Waste Heat to Power Market Assessment: Opportunities, Technologies and Barriers

Wednesday, June 24, 2015
2:00-3:00 p.m. EDT

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Jessica Lubetsky, officer, clean energy, The Pew Charitable Trusts
Susan Brodie, executive director, The Heat is Power Association

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Pew clean energy initiative

The goal is to accelerate the clean energy economy for its national security, economic and environmental benefits.

The initiative promotes the adoption of key changes to U.S. energy policy in four sectors:

- Industry
- Utilities
- Transportation
- Research and Development

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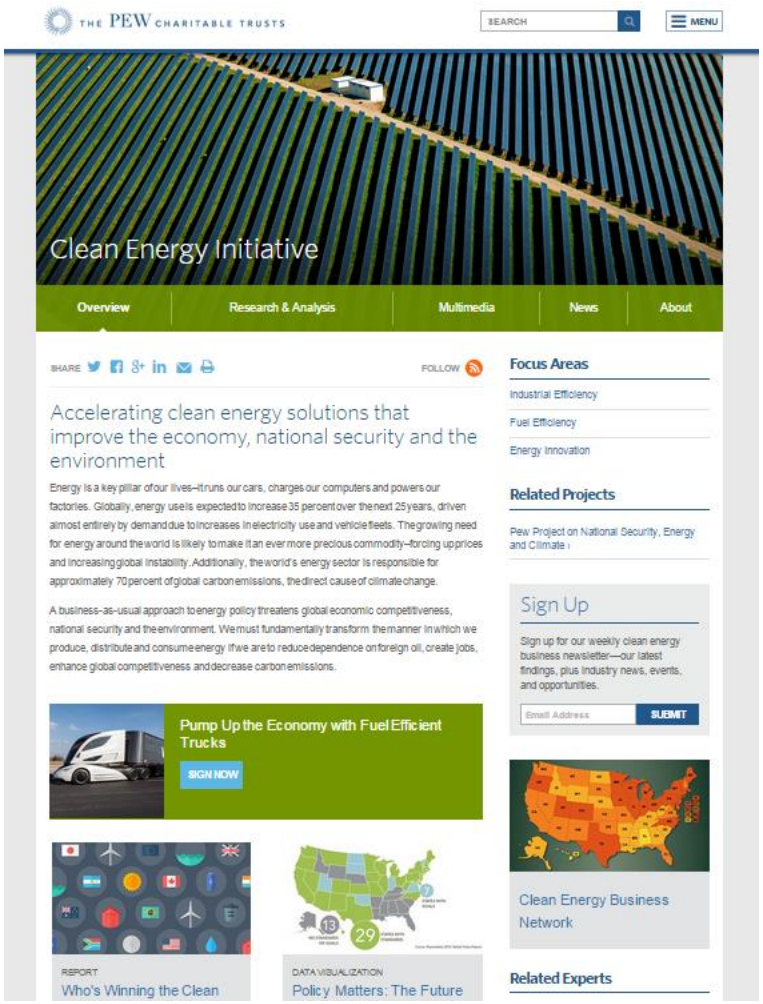
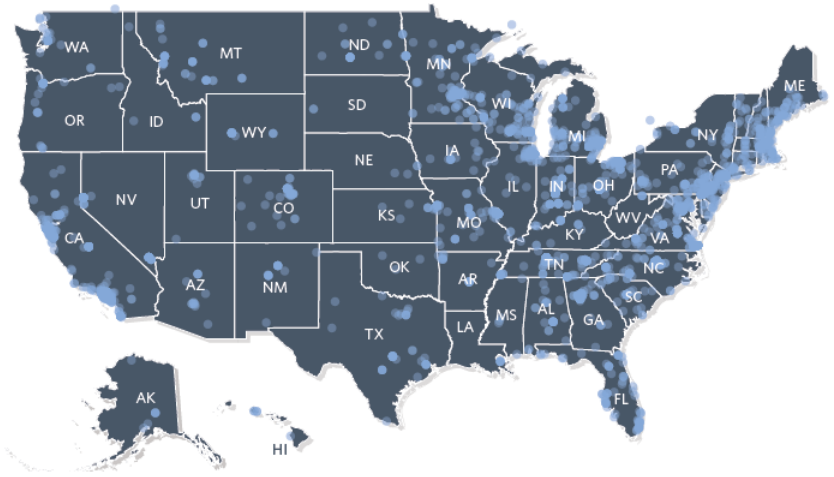


Clean Energy Business Network

Free resource to inform clean energy business leaders about Federal energy policy and share their perspectives with policymakers

Pew Clean Energy Business Network Member Locations

More than 3,000 business leaders nationwide



Industrial energy efficiency in the U.S.

The Problem

Finance is needed to help energy users cover capital costs

The currently available tax credit makes it difficult for projects to qualify and is limited in the scope of eligible technologies

The Solution

The current Investment Tax Credit is in need of changes so as to ensure efficient power generating technologies like combined heat and power (CHP) and waste heat to power (WHP) have **parity** with other clean and efficient technologies in the available energy tax incentives.

Changes would make the tax credit more accessible

Current Policy	Proposed Policy
10% ITC for CHP	Expand ITC to 30% for CHP
Does not include WHP	Include WHP
Applies to the first 15MW of CHP projects which are smaller than 50MW	Apply to first 25MW, eliminate CHP project size cap
Ends Dec. 2016	Ends Dec. 2018

Senate bills in the 114th Congress

S. 1516 The Power Efficiency and Resiliency (POWER) Act

Senators Susan Collins(R-ME) and Bob Casey(D-PA) introduced in June 2015

- ✓ Expands investment tax credit to 30%
- ✓ Adds waste heat to power as a qualifying technology
- ✓ Applies to first 25MW, eliminate project size cap
- ✓ Extends ITC to December 2018

Cosponsors: Sen. Harry Reid (D-NV)

S. 913 Waste heat to power bill

Senators Dean Heller (R-NV) and Tom Carper (D-DE) introduced in February 2015:

- Included in Senate Finance Committee markup of tax bills
- Passed out of committee and is awaiting floor consideration
  - ✓ Would make WHP eligible for the existing investment tax credit (10% credit for systems up to 50 MW in size)
  - ✓ Changes to the credit would take effect on the date of enactment and would expire with the rest of the ITC – December 2016.

House bills in the 114th Congress

H.R. 2657, The Power Efficiency and Resiliency (POWER) Act

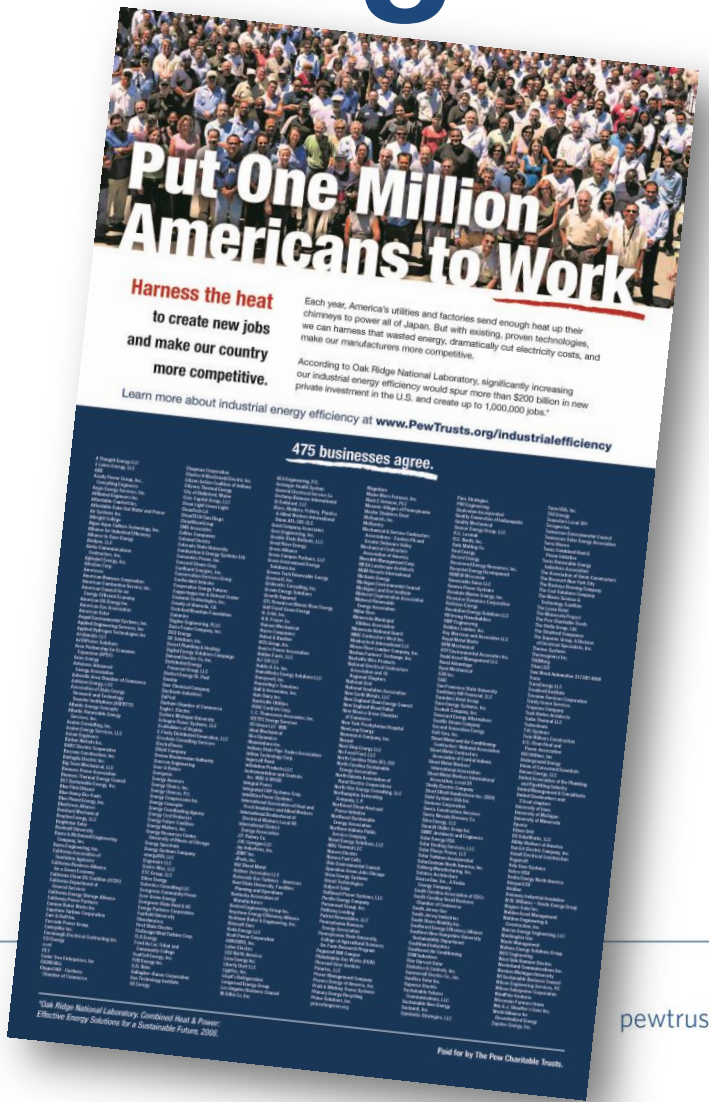
Congressmen Tom Reed(R-NY) and Earl Blumenauer(D-OR) introduced in June 2015

- ✓ Expands investment tax credit to 30%
- ✓ Adds waste heat to power as a qualifying technology
- ✓ Applies to first 25MW, eliminate project size cap
- ✓ Extends ITC to December 2018

Rep. Thomas Reed (R-NY)
Rep. Earl Blumenauer (D-OR)
Rep. Mark E. Amodei (R-NV)
Rep. Kathy Castor (D-FL)
Rep. Chris Collins (R-NY)
Rep. Christopher P. Gibson (R-NY)
Rep. Joseph J. Heck (R-NV)
Rep. Ron Kind (D-WI)
Rep. Tim Ryan (D-OH)
Rep. Steve Stivers (R-OH)
Rep. Dina Titus (D-NV)
Rep. Peter Welch (D-VT)

Broad, bipartisan support, including:

- Manufacturers
- Large energy users
- Organized labor
- National security organizations
- Environmental organizations



Messaging for WHP

Competitiveness

- Cut costs and allow manufacturers to better compete in the global marketplace
- Create as many as 100,000 highly skilled new jobs
- Free resource produced whenever an operation is running
- Produce enough energy to power 11 million homes for a year
- No additional fuel needed, no additional combustion

Questions? Contact:

Jessica Lubetsky, Officer
Pew Clean Energy Program
www.pewtrusts.org/industrialefficiency

email: jlubetsky@pewtrusts.org
phone: 202-540-6356

Interested in having your business endorse the POWER Act? Contact:

Lynn Abramson, Senior Associate
Pew Clean Energy Program
www.pewtrusts.org/businessnetwork

email: labramson@pewtrusts.org
phone: 202-540-6474

The Heat is Power Association

The industry-led advocacy organization focused exclusively on advancing waste heat to power.

Active with federal, state and regional stakeholders including business, government, agencies (DOE, EPA), industry associations and environmental groups.

Through education and advocacy, HiP seeks inclusion of WHP in federal and state legislation, regulations, and programs as an energy efficient power resource that generates electricity with no additional fuel, combustion or emissions.

The only industry association focused exclusively on reducing fuel use and emissions related to on-site power generation by increasing the U.S. market for waste heat to power.

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Support for WHP

- 17 states list WHP as a renewable resource in their RPSs and similar programs
- Pending federal legislation would:
  - Add WHP to the existing tax credit
    - Senate Finance Committee mark-up would make WHP eligible for the 10 % ITC
    - POWER Act would make WHP eligible for the 30% ITC
  - Add WHP to renewable energy definition for federal procurement
  - Improve interconnection procedures and tariff schedules and standards for supplemental, backup, and standby power fees for CHP and WHP (HEAT Act S 1202)
  - Advance the integration of clean distributed energy into electric grids (Clean Distributed Energy Grid Integration Act S 1201)
  - Extend the publicly traded partnership ownership structure to energy power generation projects, including WHP (Master Limited Partnership Parity Act)
- National Association of Clean Air Agencies (NACAA) "CPP: Menu of Options" highlights WHP as an option for complying with the Clean Power Plan

Since its establishment in 2011, Heat is Power has raised awareness of WHP opportunities and barriers and significantly increased support for WHP in federal and state legislation and programs.

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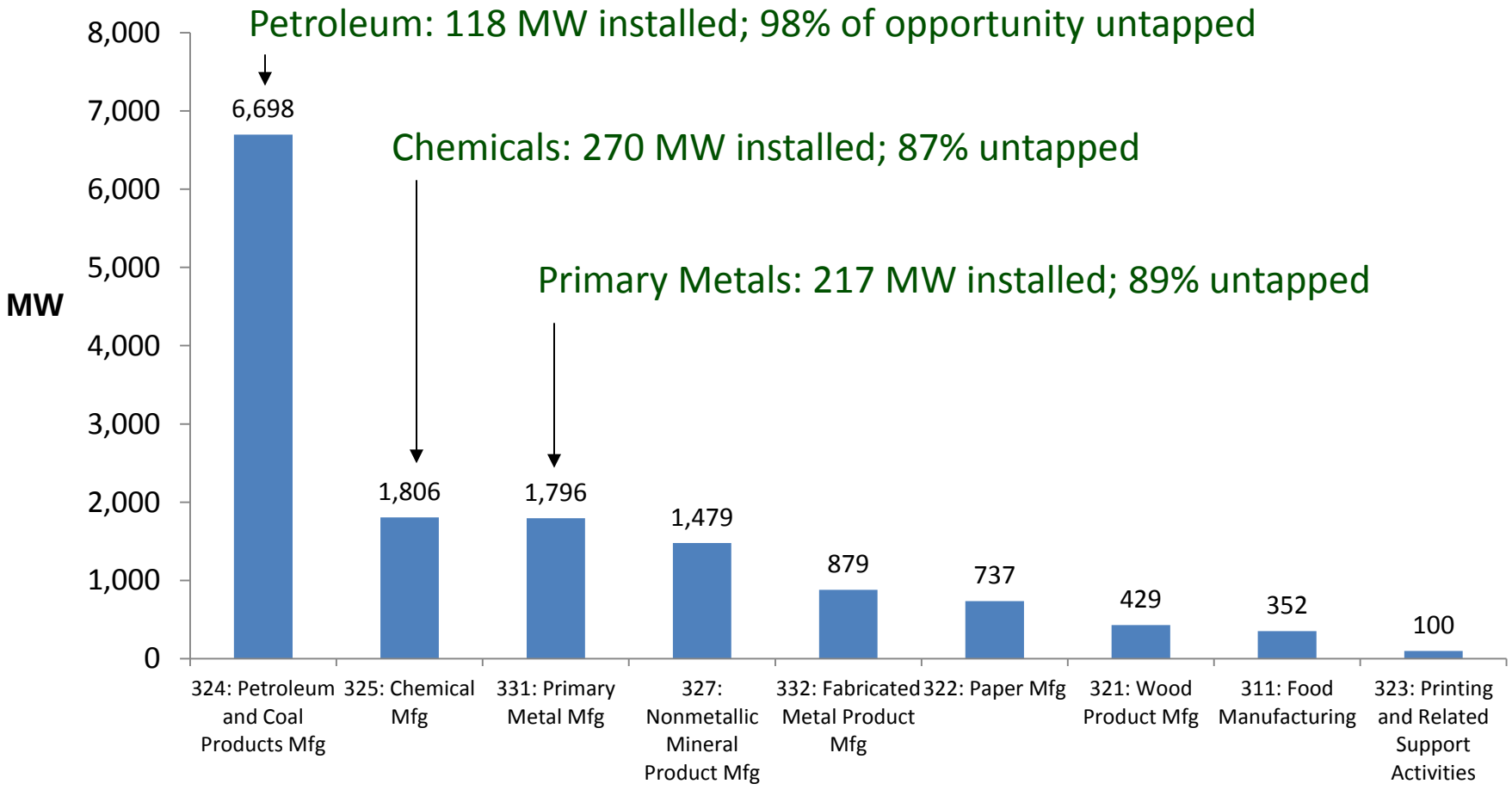
Potential for Additional WHP Projects



Source: ICF Waste Heat to Power Market Assessment March 2015

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HiP's Next Steps re: WHP Market Assessment

- The Association and its members are eager to work with industries and states that exhibit high WHP potential
- HiP members offer technologies across a wide range of temperatures, waste heat conditions, sizes, and industries
- Some members design, build, own and operate WHP projects
- HiP project fact sheets that highlight operating projects in the U.S., along with other WHP resources, are available at heatispower.org

Connecting industrial waste heat producers with solution providers. Broadening awareness of WHP as a way to address critical public policy objectives related to increasing industrial efficiency and reducing emissions of greenhouse gases and criteria pollutants.

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Building Opportunities for WHP

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For more information about HiP's efforts and membership, contact:

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630.292.1304
www.heatispower.org

WHP Market Assessment Webinar

Anne Hampson

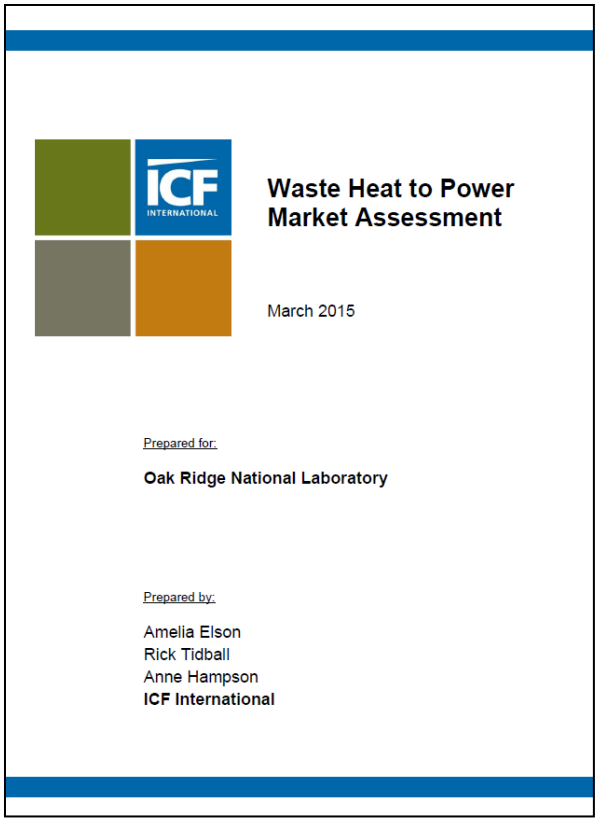
Senior Manager,
ICF International

June 24, 2015

Waste Heat to Power Market Assessment

- "Waste Heat to Power Market Assessment" report released in March 2015
  - ORNL Report No. ORNL/TM-2014/620
  - http://info.ornl.gov/sites/publications/Files/Pub52953.pdf

- Topics covered:
  - WHP Technologies and costs
  - WHP Applications
  - Existing WHP Installations
  - Technical and Economic Potential for WHP
  - Policy Drivers and Barriers



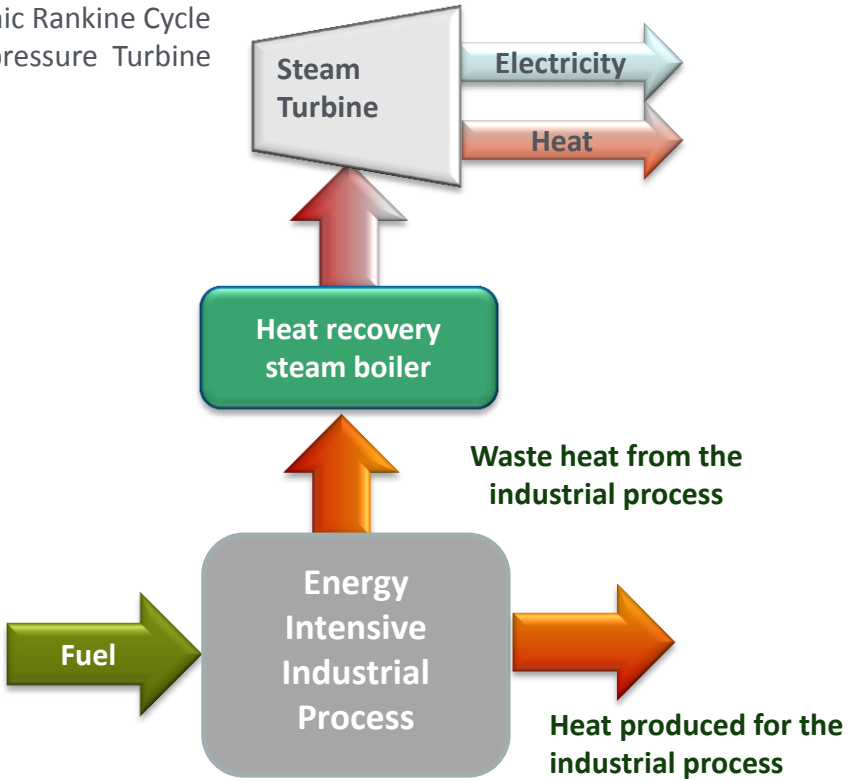
Defining Combined Heat & Power (CHP)

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



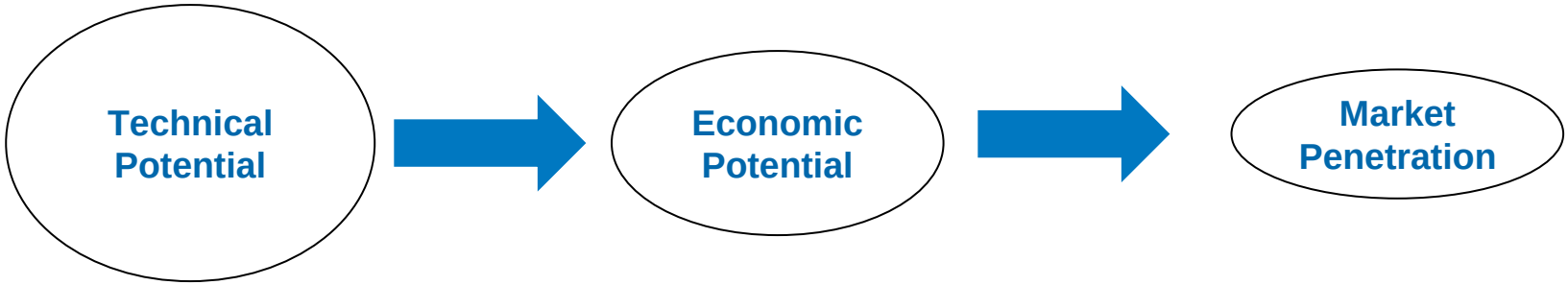
- Fuel first applied to produce useful thermal energy for the process
- Waste heat is utilized to produce electricity and possibly additional thermal energy for the process
- Simultaneous generation of heat and electricity
- No additional fossil fuel combustion *(no incremental emissions)*
- Normally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

Types of Waste Heat Streams

Source of Waste Heat Stream	**Examples** (illustrations only; not all inclusive)
Thermal Process	Energy recovered from a furnace, oven, or kiln, and subsequently used in a combined heat and power (CHP) bottoming cycle, referred to as waste heat to power (WHP).
Mechanical Drive	Energy recovered from a natural gas pipeline compressor station.
Other	Waste heat recovered from industrial or other processes that generate heat as a byproduct, such as exothermic reactions, incineration, and pressure reduction.

Approach

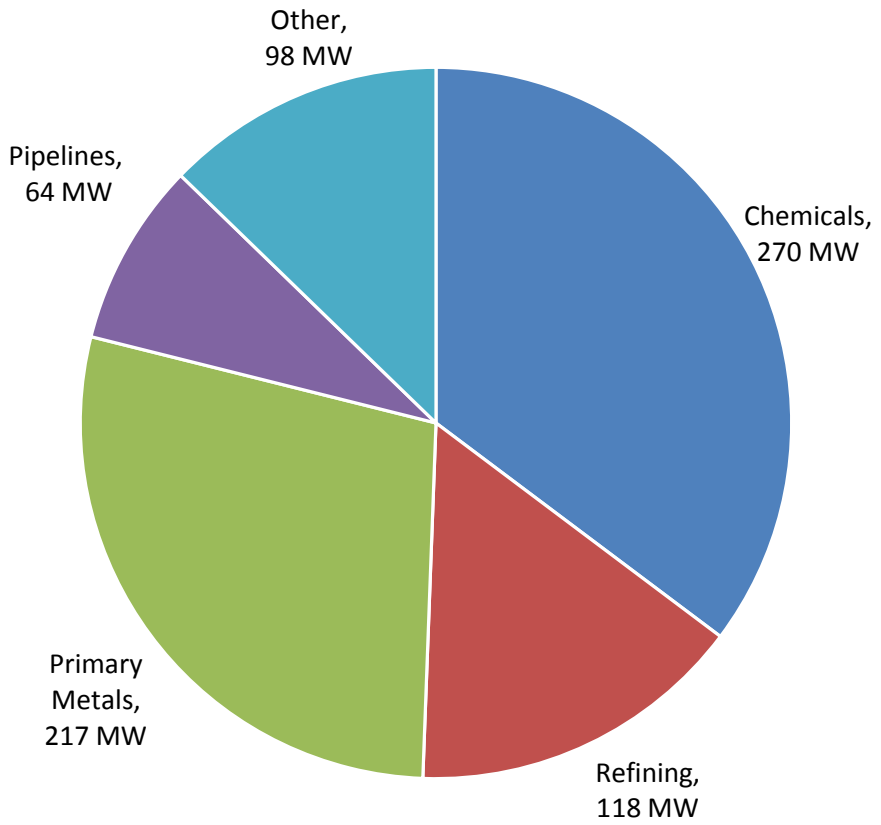
- Objective – Estimate the potential to generate electricity from industrial waste heat streams in the United States
- Type of Assessments
  - Evaluated technical potential for all temperatures – including low temperature (< 450 ^{o}F) – waste heat streams using **top-down approach**
  - Conducted more detailed market penetration analysis for medium and high temperature waste heat streams (≥ 450 ^{o}F) using **bottom-up approach**
- Approach



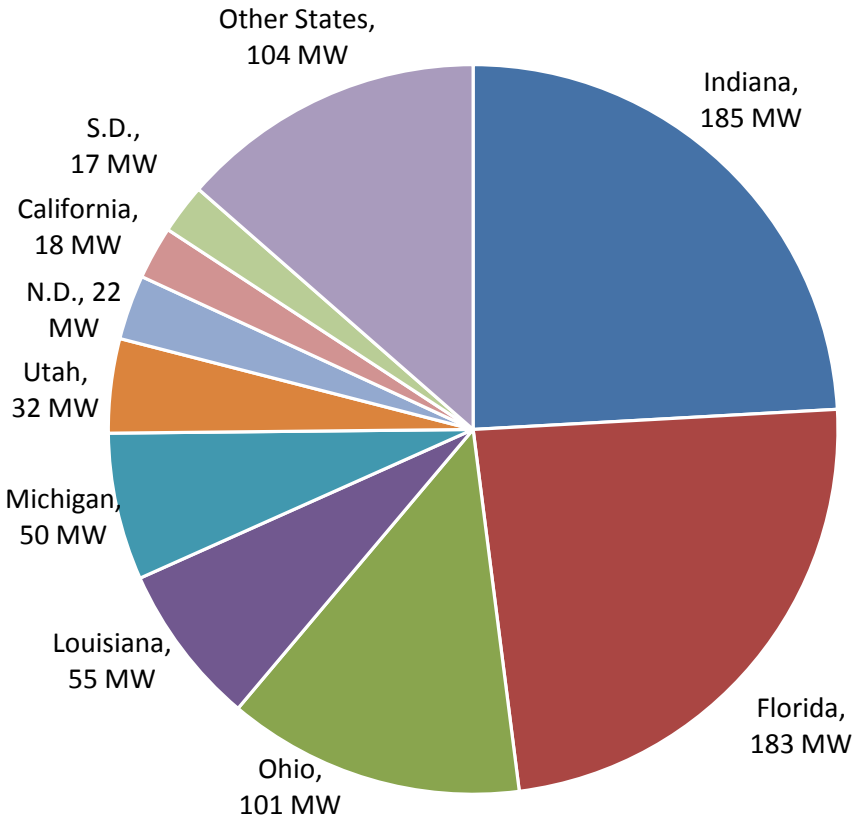
- For low temperature (<450 ^{o}F) applications, ICF did not have sufficient cost and performance data from vendors to complete a bottom-up economic analysis

Existing Waste Heat to Power
(766 MW)

Existing WHP by Application



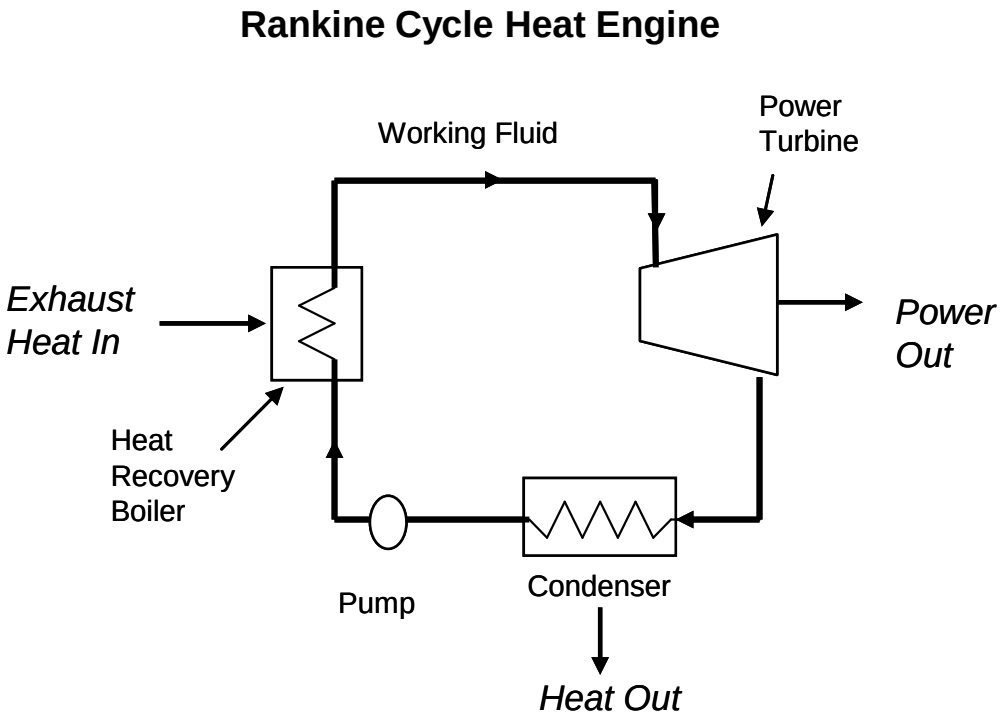
Existing WHP by State



Source: DOE/ICF CHP Installation Database (U.S. Installations as of December 31, 2013)

Technologies

- Rankine Cycle (or variations of Rankine cycle)
  - Steam Rankine Cycle (SRC)
  - Organic Rankine Cycle (ORC)
  - Kalina Cycle
  - Supercritical CO_2
- Emerging Technologies
  - Thermoelectric
  - Piezoelectric
  - Thermionic
  - Thermo-photovoltaic
  - Stirling
  - Steam

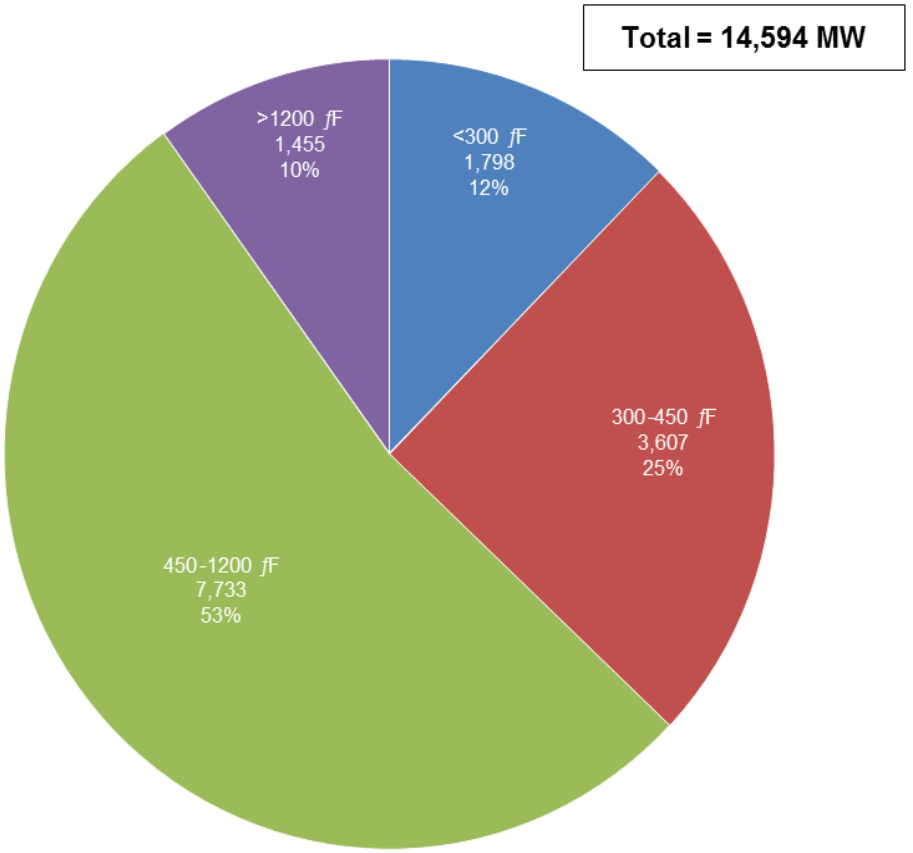


Approach for "Top-Down" Analysis of Technical Potential

- Top-down technical potential
  - Started with previously collected data on waste heat streams, including temperature and energy content from:
    - DOE, 2008. *Waste Heat Recovery: Technology and Opportunities in U.S. Industry*, prepared by BCS Inc.
    - ORNL, 2004. *An Inventory of Industrial Waste Heat and Opportunities for Thermally Activated Technologies*, prepared by United Technologies Research Center
  - Included all waste heat stream temperatures in analysis
  - Used practical efficiency based on Carnot limit to calculate WHP potential

Remaining Technical Potential for WHP in the Manufacturing Sector

(breakdown by temperature range)



Top-Down Analysis – Remaining WHP Technical Potential by NAICS Code

Industry	Electric Power (MW) by Temperature Range (°F)				
	<300	300-450	450-1200	>1200	Total
311: Food Manufacturing	13	182	157	-	352
312: Beverage and Tobacco Product Manufacturing	1	9	2	-	12
313: Textile Mills	32	11	4	-	47
314: Textile Product Mills	-	-	-	-	0
315: Apparel Manufacturing	2	-	-	-	2
316: Leather and Allied Product Manufacturing	-	-	-	-	0
321: Wood Product Manufacturing	160	242	27	-	429
322: Paper Manufacturing	129	567	42	-	737
323: Printing and Related Support Activities	40	19	29	13	100
324: Petroleum and Coal Products Manufacturing	320	687	5,628	64	6,698
325: Chemical Manufacturing	331	461	739	276	1,806
326: Plastics and Rubber Products Manufacturing	28	14	5	6	52
327: Nonmetallic Mineral Product Manufacturing	61	288	935	196	1,479
331: Primary Metal Manufacturing	499	337	62	899	1,796
332: Fabricated Metal Product Manufacturing	127	671	80	-	879
333: Machinery Manufacturing	17	34	11	-	62
334: Computer and Electronic Product Manuf.	7	13	-	-	20
335: Electrical Equipment Manufacturing	6	8	2	-	16
336: Transportation Equipment Manufacturing	15	42	7	-	64
337: Furniture and Related Product Manufacturing	5	11	4	1	21
339: Miscellaneous Manufacturing	5	11	4	1	22
Total	**1,798**	**3,607**	**7,733**	**1,455**	**14,594**
Share of Total	**12%**	**25%**	**53%**	**10%**	**100%**

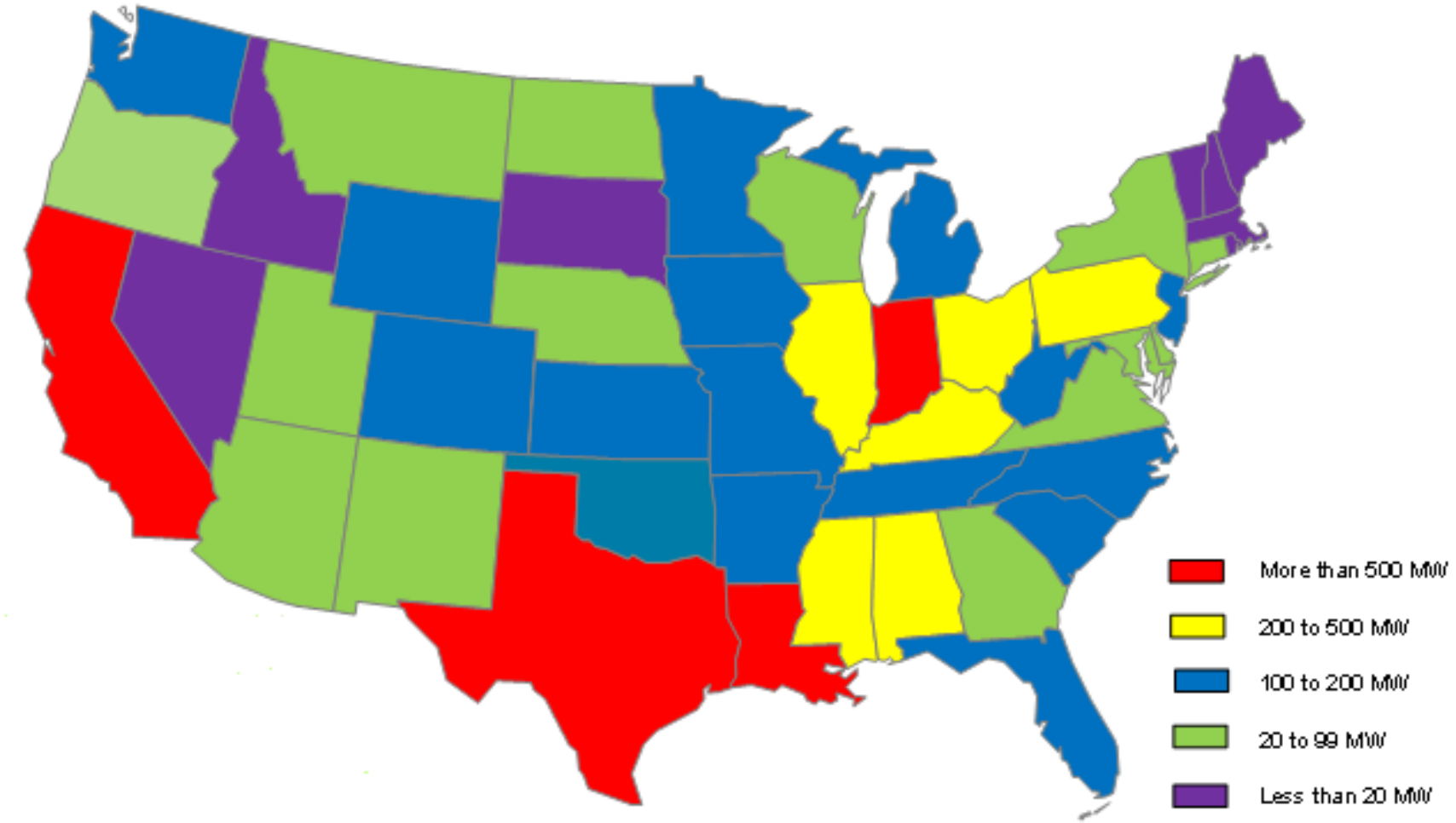
Approach for "Bottom-Up" Analysis of Technical Potential

- Identified candidate facilities using existing databases
  - EPA Greenhouse Gas Reporting Program (EPA GHGRP) Database & Landfill Database
  - EIA Compressor Station Database
  - Oil and Gas Journal's Gas Processing Plants Database & Refinery Survey
  - Portland Cement Association's Cement Kilns Database
  - Association of Iron and Steel Engineer's Directory of Iron and Steel Plants
- Calculated technical potential
  - Started with site level assessment
  - Estimated stack gas temperatures for different types of equipment
  - Estimated stack gas mass flow rates
  - Used practical efficiency based on Carnot limit
  - Calculated site level WHP technical potential
  - Rolled-up site level results to develop WHP estimates
    - By application
    - By state

Bottom-Up Analysis – Remaining WHP Technical Potential by NAICS Code

NAICS	NAICS Description	# Sites	Capacity (MW)	Share of Total Capacity
324	Total Petroleum and Coal Products	176	3,593	40.6%
331	Total Primary Metals	116	2,186	24.7%
327	Total Non-Metallic Minerals	255	1,173	13.3%
486	Pipeline Transportation	1,363	1,102	12.5%
211	Oil and Gas Extraction	427	538	6.1%
562	Waste Management	478	113	1.3%
325	Chemical	64	92	1.0%
212	Mining, except Oil and Gas	14	23	0.3%
311	Food	19	8	0.1%
322	Paper	17	5	0.1%
333	Machinery	2	4	<0.1%
336	Transportation Equipment	1	2	<0.1%
321	Wood	2	0.5	<0.1%
312	Beverage and Tobacco	2	0.3	<0.1%
323	Printing	1	0.1	<0.1%
334	Computer and Electronic Products	4	0.1	<0.1%
611	Colleges	2	0.1	<0.1%
326	Rubber	2	<0.1	<0.1%
493	Warehousing and Storage	1	<0.1	<0.1%
–	**Total**	**2,946**	**8,840**	**100%**

WHP Technical Potential Capacity by State



*** HI and AK fall into the green category (20 to 99 MW)*

Economic Potential and Market Penetration (bottom-up analysis)

- Engaged WHP community to obtain technical performance and cost characteristics
- Calculated economic potential
  - Expressed in terms of payback for each site
  - Based on cost characteristics for applicable technologies at each site
- Calculated market penetration (adoption curve as a function of payback)

Cost Assumptions for SRC and ORC

Technology	Cost Characteristic	Electric Capacity for WHP Technology				
		50-500 kW	500 kW -1 MW	1-5 MW	5-20 MW	>20 MW
Steam Rankine Cycle	Installed Capital Cost, $/kW	$3,000	$2,500	$1,800	$1,500	$1,200
	O&M Costs, $/kWh	$0.013	$0.009	$0.008	$0.006	$0.005
Organic Rankine Cycle	Installed Capital Cost, $/kW	$4,500	$4,000	$3,000	$2,500	$2,100
	O&M Costs, $/kWh	$0.020	$0.015	$0.013	$0.012	$0.010

WHP Technical Potential by Payback Range

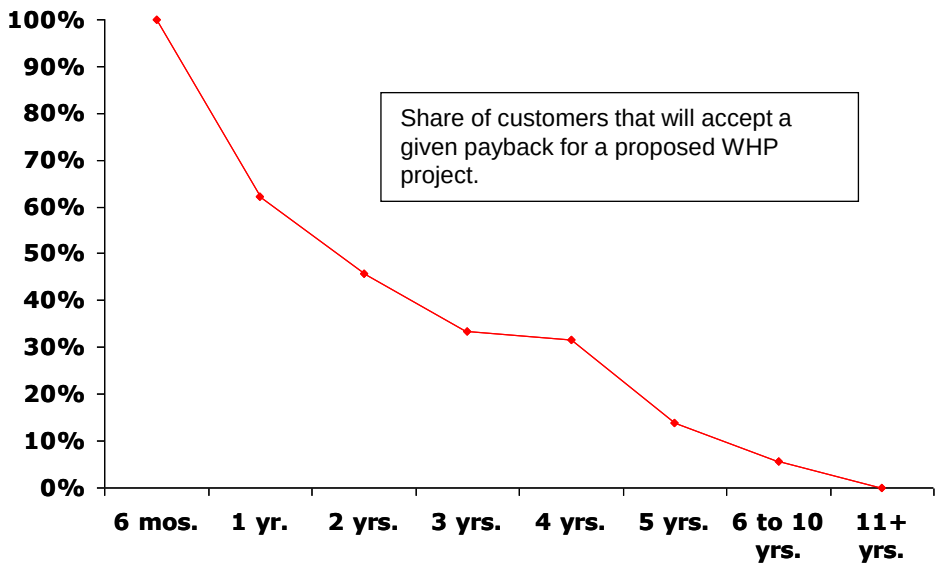
NAICS	NAICS Description	Capacity (MW) by Payback Range			
		< 2 yrs	2 to 5 yrs	> 5 yrs	Total
211	Oil and Gas Extraction	60.2	8.3	469.5	538.0
212	Mining except Oil and Gas	0.0	2.8	19.8	22.6
311	Food	0.0	3.7	4.5	8.2
312	Beverage and Tobacco	0.0	0.0	0.3	0.3
321	Wood	0.0	0.0	0.5	0.5
322	Paper	0.0	0.7	3.9	4.6
323	Printing	0.0	0.0	0.1	0.1
324	Petroleum and Coal Products	700.7	2,753.4	139.0	3,593.1
325	Chemical	0.0	45.1	47.2	92.4
326	Rubber	0.0	0.01	0.02	0.03
327	Non-Metallic Minerals	53.6	938.4	180.9	1,172.9
331	Primary Metals	77.1	2,066.4	42.3	2,185.9
333	Machinery	0.0	3.6	0.2	3.9
334	Computer and Electronics	0.0	0.1	0.0	0.1
336	Transportation Equipment	0.0	0.0	1.8	1.8
486	Pipeline Transportation	0.0	40.3	1,061.8	1,102.1
493	Warehousing and Storage	0.0	0.0	0.0	0.0
562	Waste Management	0.0	4.8	108.3	113.1
611	Colleges	0.0	0.0	0.1	0.1
Total	---	**892**	**5,868**	**2,080**	**8,840**

WHP Technical Potential for ORC and SRC

Technology	Payback (yrs)				Technical Potential (MW)
	<2	2-3	3-5	>5	
Steam Rankine Cycle (SRC)	832	3,146	2,665	421	7,064
Organic Rankine Cycle (ORC)	60	6	51	1,659	1,776
Total	**892**	**3,152**	**2,716**	**2,080**	**8,840**

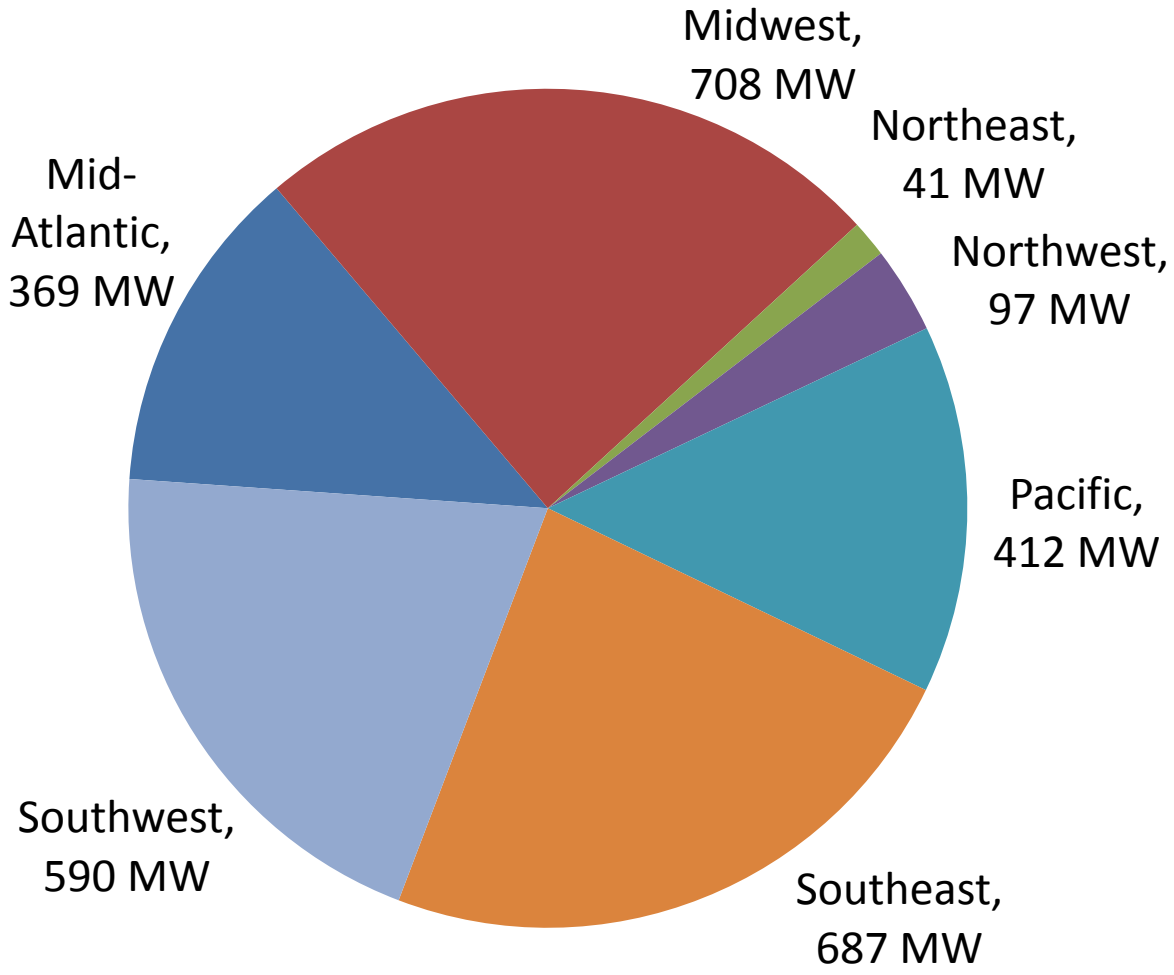
Expected Market Penetration

- Payback calculated for each site
- Market acceptance curve determines likelihood of installation based on payback
- Technical potential for each site is multiplied by market acceptance rate



Source: Primen, 2003

WHP Market Penetration Results by CHP TAP Region (2,904 MW)



Federal Policy Drivers for WHP

- FERC's "small generator" interconnection standards
- Executive Order 13624 – Sets a goal of 40 GW of new, cost-effective, industrial CHP installations by 2020
- Federal Memorandum on Energy Management – More than doubles renewable energy targets for federal agencies, and allows renewable WHP (defined as "thermal renewable energy") to help meet targets
- Federal incentives
  - Investment Tax Credit (ITC) – In February 2015, the Senate Finance Committee approved a proposal that would amend the 10% Federal ITC, allowing WHP to qualify
  - Proposed POWER Act - would add WHP to the list of qualifying technologies for the 30% Federal ITC

State Policy Drivers for WHP

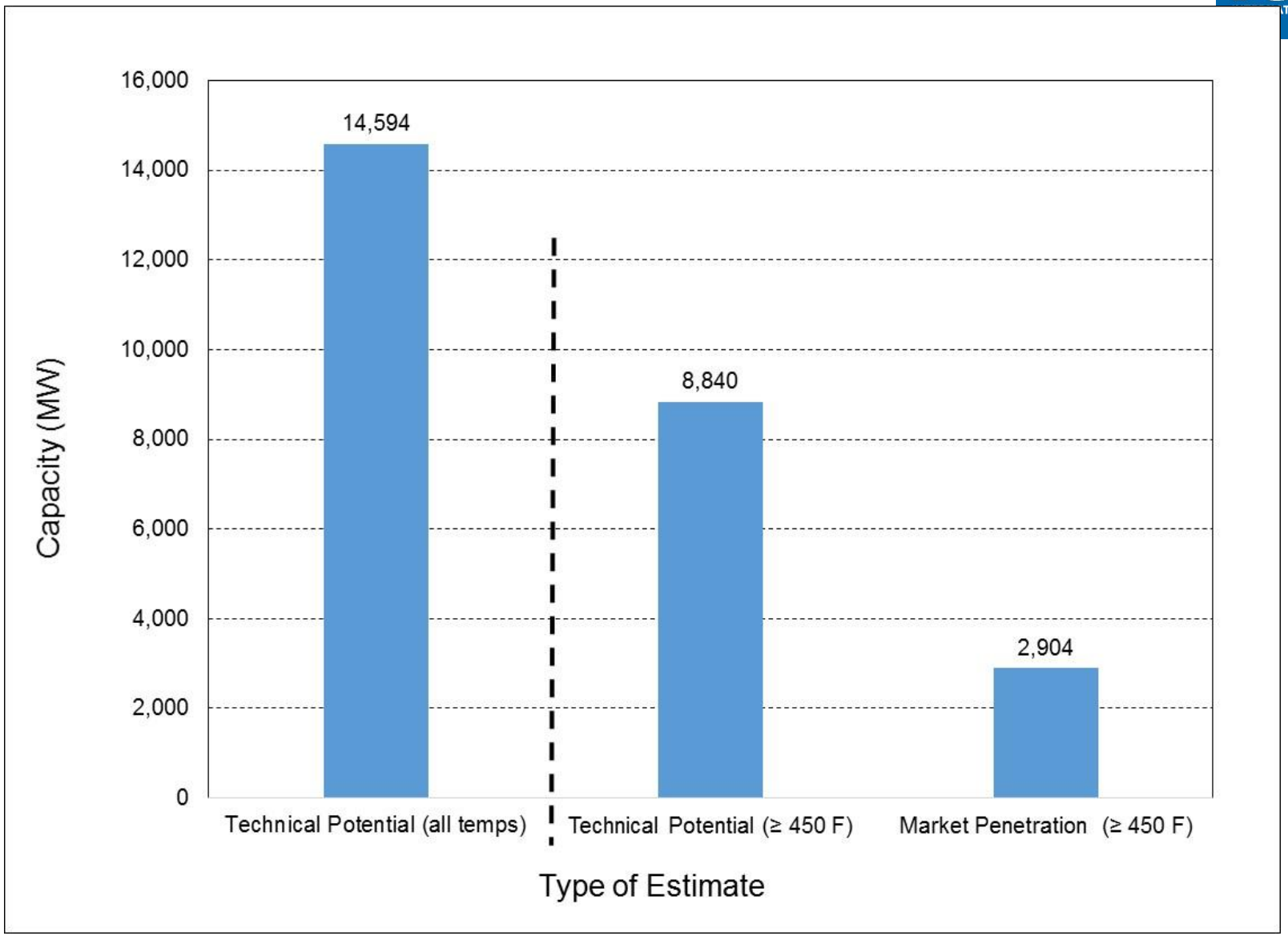
- Nine of 29 states with binding Renewable Portfolio Standards (RPS) include WHP as eligible – CO, CT, HI, MI, NV, NC, OH, PA, WV*
- Six states with nonbinding renewable energy goals include WHP in some fashion – IN, LA (pilot program)**, OK, ND, SD, UT
- Two states include WHP in stand-alone EERS targets – DE, MN
- Nine states – CA, CO, CT, IL, NC, NM, OR, SD, UT – provide other forms of incentives for WHP, such as:
  - CA: The Self Generation Incentive Program (SGIP), a rebate program, provides an incentive of $1.13/W for WHP projects.
  - IL: The Department of Commerce and Economic Opportunity (DCEO) CHP Pilot Program includes WHP, and provides grants for public sector projects.

Changes since report was released

* West Virginia passed legislation in early 2015 that removes RPS requirement.

** The Louisiana RPS pilot program has ended.

Summary of Key Results



Questions & Contact Information

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U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

WHP Market Assessment Webinar

The Pew Charitable Trusts and the Heat is Power Association

June 24, 2015

Claudia Tighe

U.S. Department of Energy

CHP Deployment Program Manager

Advanced Manufacturing Office

Continued DOE Support for WHP

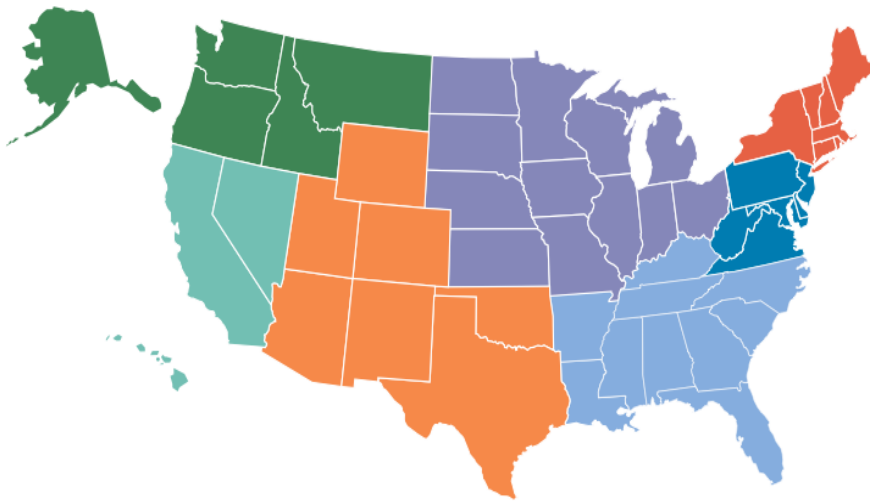
In addition to funding WHP Market Assessment Report, DOE offers the following activities to further highlight the WHP market:

- Provide technical assistance services
- Include in the upcoming CHP Market Study with traditional CHP and District Energy with CHP
- Develop WHP handout materials (forthcoming fact sheet)
- CHP TAPs to develop WHP project profiles
- Conduct additional webinars focused on specific markets for WHP

DOE CHP Technical Assistance Partnerships (CHP TAPs)

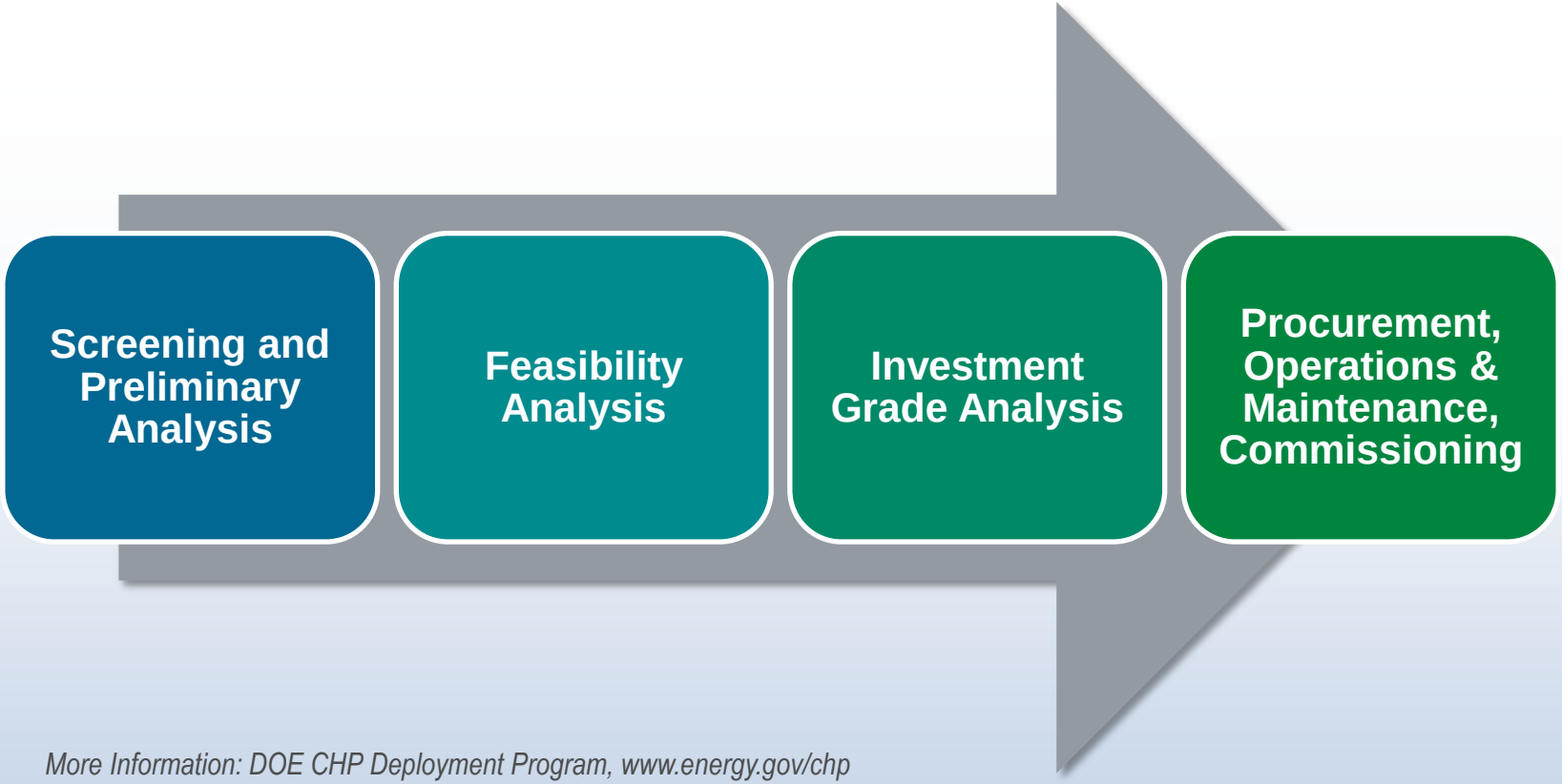
DOE's CHP TAPs promote and assist in transforming the market for CHP, waste heat to power, and district energy or microgrid with CHP throughout the United States. Key services include:

- **Market Opportunity Analysis**
  Supporting analyses of CHP market opportunities in diverse markets including industrial, federal, institutional, and commercial sectors
- **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 or microgrid with CHP in their facility and to help them through the development process from initial CHP screening to installation.



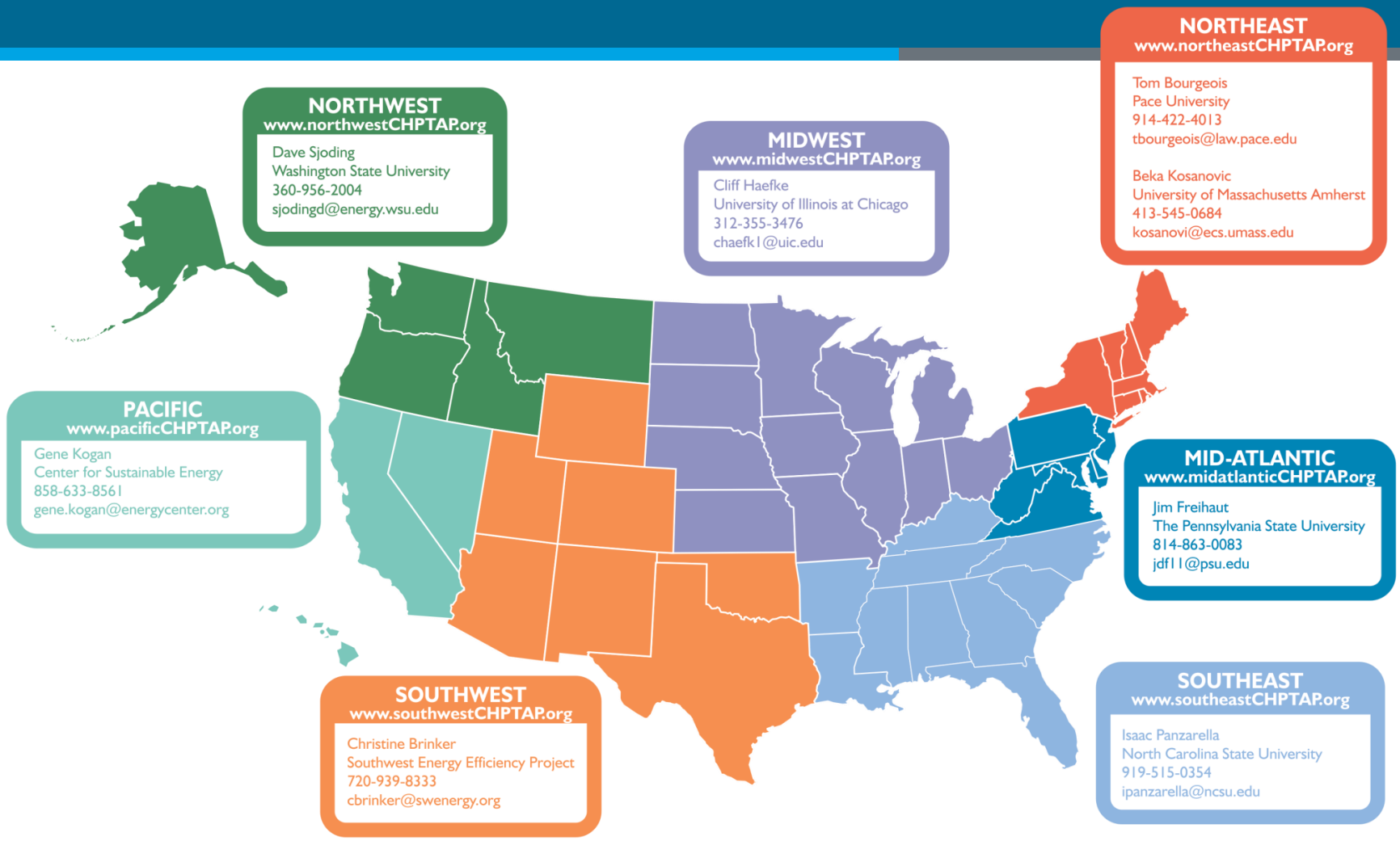
www.energy.gov/chp

CHP TAP Technical Assistance Project Support



More Information: DOE CHP Deployment Program, www.energy.gov/chp

DOE CHP Technical Assistance Partnerships (CHP TAPs)



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Waste Heat to Power Market Assessment: Opportunities, Technologies and Barriers

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