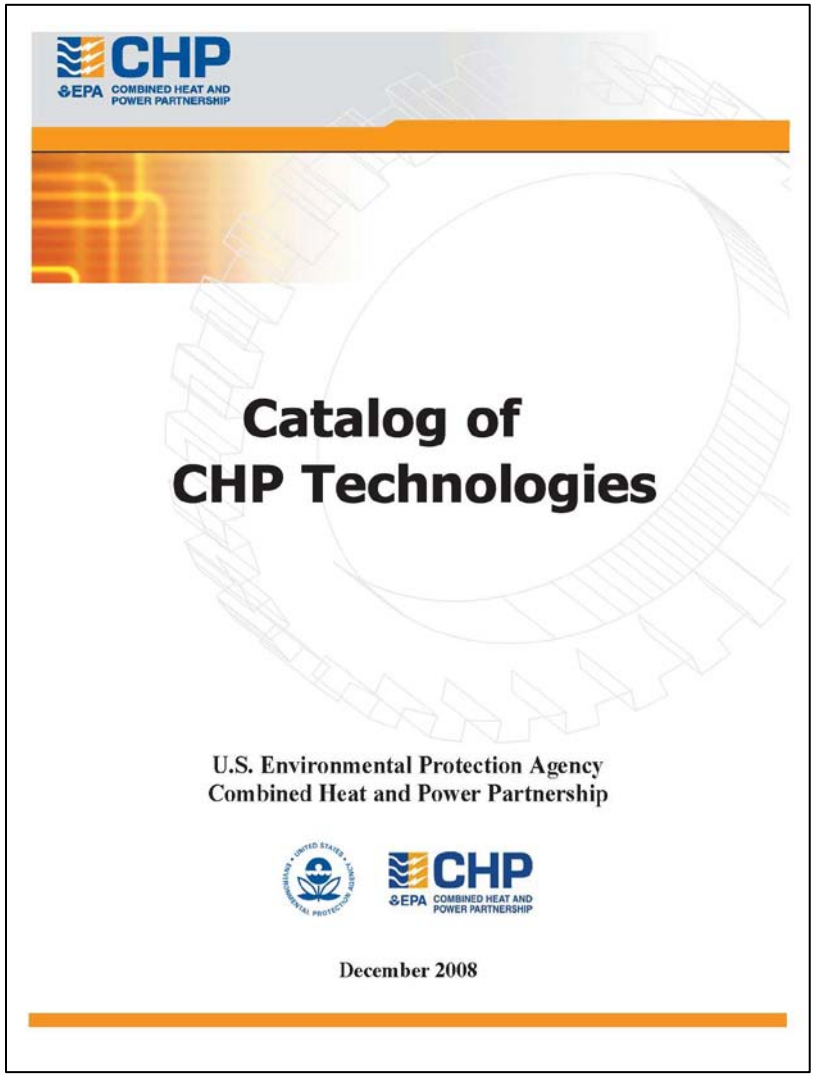
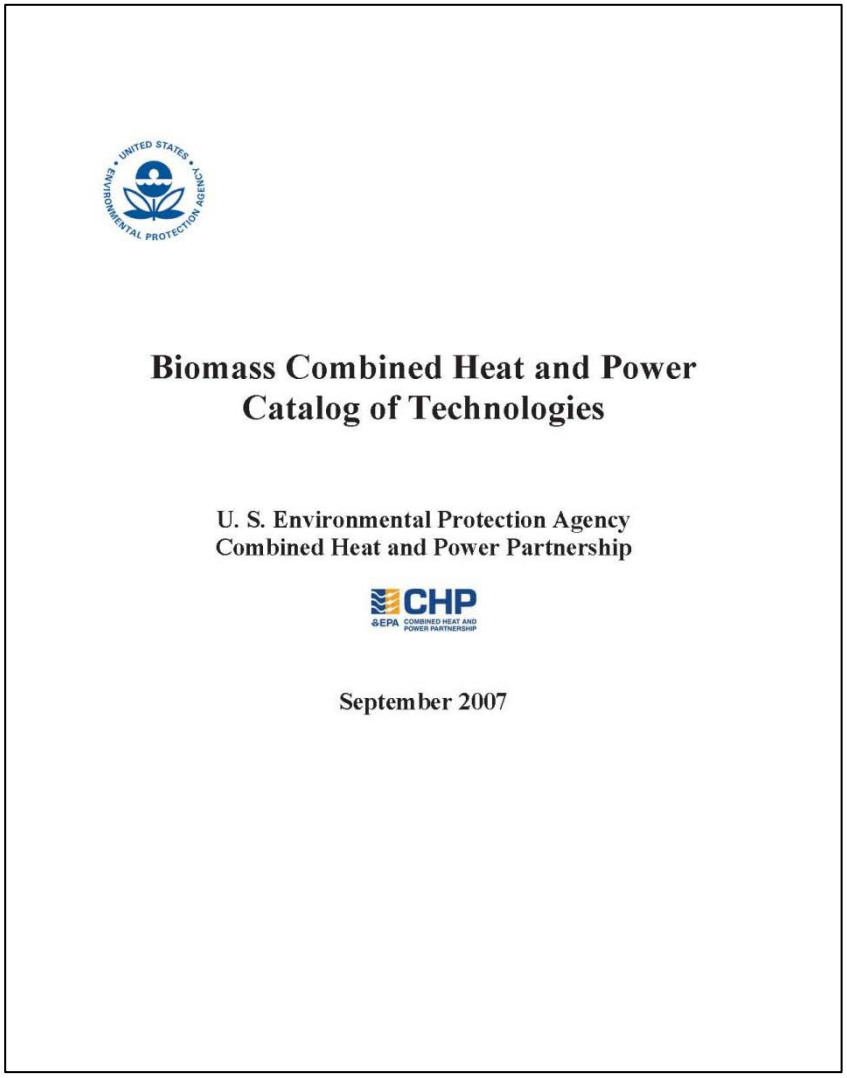




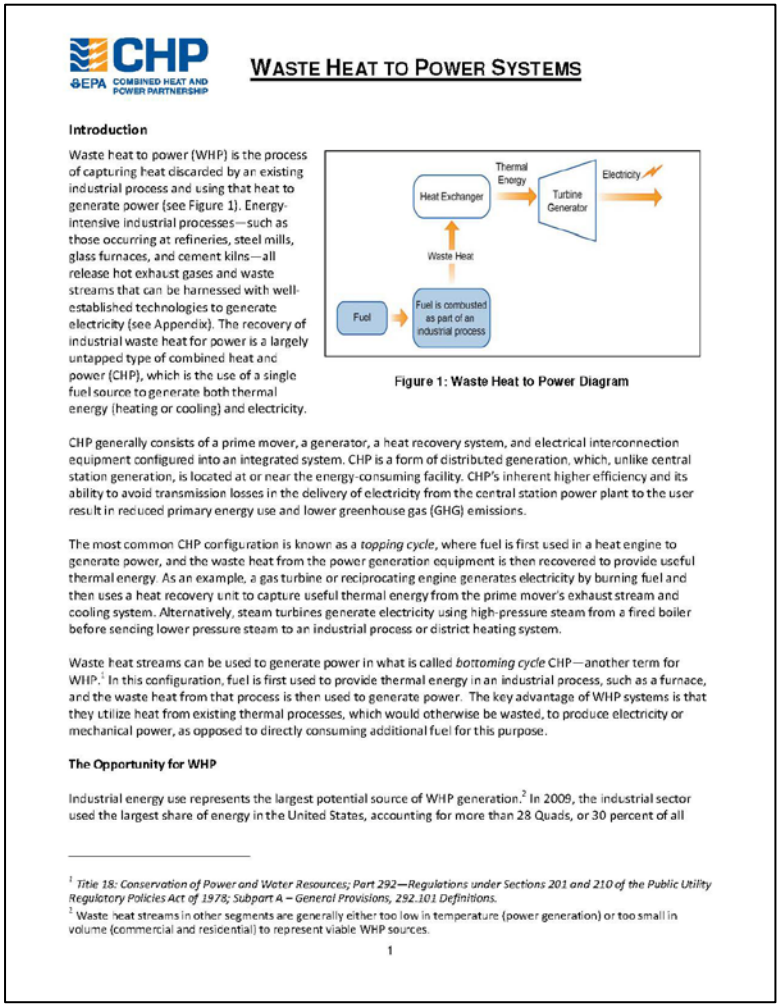
Technology Catalogs





Waste Heat to Power

- Recognized as an important category of CHP
- Incorporated into policy evaluations where appropriate
  - Portfolio standards
  - Output Based Standards
  - Energy and CO_2 savings
- Outreach materials
  - WHP Fact Sheet



CHP
EPA COMBINED HEAT AND POWER PARTNERSHIP

WASTE HEAT TO POWER SYSTEMS

Introduction

Waste heat to power (WHP) is the process of capturing heat discarded by an existing industrial process and using that heat to generate power (see Figure 1). Energy-intensive industrial processes—such as those occurring at refineries, steel mills, glass furnaces, and cement kilns—all release hot exhaust gases and waste streams that can be harnessed with well-established technologies to generate electricity (see Appendix). The recovery of industrial waste heat for power is a largely untapped type of combined heat and power (CHP), which is the use of a single fuel source to generate both thermal energy (heating or cooling) and electricity.

Figure 1: Waste Heat to Power Diagram

CHP generally consists of a prime mover, a generator, a heat recovery system, and electrical interconnection equipment configured into an integrated system. CHP is a form of distributed generation, which, unlike central station generation, is located at or near the energy-consuming facility. CHP's inherent higher efficiency and its ability to avoid transmission losses in the delivery of electricity from the central station power plant to the user result in reduced primary energy use and lower greenhouse gas (GHG) emissions.

The most common CHP configuration is known as a *topping cycle*, where fuel is first used in a heat engine to generate power, and the waste heat from the power generation equipment is then recovered to provide useful thermal energy. As an example, a gas turbine or reciprocating engine generates electricity by burning fuel and then uses a heat recovery unit to capture useful thermal energy from the prime mover's exhaust stream and cooling system. Alternatively, steam turbines generate electricity using high-pressure steam from a fired boiler before sending lower pressure steam to an industrial process or district heating system.

Waste heat streams can be used to generate power in what is called *bottoming cycle* CHP—another term for WHP.[1] In this configuration, fuel is first used to provide thermal energy in an industrial process, such as a furnace, and the waste heat from that process is then used to generate power. The key advantage of WHP systems is that they utilize heat from existing thermal processes, which would otherwise be wasted, to produce electricity or mechanical power, as opposed to directly consuming additional fuel for this purpose.

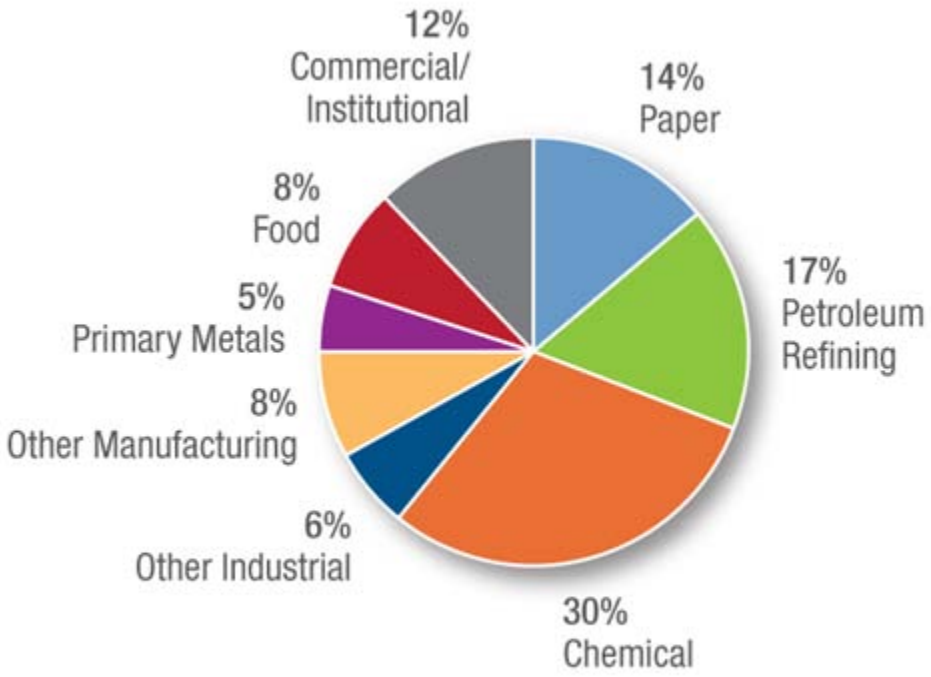
The Opportunity for WHP

Industrial energy use represents the largest potential source of WHP generation.[2] In 2009, the industrial sector used the largest share of energy in the United States, accounting for more than 28 Quads, or 30 percent of all

[1] *Title 18: Conservation of Power and Water Resources; Part 292—Regulations under Sections 201 and 210 of the Public Utility Regulatory Policies Act of 1978; Subpart A – General Provisions, 292.101 Definitions.*
[2] Waste heat streams in other segments are generally either too low in temperature (power generation) or too small in volume (commercial and residential) to represent viable WHP sources.

1

CHP Is already an Important Resource for the U.S.



Source: ICF CHP Database

- 82 GW of installed CHP at almost 4,000 industrial and commercial facilities (2011)
- Avoids more than **1.8 quadrillion Btus** of fuel consumption annually
- Avoids **241 million metric tons of CO_2** as compared to traditional separate production
- CO_2 reduction equivalent to removing **42 million cars** from the road
- CO_2 reduction equivalent to eliminating **43 1,000 MW coal power plants**

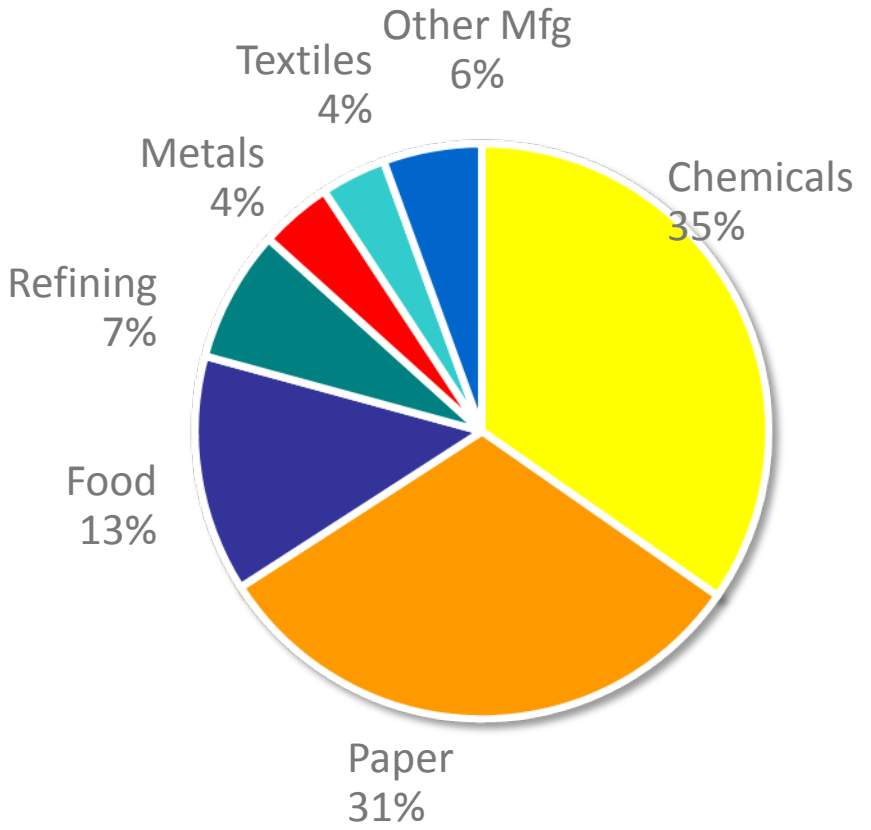
Existing Waste Heat to Power Systems

Industries	Sites	Capacity MW
Food	1	2
Chemicals	13	240
Petroleum Refining	5	131
Non-metallic Mineral Industries	1	3
Primary Metals	2	127
Miscellaneous Manufacturing	1	7
Landfill Gas Power	1	<1
Gas Compressor Stations	12	65
Total	**36**	**575**

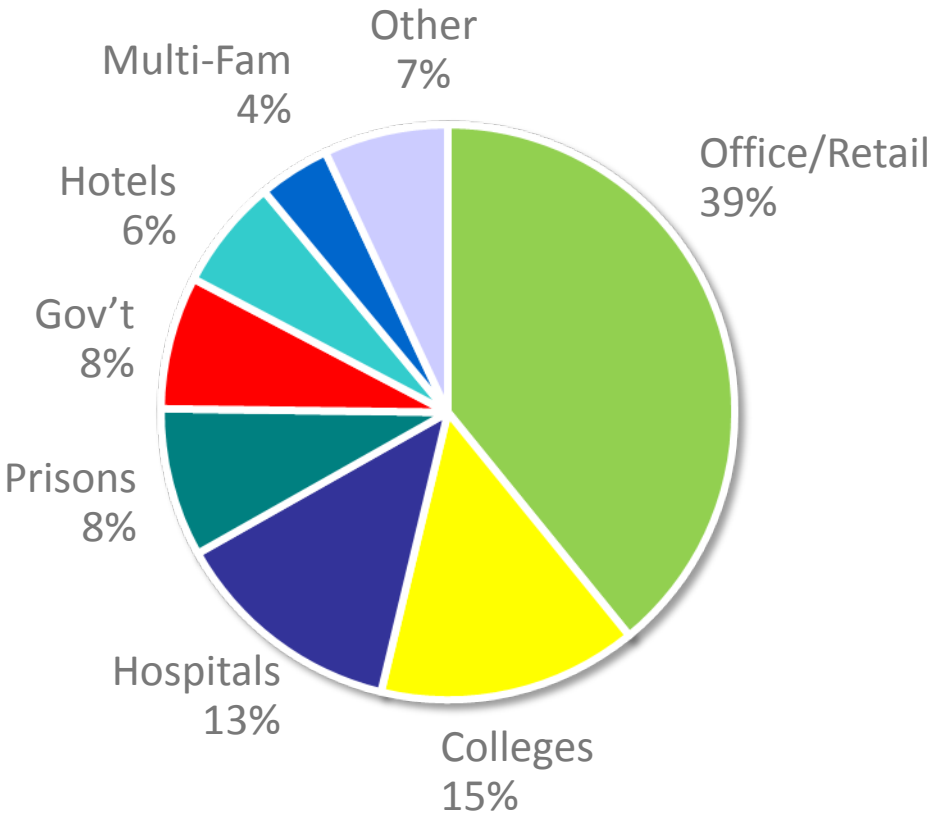
Source: *CHP Installation Database, DOE/ORNL, 2012*

The Potential for Additional CHP at Existing Factories and Buildings is Large

Systems greater than 1 MW



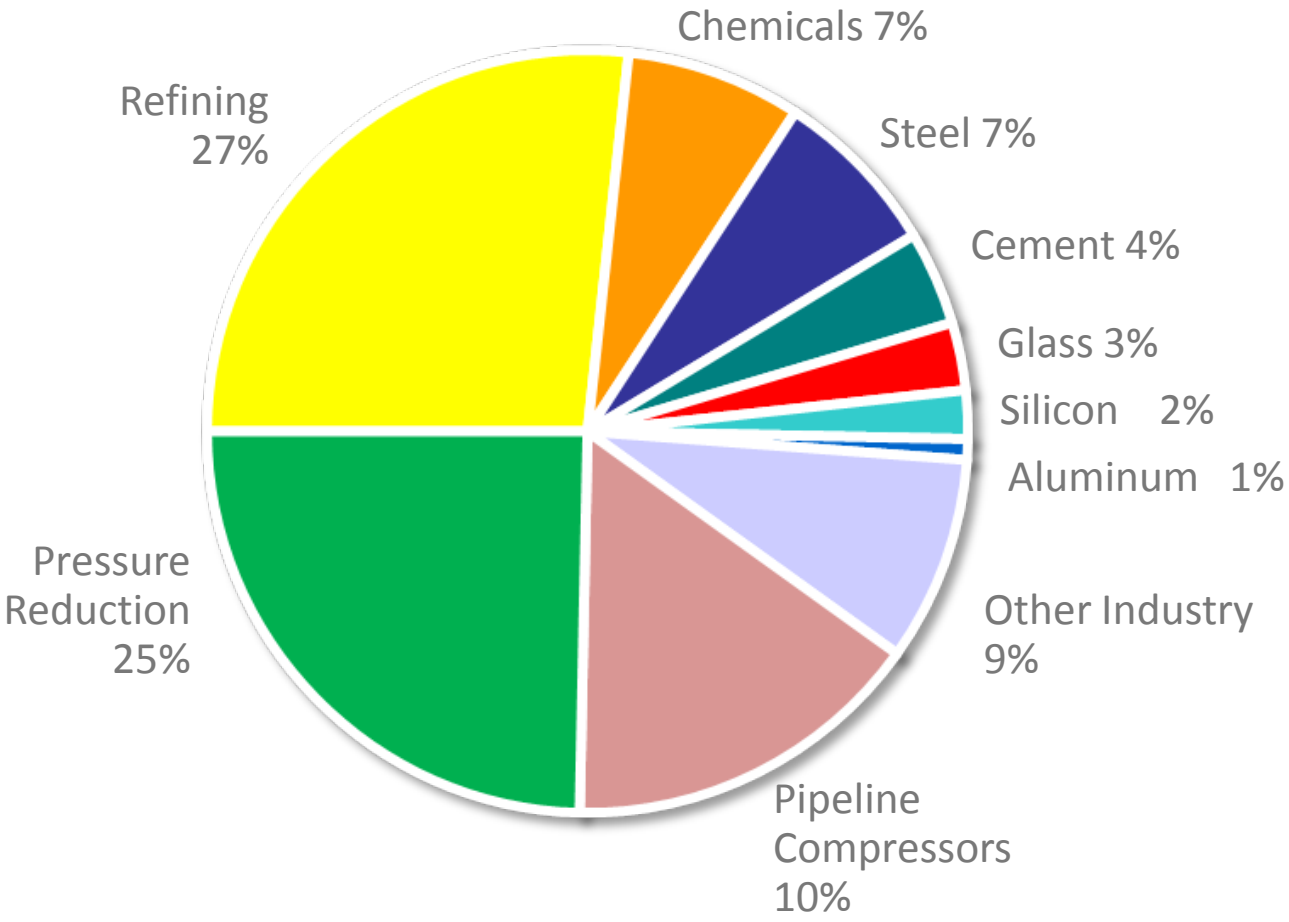
Industrial – 50 GW



Commercial/Institutional – 33 GW

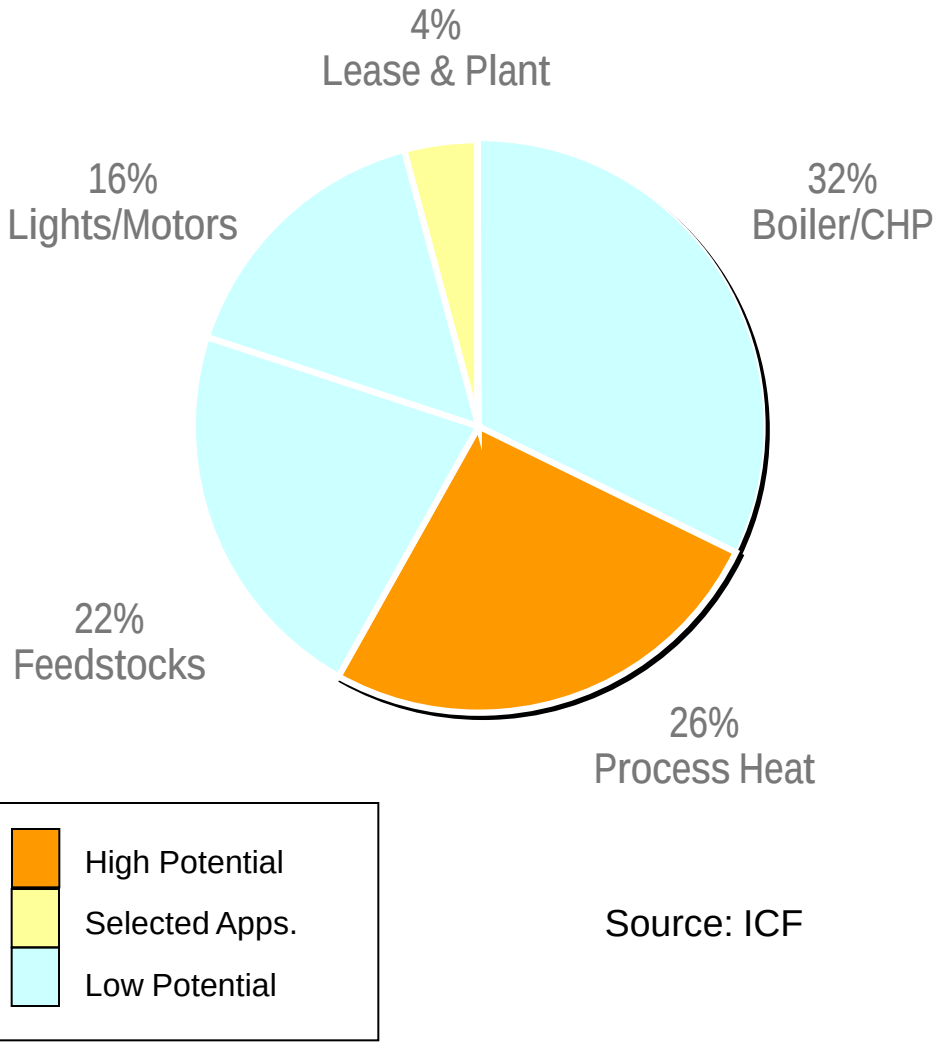
Source: ICF internal estimates

Waste Energy to Power Represents an Additional Potential of 10 GW



Source: ICF internal estimates

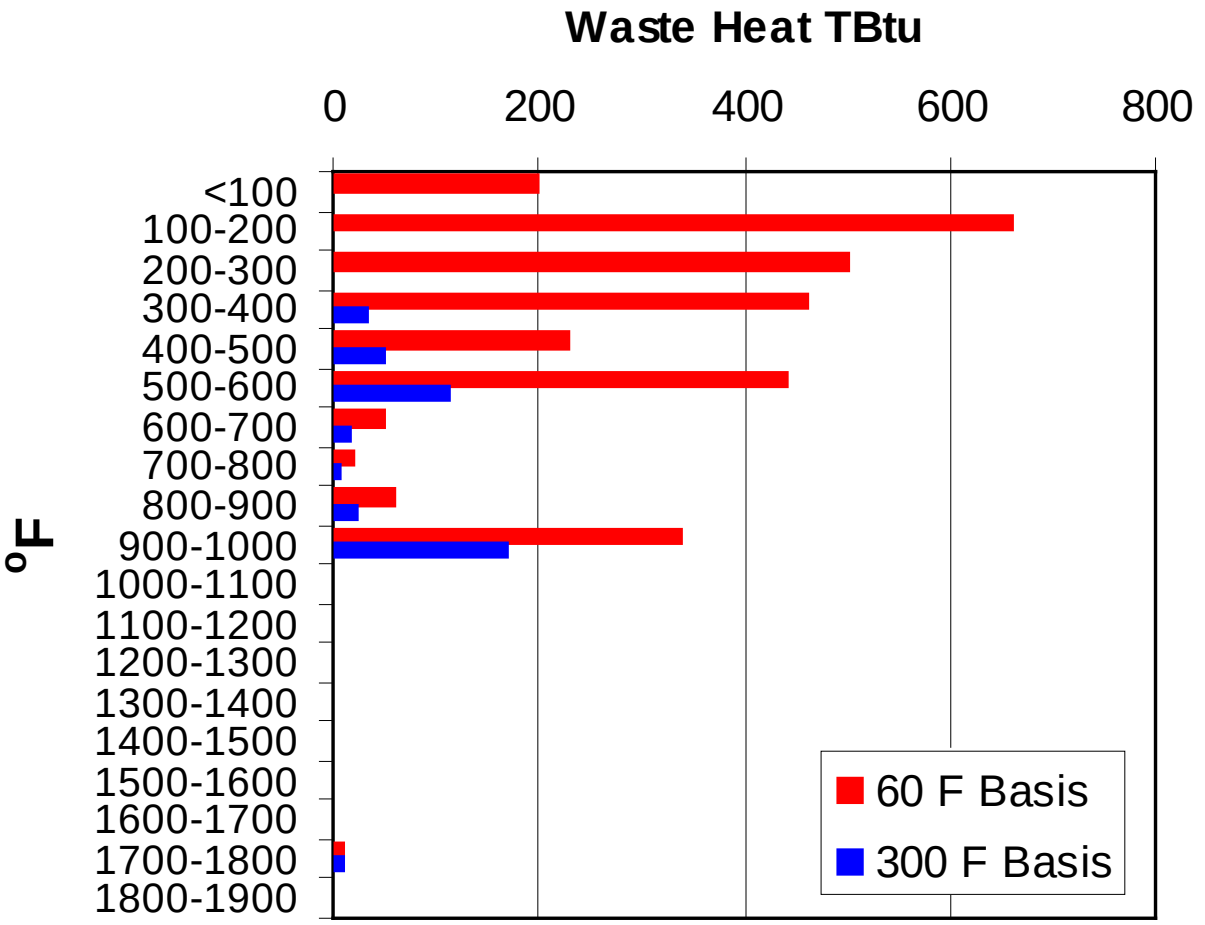
Industrial Energy Consumption by End-Use



Source: ICF

- Total 2006 energy consumption about 26 Quads
- Process heating is primary WHP target –26% of total industrial energy use
- Some high temp heat generated in exothermic processes with feedstocks
- Compressor station drives in Lease and Plant
- Exhaust temperatures from CHP and boilers generally too low for economic power

Manufacturing Sector Waste Heat by Temperature



Source: UTRC/ORNL, 2004

- UTRC 2004 Study for ORNL
- Total waste heat to ambient estimated at ~3 Quads/year most at low temperature
- Practical recoverable waste heat estimate to 300 F is 420 TBtu/year

Industrial WHP Potential

NAICS	Industry	Source	Power Generation Potential (MW)
311	Food	UTRC	98
322	Paper	UTRC	66
324	Petroleum and Coal Products	UTRC	2,594
325	Chemicals	UTRC	724
327	Nonmetallic Minerals		
327211, 327212	Glass	BCS	281
327310	Cement	BCS	391
327410	Lime	RED	269
331	Primary Metals		
331111	Primary Iron and Steel	BCS	692
331312	Primary Aluminum	BCS	85
331112	Silicon, Ferrosilicon	RED	300
3313, 3315	Metal Casting	BCS	303
332	Fabricated Metals	UTRC	79
	All other Industry	UTRC	74
Total Power Generation Potential, MW			5,957

- Synthesis of 3 Sources: UTRC, BCS, and RED
- 6,000 MW of WHP Power Potential
- UTRC and BCS based on WHP available to 300 F
- RED estimates based on example plants extrapolated to total industry production

WHP Potential from other Markets

Industry	Source	Power Generation Potential (MW)
Natural Gas Compressor Stations	ICF	1,500
Landfill Gas	EPA LMOP	1,500
Flare Gas Heat Recovery	LBNL	260
District Heating Steam Pressure Recovery	LBNL	290
Industrial Steam Pressure Recovery	LBNL	2,100
Total	---	**5,500**

WHP – Summary Economics

Cost Component	
Installed Costs, $/kW	$2,000 - $4,000
WHP Generating Costs	
Amortized Capital, $/kWh	$0.055 - $0.125
O&M Costs, $/kWh	$0.005 - $0.020
Total Power Cost, $/kWh	$0.060 - $0.125

WHP Market Issues

- WHP competes with passive heat exchangers that can recycle heat to the process or elsewhere in the facility – generally the first approach to waste heat recovery (less capital intensive)
- Heat transfer from atmospheric pressure exhaust gases is 50-80 less than from hot water – temperature ranges that work in geothermal applications will not work in industry
- High temperature waste heat streams are often dirty and therefore difficult and expensive to recover
- Industrial facilities may lack space, and integration with the process may be difficult
- Batch processes, seasonal operations, and other low load factor processing reduces economic benefits of WHP
- **Wholesale power market does not recognize or reward clean energy resources**

CHP/WHP Value Proposition

Category	10 MW CHP	10 MW WHP	10 MW PV	10 MW Wind	Combined Cycle (10 MW Portion)
Annual Capacity Factor	85%	85%	25%	34%	67%
Annual Electricity	74,446 MWh	74,446 MWh	21,900 MWh	29,784 MWh	58,692 MWh
Annual Useful Heat	103,417 MWh_t	None	None	None	None
Footprint Required	6,000 ft^2	6,000 ft^2	1,740,000 ft^2	76,000 ft^2t	N/A
Capital Cost	$24 million	$30 million	$60.5 million	$24.4 million	$10 million
Annual Energy Savings	343,747 MMBtu	767,176 MMBtu	225,640 MMBtu	306,871 MMBtu	156,708 MMBtu
Annual CO_2 Savings	44,114 Tons	68,864 Tons	20,254 Tons	27,546 Tons	27,023 Tons
Annual NOx Savings	86.9 Tons	91.1 Tons	26.8 Tons	36.4 Tons	59.2 Tons

Based on: 10 MW Gas Turbine CHP - 30% electric efficiency, 70% total efficiency, 15 PPM NOx
Electricity displaces National All Fossil Average Generation (eGRID 2010) -
9,720 Btu/kWh, 1,745 lbs CO_2/MWh, 2.3078 lbs NOx/MWH, 6% T&D losses
Thermal displaces 80% efficient on-site natural gas boiler with 0.1 lb/MMBtu NOx emissions

Thank You!

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