DISCUSSION PAPER SERIES

CHP Industrial Bottoming and Topping Cycle with Energy Information Administration Survey Data

Paul Otis, August 14, 2015

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Background

The Energy Information Administration (EIA) Form 860 Survey data of electricity generators from 2013 is used to analyze the current state of the Combined Heat and Power (CHP) industrial bottoming and topping cycle.[1] The bottoming cycle is the focus of the paper since this approach to CHP is underutilized and also presents challenges in addition to those for the topping cycle. CHP technology is overviewed before the data analysis is presented.

There are two types of CHP referred to as topping and bottoming cycle. Figure 1 illustrates the typical CHP topping cycle.[2] For the topping cycle, fuel is used in a prime mover such as a gas turbine or reciprocating engine that generates electricity or mechanical power. The generated electricity may be used on-site for the building or facility or transferred off-site to the power grid. The prime mover's hot exhaust is then used to provide process heat, hot water, or space heating/cooling for the site.

Figure 1: Combined Heat and Power Topping Cycle

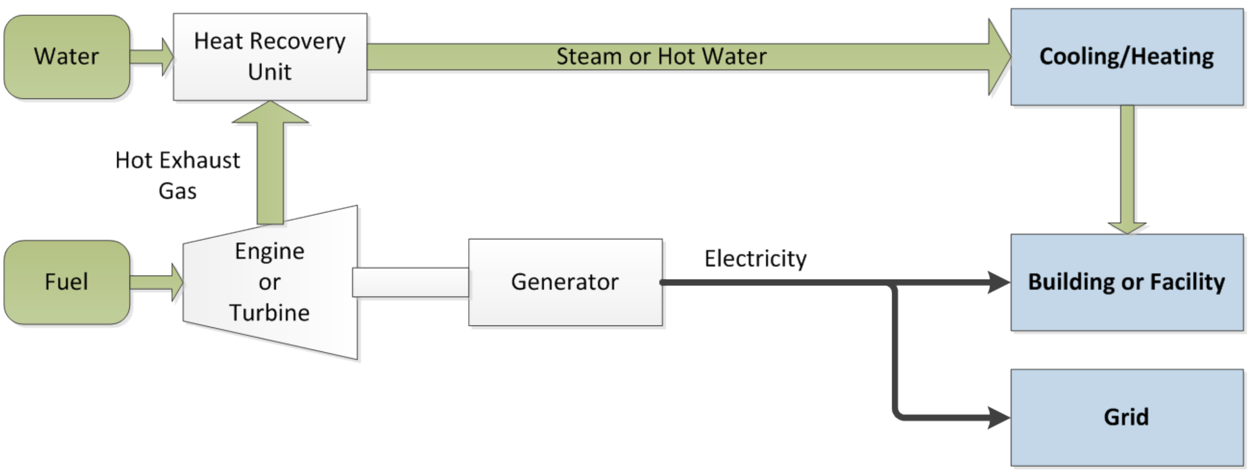
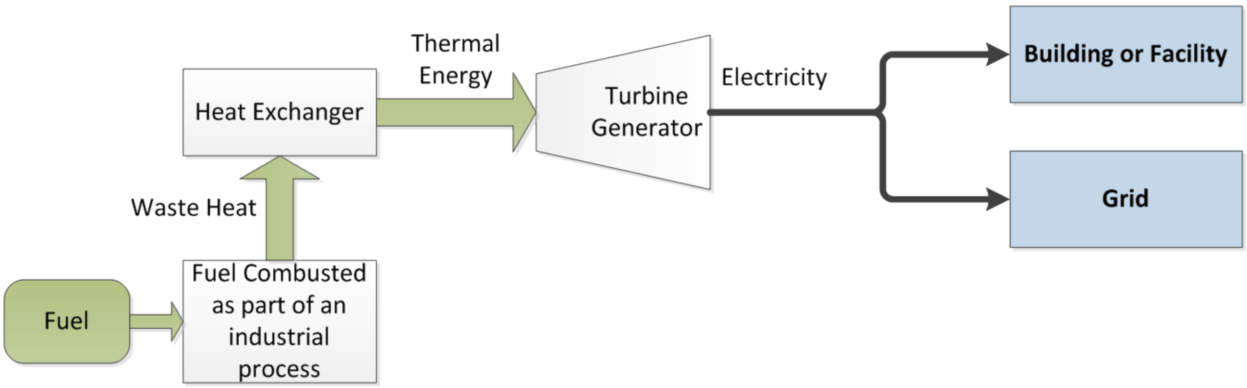


Figure 2 illustrates the CHP bottoming cycle.[3] In a bottoming cycle, which is also referred to as Waste Heat to Power (WHP), fuel is first used to provide thermal input to a furnace or other high temperature industrial processes. A portion of the rejected heat is then recovered and used for power production, typically in a waste heat boiler/steam turbine system. The energy associated with waste heat would otherwise be wasted. The generated electricity may be used on-site for the building or facility or transferred off-site to the power grid.

Figure 2: Combined Heat and Power Bottoming Cycle



While estimates vary, as of 2012, there are up to 130 Gigawatts (GW) of untapped technical CHP potential at existing industrial and commercial facilities. To be effective, a bottoming cycle must have a source of waste heat that is of sufficiently high temperature for the system to be both thermodynamically and economically feasible. The key advantage of the bottoming cycle is that heat is utilized from an existing thermal process that would otherwise be wasted to produce electricity or mechanical power, as opposed to directly consuming additional fuel for this purpose. CHP systems typically achieve total system efficiency of 60% to 80%, compared to only about 50% for conventional separate electricity and thermal energy generation. In addition to the efficiency benefits, CHP can enhance electricity reliability and resiliency for the user and for the grid itself.[4]

There are barriers to both bottoming and topping cycle CHP related to electricity generation and utility requirements. These barriers are summarized below:[5]

- Standby rates: Utilities charge standby rates to compensate for providing services such as backup power for an unplanned generator outage, maintenance power during scheduled generator maintenance, supplemental power when on-site generation does not meet power needs, economic replacement of power when it costs less than on-site generation, and delivery associated with the energy services.
- Interconnection Standards: A key element to the market success of CHP is the ability to safely, reliably, and economically interconnect with the existing utility grid. In some cases the interconnection standards of a utility may not be a barrier. However, non-standardized interconnect requirements and uncertainty in the timing and cost of the application process have long been seen as barriers. There are also interconnection fees that need to be commensurate with system complexity and not excessive to not be a barrier.

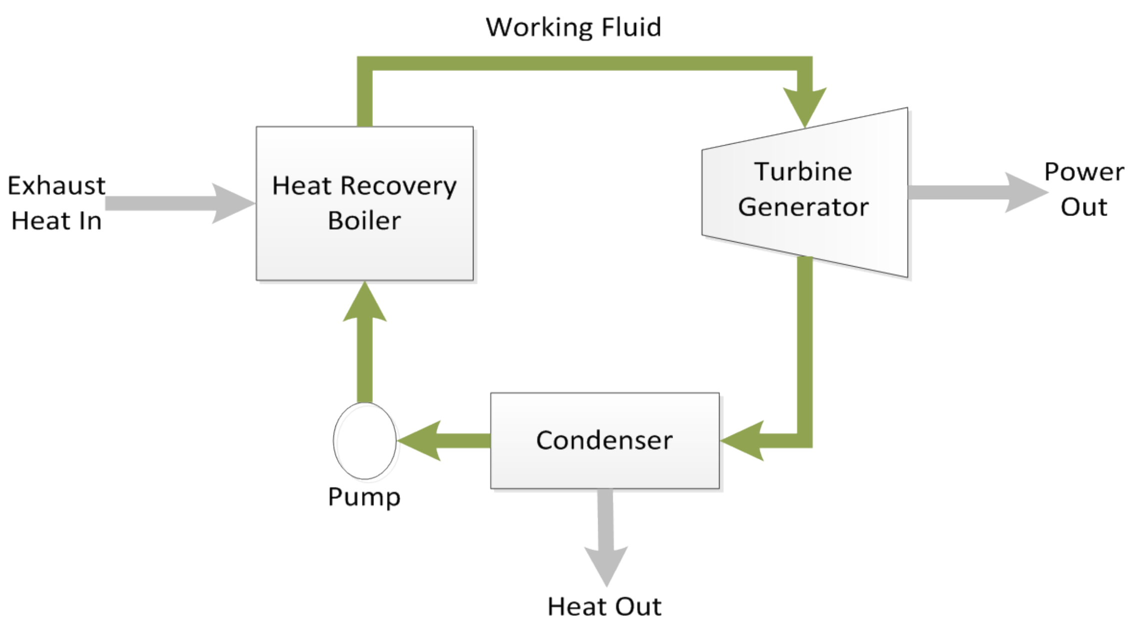
- Excess Power Sales: There are regulations from the Federal Energy Regulatory Commission (FERC) that require electric utilities to purchase energy and capacity from qualifying facilities at the utilities avoided cost. The Public Utility Regulatory Policies Act (PURPA) requires utilities to purchase power at rates that are just and reasonable to the utilities' customers and in the public interest. The purchase price can vary and potentially be a barrier.

Bottoming Cycle[6]

Roughly one-third of the energy consumed by industry is discharged as thermal losses directly to the atmosphere or to cooling systems. The efficiency of generating power from waste heat is heavily dependent on the temperature of the waste heat stream. In general, a temperature of over 500 degrees Fahrenheit is needed for economical bottoming cycle CHP. The Rankine Cycle in Figure 3 is the most typical bottoming cycle CHP that may use different working fluids. The Steam Rankine Cycle (SRC) is the most commonly used system for power generation from waste heat. Waste heat is used to generate steam in a waste heat boiler, which then drives a steam turbine. The working fluid is water. There are technological advances that are lowering this temperature limit such as the Organic Rankine Cycle and the Kalina Cycle.

The Organic Rankine Cycle (ORC) uses other working fluids with better efficiencies at lower heat source temperatures. ORC systems use an organic working fluid that has a lower boiling point, higher vapor pressure, higher molecular mass, and higher mass flow compared to water. This allows higher turbine efficiencies than in a SRC. ORC systems can be utilized for waste heat sources as low as 300 degrees Fahrenheit. The Kalina Cycle uses a mixture of water and ammonia as the working fluid. The operating temperature range can accept waste heat at temperatures from 200 to 1000 degrees Fahrenheit and is 15% to 25% more efficient than ORCs at the same temperature level.

Figure 3: Rankine Bottoming Cycle



The bottoming cycle CHP is economically feasible in energy intensive industries such as: primary metals, nonmetallic minerals, petroleum refineries, paper, and the chemical industry. In addition, natural gas compressor stations, landfill gas energy systems, and oil and gas production may also use bottoming cycle CHP. There are issues related to the waste stream that affects the economic feasibility as well as the implementation approach of the bottoming cycle such as:

- Is the waste stream a gas or liquid stream?
- Is the waste stream availability continuous, cyclic, or intermittent?
- What is the load factor and are annual operating hours sufficient?
- Does the temperature of the waste stream vary over time?
- What is the flow of the waste stream and does it vary over time?
- Is the waste stream at a positive or negative pressure and does it vary?
- What is the composition of the waste stream?
- Are there contaminants that may corrode or erode the heat recovery equipment?

Effective Use of Waste Heat

The bottoming CHP cycle makes use of waste heat that can also be made use of in other ways. Before the bottoming CHP cycle is identified as the best use of waste heat, other options to reduce or use waste heat should perhaps be considered. A study identified Research, Development, and Demonstration (RD&D) efforts to expand waste heat recovery practices in the U.S. industrial sector. This includes the analysis of selected industrial processes that consume about 1/3 of the energy delivered to U.S. industrial facilities based on 2006 data.[7] The quantity of waste heat contained in a waste steam is a function of both the temperature and the mass flow rate of the stream. A valuable alternative approach to improving overall energy efficiency is to capture and reuse the lost or “waste heat” that is intrinsic to industrial manufacturing. As much as 20% to 50% of the energy consumed is ultimately lost via waste heat contained in streams of hot exhaust gas and liquids, as well as through heat conduction, convection, and radiation from hot equipment surfaces and from heated product streams. In some cases, such as industrial furnaces, efficiency improvements resulting from waste heat recovery can improve energy efficiency by 10% to as much as 50%. The waste steams analyzed in this study showed that roughly 60% of unrecovered waste and heat is low quality (i.e., temperatures below 450 degrees Fahrenheit). New and developing technologies offer more opportunities in recovering waste heat. One example for power generation from waste heat is the Kalina Cycle. There are also direct conversion technologies such as thermoelectric generation. Thermoelectric materials are semiconductor solids that allow direct generation of electricity when subject to a temperature differential. These systems are based on a phenomenon known as the Seebeck effect: when two different semiconductor materials are subject to a heat source and heat sink, a voltage is created between the two semiconductors.

The first step may be to identify and implement ways to improve energy efficiency. Such changes will often modify waste heat streams. There are many other opportunities for energy efficiency improvements in areas such as high-yield catalysts, equipment advances, improvements in process design procedures, process control and real-time optimization, energy-focused maintenance programs, and changes in corporate policy. There can also be simple, often overlooked changes and activities that can yield dramatic gains in energy efficiency. In energy intensive industries, such as the chemical process industries, a common inefficiency is the cooling of a process stream that should not be cooled.

For example, an air cooler on the feed line of a distillation column is used to prevent the condenser from being overloaded during abnormal operating conditions. However, the air cooler may be run continuously during normal operating conditions requiring the reboiler to work harder, thereby increasing the boiler's heat load.[8]

The second step is to identify methods of waste heat recovery which can include use of bottoming cycle CHP where there are appropriate waste streams with appropriate temperatures. Waste heat recovery options that are not CHP are vast and dependent on the type of facility. The following are some examples of waste heat recovery approaches:

- Carpet producer: Recovered heat is used to displace heat provided from energy sources such as steam or fuel. Recovered heat may be transferred to boiler make-up water and rinse water. Air compressors discard about 80% of the input energy via waste heat. This waste heat is one example of a waste heat stream that may be used for boiler make-up water and to reduce fuel-use year-round.[9]
- Chemical process industry: Distillation columns are common in this industry. Column integration is a heat exchange link between the column heating/cooling duties and the process heating/cooling duties. Appropriate column integration can provide substantial energy benefits. These benefits must be compared against associated capital investment and difficulties in operation.[10]

Improving energy efficiency through heat integration can also be done through Pinch analysis for process energy optimization, which can be applied to identify CHP opportunities. Pinch analysis is a systematic methodology for energy savings in processes and total sites. The methodology is based on thermodynamic principles. Changes to core process conditions are identified that result in energy savings. A key element is the analysis of thermal data where hot streams are the streams that need cooling (i.e., heat sources) while cold streams are the streams that need heating (i.e., heat sinks). These hot and cold streams are then mapped to what is called a composite curve. This is a Temperature-Enthalpy (internal energy plus the product of pressure and volume) profile of heat availability in the process (hot composite curve) and heat demands in the process (cold composite curve). The minimum temperature difference between the hot and cold composite curves is referred to as the pinch. The sophisticated approach after this basic analysis identifies the cost effective heat transfer between the hot and cold streams. The appropriate technology and optimization approaches to actual implementation of the heat transfers identified are also defined.[11]

Pinch analysis has been successfully used across the full spectrum of chemical process industries. The pinch analysis approach is best applied during the planning of a major capital project, but it also works during retrofits. Pinch analysis is an approach to the design of optimum heat exchanger networks (HENs). Typical fuel savings are 20% or more compared to the existing or previous best design. It complements, rather than supplants, a conventional energy audit that addresses things such as insulation, boiler efficiency, steam traps, air compressor management, Adjustable Speed Drive (ASD), HVAC systems, lighting, and so on. Energy audits can deliver 5-10% savings in energy. But the big energy savings potential of 20-30% of the site energy bill is on the process side. This includes heat recovery in cogeneration and process simplification which can be identified through pinch analysis.[12]

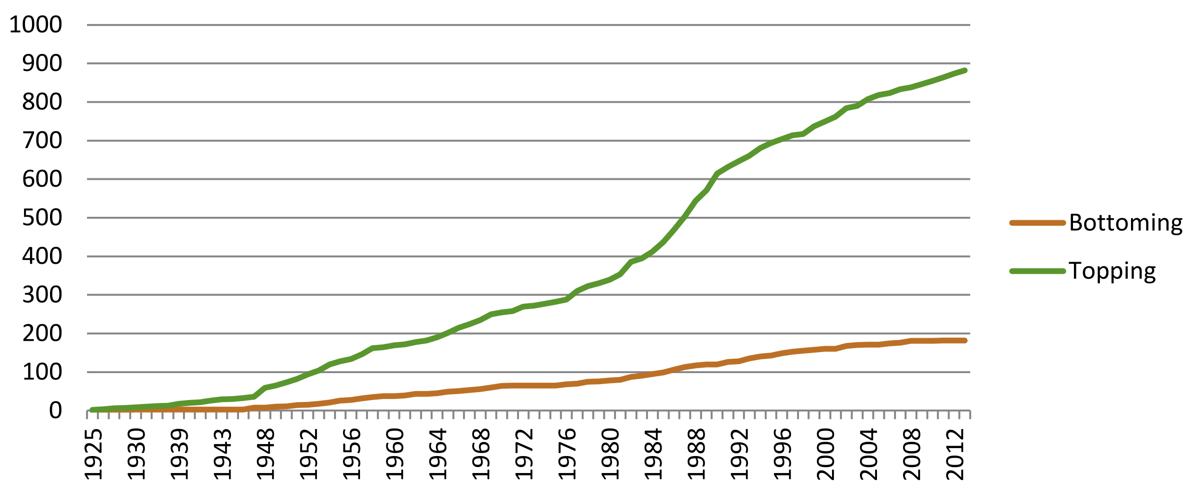
Data Analysis

The data compiled from the EIA-860 survey form includes currently operable electric generating plants, proposed electric generating plants, and retired or cancelled electric generating plants. This analysis is focused on the operable electric generating plants where the topping and bottoming cycle is identified. Electric generating facilities that meet the following criteria are required to submit form EIA-860:

1. Have a total generator nameplate capacity (sum for generators at a single site) of 1 megawatt (MW) or greater; and
2. When the generator(s), or the facility in which the generator(s) reside, is connected to the local or regional electric power grid and has the ability to draw power from the grid or deliver power to the grid.

Figure 4 summarizes the cumulative number of operable industrial topping and bottoming cycle CHP generating units as of 2013 by the year of initial operation. There will be some small scale or isolated CHP generating units that are not a part of the data that are being analyzed. A significant increase in CHP generating units began in the 1940s and then an even larger increase began in the late 1970s. The bottoming cycle increases are significantly less than the topping cycle increases. There have not been additions for the bottoming cycle since 2008 except for the addition of just one generating unit in 2011. As of 2013 there are 882 operable topping cycle units and 182 operable bottoming cycle generating units.

Figure 4: Cumulative Count of Operable Bottoming Cycle and Topping Cycle Industrial CHP Units as of December 2013 by Year of Initial Operation



Source: EIA-860 2013 Survey

Table 1 is a high-level summary of the 2013 operable electric generating capacity in megawatts (MW) by sector. The summer capacity represents the actual or expected generating capacity that generating equipment can supply at the time of summer peak demand. For industrial CHP if there is at least one CHP generator at the facility, then the entire facility is classified as a CHP facility. However, only CHP generators at that facility have to answer the topping/bottoming question.

Table 1: Operable Electric Generating Capacity by Sector

Row Labels	Summer Capacity (MW)
Commercial CHP	2,479.3
Commercial Non-CHP	1,071.7
Electric Utility	616,799.4
Industrial CHP	25,193.2
Industrial Non-CHP	2,350.3
IPP CHP	34,871.3
IPP Non-CHP	377,298.3
Grand Total	1,060,063.5

Source: EIA-860 2013 Survey

The CHP summer capacity in Commercial Buildings, Industrial Facilities, and Independent Power Producers (IPP) is about 62 gigawatts (GW) and represents about 6.0% of total generating capacity. Industrial CHP is about 25 GW and represents about 2.4% of total generating capacity. IPP CHP may supply steam to utilities for district heating and industrial users. There is also Commercial Buildings, Industrial, and IPP power generation that does not make use of heat and is therefore non-CHP.

Table 2 summarizes how operable topping cycle industrial CHP summer capacity and operable bottoming cycle industrial CHP summer capacity is distributed by industry. The table is sorted by the percent of the bottoming cycle summer capacity. The energy intensive industries of chemicals, paper, primary metals (mostly iron and steel and aluminum), and petroleum and coal products represent about 90% of the bottoming cycle industrial CHP summer capacity and 86% of the topping cycle industrial CHP summer capacity. For the topping cycle food manufacturing brings the capacity percent to about 94% of the total topping cycle industrial CHP summer capacity. For the bottoming cycle food manufacturing and nonmetallic mineral production (mostly Glass, Cement, and Lime) also brings the capacity to about 94% of the total bottoming cycle industrial CHP summer capacity. Almost all CHP electric generating capacity is therefore associated with the energy intensive process industries that both generate and use a lot of heat energy.

Table 2: Percent of Operable Industrial CHP Summer Capacity by Industry and Cycle

NAICS	Description	Percent of Total Bottoming Cycle Industrial CHP Summer Capacity	Percent of Total Topping Cycle Industrial CHP Summer Capacity
325	Chemical Manufacturing	54.29%	32.73%
322	Paper Manufacturing	23.22%	30.65%
331	Primary Metal Manufacturing	7.71%	3.07%
324	Petroleum and Coal Products Manufacturing	4.84%	19.63%

NAICS	Description	Percent of Total Bottoming Cycle Industrial CHP Summer Capacity	Percent of Total Topping Cycle Industrial CHP Summer Capacity
339	Miscellaneous Manufacturing	3.35%	0.04%
311	Food Manufacturing	2.04%	7.73%
327	Nonmetallic Mineral Product Manufacturing	1.80%	0.03%
111	Crop Production	1.32%	0.00%
321	Wood Product Manufacturing	1.08%	1.26%
332	Fabricated Metal Product Manufacturing	0.12%	0.06%
323	Printing and Related Support Activities	0.07%	0.01%
336	Transportation Equipment Manufacturing	0.07%	0.44%
212	Mining (except Oil and Gas)	0.05%	0.29%
211	Oil and Gas Extraction	0.02%	3.68%
333	Machinery Manufacturing	0.02%	0.05%
326	Plastics and Rubber Products Manufacturing	0.00%	0.05%
314	Textile Product Mills	0.00%	0.17%
115	Support Activities for Agriculture and Forestry	0.00%	0.01%
334	Computer and Electronic Product Manufacturing	0.00%	0.02%
112	Animal Production and Aquaculture	0.00%	0.01%
312	Beverage and Tobacco Product Manufacturing	0.00%	0.07%

Source: EIA-860 2013 Survey

Table 3 summarizes how operable topping cycle industrial CHP summer capacity and operable bottoming cycle industrial CHP summer capacity is distributed by primary energy source. Waste heat not directly attributed to a fuel source and municipal solid waste are less than 10% of the primary fuel for the bottoming cycle CHP generators, and are not used for the topping cycle. The topping cycle uses a wider variety of fuels although the additional fuels are a small percentage of the topping cycle fuel generator use. CHP generators often use more than one fuel. Table 4 summarizes the count of Industrial CHP generators for the bottoming and topping cycle that use more than one fuel. The percentage of bottoming and topping cycle facilities that may use up to five additional fuels is similar and declines rapidly.

Table 3: Percent of Industrial CHP Summer Capacity by Primary Energy Source and Cycle,

Code	Fuel Description	Percent of Total Bottoming Cycle Industrial CHP Summer Capacity	Percent of Total Topping Cycle Industrial CHP Summer Capacity
NG	Natural Gas	34.07%	48.75%
BIT	Bituminous Coal	12.64%	11.45%
BLQ	Black Liquor	12.64%	14.63%
WDS	Wood/Wood Waste Solids	7.69%	6.80%
WH	Waste heat not directly attributed to a fuel source	7.14%	0.00%
PC	Petroleum Coke	6.59%	0.45%
OTH	Other Fuel	4.95%	0.23%
BFG	Blast Furnace Gas	3.85%	1.25%
OG	Other Gas	3.85%	4.99%
AB	Agricultural By-Products	2.20%	1.36%
SUB	Subbituminous Coal	1.65%	4.42%
WDL	Wood Waste Liquids excluding Black Liquor	1.10%	0.11%
MSW	Municipal Solid Waste	0.55%	0.00%
PUR	Purchased Steam	0.55%	1.25%
RFO	Residual Fuel Oil	0.55%	0.11%
DFO	Distillate Fuel Oil	0.00%	1.93%
LFG	Landfill Gas	0.00%	0.34%
LIG	Lignite Coal	0.00%	0.23%
OBG	Other Biomass Gas	0.00%	0.79%
OBS	Other Biomass Solids	0.00%	0.11%
RC	Refined Coal	0.00%	0.34%
WC	Waste/Other Coal	0.00%	0.11%
WO	Waste/Other Oil	0.00%	0.34%

Source: EIA-860 2013 Survey

Table 4: Number of Fuel Sources used by Industrial CHP Electric Generating Unit

	Use at Least One Fuel Source	Use at Least Two Fuel Sources	Use at Least Three Fuel Sources	Use at Least Four Fuel Sources	Use at Least Five Fuel Sources	Use at Least Six Fuel Source s6
Count of Topping Cycle Industrial CHP Electric Generating Units	882	495	277	196	124	62
Count of Bottoming Cycle Industrial CHP Electric Generating Units	182	126	50	38	22	13
Percent of All Topping Cycle Industrial CHP Electric Generating Units	100.00%	56.12%	31.41%	22.22%	14.06%	7.03%
Percent of All Bottoming Cycle Industrial CHP Electric Generating Units	100.00%	69.23%	27.47%	20.88%	12.09%	7.14%

Source: EIA-860 2013 Survey

Table 5 summarizes how existing topping cycle industrial CHP summer capacity and existing bottoming cycle industrial CHP summer capacity are distributed by both fuel type and by industry for energy intensive industries. These energy intensive industries have 727 operable topping cycle electric generating units and only 157 bottoming cycle electric generating units. These energy intensive industries present the primary opportunity for increases in bottoming cycle CHP since high temperature waste heat streams make the bottoming cycle more economically feasible. Each of these industry fuel uses is summarized below:

- Food Manufacturing: This industry is a significant portion of the population of operable industrial CHP units with 124 topping units and 11 bottoming units. A wide variety of fuels are used, but mostly fossil fuels with some renewables such as Agricultural By-Products (AB).
- Paper Manufacturing: This industry is one of the primary portions of the population of operable industrial CHP units with 263 topping units and 42 bottoming units. This industry is also the primary user of renewable fuels such as Black Liquor (BLQ) and Wood/Wood Waste Solids (WDS). Non-renewable fuels are primarily Natural Gas (NG).
- Petroleum and Coal Products Manufacturing: This industry is a significant portion of the population of operable industrial CHP units with 127 topping units and 13 bottoming units. Natural Gas (NG) and Other Gases (OG) are the primary fuels.

- Chemical Manufacturing: This industry makes up a significant portion of the population of operable industrial CHP units with 180 topping units and 76 bottoming units. Fossil fuels and particularly Natural Gas (NG) are the primary fuel sources.
- Nonmetallic Mineral Product Manufacturing: There are only 2 topping units and 7 bottoming units associated with this industry that use fossil fuels.
- Primary Metal Manufacturing: This industry makes up some of the population of operable industrial CHP units with 31 topping units and 8 bottoming units. A variety of fossil fuels are the primary fuel sources.

Table 5: Count of Operable CHP Electric Generating Units for Energy Intensive Process Industries

FUEL	Description	Bottoming	Topping
	Food Manufacturing (311)		
AB	Agricultural By-Products	0	11
BIT	Bituminous Coal	2	25
DFO	Distillate Fuel Oil	0	11
LIG	Lignite Coal	0	2
NG	Natural Gas	5	48
PC	Petroleum Coke	1	0
PUR	Purchased Steam	0	2
SUB	Subbituminous Coal	3	23
WDS	Wood/Wood Waste Solids	0	2
	Paper Manufacturing (322)		
BIT	Bituminous Coal	4	37
BLQ	Black Liquor	23	129
NG	Natural Gas	6	52
PC	Petroleum Coke	0	3
PUR	Purchased Steam	0	5
RFO	Residual Fuel Oil	1	1
SUB	Subbituminous Coal	0	7
WC	Waste/Other Coal	0	1
WDL	Wood Waste Liquids excluding Black Liquor	2	1
WDS	Wood/Wood Waste Solids	6	27
	Petroleum and Coal Products Manufacturing (324)		
MSW	Municipal Solid Waste	1	0
NG	Natural Gas	5	88
OG	Other Gas	2	35
PC	Petroleum Coke	4	1
WH	Waste heat not directly attributed to a fuel source	1	0
WO	Waste/Other Oil	0	3
	Chemical Manufacturing (325)		

FUEL	Description	Bottoming	Topping
BFG	Blast Furnace Gas	0	1
BIT	Bituminous Coal	7	30
NG	Natural Gas	41	132
OBG	Other Biomass Gas	0	3
OBS	Other Biomass Solids	0	1
OG	Other Gas	4	0
OTH	Other Fuel	9	2
PC	Petroleum Coke	2	0
PUR	Purchased Steam	1	0
RC	Refined Coal	0	3
SUB	Subbituminous Coal	0	6
WDS	Wood/Wood Waste Solids	0	2
WH	Waste heat not directly attributed to a fuel source	12	0
Nonmetallic Mineral Product Manufacturing (327)			
BIT	Bituminous Coal	2	0
NG	Natural Gas	0	2
PC	Petroleum Coke	5	0
Primary Metal Manufacturing (331)			
BFG	Blast Furnace Gas	7	10
NG	Natural Gas	0	11
OG	Other Gas	1	4
PUR	Purchased Steam	0	4
SUB	Subbituminous Coal	0	2

Source: EIA-860 2013 Survey

Table 6 summarizes how existing topping cycle industrial CHP summer capacity and existing bottoming cycle industrial CHP summer capacity are distributed by both fuel type and by industry for non-energy intensive industries. These non-energy intensive industries have 155 operable topping cycle electric generating units and only 25 operable bottoming cycle electric generating units. The majority of the topping facilities are with the Oil and Gas Extraction and Wood Product Manufacturing industries. Other industries have very few CHP units suggesting that CHP may not be economical for many non-energy intensive industrial facilities. Each of these industry fuel uses is summarized below:

- Crop Production: Only 4 bottoming units that use the renewable fuel of Agricultural By-Products (AB).
- Animal Production and Aquaculture: Only 4 topping units that uses the renewable fuel Other Biomass Gas (OBG).
- Support Activities for Agriculture and Forestry: Only 1 topping unit that uses the renewable fuel of Agriculture By-Products (AB).

- Oil and Gas Extraction: Significant CHP use with 66 topping units and only 1 bottoming unit. The fuel is primarily Natural Gas (NG) with other gases (OG) sometimes used.
- Mining (Except Oil and Gas): Only 9 topping units and 1 bottoming unit that all use Natural Gas (NG).
- Beverage and Tobacco Product Manufacturing: Only 3 topping units that uses fossil fuels.
- Textile Product Mills: Only 11 topping units that all use fossil fuels.
- Wood Product Manufacturing: There are 30 topping units and 8 bottoming units. Almost all of the CHP units use renewables of Wood/Wood Waste solids (WDS) as fuel.
- Printing and Related Support Activities: Only 2 topping units and 1 bottoming units. The fuel is Natural Gas (NG).
- Plastics and Rubber Product Manufacturing: Only 2 topping units that use the renewable fuel of Landfill Gas (LFG).
- Fabricated Metal Product Manufacturing: Only 5 topping units and 1 bottoming unit with Natural Gas (NG) as the fuel.
- Machinery Manufacturing: Only 8 topping units and 1 bottoming unit that use fossil fuels.
- Computer and Electronic Product Manufacturing: Only 2 topping unit that uses Natural Gas (NG) as the fuel.
- Transportation Equipment Manufacturing: Only 9 topping units and 1 bottoming unit. Primarily Natural Gas (NG) as the fuel.
- Miscellaneous Manufacturing: Only 3 topping units and 7 bottoming units that use fossil fuels.

Table 6: Count of Operable CHP Electric Generating Units for Non-Energy Intensive Industries

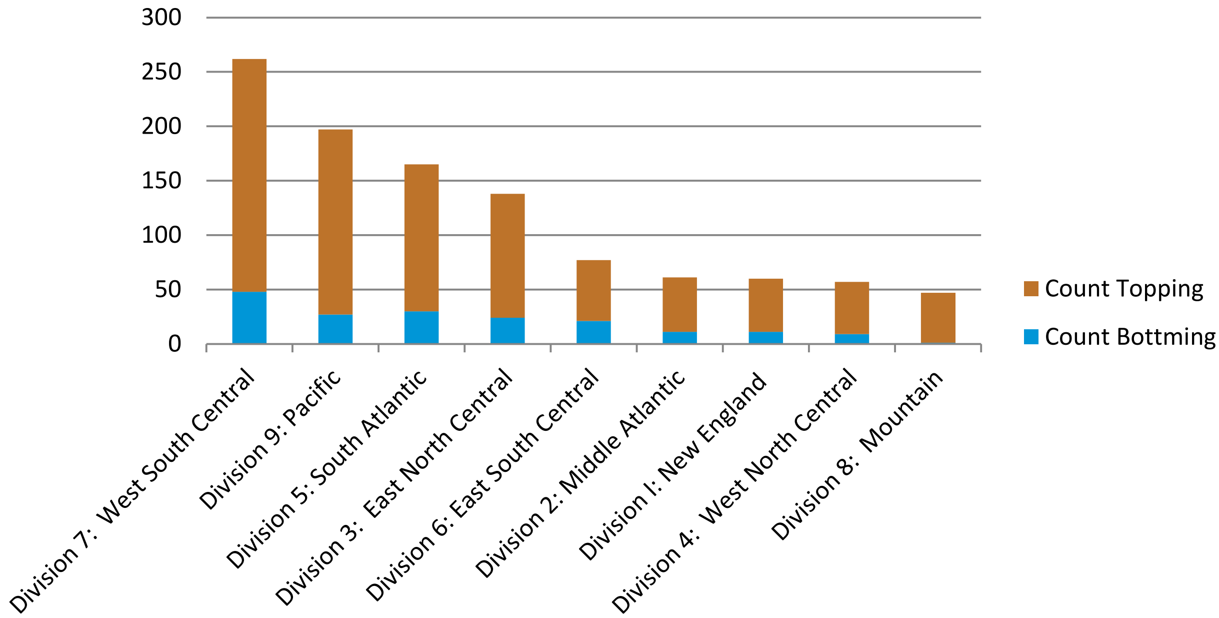
FUEL	Description	Bottoming	Topping
Crop Production (111)			
AB	Agricultural By-Products	4	0
Animal Production and Aquaculture (112)			
OBG	Other Biomass Gas	0	4
Support Activities for Agriculture and Forestry(115)			
AB	Agricultural By-Products	0	1
Oil and Gas Extraction(211)			
NG	Natural Gas	1	61
OG	Other Gas	0	5
Mining except Oil and Gas (212)			
NG	Natural Gas	1	9
Beverage and Tobacco Product Manufacturing (312)			
BIT	Bituminous Coal	0	1
NG	Natural Gas	0	1
SUB	Subbituminous Coal	0	1
Textile Product Mills (314)			
BIT	Bituminous Coal	0	4
DFO	Distillate Fuel Oil	0	6

FUEL	Description	Bottoming	Topping
NG	Natural Gas	0	1
Wood Product Manufacturing (321)			
BIT	Bituminous Coal	0	1
WDS	Wood/Wood Waste Solids	8	29
Printing and Related Support Activities (323)			
NG	Natural Gas	1	2
Plastics and Rubber Products Manufacturing (326)			
LFG	Landfill Gas	0	2
Fabricated Metal Product Manufacturing (332)			
NG	Natural Gas	1	5
Machinery Manufacturing (333)			
BIT	Bituminous Coal	1	3
NG	Natural Gas	0	5
Computer and Electronic Product Manufacturing (334)			
NG	Natural Gas	0	2
Transportation Equipment Manufacturing (336)			
LFG	Landfill Gas	0	1
NG	Natural Gas	1	8
Miscellaneous Manufacturing (339)			
BIT	Bituminous Coal	7	0
NG	Natural Gas	0	3

Source: EIA-860 2013 Survey

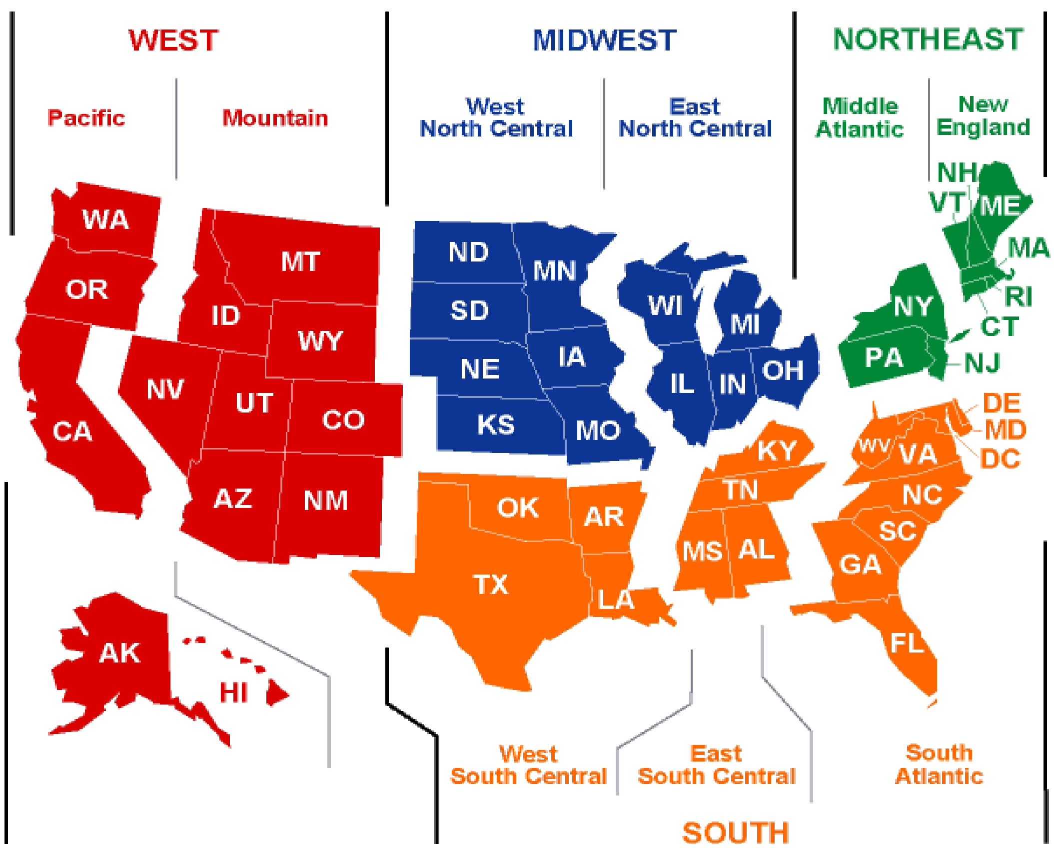
Figure 5 displays the distribution of operable industrial CHP units by census region. The prevalence of CHP certainly depends on the location of industries that use substantial CHP. However, state regulations related to CHP also influence the use of CHP. As an example, the two States with the most CHP facilities are California (Division 9: Pacific) and Texas (Division 7: West South Central). The table is sorted by the total CHP count by State. California has 141 and Texas has 154 of the total CHP count of 1064. Figure 6 is a map of the census regions.[13]

Figure 5: Distribution of Operable Industrial CHP Units by Census Region



Source: EIA-860 2013 Survey

Figure 6: Map of Census Regions



Conclusion

The greatest potential for the expansion of bottoming cycle CHP will be in the energy intensive process industries that have significant high temperature waste streams that can provide the input to generate electricity.[14] Technological advances that use working fluids that allow lower temperature waste streams to be utilized can increase the potential for the bottoming cycle. These new technologies with lower temperature requirements can also help to expand the bottoming cycle for non-energy intensive industries.

Determining the applicability of the bottoming cycle requires more complex analysis than is the case with the topping cycle. Pinch Analysis in the energy intensive process industries is an example of the type of complex analysis that may be required to identify economically feasible bottoming cycle implementations. Although the effective implementation of bottoming cycle CHP is more complex than topping cycle CHP the energy that is converted to electricity would otherwise be wasted. The use of waste heat will also allow the use of other purchased fuels to be reduced.

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