Reducing Energy Costs with Waste Heat to Power

Gavin Dillingham, PhD - Southwest CHP TAP

March 14, 2017
Agenda

- WHP Overview
- WHP Examples
- WHP Deployment - Industry Perspective – Ormat
- WHP Financing Options - SWEEP
- WHP/CHP Project Services from DOE CHP TAPs
- Q&A
Thank You
U.S. DOE CHP Deployment Program

- **Market Analysis and Tracking** – Supporting analyses of CHP market opportunities in diverse markets including industrial, federal, institutional, and commercial sectors.

- **Technical Assistance through DOE's CHP Technical Assistance Partnerships (CHP TAPs)** – Promote and assist in transforming the market for CHP, waste heat to power, and district energy with CHP throughout the United States.

- **Just Launched Combined Heat and Power (CHP) for Resiliency Accelerator** - Collaborating with Partners to support consideration of CHP and other distributed generation solutions for critical infrastructure resiliency planning at the state, local, and utility levels.

- **Packaged CHP System eMarket Initiative (under development)** - Increase CHP deployment in underdeveloped markets with standardized, and warrantied packaged CHP systems driven by strong end-user engagement via Market Mover Partners, such as cities, states, and utilities.

www.energy.gov/chp
CHP Technical Assistance Partnerships

- **Education and Outreach**
  Providing information on the energy and non-energy benefits and applications of CHP to state and local policy makers, regulators, end users, trade associations, and others.

- **Technical Assistance**
  Providing technical assistance to end-users and stakeholders to help them consider CHP, waste heat to power, and/or district energy with CHP in their facility and to help them through the development process from initial CHP screening to installation.

- **Market Opportunity Analysis**
  Supporting analyses of CHP market opportunities in diverse markets including industrial, federal, institutional, and commercial sectors.
WHP Overview
Defining Combined Heat & Power (CHP)

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

Conventional CHP
(also referred to as Topping Cycle CHP or Direct Fired CHP)

Separate Energy Delivery:
- Electric generation – 33%
- Thermal generation – 80%
- Combined efficiency – 45% to 55%

CHP Energy Efficiency (combined heat and power)
70% to 85%
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)

- 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)
Three Categories for WHP

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

Source: ORNL Waste Heat to Power Market Assessment 2015
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
  - Thermo-photovoltaic Generation
  - Stirling Engine
  - Steam Engine

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, and
- Providing a source of pollution-free energy.

Port Arthur Steam Energy/Oxbow Corp.
WHP Today in the United States

Capacity: MW

- Chemicals: 270 MW
- Refining: 118 MW
- Primary Metals: 217 MW
- Other: 98 MW
- Pipeline: 64 MW

766 MW of installed WHP at over 96 industrial facilities

Source: ORNL Waste Heat to Power Market Assessment 2015
Things 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?

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
Most Common Applications

- Primary Metals
- Nonmetallic Mineral Product Processing
- Petroleum Refining
- Chemical
- Fabricated Metals
- Natural Gas Compressor Stations
- Oil and Gas Production

WHP Technical Potential

![Bar chart showing the distribution of technical potential and market penetration based on payback periods. The chart indicates that the highest technical potential is for heat streams at temperatures ≥ 450°F, with a market penetration of 56%. The chart also shows market penetrations for different payback periods, with the highest for payback periods less than 2 years and the lowest for payback periods greater than 5 years.]

Source: ORNL Waste Heat to Power Market Assessment 2015
Waste Heat Inventory by Sector

Source: ORNL Waste Heat to Power Market Assessment 2015
# Costs to Install

## Technology and Cost Characteristics

<table>
<thead>
<tr>
<th>Technology</th>
<th>Cost Characteristic</th>
<th>Electric Capacity for WHP Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>50-500 kW</td>
</tr>
<tr>
<td>Steam Rankine Cycle</td>
<td>Installed Capital Cost, $/kW</td>
<td>$3,000</td>
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<tr>
<td></td>
<td>O&amp;M Costs, $/kWh</td>
<td>$0.013</td>
</tr>
<tr>
<td>Organic Rankine Cycle</td>
<td>Installed Capital Cost, $/kW</td>
<td>$4,500</td>
</tr>
<tr>
<td></td>
<td>O&amp;M Costs, $/kWh</td>
<td>$0.020</td>
</tr>
</tbody>
</table>

*Source: ICF analysis based on equipment manufacturer input.*
WHP Projects
Project Snapshot: Waste Heat to Power

Port Arthur Steam Energy/Oxbow Corp.
Port Arthur, TX

Application/Industry: Petroleum Coke Production
Capacity (MW): 5 MW
Equipment: Waste heat recovery boilers, back pressure steam turbine
Recovered Energy: 5 trillion Btus per year
Thermal Use: Steam and Electricity Generation
Installation Year: 2005
Emission Savings: Reduces facility emissions by 159,000 tons per 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

Source: http://www.southwestchptap.org/data/sites/1/documents/profiles/Port_Arthur_Steam-Project_Profile.pdf
Project Snapshot: Waste Heat to Power

Trailblazer Pipeline
Peetz, CO

**Application/Industry:** Pipeline
**Capacity (MW):** 3.5 MW
**Equipment:** Ormat Organic Rankine Cycle
**Energy Output:** 27,600 MWh per year
**Use of Electrical Energy:** Power export to grid
**Installation Year:** 2009
**Yearly Savings:** $600,000+
**Emission Savings:** 27,600 CO2 reduction per year

**Fast Fact:** Tri-State’s distributed and renewable energy policies make it easier and more economical for its member co-ops to pursue waste heat to power. Each co-op can self-supply up to 5% of its own load with locally-produced clean energy.

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Different Applications of WHP

- OEC
- Gas Turbines
- Original Stack
- Diverter
- Compressor Building
- Waste Heat Oil Heater
- Cement Plant
- Oil Refinery
- Gas Engine
Success Story: WHP in a Compressor Station

Pipeline – Kern River Gas Transmission - Veyo REG Project in Utah
• Commissioned in May 2016
• Owned and Operated by Utah Associated Municipal Power Systems
  • Funded by 7 UAMPS utility members
• Gas Turbines: 3 Solar Mars 100’s
• Net generating capacity: 7.8 MW, enough to provide electricity to ~7800 homes

Project Results*
• Built by Ormat under EPC agreement
• Project exceeded performance guarantee
• Commissioned in 18.5 months from NTP, 4 months ahead of schedule
• Project site construction: complete in less than 8 months after groundbreaking
• Issued first Utah tax-exempt green bond for carbon-free power plant

* From article published in Utah Policy.com.
Success Story: WHP in a Gas Processing Plant

Installed on gas processing plant in Louisiana
- Neptune Plant - Owned and operated by Enterprise Products
- 2 Solar Mars 100 gas turbines
- Gross generating capacity: 4.5MW

Project Results
- ~3 year payback*
- Operating reliably since February 2004
- Serves gas plant loads reducing power bills
- Excess power sold to utility, enhancing revenues
- Gas plant reliability increased
- Eliminated gas plant turbine trips and outages due to utility interruptions
- Black start capability
- Can operate islanded from the grid, reducing plant down-time

* From article published in Pipeline and Gas Technology.
General Project Economics

- **Build / own / operate arrangements**
  a) Developer builds, commissions and owns the WHP facility
  - Energy sales to utility/off-taker typically under long-term PPA
  - Negotiated PPA pricing between offtaker and project owner – must be competitive with other renewable resource options
  - Host fees for heat and land
    - Can be structured as
      - Flat fee
      - Percentage of revenues
      - Bandwidth
      - Other
  - O&M services/fees
  - Capital costs of interconnection to utility
b) Build under EPC for sale to utility/Commercial&Industrial (C&I) customer

- Developer builds and commissions the WHP facility
- Developer sells the WHP unit at negotiated price to:
  i) Load Serving Entity (LSE)
    - LSE may rate base unit and use power to serve its customers
    - LSE responsible for host fees and land costs
    - LSE responsible for electrical interconnection
    - O&M can be performed by developer, C&I customer, or a 3rd party
  ii) C&I Customer
    - C&I Customer uses power to serve its on-site load (behind-the-meter application)
    - C&I Customer responsible for any departing load costs of utility
    - C&I Customer coordinates and pays for electrical interconnection requirements with utility
    - O&M can be performed by developer, C&I customer or a 3rd party.
WHP Project Development Challenges

- Host requirements
  - Site location: size, existing equipment, underground facilities
  - Operations: no heat stream guarantee, PSM compliance, back pressure limitations, fire suppression
- Remote WHP plant locations
  - Address electrical interconnection requirements, both technical and economic
- Utility / Off-taker requirements
  - PPA energy sales rates
  - Available incentives or programs
  - RPS standards
- Regulatory Framework
  - Qualification as renewable energy facility
  - No ITC/PTC
WHP Project Improvements

- Power cycle efficiency improvements
  - Higher efficiency turbine design
  - Higher efficiency heat exchangers with superheating
  - Higher efficiency recuperators
  - Reductions in auxiliary loads
- Heat trace improvements for winter conditions
- Installed VFD’s on motive fluid pumps to improve performance and efficiency
- Coordination of utility relay and monitoring settings
- Coordination of fire system alarms settings
- Surveillance cameras used at all installations
WHP Benefits

- Creates carbon footprint reduction
- Creates tradable renewable energy credits and emission reduction/offset credits (CO$_2$, SO$_X$, NO$_X$)
- Improves efficiency of industrial facilities
- Baseload power generation
- No requirement for licensed steam operator
- Reliable, unattended operation
- Operates remotely
- Customized to specific heat source and site
- No water usage
- No interference with host operations
The Power of Experience
Recycled Energy Financing Options

Neil Kolwey, Sr. Associate, SWEEP
March 14, 2017
Promoting energy efficiency programs and policies in six Southwest states
Financing Options

Loans
Leases and Energy Service Agreements (ESA)
PACE financing
Incentive for Recycled Energy (for Xcel Energy customers)
Loans

- Through a manufacturer or contractor, or directly with a bank or credit union
- Customer needs to be credit-worthy and OK with risks of equipment performance
- Often requires down-payment (e.g., 20%)
Leases

Capital (or finance) lease

- Customer owns* the equipment over lease period, can purchase at the end for discounted price
- Like a loan, but no down-payment, less paperwork, quicker approval

Operating lease

- Customer does not own the equipment during lease period; lease payments are an operating expense
- Option to purchase at end of lease period
Energy Service Agreements

- Third-party developer owns equipment and assumes responsibility for operation and maintenance
- Off-balance sheet for customer
- Typically a longer contract period (15-20 years) than for leases
- Customer makes monthly payments which include power purchases from the WHP/recycled energy system
Lease or ESA Contract with Shared Savings

- Electricity bill before project
- Electricity bill after project
- Contract Payments
- $ Savings
- Positive Cash Flow

Years
Comparison of Risks and Responsibilities for Financing Options

- Loan
- Financial lease
- Operating lease
- ESA

Increasing responsibility and risk for financing entity
Decreasing control and debt impacts for industrial customer
Possible Legal Issues

- In some utility territories (e.g., Xcel, Black Hills Energy), third-party ownership, with sale of electricity to customer, may not be allowed
- Capital leases still a viable option
PACE Financing

Colorado Commercial Property Assessed Clean Energy (C-PACE)

- Typical loan period of 15-20 years, with low-interest rate (6-7%)
- Off-balance sheet
- Project financed through a lien on the facility
- Paid back through the facility’s county property taxes
- Currently available in 14 Colorado counties

(See [http://copace.com/participating-counties/](http://copace.com/participating-counties/) )
Xcel Energy Recycled Energy Incentive

- $500/kW of RE system capacity installed
- Paid monthly over 10 years at rate of ~$.012/kWh (until net present value of payments reaches $500/kW)
- Incentive available for RE systems up to 10 MW
- Required pre-approval process
Neil Kolwey, Senior Associate
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nkolwey@swenergy.org
How to Implement a WHP Project with the Help of the CHP TAP
CHP TAP Technical Assistance

US DOE CHP TAP Services:

US DOE CHP TAP Services:

- Screening and Preliminary Analysis: Quick screening questions with spreadsheet payback calculator.
- Investment Grade Analysis: 3rd Party review of Engineering Analysis. Review equipment sizing and selection.
High level assessment to determine if site shows potential for a WHP project

- Qualitative Analysis
  - Energy Consumption & Costs
  - Estimated Energy Savings & Payback
  - CHP System Sizing

- Quantitative Analysis
  - Understanding project drivers
  - Understanding site peculiarities

### Annual Energy Consumption

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<th>Base Case</th>
<th>CHP Case</th>
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<tr>
<td>Purchased Electricity, kWh</td>
<td>88,250,160</td>
<td>5,534,150</td>
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<tr>
<td>Generated Electricity, kWh</td>
<td>0</td>
<td>82,716,010</td>
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<tr>
<td>On-site Thermal, MMBtu</td>
<td>426,000</td>
<td>18,872</td>
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<td>CHP Thermal, MMBtu</td>
<td>0</td>
<td>407,128</td>
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<tr>
<td>Boiler Fuel, MMBtu</td>
<td>532,500</td>
<td>23,590</td>
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<td>CHP Fuel, MMBtu</td>
<td>0</td>
<td>969,845</td>
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<tr>
<td>Total Fuel, MMBtu</td>
<td>532,500</td>
<td>993,435</td>
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### Annual Operating Costs

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<tr>
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<th>Base Case</th>
<th>CHP Case</th>
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<tbody>
<tr>
<td>Purchased Electricity, $</td>
<td>$7,060,013</td>
<td>$1,104,460</td>
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<tr>
<td>Standby Power, $</td>
<td>$0</td>
<td>$0</td>
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<td>On-site Thermal Fuel, $</td>
<td>$3,195,000</td>
<td>$141,539</td>
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<td>CHP Fuel, $</td>
<td>$0</td>
<td>$5,819,071</td>
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<td>Incremental O&amp;M, $</td>
<td>$0</td>
<td>$744,444</td>
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<tr>
<td>Total Operating Costs, $</td>
<td>$10,255,013</td>
<td>$7,809,514</td>
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### Simple Payback

- Annual Operating Savings, $ $2,445,499
- Total Installed Costs, $/kW $1,400
- Total Installed Costs, $/k $12,990,000
- Simple Payback, Years 5.3

### Operating Costs to Generate

- Fuel Costs, $/kWh $0.070
- Thermal Credit, $/kWh ($0.037)
- Incremental O&M, $/kWh $0.009
- Total Operating Costs to Generate, $/kWh $0.042
Do you pay more than $.06/kWh on average for electricity (including generation, transmission and distribution)?

Are you concerned about the impact of current or future energy costs on your operations?

Are you concerned about power reliability? What if the power goes out for 5 minutes... for 1 hour?

Does your facility operate for more than 3,000 hours per year?

Do you have thermal loads throughout the year? (including steam, hot water, chilled water, hot air, etc.)
Screening Questions (cont.)

- Does your facility have an existing central plant?
- Do you expect to replace, upgrade, or retrofit central plant equipment within the next 3-5 years?
- Do you anticipate a facility expansion or new construction project within the next 3-5 years?
- Have you already implemented energy efficiency measures and still have high energy costs?
- Are you interested in reducing your facility's impact on the environment?
- Do you have access to on-site or nearby biomass resources? (i.e., landfill gas, farm manure, food processing waste, etc.)
WHP Project Resources

DOE Project Profile Database
(150+ case studies)

DOE Database of Incentives & Policies (DSIRE)

www.eere.energy.gov/chp-profiles

www.dsireusa.org
WHP Project Resources

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

No-Cost CHP Screening and Other Technical Assistance from the CHP TAP

www.eere.energy.gov/chp-installs

www.eere.energy.gov/chp-contacts
Next Steps

Resources are available to assist in developing WHP Projects.

Contact the DOE CHP TAPs to:

- Perform WHP Qualification Screening for a particular WHP candidate site
- Identify existing WHP sites for new Project Profiles
- Need an unbiased 3rd Party Review of a WHP proposal
- Need a feasibility study to determine WHP sizing, savings
Summary

- WHP plays a key role in industrial, refining and oil and gas operations by providing energy savings, reduced emissions, and opportunities for resiliency

- Emerging economic and environmental drivers are creating new opportunities to evaluate WHP and numerous examples exist to learn more about how other facilities have incorporated WHP

- Engage with the US DOE CHP TAPs to learn more about the technical assistance offerings in evaluating WHP for your facility
Questions??

Gavin Dillingham, PhD, Director
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A program sponsored by
www.energy.gov/chp