

# Industrial Waste Heat to Power Applications and Market Trends

August 20, 2020



**CHP Technical Assistance Partnerships**  
SOUTHCENTRAL



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# Agenda

- CHP TAPs Overview
- Waste Heat to Power Technologies Overview
- Waste Heat to Power Market Potential
- Case Studies
- Working with the CHP TAPs
- Q&A

# DOE CHP Technical Assistance Partnerships (CHP TAPs)

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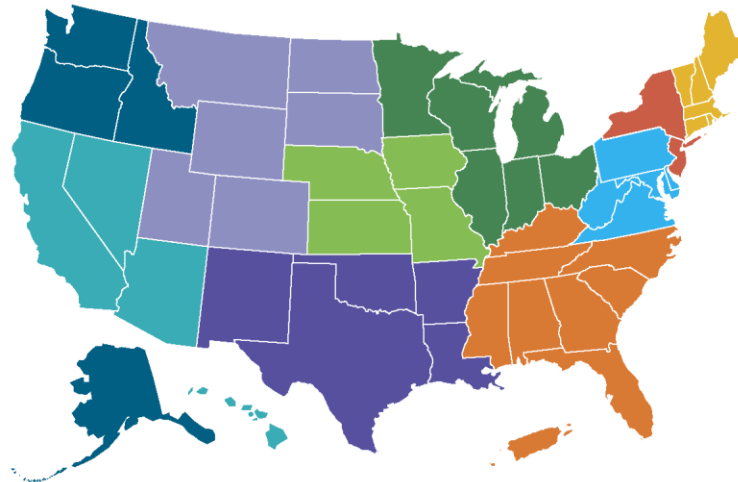
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# DOE CHP Technical Assistance Partnerships (CHP TAPs)

- **End User Engagement**

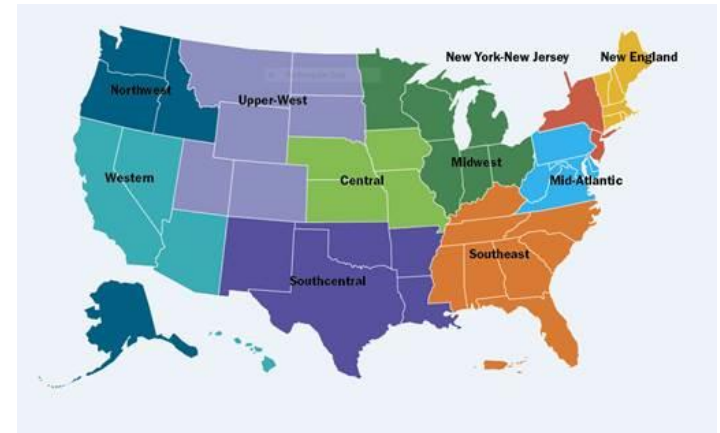
Partner with strategic End Users to advance technical solutions using CHP as a cost effective and resilient way to ensure American competitiveness, utilize local fuels and enhance energy security. CHP TAPs offer fact-based, non-biased engineering support to manufacturing, commercial, institutional and federal facilities and campuses.

- **Stakeholder Engagement**

Engage with strategic Stakeholders, including regulators, utilities, and policy makers, to identify and reduce the barriers to using CHP to advance regional efficiency, promote energy independence and enhance the nation's resilient grid. CHP TAPs provide fact-based, non-biased education to advance sound CHP programs and policies.

- **Technical Services**

As leading experts in CHP (as well as microgrids, heat to power, and district energy) the CHP TAPs work with sites to screen for CHP opportunities as well as provide advanced services to maximize the economic impact and reduce the risk of CHP from initial CHP screening to installation.



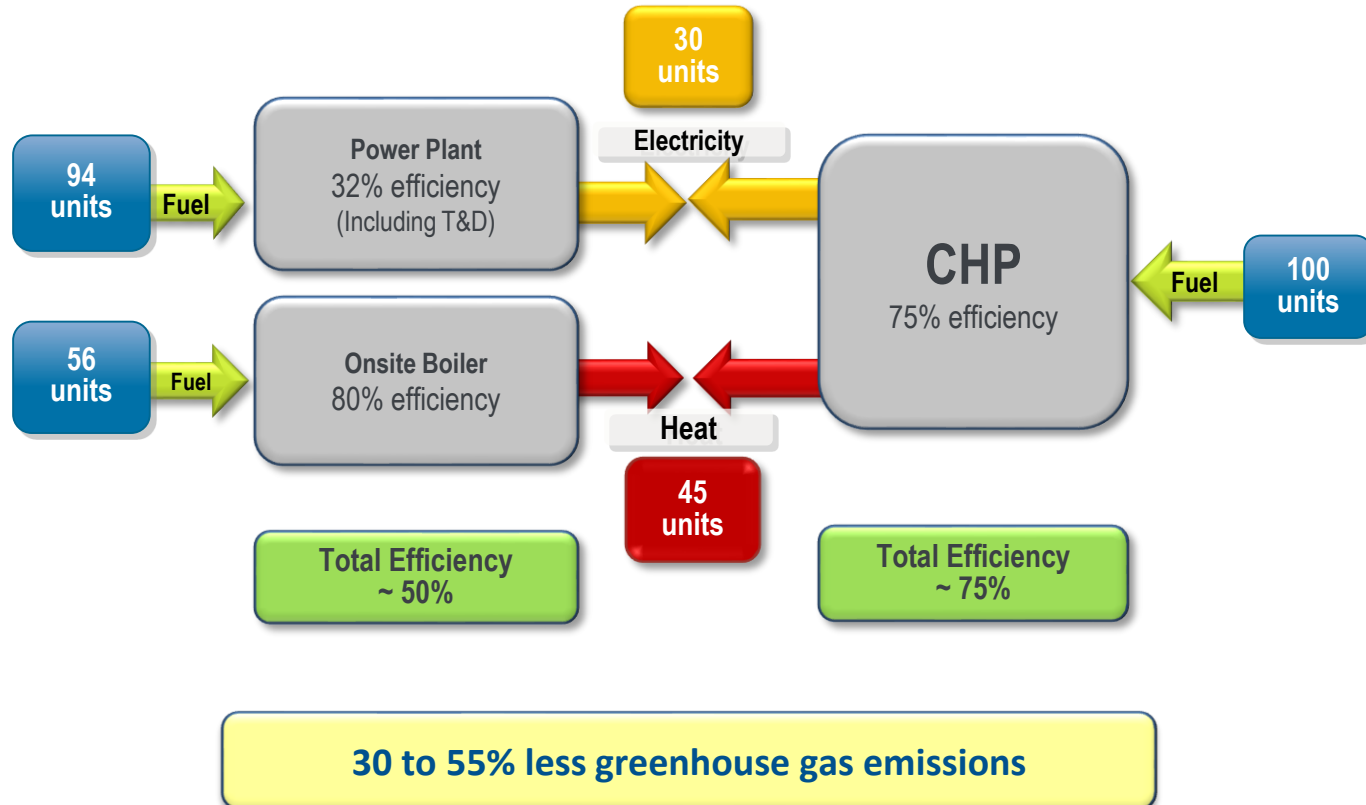
[www.energy.gov/chp](http://www.energy.gov/chp)



# WHP Overview



# CHP Recaptures Heat of Generation, Increasing Energy Efficiency, and Reducing GHGs

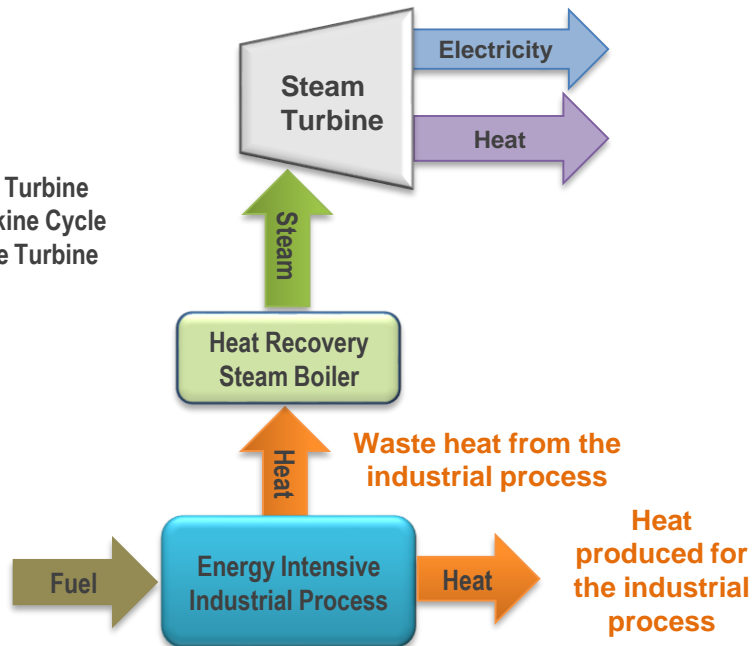


# Defining Combined Heat & Power (CHP)

The on-site simultaneous generation of two forms of energy (heat and electricity) from a single fuel/energy source

## Waste Heat to Power CHP (also referred to as *Bottoming Cycle CHP* or *Indirect Fired CHP*)

- HRSG/Steam Turbine
- Organic Rankine Cycle
- Backpressure Turbine



- Fuel first applied to produce useful thermal energy for the process
- Waste heat is utilized to produce electricity and possibly additional thermal energy for the process
- Simultaneous generation of heat and electricity
- No additional fossil fuel combustion (*no incremental emissions*)
- Normally produces larger amounts electric generation (*often exports electricity to the grid; base load electric power*)



# Main Sources of Waste Heat

- Waste Heat from a Thermal Process
- Waste Heat from a Mechanical Drive
- Waste heat from other systems



Port Arthur Steam Energy/Oxbow Corp, Texas



Northern Boarder Pipeline, North Dakota



# WHP Power Generation Technology

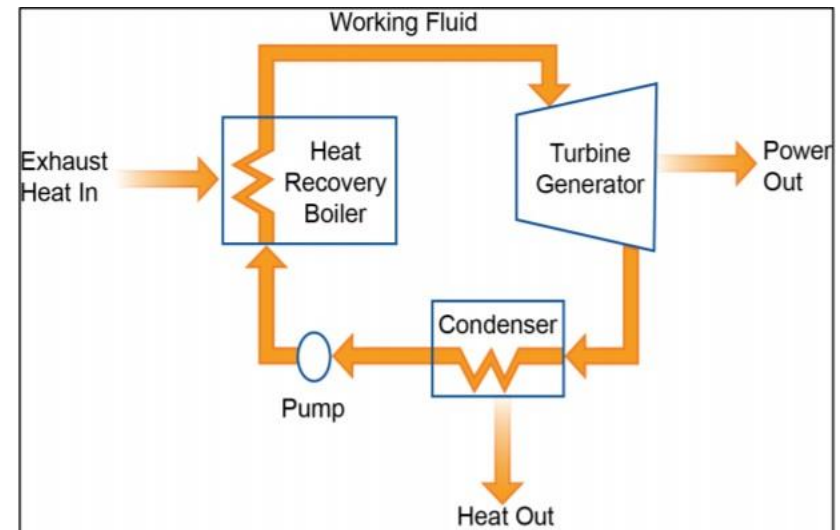
## ■ Rankine Cycle

- Steam Rankine Cycle (SRC)
- Organic Rankine Cycle (ORC)

## ■ Back Pressure Steam Turbine

## ■ Emerging Technologies

- Kalina Cycle
- Thermoelectric Generation
- Piezoelectric Power Generation
- Thermionic Generation
- Stirling Engine
- Steam Engine



Source: Waste Heat to Power Systems – EPA 2012

Source: ORNL Waste Heat to Power Market Assessment 2015

# Benefits of WHP

- Utilize heat from existing thermal processes, which would otherwise be wasted to produce electricity.
- Important resource for vastly increasing industrial energy efficiency.
- Improving the competitiveness of the U.S. industrial sector.
- Providing a source of pollution-free power.



Port Arthur Steam Energy/Oxbow Corp.

# Technical Factors to Consider

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

Source: Waste Heat to Power Systems – EPA 2012

# Economic Factors to Consider

- **Waste heat recovery options**
  - Uses with other thermal processes or power generation?
- **Cost of Grid Electricity**
- **Integration of WHP**
  - Site Factors to Consider
- **Availability of Financial Incentives**

# WHP Markets



# Waste Heat to Power CHP Technical Potential

- According to the CHP Installation Database, there are 105 operational WHP systems with 813 MW of capacity (data as of June 30, 2020).
- Estimated 7.6 GW of remaining WHP technical potential in the U.S. (2016)
  - Process to determine WHP technical potential:
    - Identified target markets based on electric consumption and waste heat data
    - Quantified the number of target facilities
    - Estimated WHP potential MW electric capacity, based on waste heat quality and electric load
- **The top sectors are those with large waste heat streams available for capture at temperatures conducive to generating electric power**
  - **98% of all WHP potential is found in four sectors:**
    - Petroleum refining
    - Primary metals
    - Stone/Clay/Glass
    - Oil/gas extraction
- **WHP potential found in 48 states**
- **Most potential for new WHP in Texas, Louisiana, and California**

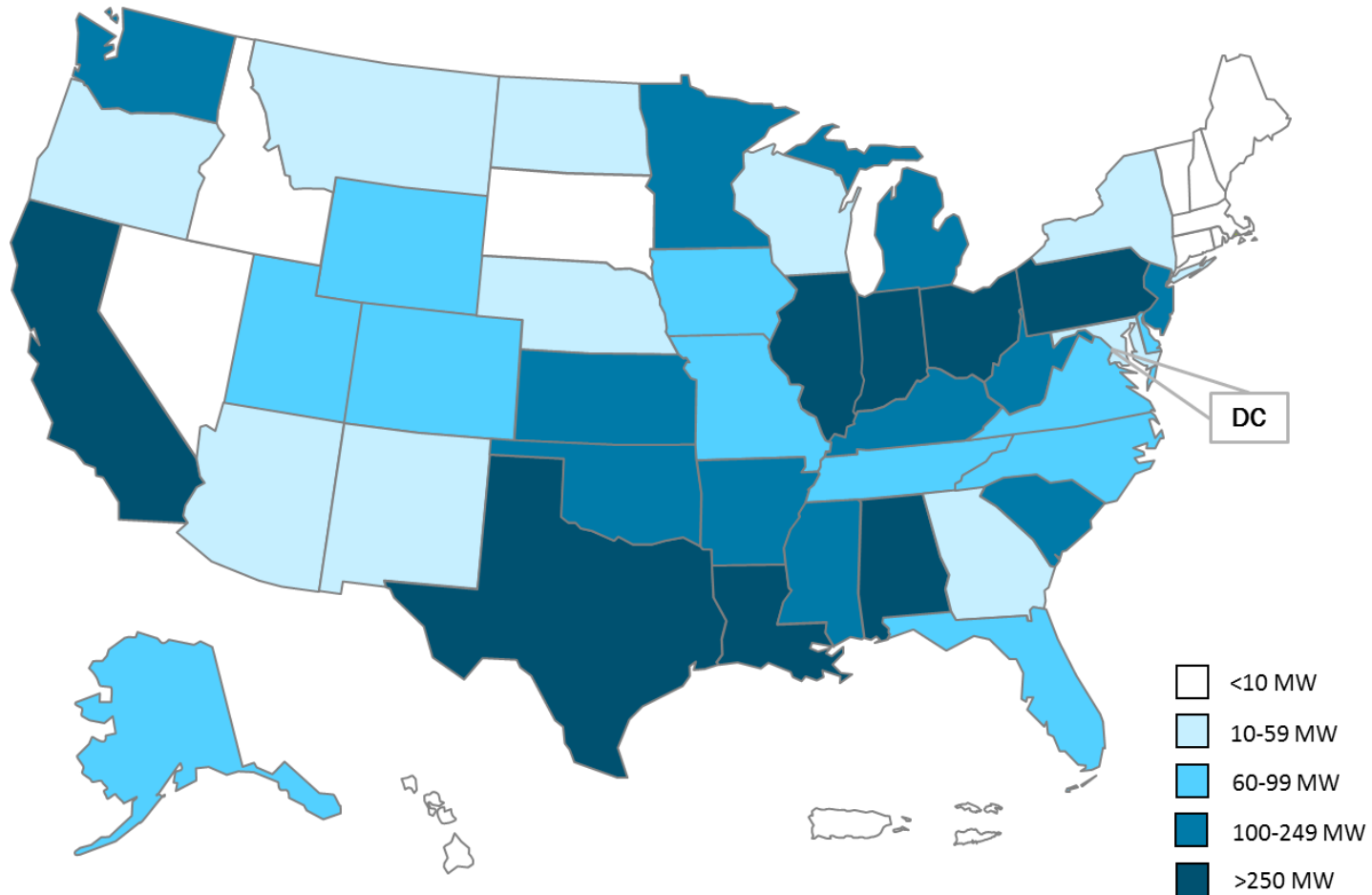
Sources: "Combined Heat and Power (CHP) Technical Potential in the United States", March 2016, [energy.gov/chp-potential](http://energy.gov/chp-potential)

# WHP CHP Technical Potential by State

State	# of Sites	Potential (MW)	State	# of Sites	Potential (MW)
Alabama	35	251	Missouri	15	85
Alaska	7	73	Montana	7	58
Arizona	4	28	Nebraska	9	39
Arkansas	11	162	Nevada	2	7
California	62	729	New Jersey	10	106
Colorado	32	84	New Mexico	28	43
Connecticut	1	0	New York	13	50
Delaware	2	60	North Carolina	14	82
Florida	13	65	North Dakota	9	10
Georgia	7	14	Ohio	38	307
Hawaii	2	7	Oklahoma	70	165
Idaho	1	2	Oregon	5	29
Illinois	25	353	Pennsylvania	52	402
Indiana	27	473	Rhode Island	1	0
Iowa	16	88	South Carolina	12	156
Kansas	21	122	South Dakota	3	8
Kentucky	18	211	Tennessee	16	82
Louisiana	93	782	Texas	244	1,432
Maine	3	4	Utah	21	61
Maryland	4	40	Virginia	11	65
Massachusetts	3	3	Washington	14	138
Michigan	36	154	West Virginia	14	148
Minnesota	12	123	Wisconsin	15	57
Mississippi	9	176	Wyoming	38	91
			<b>Total</b>	<b>1,105</b>	<b>7,624</b>

Source: "Combined Heat and Power (CHP) Technical Potential in the United States", March 2016, [energy.gov/chp-potential](http://energy.gov/chp-potential)

# WHP CHP Technical Potential by State



Source: "Combined Heat and Power (CHP) Technical Potential in the United States", March 2016, [energy.gov/chp-potential](http://energy.gov/chp-potential)



# WHP Technical Potential by Application

Application	# of Sites	Potential (MW)
Mining	14	23
Oil/Gas Extraction	427	538
Food Processing	19	8
Beverage and Tobacco	2	0.3
Lumber and Wood	2	1
Paper	17	5
Chemicals	64	92
Petroleum Refining	176	3,593
Stone/Clay/Glass	255	1,173
Primary Metals	116	2,186
Machinery/Computer Equip.	2	4
Transportation Equip.	1	2
Other	10	0.3
<b>Total</b>	<b>1,105</b>	<b>7,624</b>

Source: "Combined Heat and Power (CHP) Technical Potential in the United States", March 2016, [energy.gov/chp-potential](http://energy.gov/chp-potential)

# Case Studies



# Project Snapshot 1:

## Waste heat to power and process heat, Port Arthur, TX

Application/Industry: Petroleum Refining

Capacity: 5 MW

Equipment: Waste heat recovery boilers; back pressure steam turbine

Fuel Type: Waste heat

Thermal Use: Steam and electricity generation

Installation Year: 2005

Environmental Benefits: CO<sub>2</sub> emissions reduced by 159,000 tons/year

Testimonial: “Through the recovery of otherwise-wasted heat to produce high pressure steam for crude oil processing, Port Arthur Steam Energy LLP has demonstrated exceptional leadership in energy use and management.”

- U.S. Environmental Protection Agency, in giving the 2010 Energy Star Award



# Project Snapshot 2:

## Flare Gas to Electricity Bakken, ND

**Testimonial:** “It proves that using 100-year-old boiler technology and some newer technology married together is a good simple offering to produce electricity – Hess “

**Application/Industry:** Oil and Gas Extraction

**Capacity (MW):** 65 kW

**Equipment:** ElectraTherm Organic Rankine Cycle Power + hot water boiler

**Fuel Type:** Flare Gas

**Thermal Use:** Electricity generation

**Installation Year:** 2015

**Environmental Benefits:**

**CO avg% reduction:** 89.1

**NOx avg% reduction:** 48.1

**VOC avg % reduction:** 92.8



# Project Snapshot 3:

## Williams Ignacio Gas Plant Durango, CO

Application/Industry: Oil and Gas Extraction

Capacity (MW): 6.2 MW

Power Output: 43,800 MWh per year

Prime Mover: Steam turbine

Fuel Type: WHP

Electrical Use: Waste heat from turbines  
drives centrifugal compressors

Installation Year: 1984, upgraded 2014

Emissions Savings: 2,480 tons per year

- Nitrogen oxides (NOx) reduced 88%
- Carbon oxides (CO) reduced 48%
- Volatile Organic Compounds (VOC) reduced 82%
- Particular matter (PM) reduced 59%



### Steam Turbine Waste Heat Recovery

Facility provides compression, dehydration and natural gas liquids recovery and produces liquefied natural gas (LNG) as part of the company's San Juan Gathering System. A recycled energy system captures waste heat from the compression process and uses it to generate electricity.



# Project Snapshot 4:

## Northern Border Pipeline

St. Anthony, ND

Application/Industry: Midstream

Capacity (MW): 5.5 MW

Equipment: Organic Rankine Cycle Ormat

Fuel Type: Waste Heat

Thermal Use: Electricity generation

Installation Year: 2006

Annual Emissions Reductions:

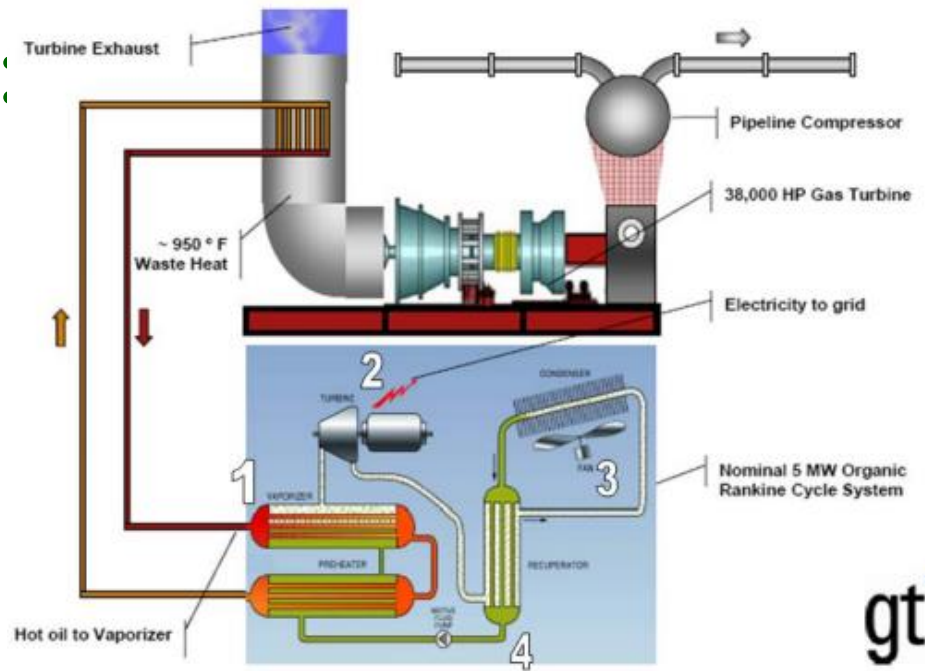
27,600 tons of CO<sub>2</sub>

34,500 kg of NO<sub>x</sub>

124,200 kg of SO<sub>2</sub>

Estimated Savings : \$600,000 per year

Testimonial: This project was a result of a successful collaboration among several organizations. Northern Border Pipeline supplies the land and waste heat to ORMAT in exchange for a royalty on electric sales. ORMAT built, owns and operates the ORC plant, using its Power Purchase Agreement (PPA) with Basin Electric to finance the project. Basin Electric executes a 25-year PPA with ORMAT for all electricity.



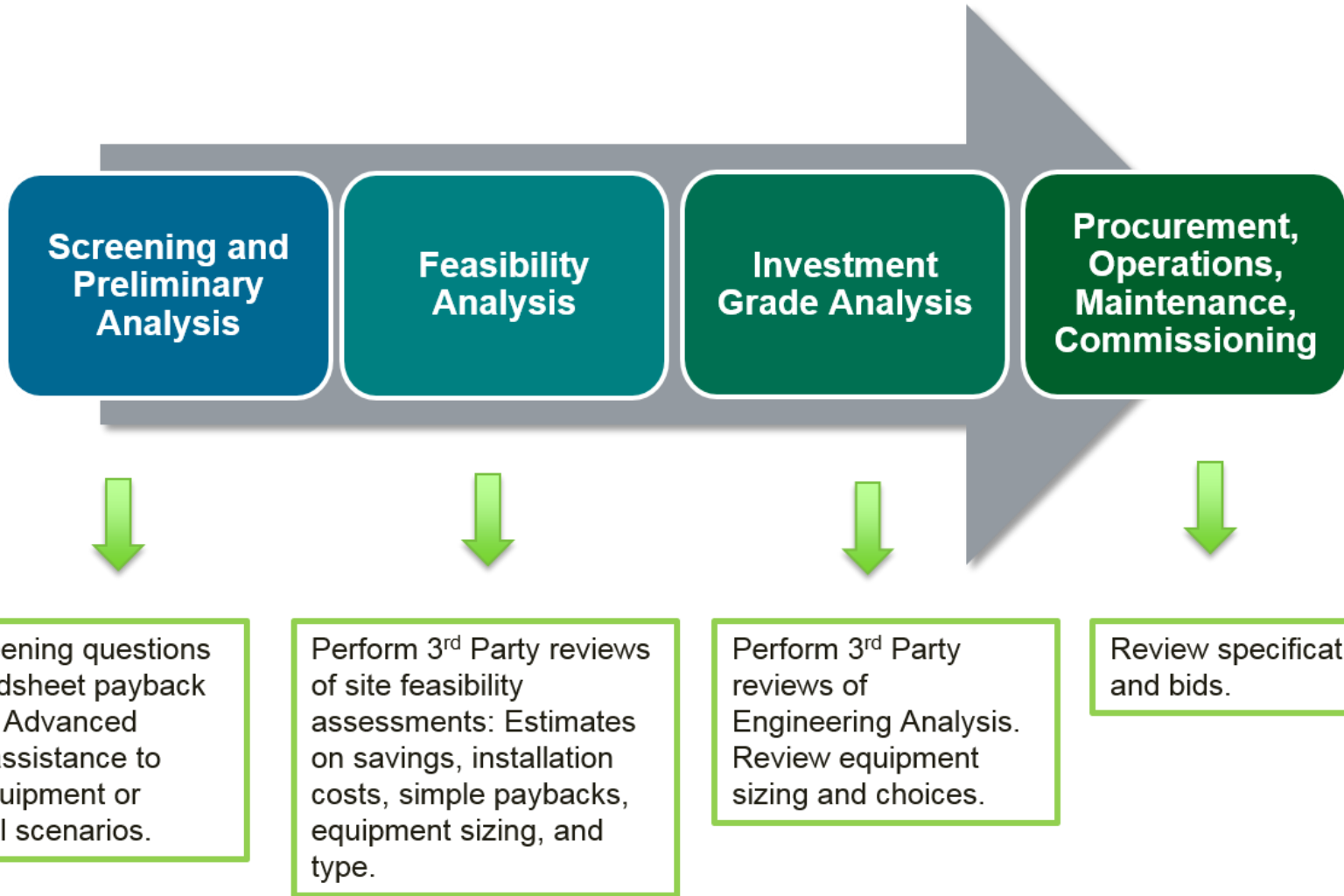
Source: <http://www.midwestchptap.org/profiles/ProjectProfiles/NorthernBorderPipeline.pdf>



# How to Implement a WHP Project with the Help of CHP TAP



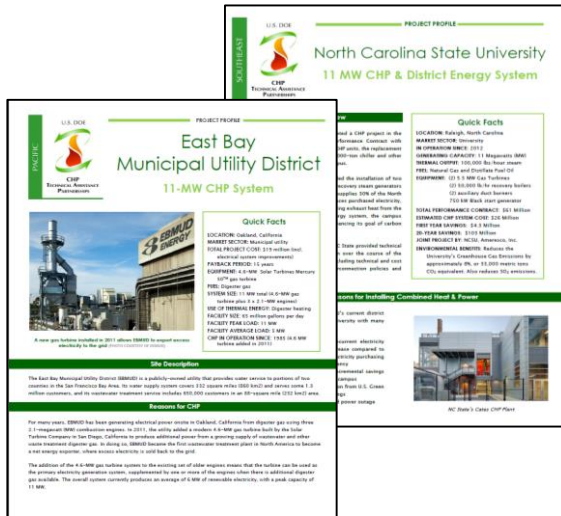
# CHP TAP Role: Technical Assistance





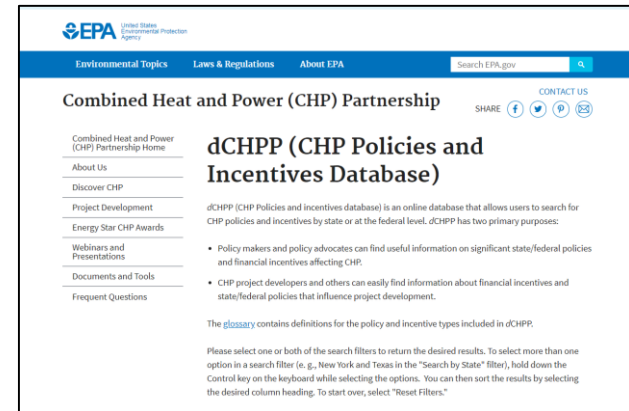
# CHP Project Resources

## DOE Project Profile Database



[energy.gov/chp-projects](https://energy.gov/chp-projects)

## EPA dCHPP (CHP Policies and Incentives Database)



<https://www.epa.gov/chp/dchpp-chp-policies-and-incentives-database>

# CHP Project Resources

## DOE CHP Technologies Fact Sheet Series

## Good Primer Report

**Table 4. Gas Turbine Emission Characteristics**

Parameter	1	2	3	4	5	6
NOx (ppm)	1,000	4,500	1,800	10,000	20,000	45,000
CO (ppm)	100	100	100	100	100	100
SOx (ppm)	100	100	100	100	100	100

**Table 2. Gas Turbine Performance Characteristics**

Parameter	1	2	3	4	5	6
Net Power (kW)	1,000	4,500	1,800	10,000	20,000	45,000
Efficiency (%)	30	35	40	45	50	55
Capacity (kW)	1,000	4,500	1,800	10,000	20,000	45,000

**Table 1. Summary of Gas Turbine Attributes**

Attribute	Description
Size range	Simple cycle turbines are available in sizes from 250 kW to 100,000 kW. Combined cycle turbines are available in sizes from 1,000 kW to 100,000 kW.
Efficiency	Simple cycle turbines have efficiencies of 30-40%. Combined cycle turbines have efficiencies of 50-60%.
Flexibility	Gas turbines can be started up and shut down quickly, making them ideal for peaking and load following applications.

**Table 3. Comparison of Gas Turbine and Other Power Generation Technologies**

Technology	Efficiency (%)	Start-up Time (min)	Operating Hours (hrs/yr)
Gas Turbine (Simple Cycle)	30-40	15-30	2,000-5,000
Gas Turbine (Combined Cycle)	50-60	15-30	2,000-5,000
Internal Combustion Engine (ICE)	30-40	15-30	2,000-5,000
Steam Turbine	40-50	15-30	2,000-5,000
Hydroelectric	70-90	15-30	2,000-5,000
Wind	30-45	15-30	2,000-5,000
Solar PV	15-20	15-30	2,000-5,000

**Table 5. CHP System Characteristics**

Parameter	Value
Net Power (kW)	1,000
Efficiency (%)	50
Capacity (kW)	1,000

**Table 6. CHP System Applications**

Application	Description
Industrial Process	Gas turbines can be used to generate power for industrial processes, such as chemical production and food processing.
Commercial Buildings	Gas turbines can be used to generate power for commercial buildings, such as hotels, hospitals, and universities.
Power Plants	Gas turbines can be used to generate power for power plants, such as peaking and load following units.

**Table 7. CHP System Advantages**

Advantage	Description
High Efficiency	CHP systems can achieve efficiencies of 70-90%, significantly higher than separate heat and power generation.
Flexibility	CHP systems can be sized and configured to meet specific site requirements.
Reliability	CHP systems are highly reliable and have long lifetimes.

**Table 8. CHP System Disadvantages**

Disadvantage	Description
High Initial Cost	CHP systems can have high initial costs due to the complexity of the technology.
Space Requirements	CHP systems can require significant space for the equipment and associated infrastructure.
Noise	Gas turbines can be noisy, which may be a concern for nearby communities.

**Table 9. CHP System Case Studies**

Case Study	Description
Industrial Process	Gas turbines are used to generate power for an industrial process, such as chemical production.
Commercial Buildings	Gas turbines are used to generate power for a commercial building, such as a hotel.
Power Plant	Gas turbines are used to generate power for a power plant, such as a peaking unit.

**Table 10. CHP System Future Outlook**

Outlook	Description
Market Growth	The CHP market is expected to grow significantly in the coming years.
Technology Advancements	Continued research and development will lead to more efficient and flexible CHP systems.
Policy Support	Government incentives and regulations will continue to support the growth of the CHP market.

**Combined Heat and Power  
A Clean Energy Solution**

August 2012

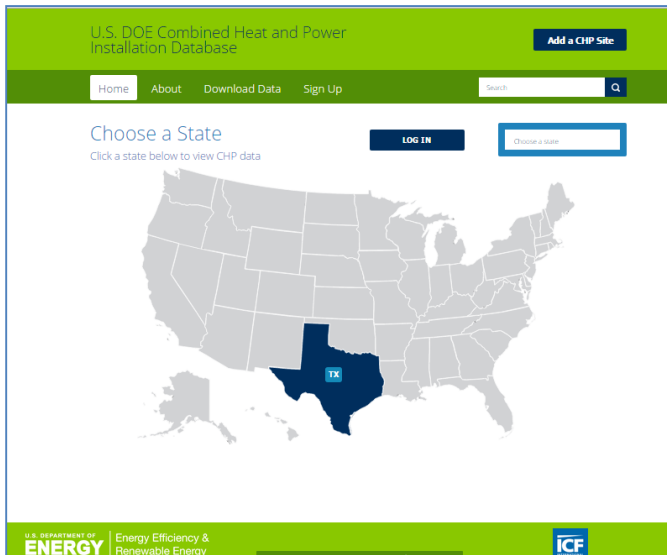
**U.S. DEPARTMENT OF ENERGY** **EPA** United States Environmental Protection Agency

[www.eere.energy.gov/chp](http://www.eere.energy.gov/chp)

[www.energy.gov/chp-technologies](http://www.energy.gov/chp-technologies)

# CHP Project Resources

## DOE CHP Installation Database (List of all known CHP systems in U.S.)



[energy.gov/chp-installs](http://energy.gov/chp-installs)

## Low-Cost CHP Screening and Other Technical Assistance from the CHP TAP

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[energy.gov/CHPTAP](http://energy.gov/CHPTAP)

# Next Steps

Resources are available to assist in developing WHP Projects.

## Contact the Southcentral CHP TAP to:

- Perform CHP and WHP Qualification Screening for a particular facility
- Advanced Technical Assistance
- Identify existing CHP sites for Project Profiles

# Summary

- WHP gets the most out of waste heat flows, enabling
  - Higher overall utilization efficiencies
  - Reduced environmental footprint
  - **Reduced operating costs**
- CHP and WHP can be used in different strategies, including **critical infrastructure resiliency** and emergency planning
- **Proven technologies** are commercially available and cover a full range of sizes and applications

# Thank You



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