# Industrial Waste Heat to Power Applications and Market Trends

August 20, 2020

CHP Technical Assistance Partnerships
SOUTHCENTRAL

20AIChE Spring Meeting

16TH GLOBAL CONGRESS ON PROCESS SAFETY

# 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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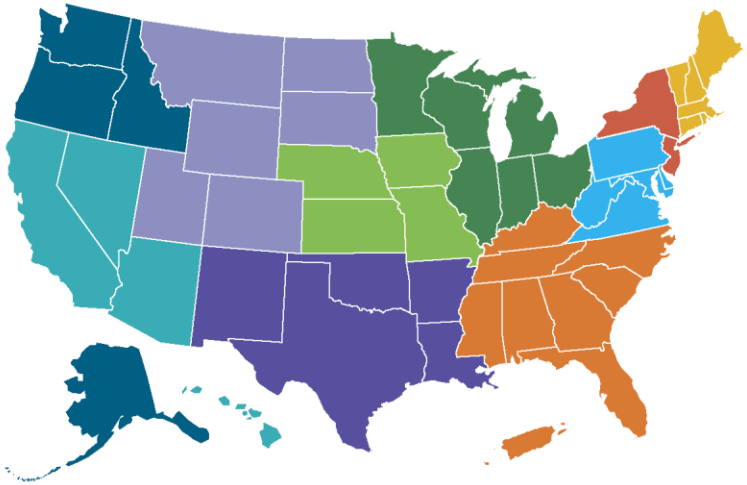

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# DOE CHP Technical Assistance Partnerships (CHP TAPs)

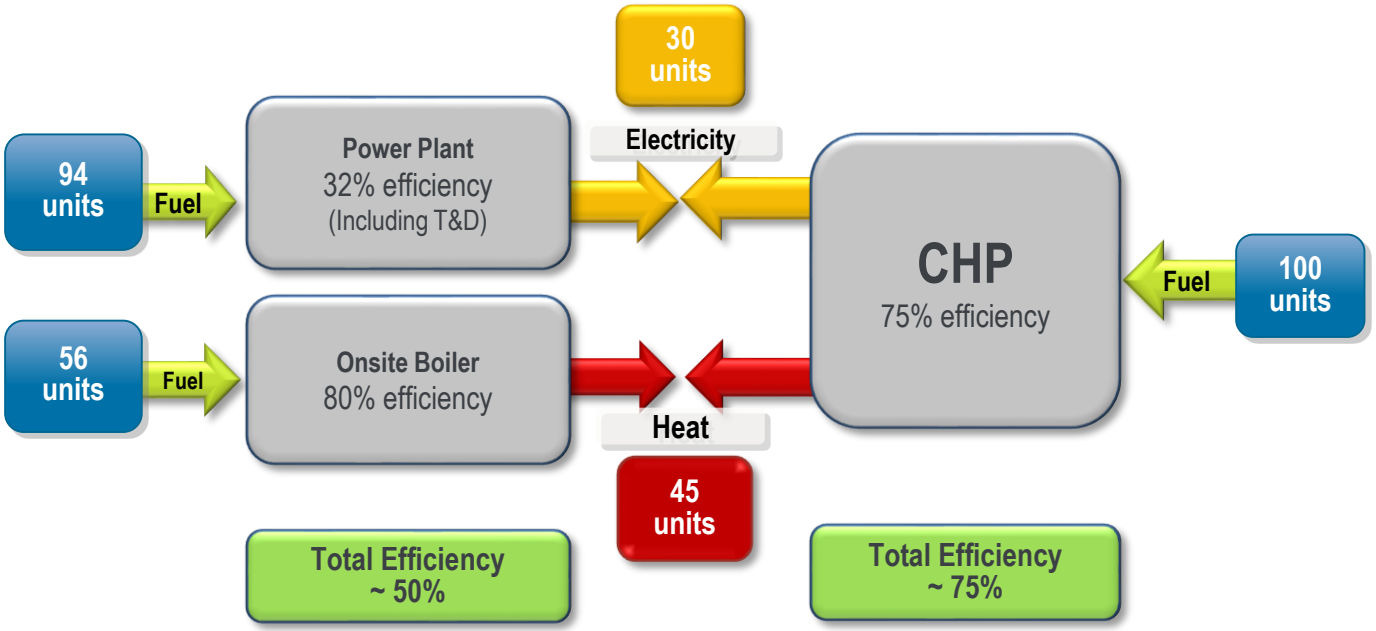
- **End User Engagement**
  Partner with strategic End Users to advance technical solutions using CHP as a cost effective and resilient way to ensure American competitiveness, utilize local fuels and enhance energy security. CHP TAPs offer fact-based, non-biased engineering support to manufacturing,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

# WHP Overview



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



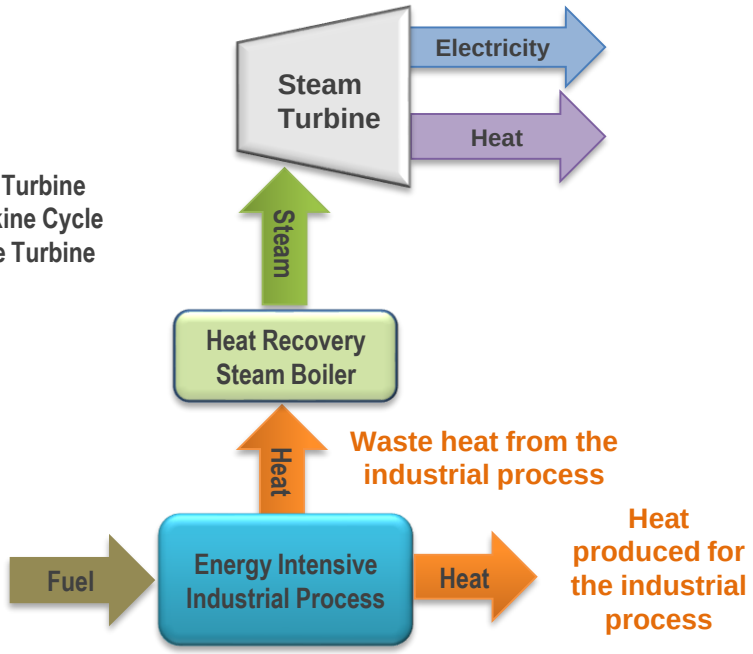

**30 to 55% less greenhouse gas emissions**

# 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

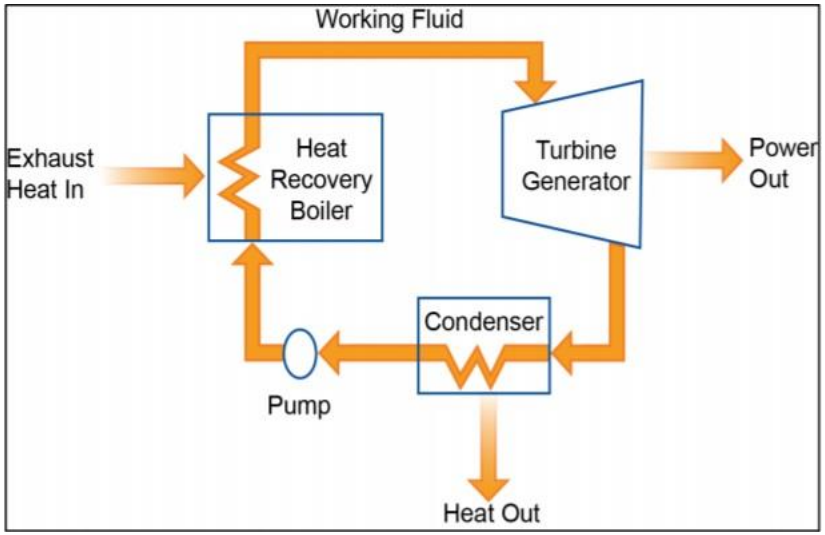
- Waste Heat from a Thermal Process
- Waste Heat from a Mechanical Drive
- Waste heat from other systems

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**

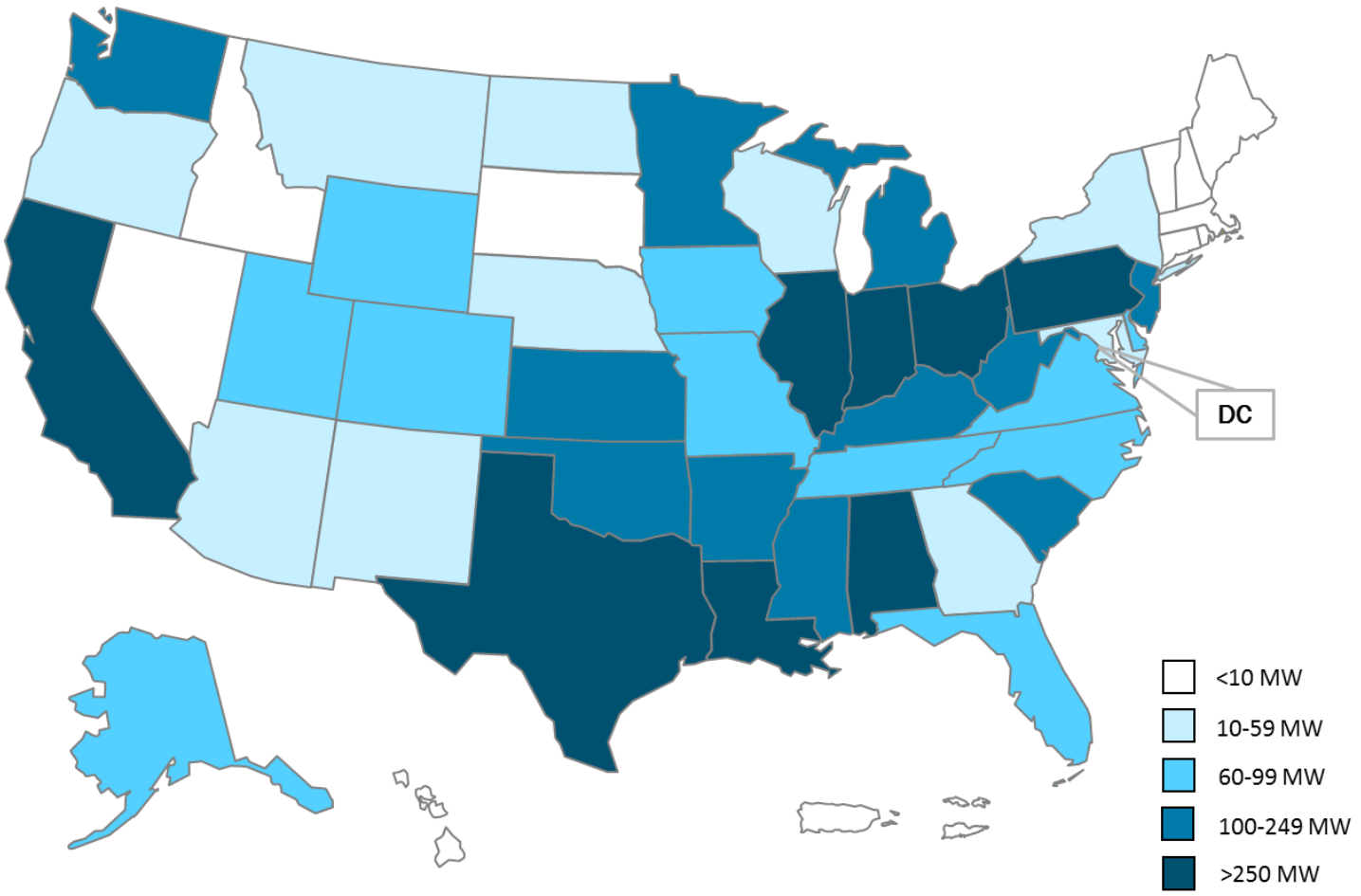
Sources: "Combined Heat and Power (CHP) Technical Potential in the United States", March 2016, energy.gov/chp-potential

# 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 |
| | | | **Total** | **1,105** | **7,624** |

Source: “Combined Heat and Power (CHP) Technical Potential in the United States”, March 2016, 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

# 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 |
| **Total** | **1,105** | **7,624** |

Source: “Combined Heat and Power (CHP) Technical Potential in the United States”, March 2016, 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: **CO2 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%

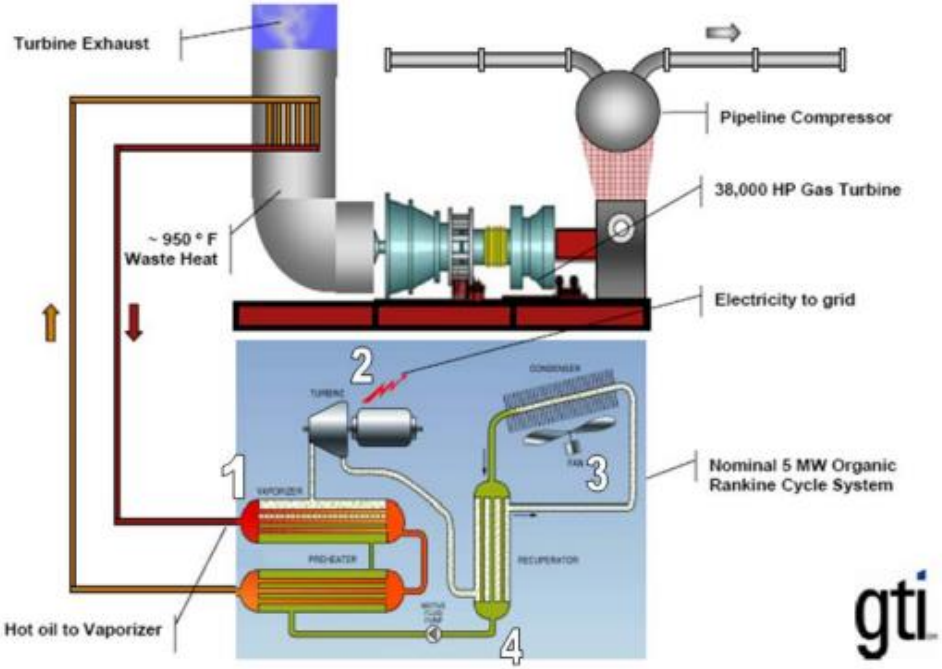
**Steam Turbine Waste Heat Recovery**
Facility provides compression, dehydration and natural gas liquids recovery and produces liquefied natural gas (LNG) as part of the company's San Juan Gathering System. A recycled energy system captures waste heat from the compression process and uses it to generate 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 $CO_2$**
**34,500 kg of $NO_x$**
**124,200 kg of $SO_2$**
**Estimated Savings : $600,000 per year**




Northern Border Pipeline Company
Operated by TransCanada

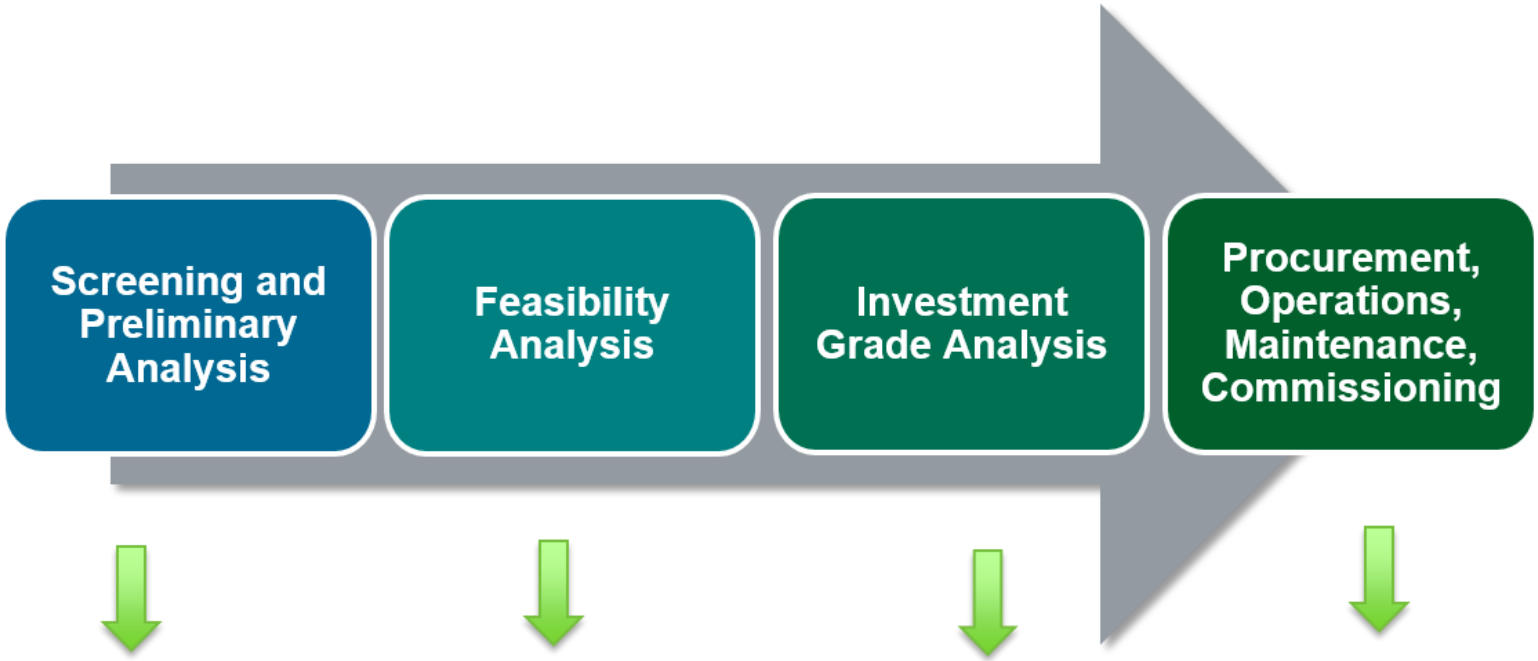
Testimonial: This project was a result of a successful collaboration among several organizations. Northern Border Pipeline supplies the land and waste heat to ORMAT in exchange for a royalty on electric sales. ORMAT built, owns and operates the ORC plant, using its Power Purchase Agreement (PPA) with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




Quick screening questions with spreadsheet payback calculator; Advanced technical assistance to explore equipment or operational scenarios.

Perform 3rd Party reviews of site feasibility assessments: Estimates on savings, installation costs, simple paybacks, equipment sizing, and type.

Perform 3rd Party reviews of Engineering Analysis. Review equipment sizing and choices.

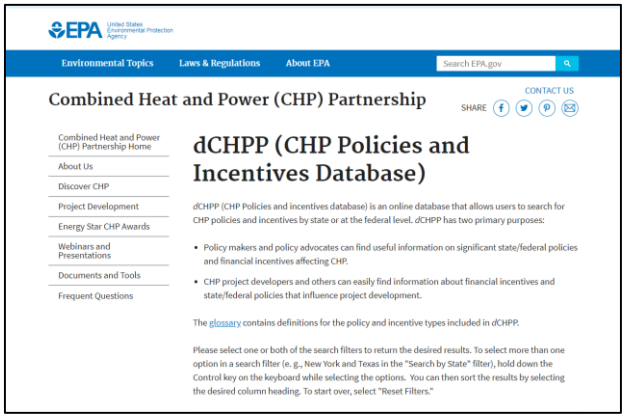
Review specifications and bids.

# CHP Project Resources

## DOE Project Profile Database


energy.gov/chp-projects

## EPA dCHPP (CHP Policies and Incentives Database)



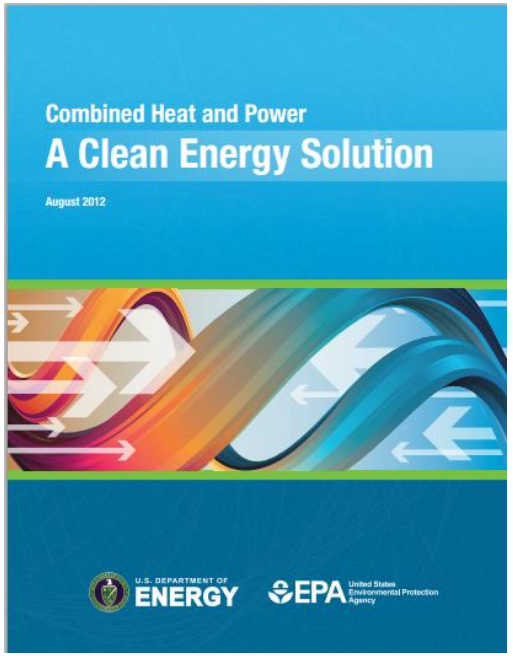

https://www.epa.gov/chp/dchpp-chp-policies-and-incentives-database

# CHP Project Resources

## DOE CHP Technologies Fact Sheet Series


www.energy.gov/chp-technologies

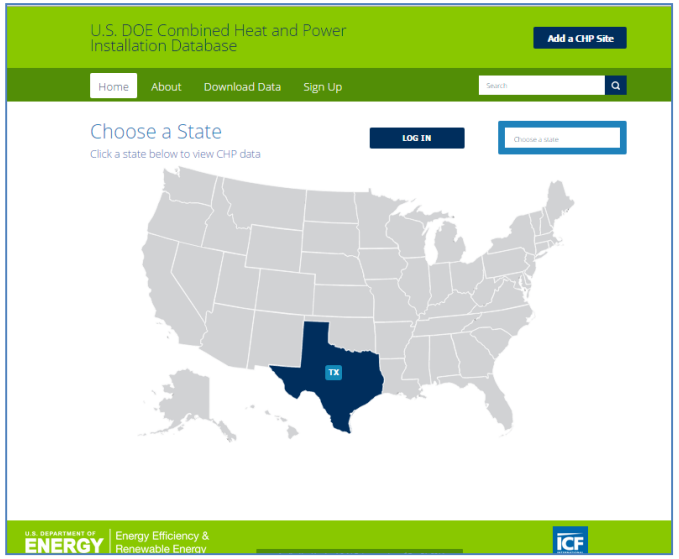
## Good Primer Report




www.eere.energy.gov/chp

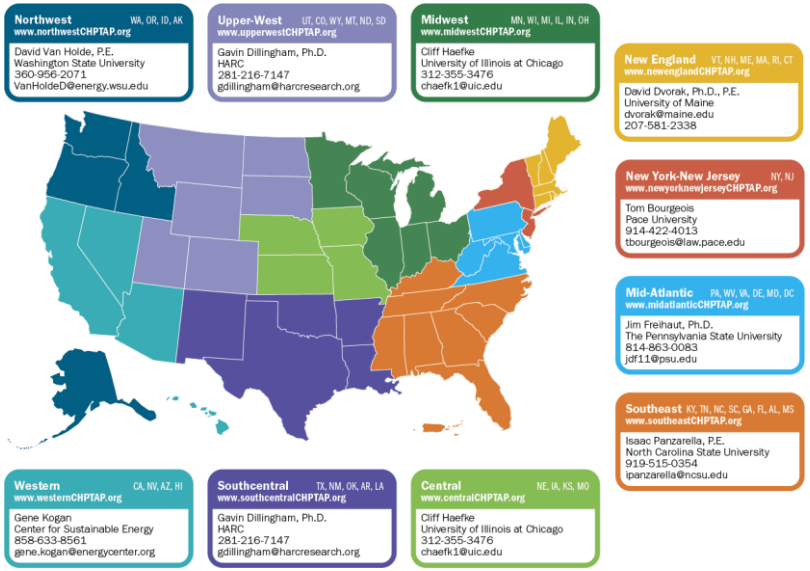
# CHP Project Resources

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




energy.gov/chp-installs

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




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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