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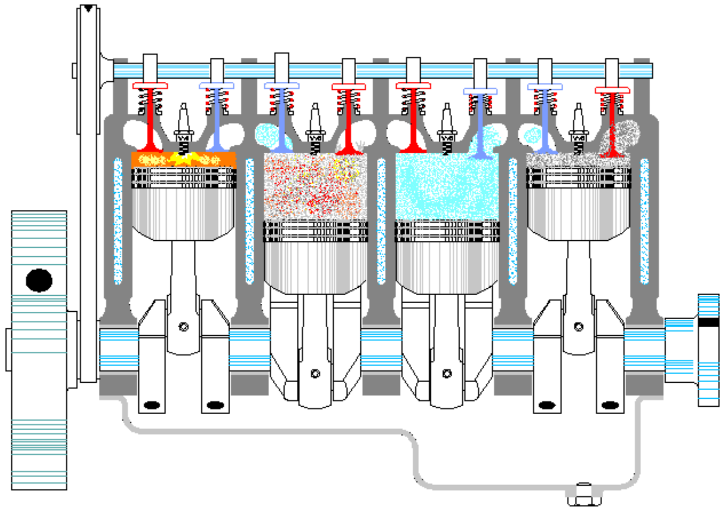
Energy Industry Fundamentals

Combined Heat & Power 101

Eric Burgis, Energy Solutions Center

Presentation Outline

- Combined Heat & Power Terminology
- CHP Market Overview
- Energy Cost and CHP Efficiency
- Why CHP?
- Power Generation Equipment
- Heat Recovery
- Economics and Incentives
- Resources



https://www.michigan.gov

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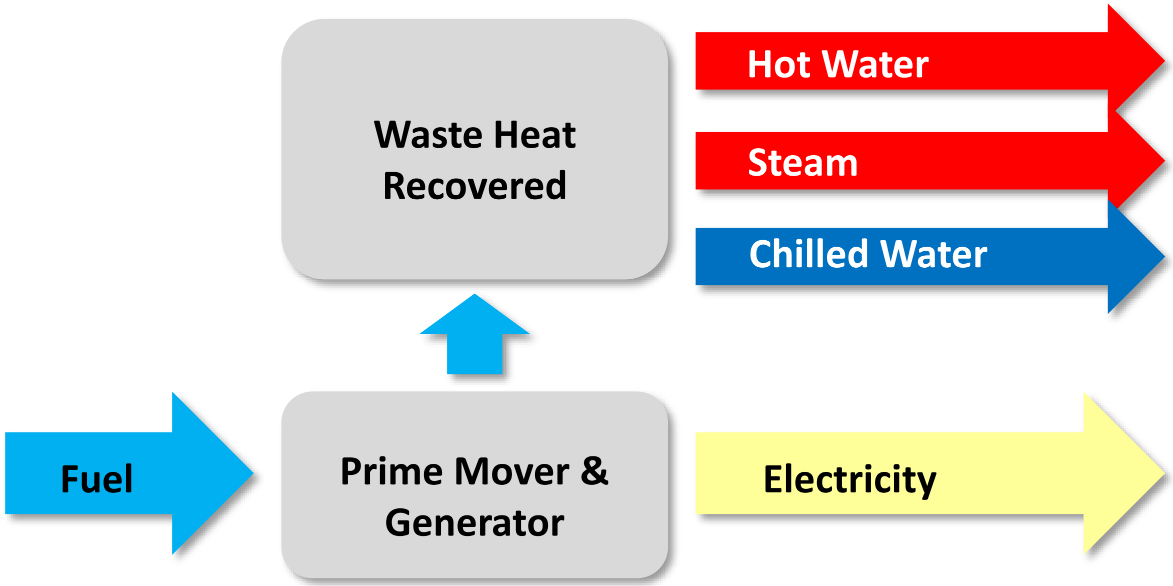
CHP Terminology

What is CHP?

Combined Heat and Power (CHP) by definition is the generation of two forms of energy from one common source of fuel also known as Cogeneration.



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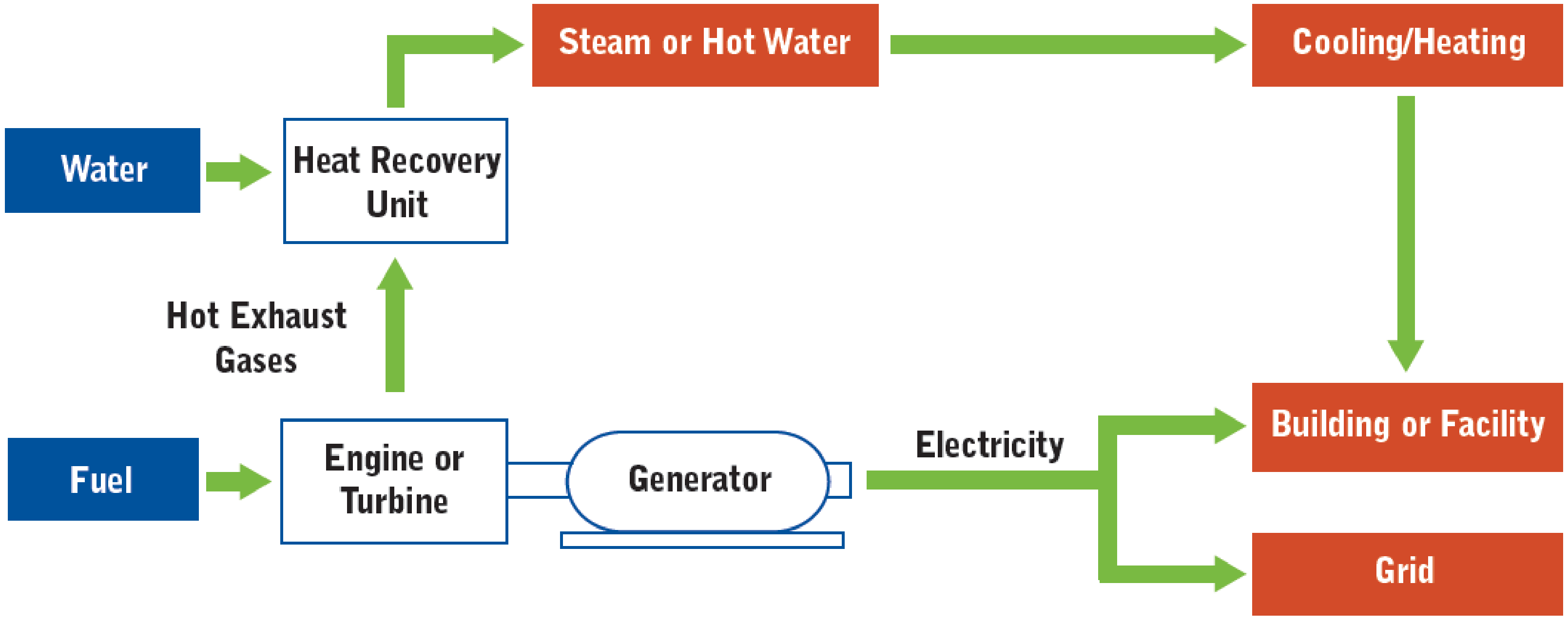
How CHP works

Combined Heat & Power systems provide power independence with around 75% - 85% overall system efficiency



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Known by Many Names

- CCHP (Combined Cooling, Heating & Power)
- CHPB (CHP for Buildings)
- Cogen (Cogeneration)
- DE (Distributed Energy)
- DG (Distributed Generation)
- IES (Integrated Energy Systems)
- TES (Total Energy Systems)
- Trigen (Trigeneration)
- Today we will use CHP (Combined Heat and Power) to reinforce the importance of recovering the waste heat!

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"Cogeneration"

- "CHP" has come to replace the word "Cogeneration" in many modern applications
- "Cogeneration" is specifically listed in the Public Utility Regulatory Policies Act of 1978 (PURPA)
  - This act further defines a Qualifying Facility (QF)
  - Electric Utilities must allow interconnection from QFs
  - There is lots of paperwork to become a QF
- The term "CHP" is often used to distance a project from PURPA rules

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Components of CHP

- CHP systems consist of an integrated package
  - Prime mover – engine, turbine or fuel cell
  - Generator
  - Heat recovery system
  - Electrical interconnections

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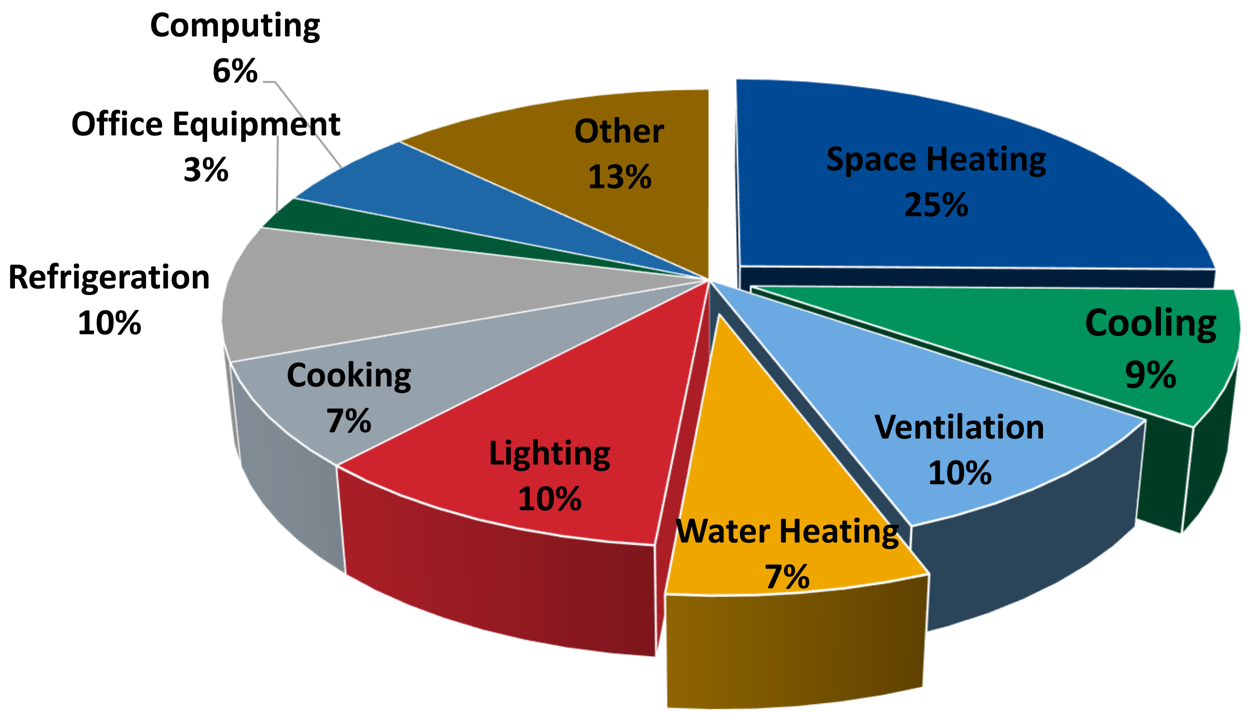
Combined Heat and Power Market Overview

Typical Commercial Building Energy Profile

Energy Use in Commercial Buildings
(Electric, hot water, heating, & cooling be supplied through CHP)



41% of energy use in commercial buildings is for heating, water heating, and cooling.

Source: EIA CBECS Table 5

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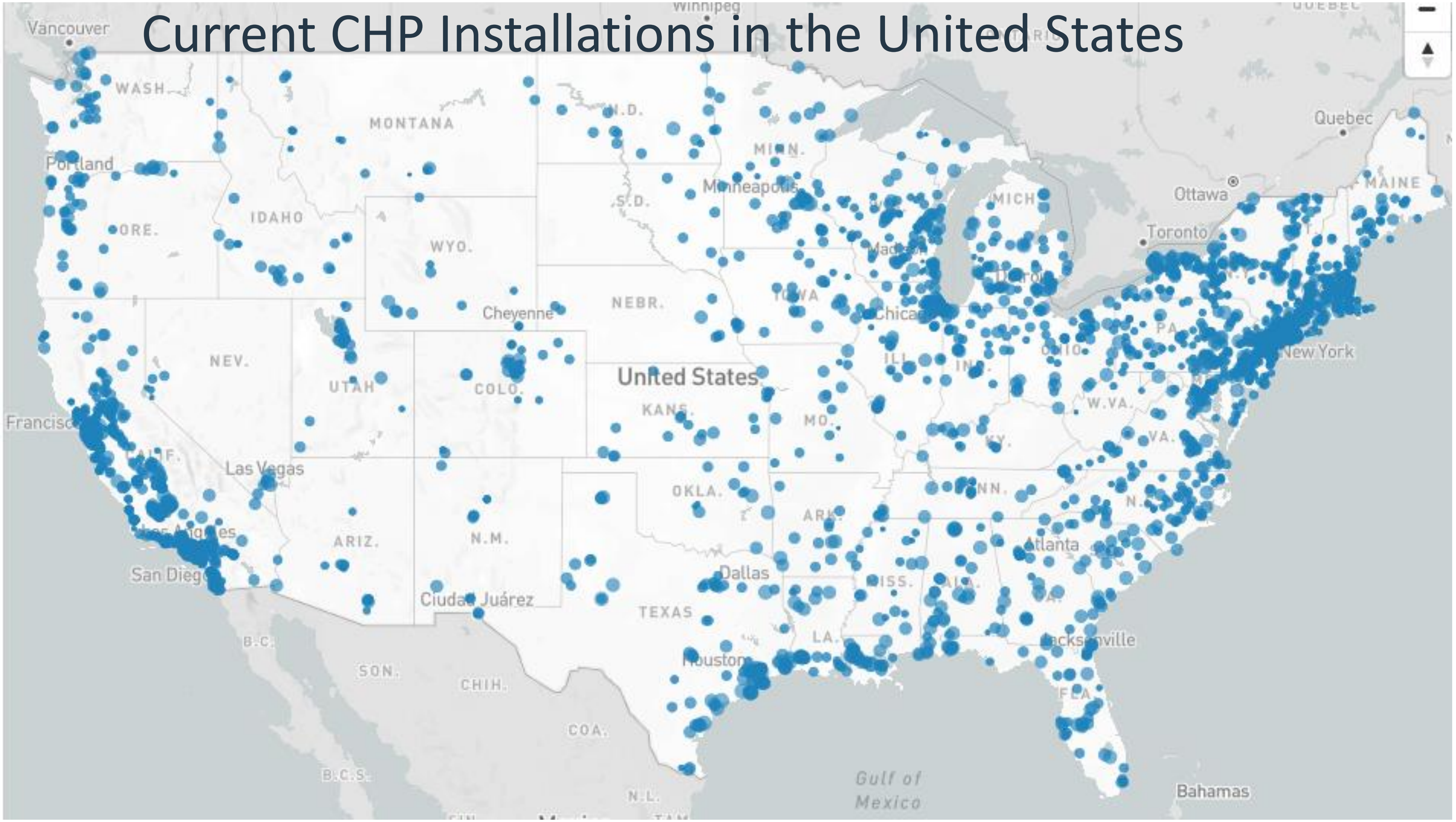
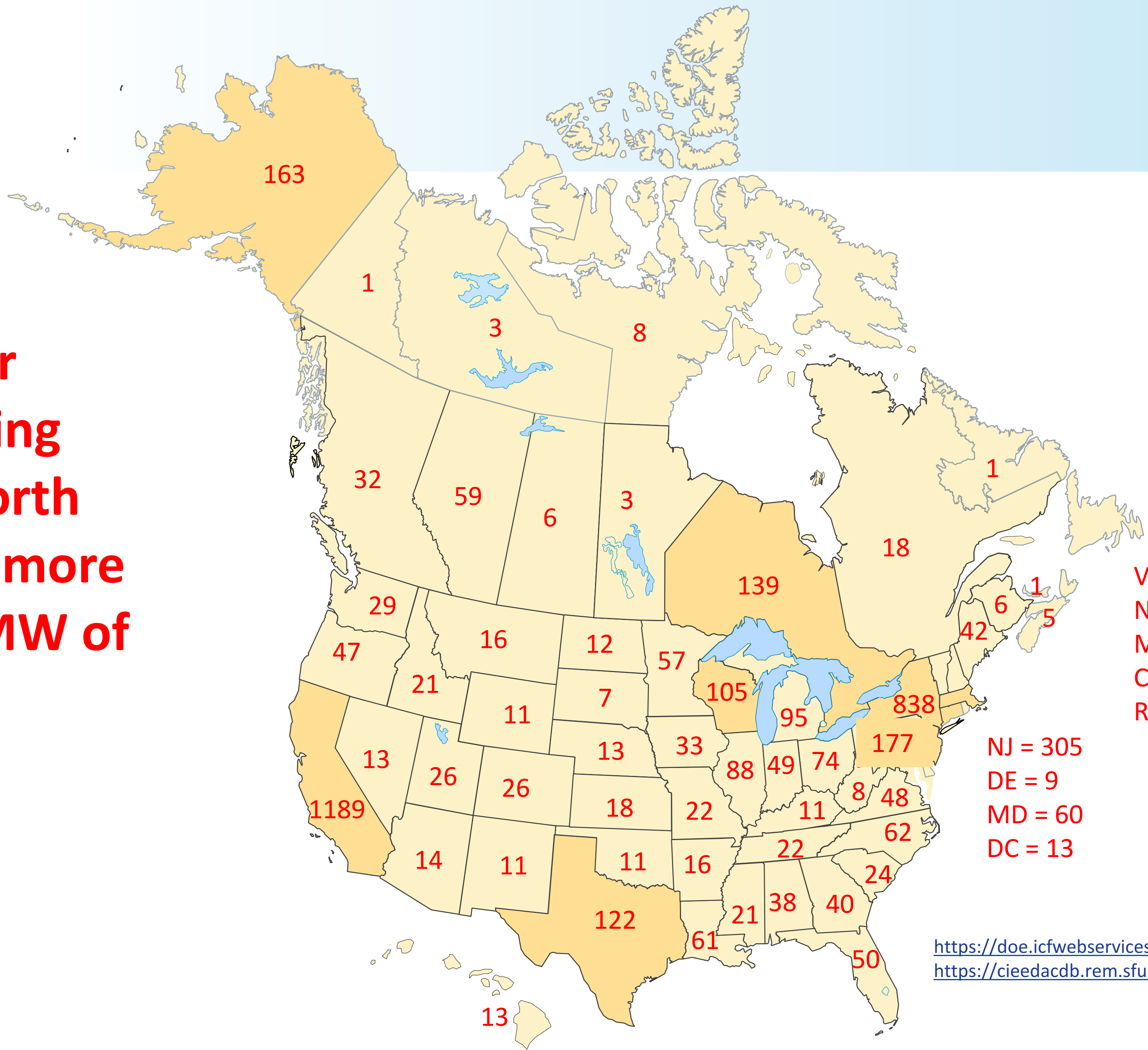
Combined Heat & Power (CHP)



https://doe.icfwebservices.com/chpdb/

of CHP Sites

There are over 5,000 sites using CHP across North America with more than 84,000 MW of CHP Capacity.



In the U.S., CHP capacity is equal to about 6.3% of total power plant generation name plate capacity

VT = 37
NH = 19
MA = 266
CT = 207
RI = 35

NJ = 305
DE = 9
MD = 60
DC = 13

https://doe.icfwebservices.com/downloads/chp
https://cieedacdb.rem.sfu.ca/cogeneration-database/

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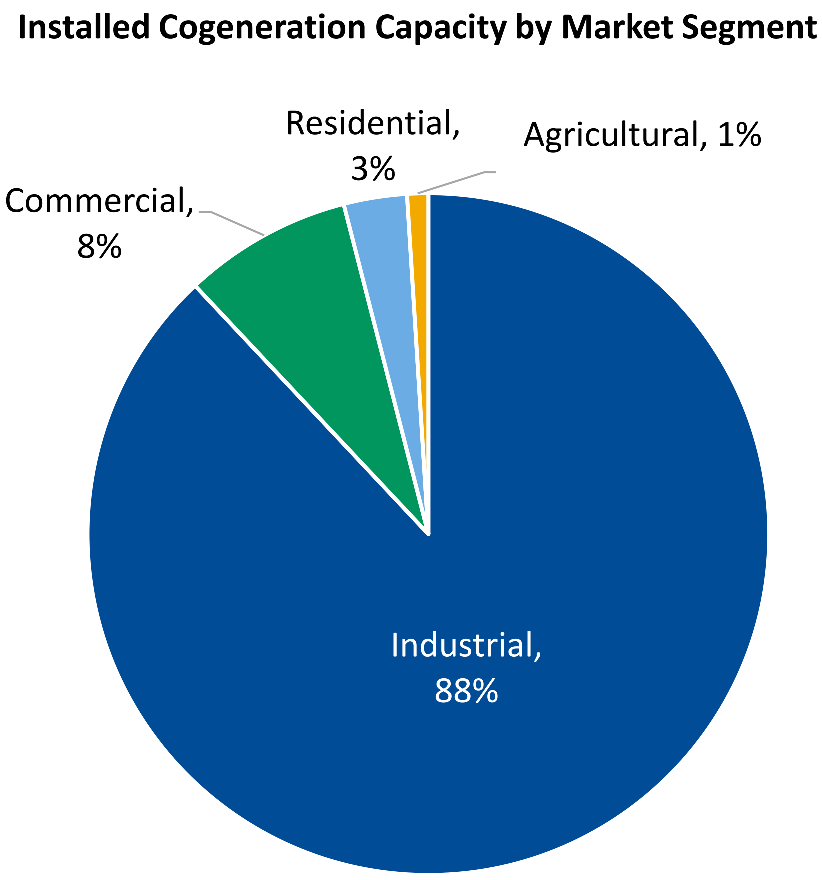
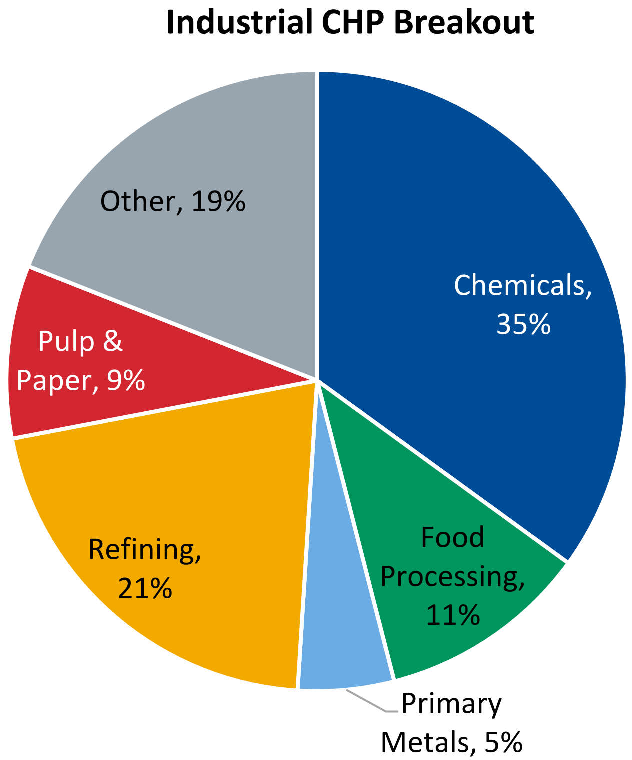
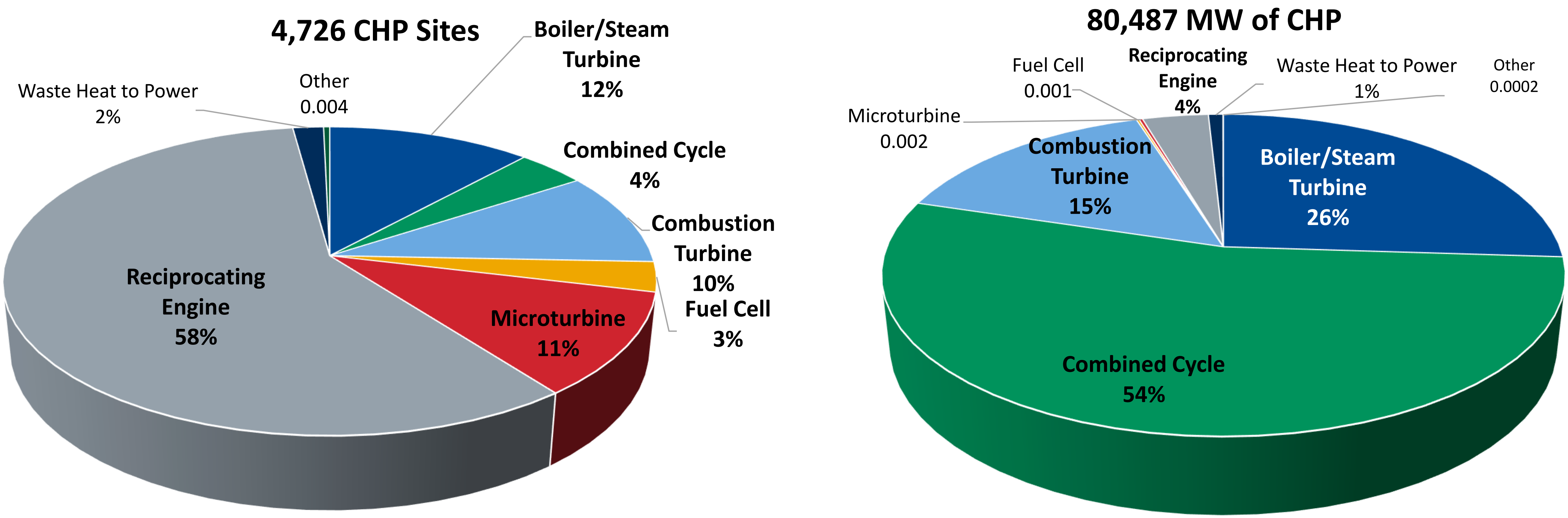
Existing CHP Capacity by Market





Data from: Combined Heat & Power Study, IHS Market

CHP Installations by Technology (U.S.)



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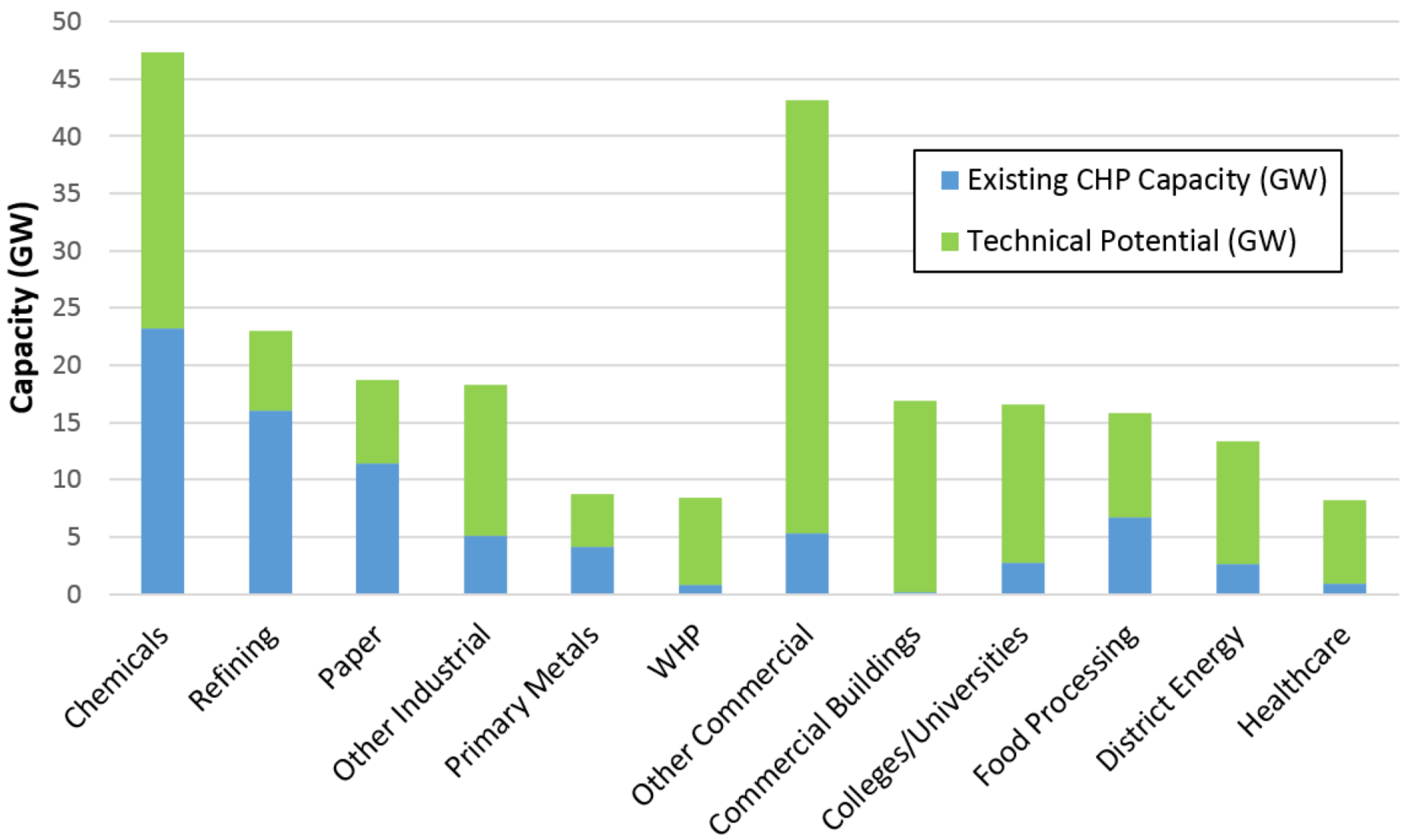
https://doe.icfwebservices.com/downloads/chp

Technical Potential for CHP

More than 149 GW of CHP/WHP technical potential at over 291,000 sites in the U.S.



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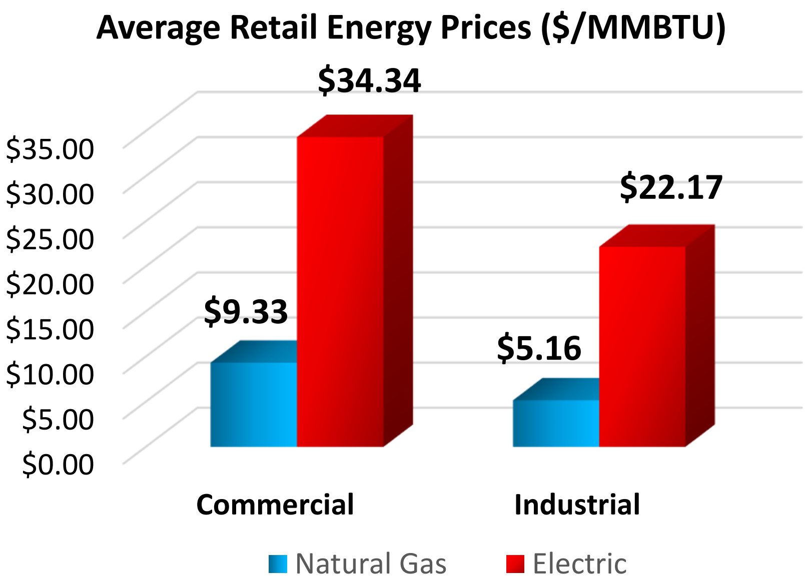
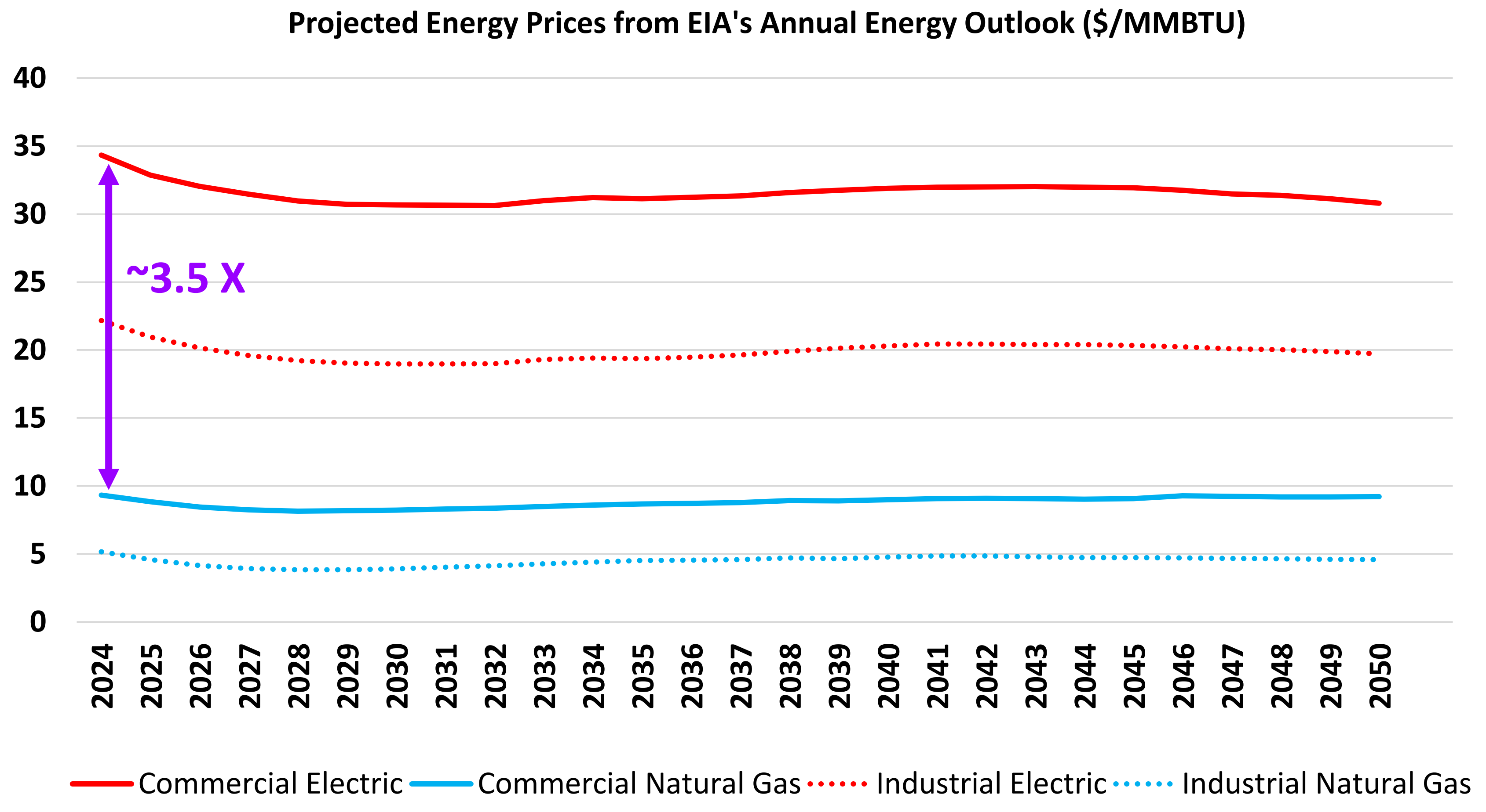
Source: USDOE, "Combined Heat and Power (CHP) Technical Potential in the United States"

Energy Costs & CHP Efficiency

Source Efficiency Impacts Retail Costs





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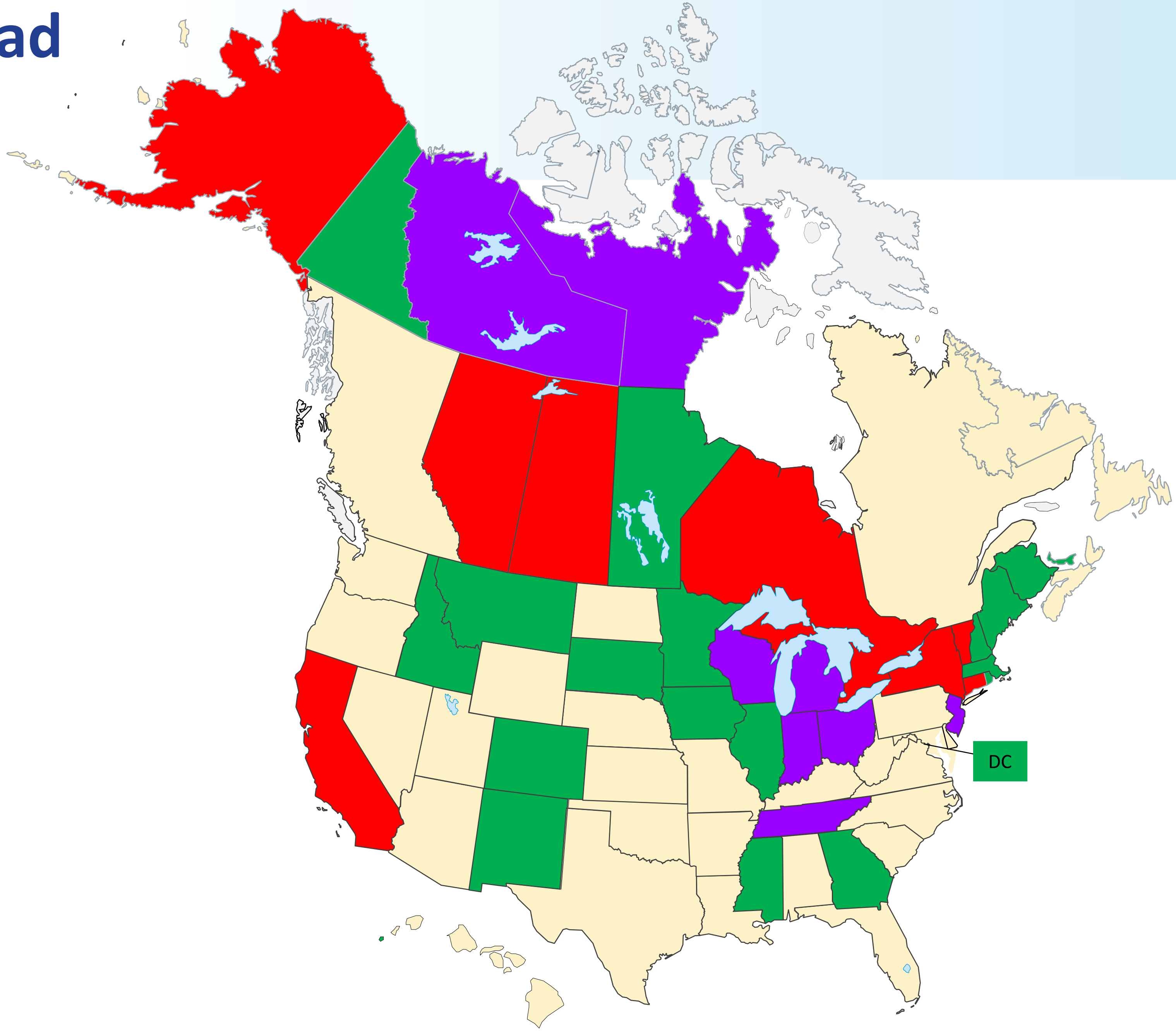
*EIA STEO data. Uses 1032 BTU/CF Natural Gas and 3412 BTU/KWH Electric

Spark Spread



Spark Spread > 5

Spark Spread 4-5

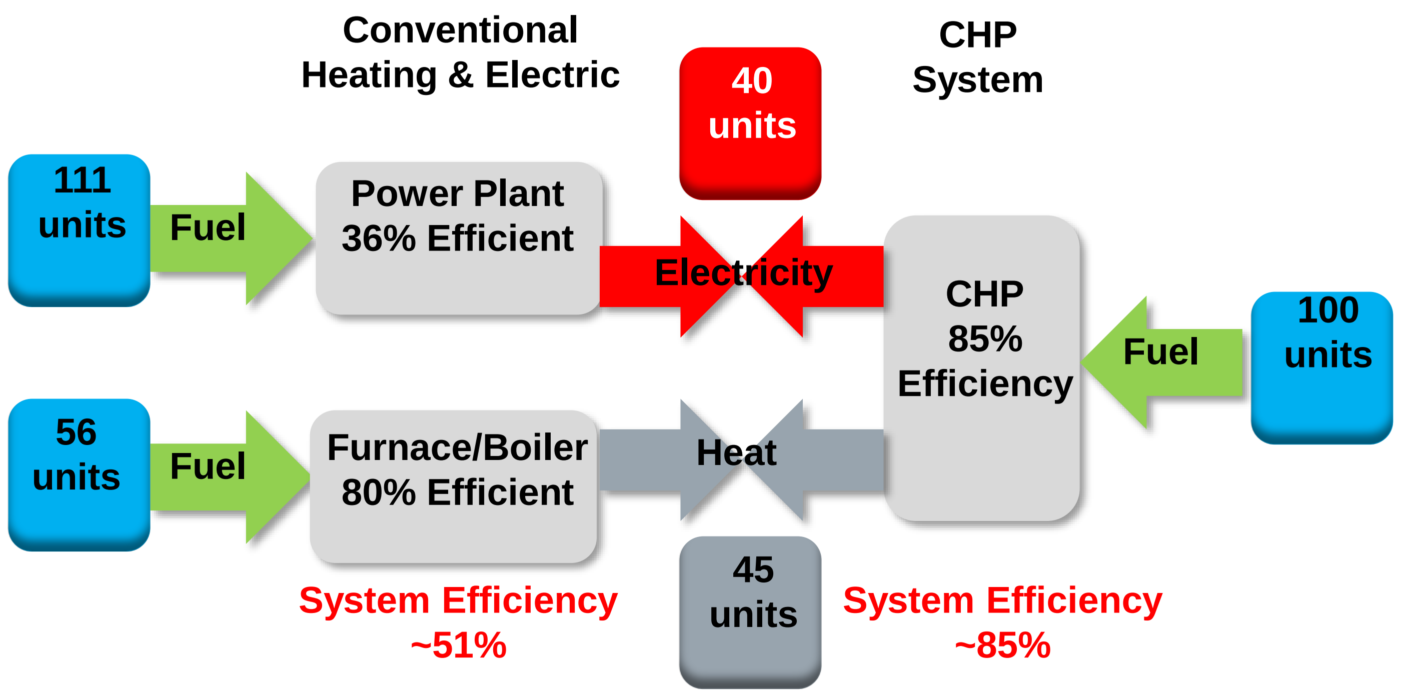
Spark Spread 3-4

Spark Spread 2-3

A 3 or higher on a scale from 1-5 is a good spark spread.

Based on 2023 retail commercial energy rates from EIA.

CHP is more Efficient



Compared to purchasing electric from the grid and producing heat with a furnace or boiler for the home or business, CHP is much more efficient.

Why Consider CHP?

Why Consider Combined Heat & Power?

- Help Stabilize the Grid
- Economical
- Efficient
- Power Quality
- Environmentally Responsible
- Least Cost Electric Storage Option

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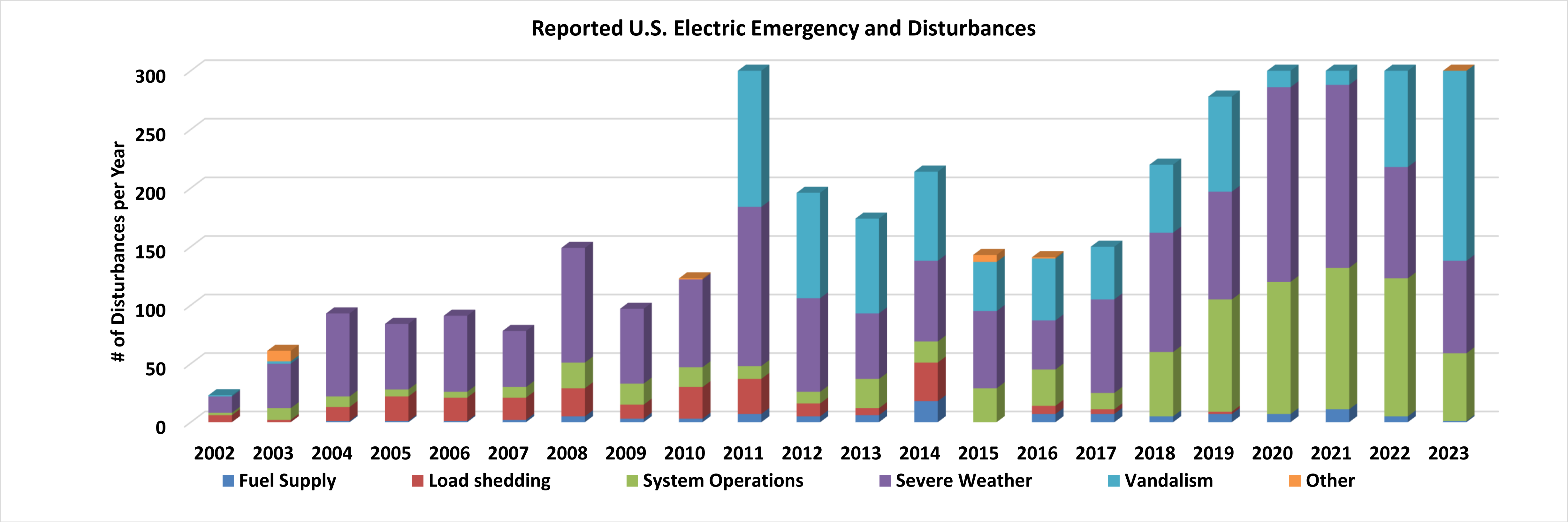
CHP Systems Reduce Grid Demand and Help Stabilize it

- The electric grid is stressed with congestion and constraints leading to more outages
- Offers reliability during outages – less downtime



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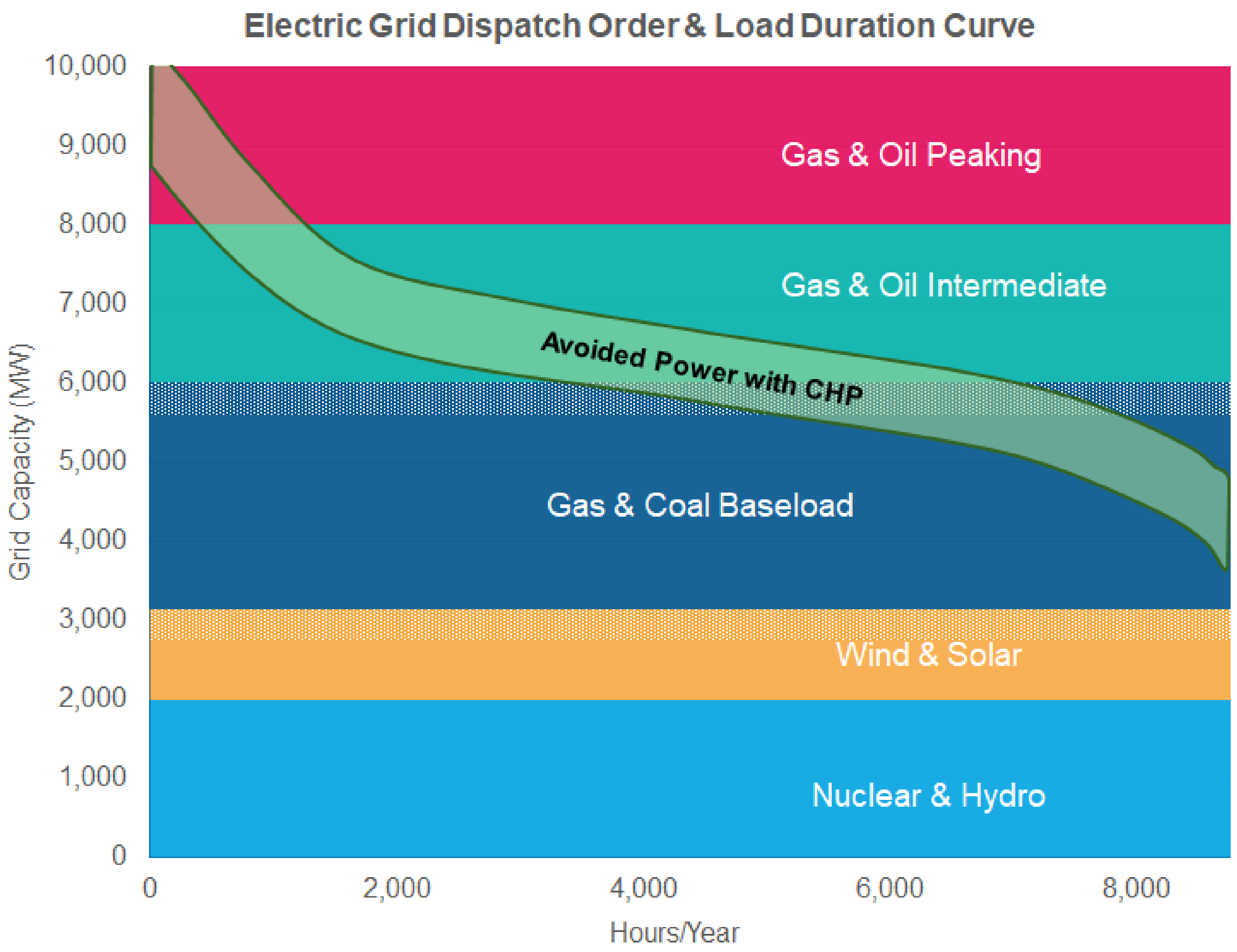
OE-417 Electric Emergency and Disturbance Reports

Avoided Power with CHP Example



Combined Heat and Power Potential for Carbon Emission Reductions, ICF, July 2020

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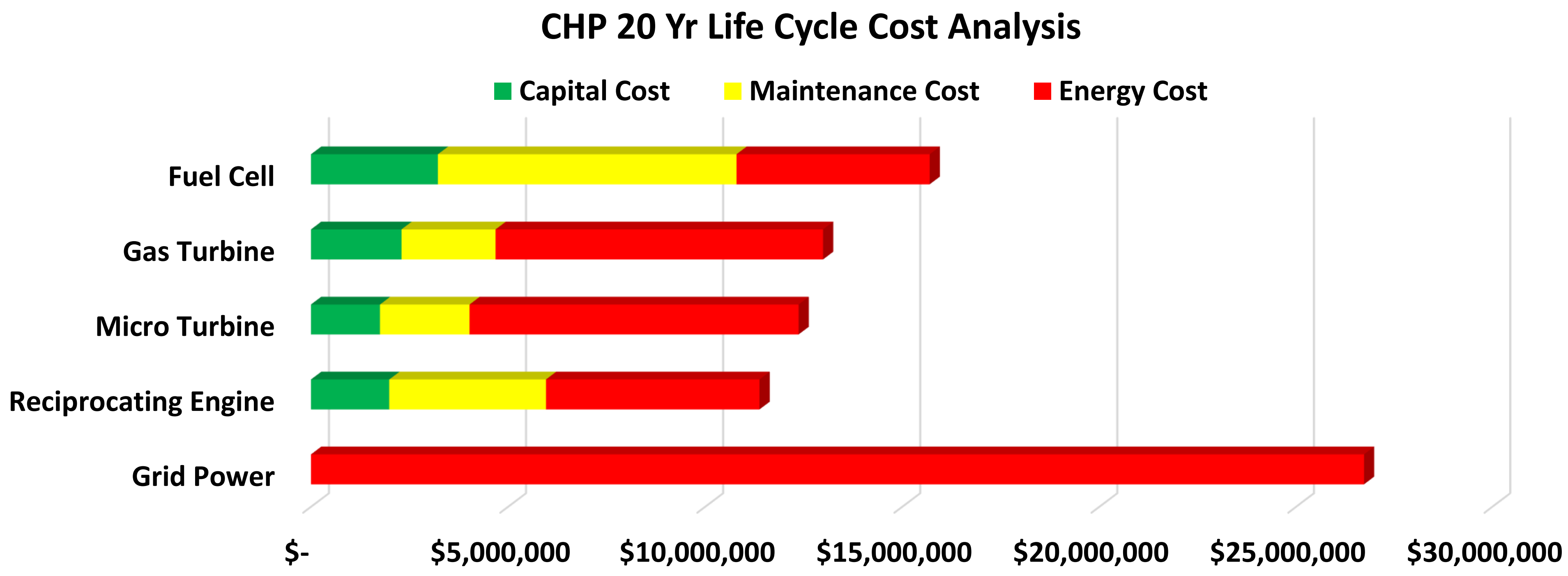
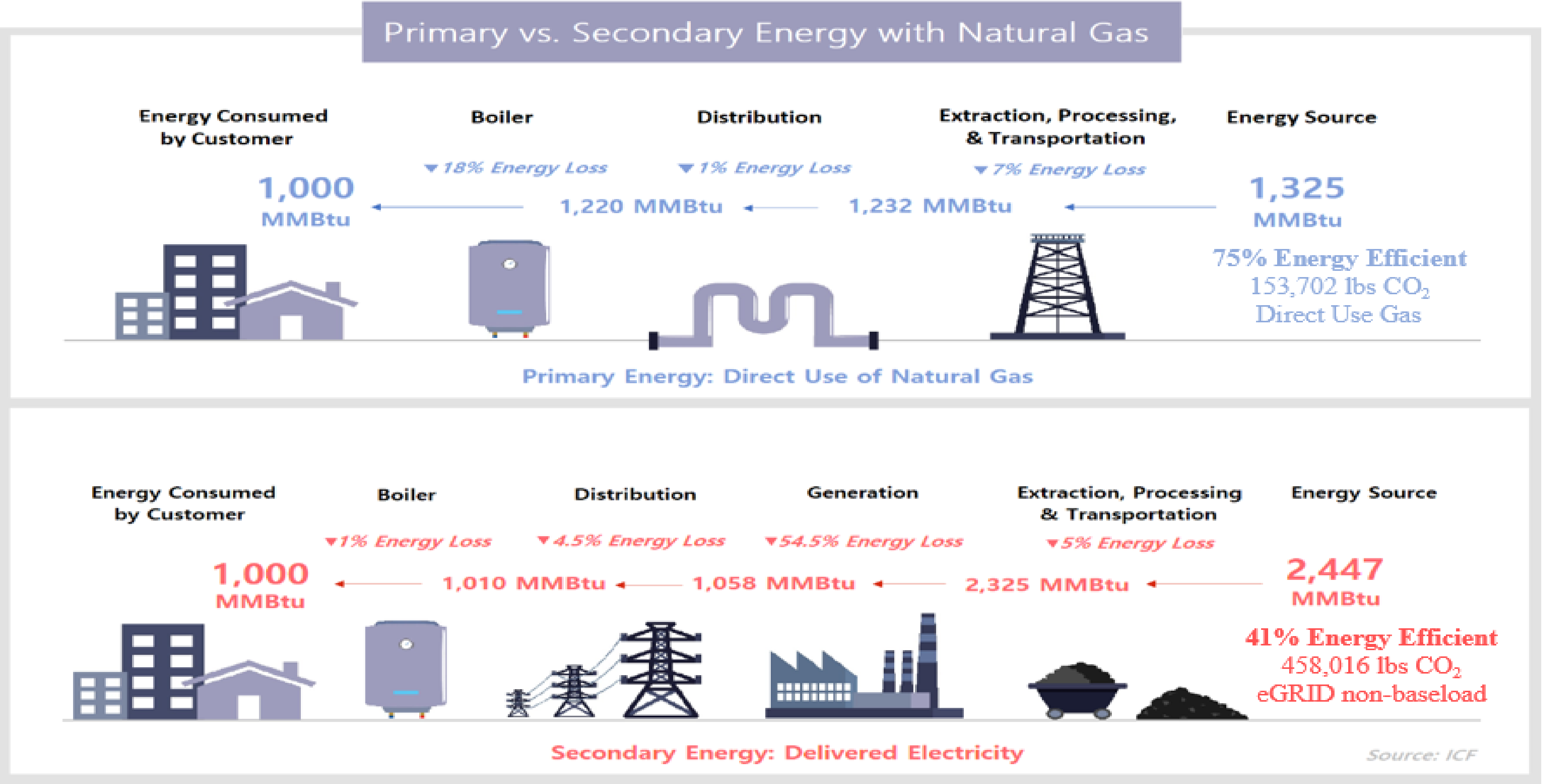
Combined Heat & Power is Economical

- Improves overall energy efficiency and fuel utilization - thereby lowering electric and overall energy costs
- CHP systems generally have lower life cycle costs compared to buying power from the grid



https://understandingchp.com/resources/payback-tool/

CHP is more Efficient than Source Energy



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Reduce Generation Losses and T&D Line Losses with CHP

Improved power quality with CHP

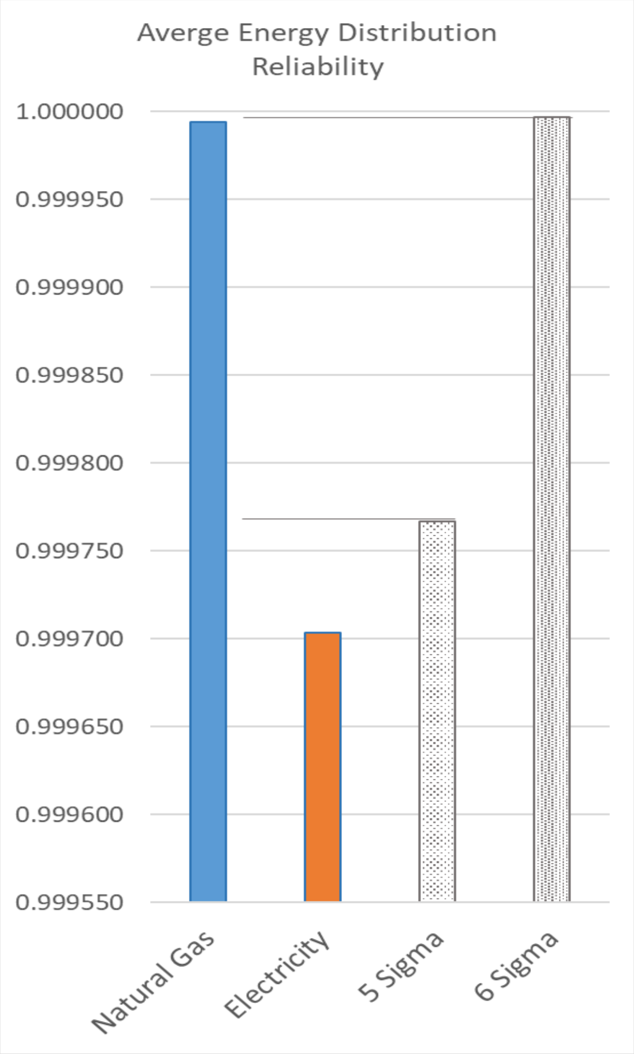
- Power Quality
  - Very consistent power quality
  - Avoids outages from transmission and distribution problems
  - Alleviates electric grid congestion & constraints
  - Decentralized CHP locations less vulnerable to major system problems

Table 1: Summary Energy Distribution Reliability and Outage Rate Results

Metric	Natural Gas Distribution	Electric Distribution
Average Reliability/Availability (Planned and Unplanned)	0.9999957	0.999703
Average Reliability/Availability (Unplanned)	0.9999991	--
Average Outage Rate – Planned and Unplanned (Event Per Customer Per Year)	0.00895	1.017
Estimated Unplanned Outage Rate (Event Per Customer Per Year)	0.00125	--

Data from GTI Topical Report: Assessment of Natural Gas & Electric Distribution Service Reliability–7/19/18.

http://www.gastechnology.org/Solutions/Documents/Assessment-of-Natural-Gas-Electric-Distribution-Service-Reliability-TopicalReport-Jul2018.pdf



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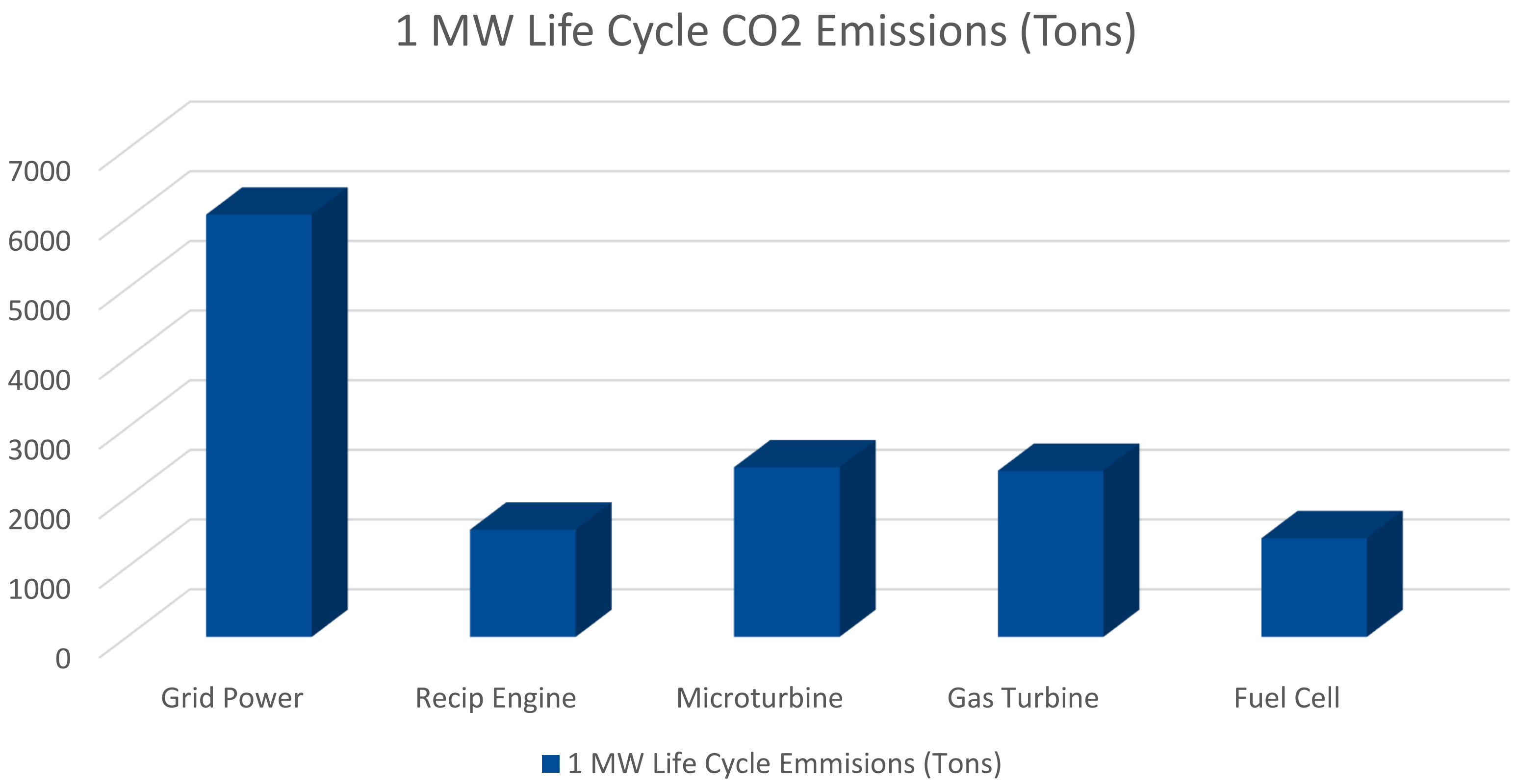
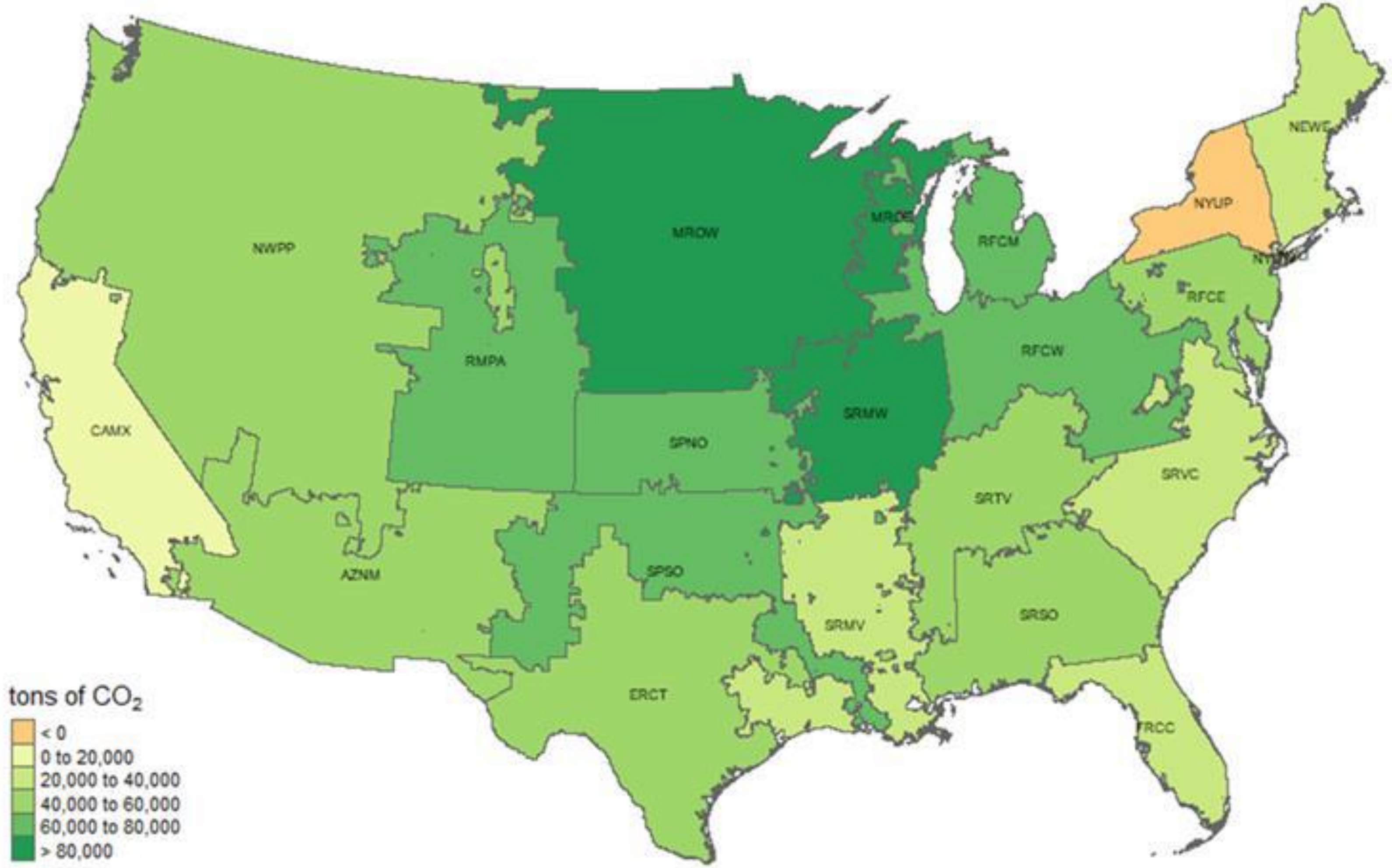
Lower Emissions

- Environmentally Responsible
  - Produces lower emissions compared to separate power and heat production
  - Conserves natural resources



https://understandingchp.com/resources/payback-tool/

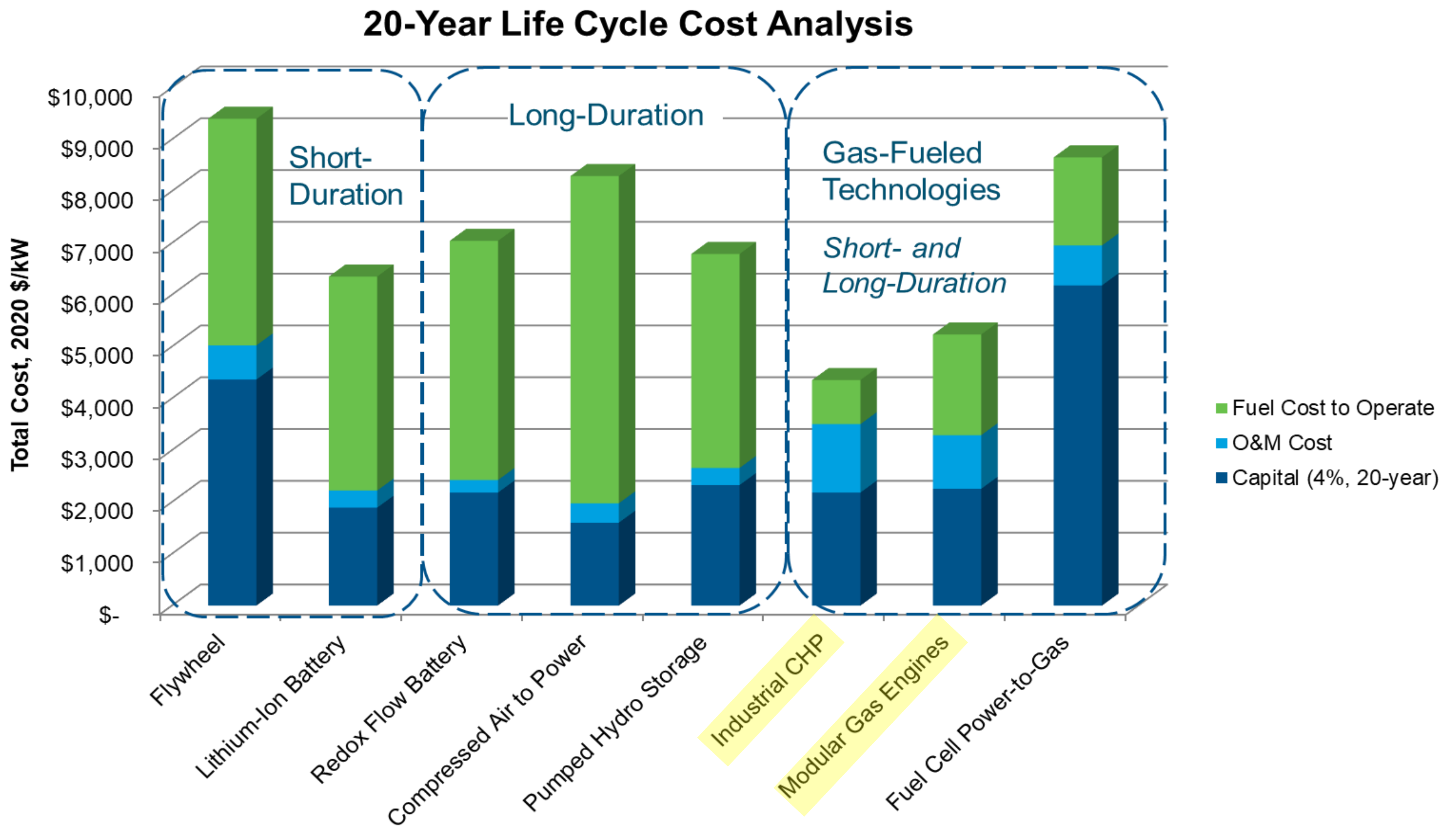
Lifetime Carbon Emission Reductions for 1 MW 24/7 CHP System on Natural Gas, installed in 2020 and retired in 2035



Combined Heat and Power Potential for Carbon Emission Reductions, ICF, July 2020

Cost of Electric Storage

(CHP has lowest Life cycle cost compared to other forms of electric storage)



Energy Storage Comparison Analysis with Gas-Fueled Technologies, ICF, September 2020

Combined Heat & Power

- Best Applications for CHP
  - High coincidental thermal and electric loads
  - Long operating hours
  - Central heating and cooling system
  - Minimal electric distribution connections
  - Favorable cost of natural gas relative to cost of buying electric power from grid (Good Spark Spread)
  - Reasonable installed cost differential between conventional and CHP systems
  - Special electrical, cooling or heating needs

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CHP is a Crowd Pleaser
Compared to the Alternative

- Groups you typically run into when trying to build a new power plant:
  - **NIMBY:** Not in My Back Yard
  - **Banana:** Build Absolutely Nothing Anywhere or Near Anybody
  - **Cave:** Citizens Against Virtually Everything

Neighbors don't generally challenge a business looking to install CHP.

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Prime Movers

Internal Combustion Engine
Turbines
Microturbines
Fuel Cells

Engine Driven Generators

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Engine Drives

- Reciprocating internal combustion engines
- Products are available for a range of power generation market applications and duty cycles
  - Standby and emergency power
  - Peaking service
  - Intermediate and base load power
  - Combined Heat and Power (CHP)
- Reciprocating engines are available for power generation applications in sizes ranging from ~ 5 kW to over 8+ MW

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Engine Drives – Facts

- Reciprocating Engines
  - Two basic types
    - Spark ignition – natural gas preferred for CHP
    - Compression ignition: bi-fuel and diesel fueled
  - Low first cost
  - Fast start-up
  - Proven reliability when properly maintained
  - Excellent load-following characteristics
  - Significant heat recovery potential
  - Most engines are water cooled. Smaller packaged systems may be air cooled

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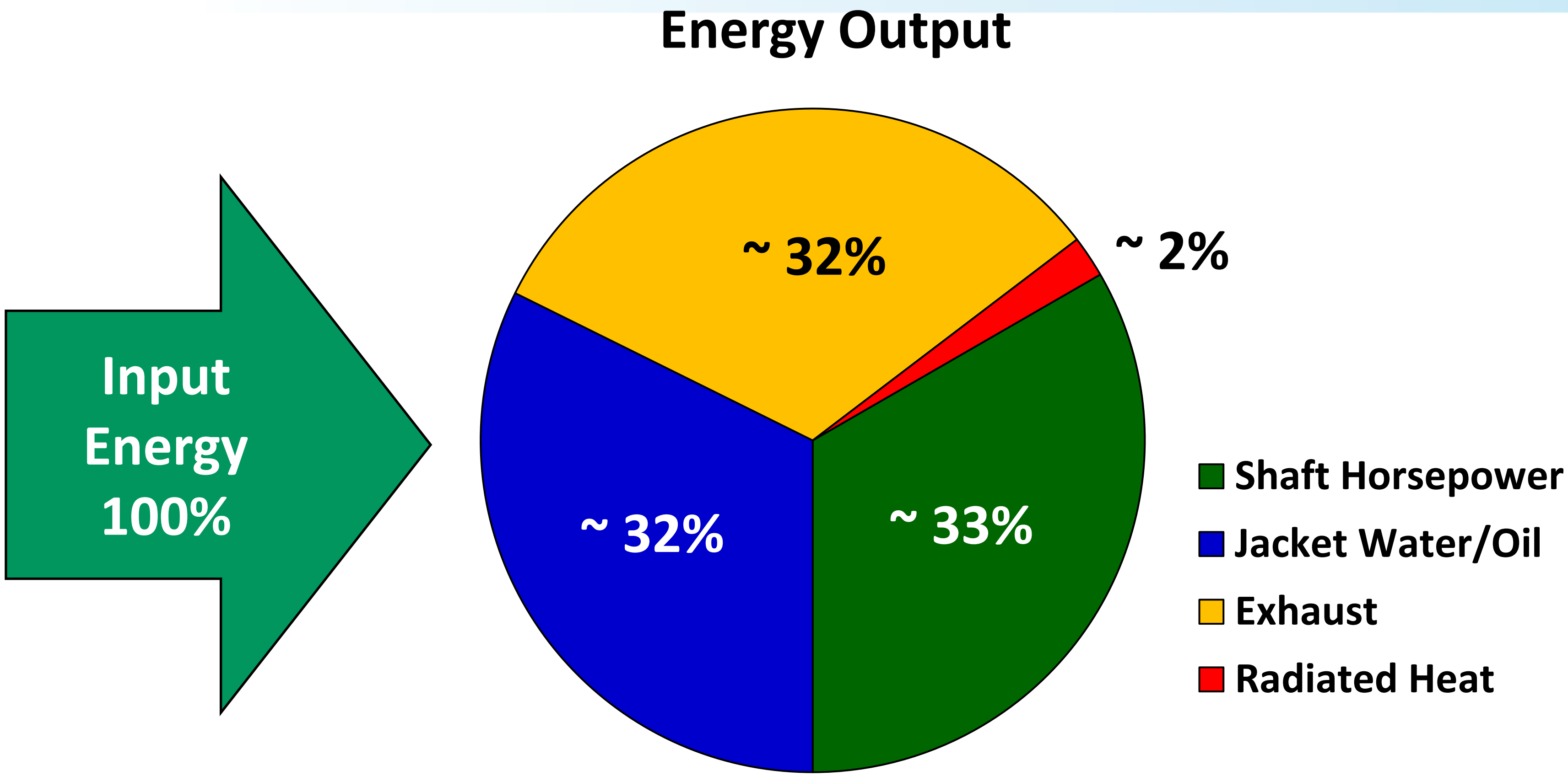
Engine Drive Energy Use



Engines these days can be in the range of 42 to 46 % efficient LHV

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Black Start Capability

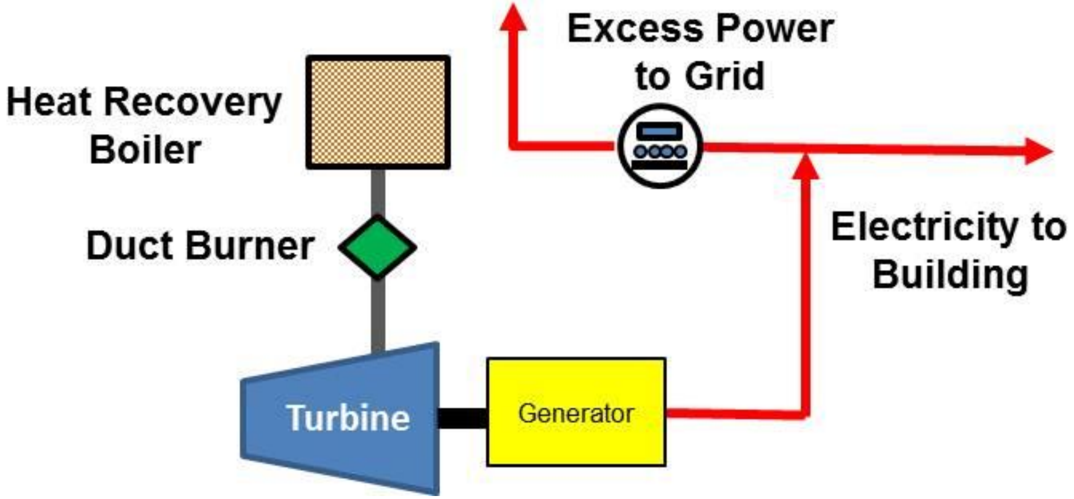
- Black-Start (not available on all units)
  - The use of a permanent magnet generator and inverter together can provide the CHP unit with added “black-start” capability to come online when the utility grid is down
  - Generator units without “black-start” capability can only operate when the electric utility is online.
  - Provides the facility with “supplemental/stand-by” generation during utility outages

Turbine Generators

www.ge-flexibility.com

Turbines

- A turbine is a rotary engine that extracts energy and converts it into useful work
- Excellent heat recovery opportunities
- Minimal working parts
- Run at high speed



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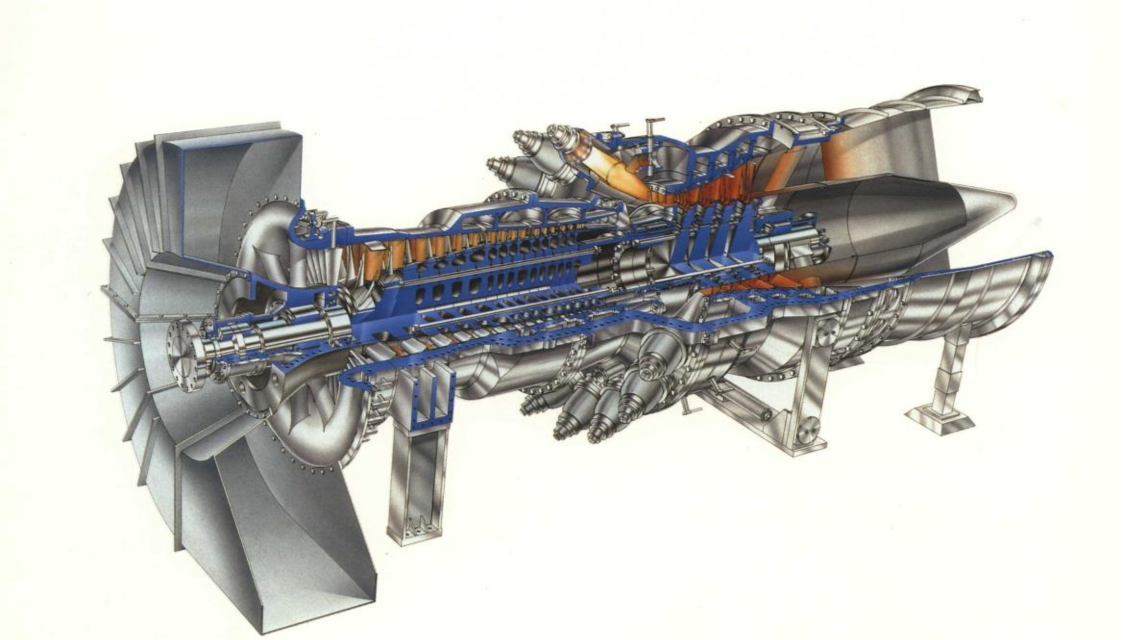
Turbine Types

- Natural Gas Combustion Turbines
- Steam Turbines
- Microturbines



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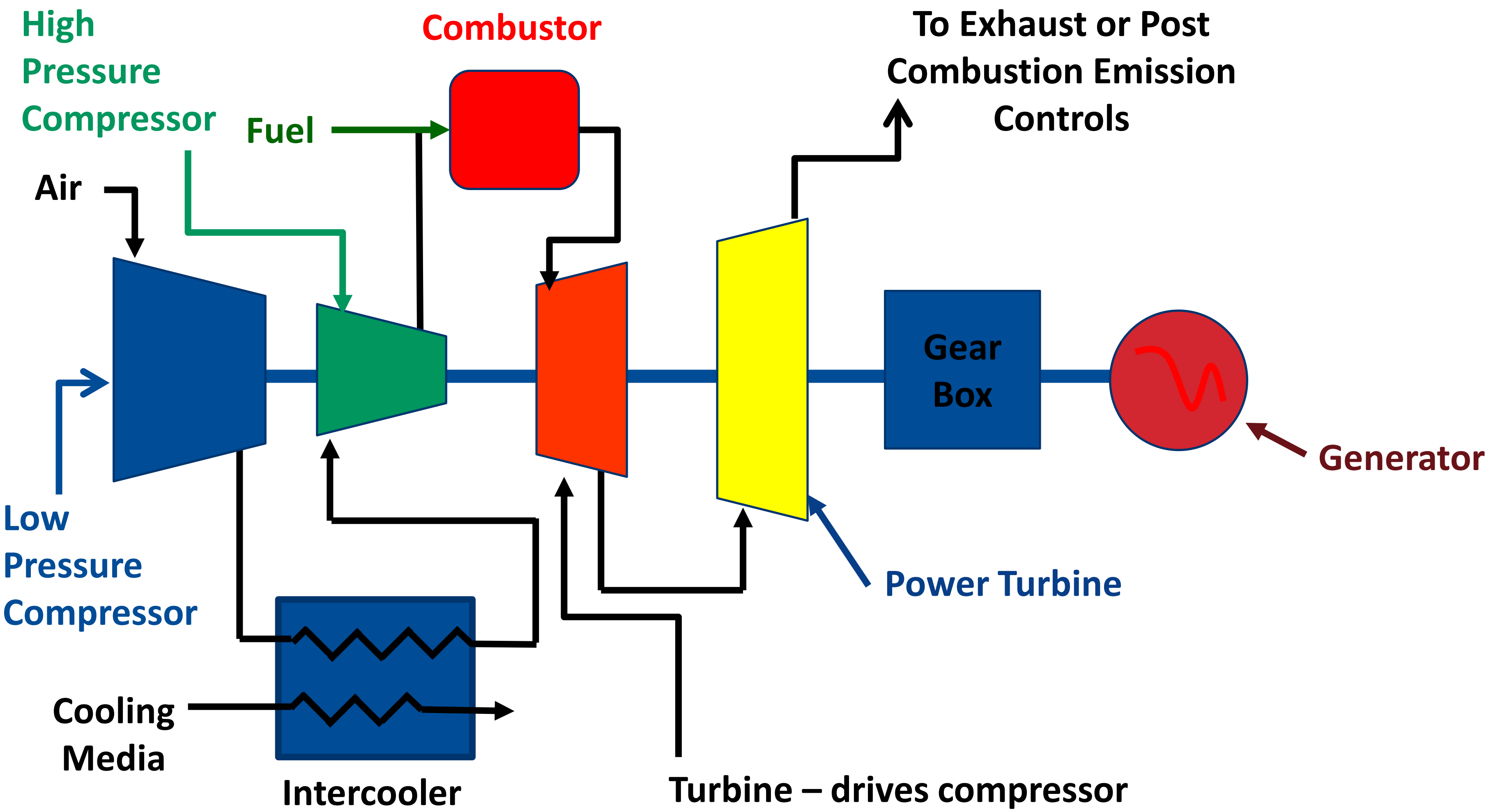
Natural Gas Turbine Generator

One large packaged unit will provide power and engineered heat recovery

Gas Turbine

- Gas Turbines – several hundred kilowatts to over several hundred megawatts
  - Run at high speeds
  - Used in power-only generation or in combined heat and power (CHP) systems
  - Produce high quality heat
  - Lower maintenance compared to engines
    - Requires higher skilled maintenance person

Schematic of Gas Turbine System



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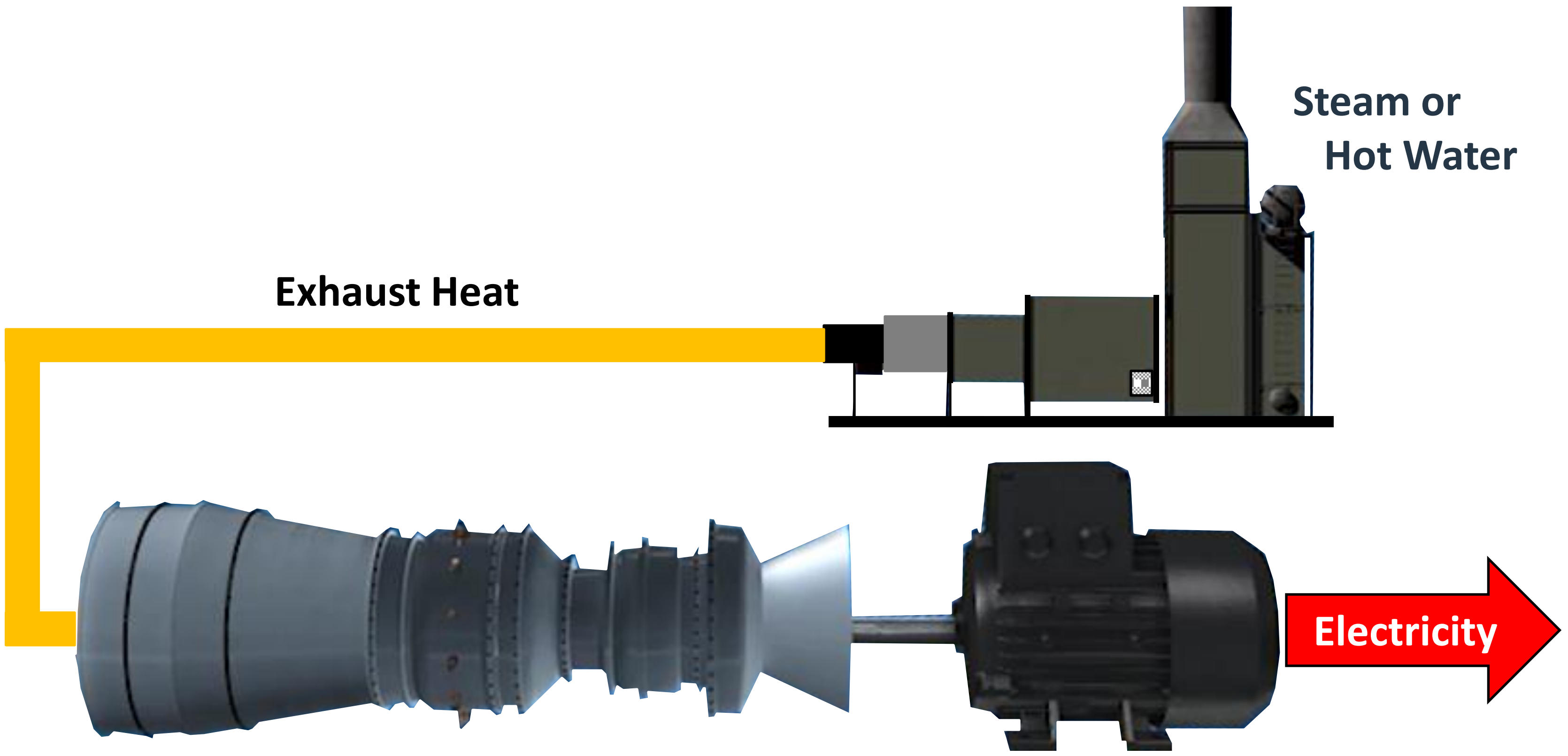
Turbine CHP – Simple Cycle



Use Natural gas and produce electricity and hot water or steam

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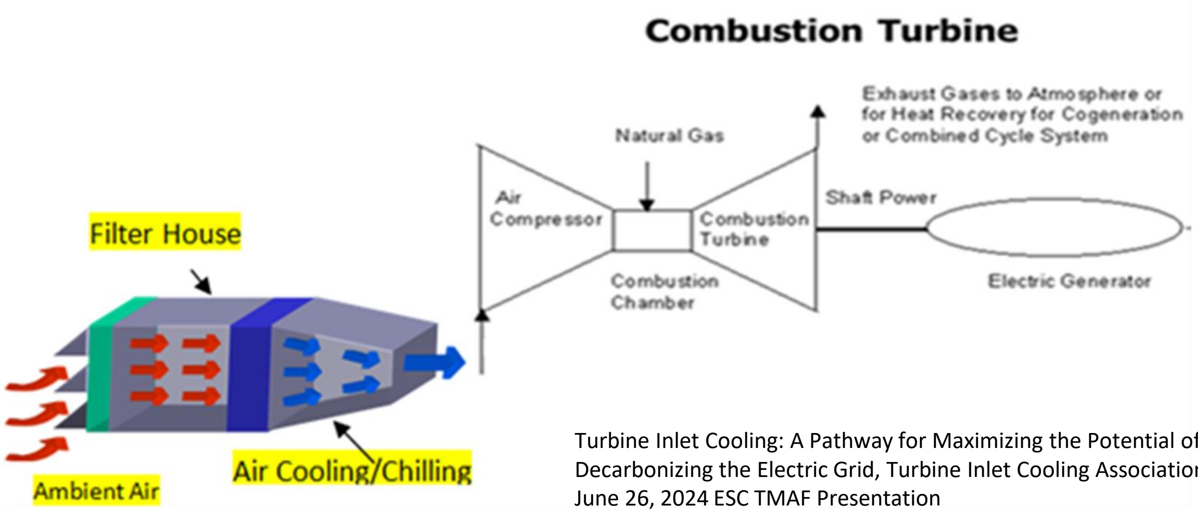
Gas Turbines

- High reliability
- Low emissions
- Able to produce high quality steam for:
  - Building heat or absorption chillers and process heating/consumption
  - District heating steam
  - Steam turbines in combined-cycle plant configurations
- Well suited for larger continuous duty CHP applications
- No cooling required (except in inlet cooling applications)

Gas Turbines – Efficiency Gains

- Turbine inlet cooling
- Cooling the turbine inlet air -- even by a few degrees – increases power output
  - Cooled air is denser, giving the turbine a higher mass-flow rate
  - Produces increased turbine output and efficiency -- as much as 0.4% per degree Fahrenheit



Turbine Inlet Cooling: A Pathway for Maximizing the Potential of CHP for Decarbonizing the Electric Grid, Turbine Inlet Cooling Association, June 26, 2024 ESC TMAF Presentation

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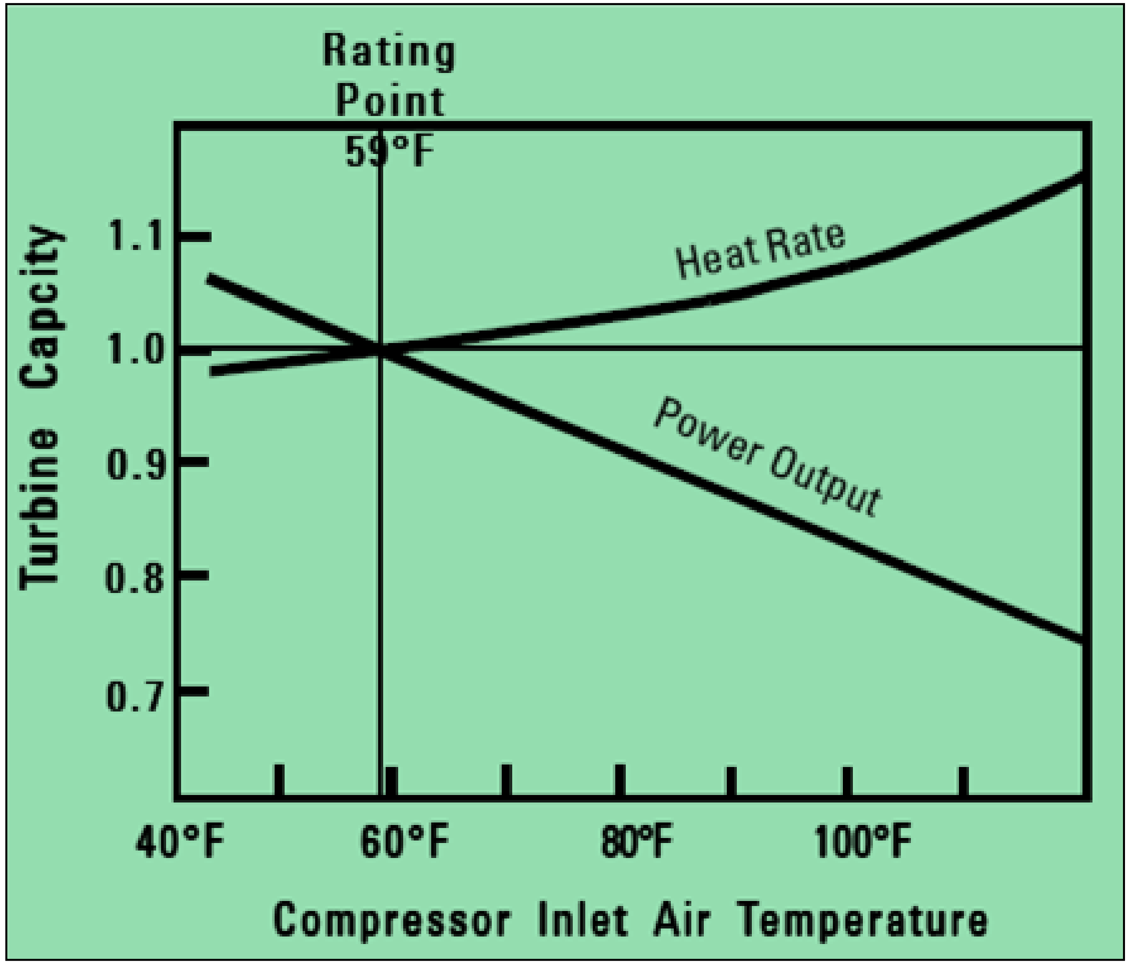
Optimizing Inlet Air Temperature Increases Power Output

A gas turbine generator with cooling system installed at a site having an ambient temperature of 100°F (37.7 °C) and a relative humidity of 30% could deliver up to 7.6% more power than a gas turbine without inlet cooling



Source: ASHRAE, Donaldson Co.

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Combined Cycle Plants

- Combines Gas Turbine with a Steam Turbine
  - Gas Turbine driven Generators with Heat Recovery Steam Generator (HRSG) to provide steam to drive a Steam Turbine Generator
  - Offers all advantages of two prime movers, plus large amounts of power on short notice
- Sizes: Very large

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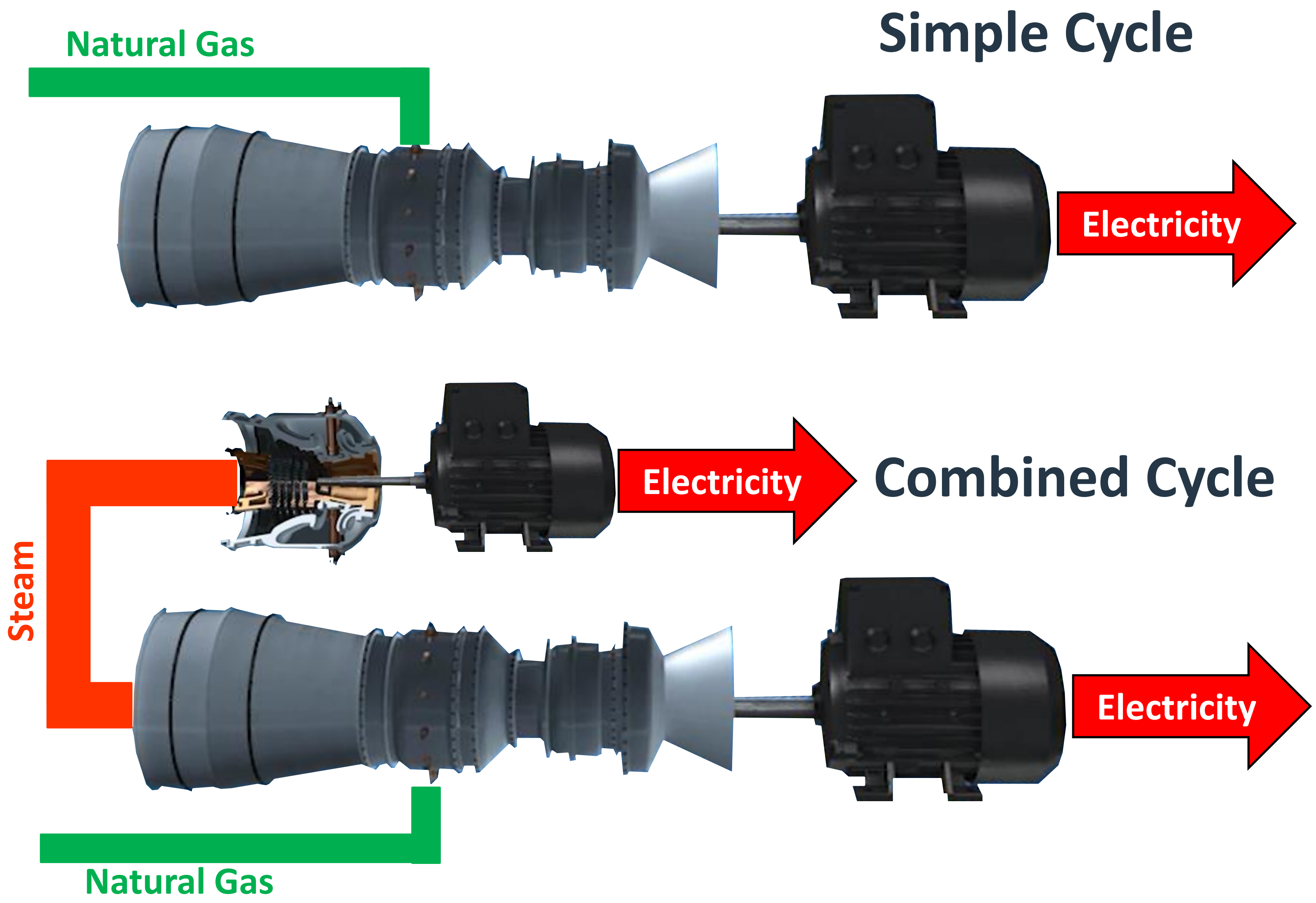
Turbine CHP – Simple vs. Combined Cycle



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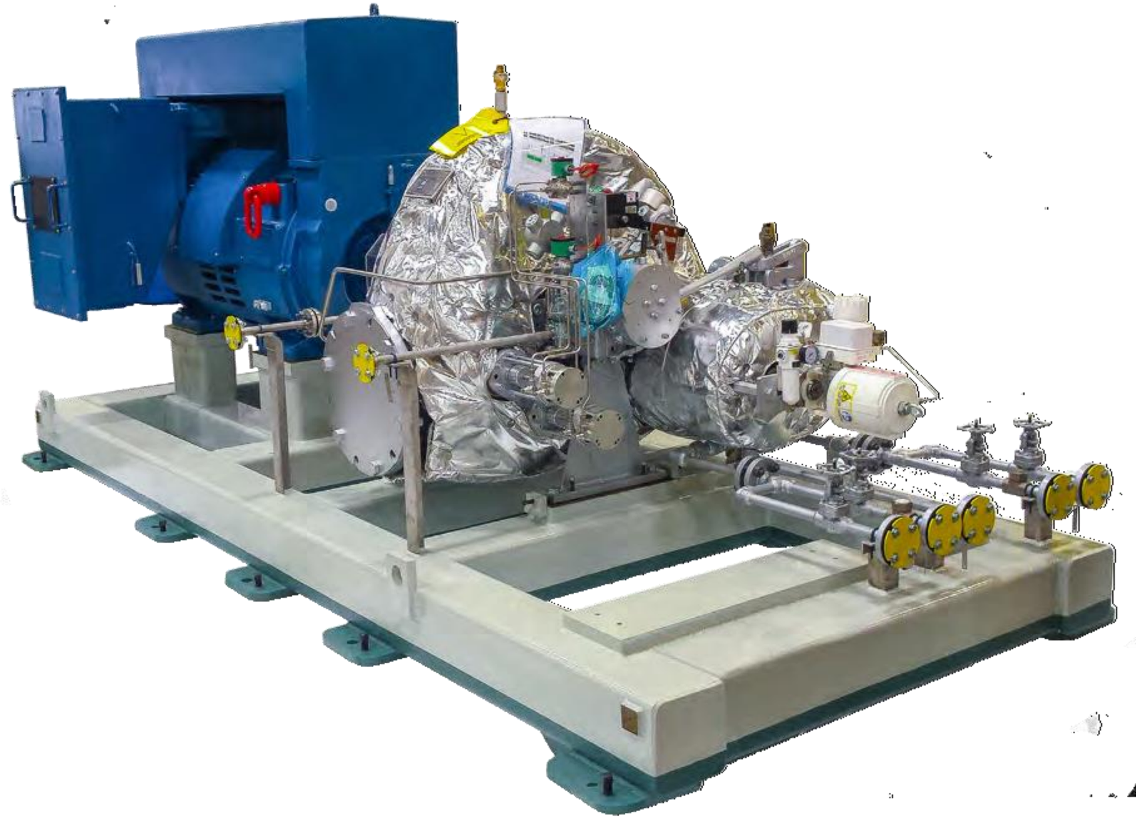
Steam Turbines

- Energy transferred from boiler to turbine through high-pressure steam that powers the turbine and generator
- Ideal in situations where large amounts of steam relative to electricity are needed
- Offers extremely long life and simple maintenance

Steam Turbine Generator

- Power range from 50 kW to 50 MW
- Synchronous or induction generator options
- Able to meet more than one site heat grade requirement
- Power to heat ratio can be varied
- Optional back-pressure turbine can be incorporated to reduce steam pressure in high pressure steam systems and generate electricity



http://www.elliott-turbo.com/default

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Microturbines

- Microturbines 65 – 200 kW
- Run at high speeds
- Able to operate on a variety of fuels, including natural gas, sour gases (high sulfur, low Btu content), and liquid fuels such as gasoline, kerosene, and diesel fuel/distillate heating oil
- Several small units can be ganged together to provide power and engineered heat recovery

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Microturbines

- Small, compact and lightweight packaged systems
- High grade heat available
- Known for installation flexibility
- Low emissions
- No cooling required
- Sizes: 65 to 200 kW
- More than one unit can be connected together to meet larger power requirements.

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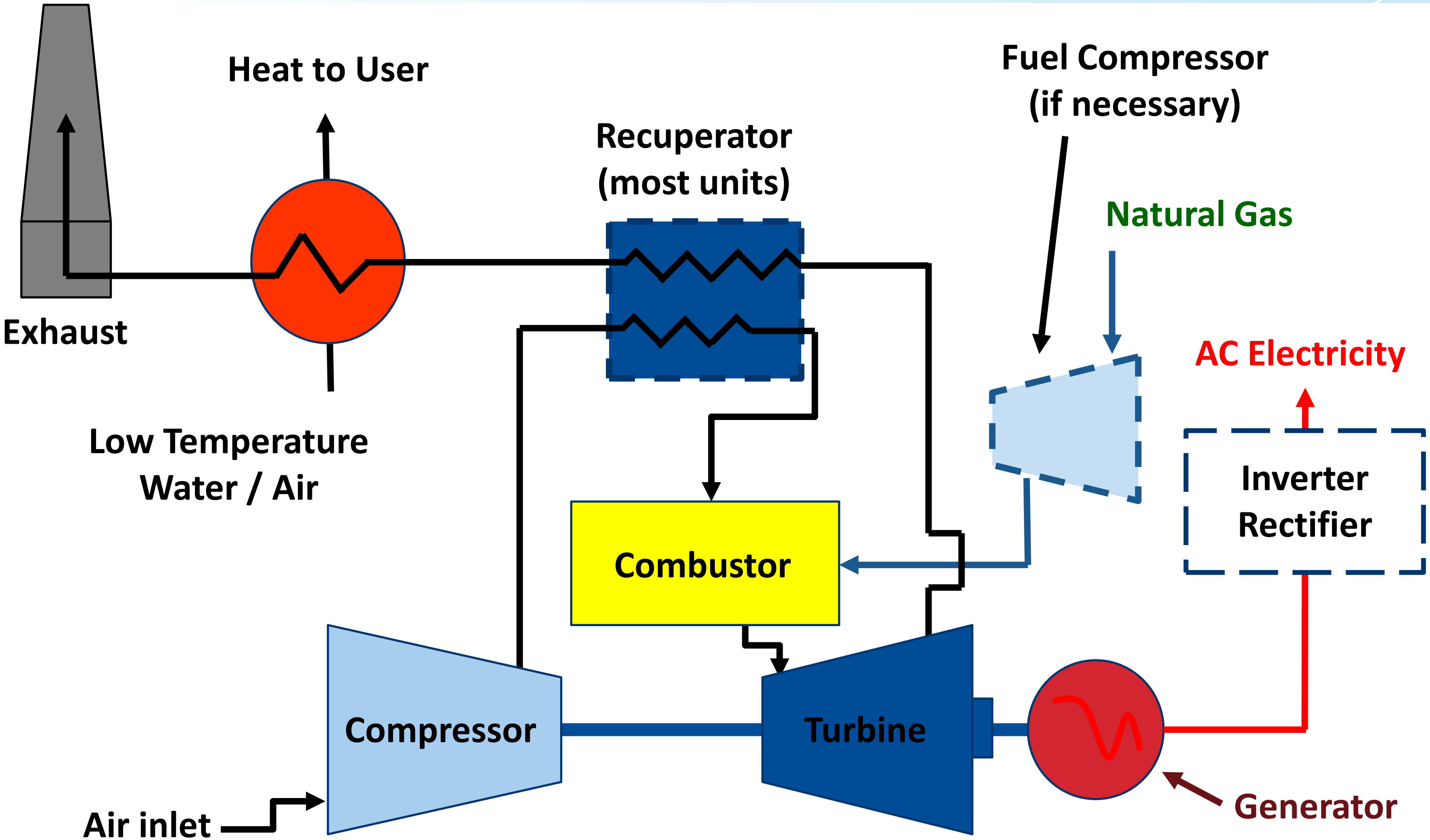
Schematic of Microturbine System



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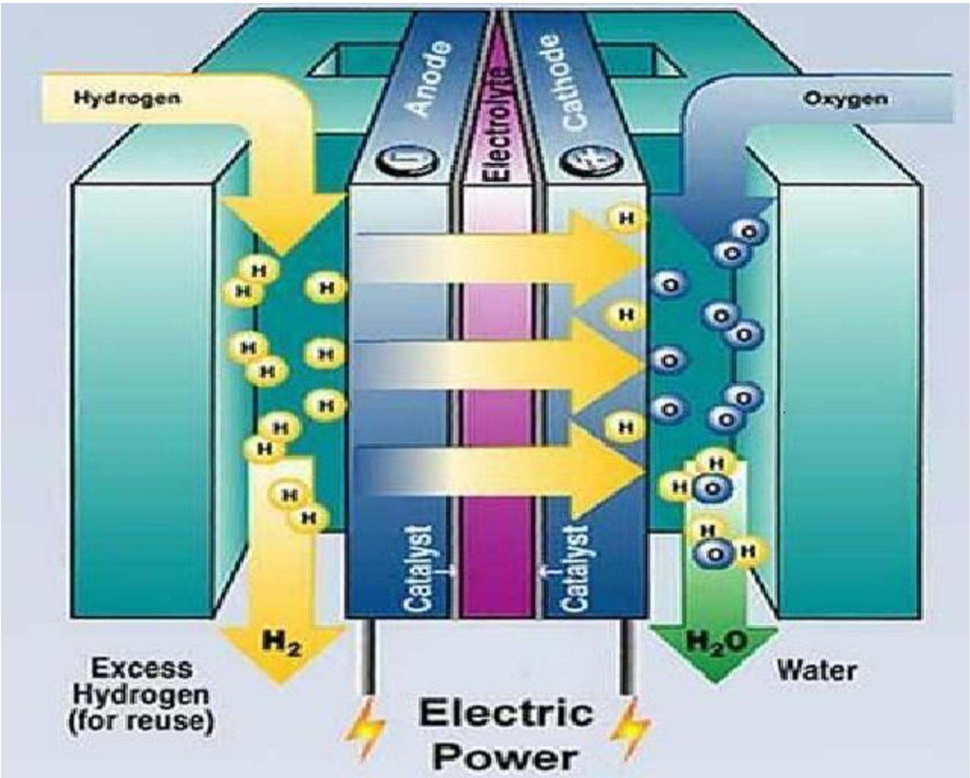
Fuel Cells


Hydrogen
Anode
Electrolyte
Cathode
Oxygen
Catalyst
Catalyst
H_2
Excess
Hydrogen
(for reuse)
Electric
Power
H_2O
Water

Fuel Cells

- Fuel cell systems are composed of three primary subsystems:
  - Fuel cell stack that generates direct current electricity
  - Many include a Fuel processor that converts the natural gas into a hydrogen rich feed stream
  - The power conditioner that processes the electric energy into alternating current or regulated direct current
- Can be fairly quiet
- Produce no pollutants if run on hydrogen
- Have few moving parts
- Have potentially high system fuel efficiencies

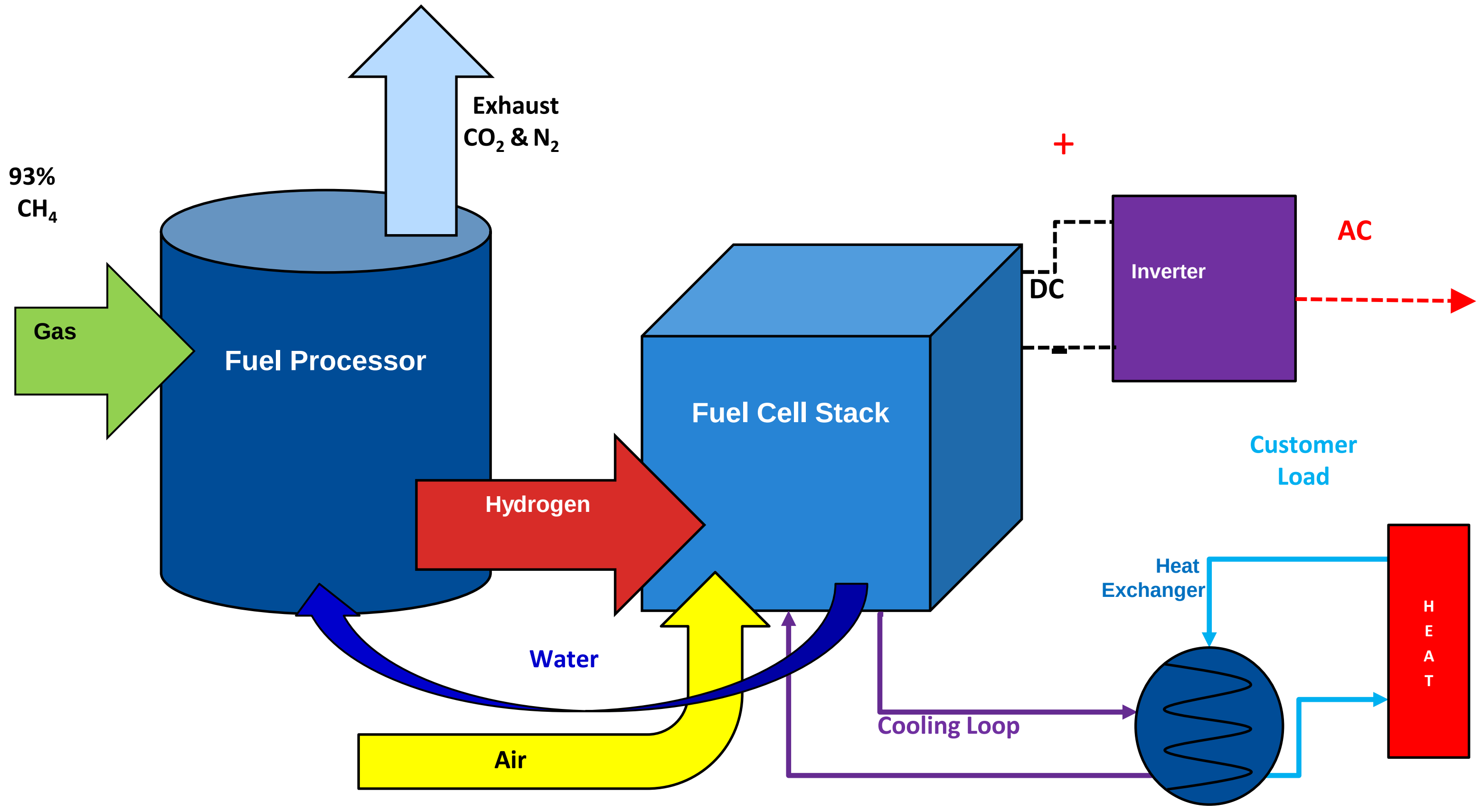
Fuel Cell Technologies

- Fuel cells produce power electrochemically from hydrogen delivered to the negative pole (anode) of the cell and oxygen delivered to the positive pole (cathode)
- The hydrogen can come from a variety of sources, but the most economic method is by reforming of natural gas or liquid fuels

Fuel Cell Technologies

- Several liquid and solid media support the electrochemical reactions:
  - Phosphoric acid (PAFC)
  - Molten carbonate (MCFC)
  - Solid oxide (SOFC)
  - Proton exchange membrane (PEM)
- Each type comprises a distinct fuel cell technology with its own performance characteristics and development schedule

Schematic of Fuel Cell System



Micro CHP (mCHP)

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Micro CHP (mCHP)

- Small scale cogeneration system for small commercial use
- Converts fuel to heat and electricity
- Micro-CHP units are sized up to 50 kWe
- Types Available
  - Engine driven
  - Fuel Cell
- Potential future technologies: ORC, Stirling Engine, TAC, small scale microturbines

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mCHP versus Standard CHP

- In many cases large commercial & industrial CHP systems are **Electricity-led**
  - Electricity is the main output and heat is the by product
- Micro-CHP systems in smaller commercial applications are often **Heat-led**
  - Heat as the main output and electricity as the by-product
  - We generally size Micro-CHP to not exceed heat & hot water requirements

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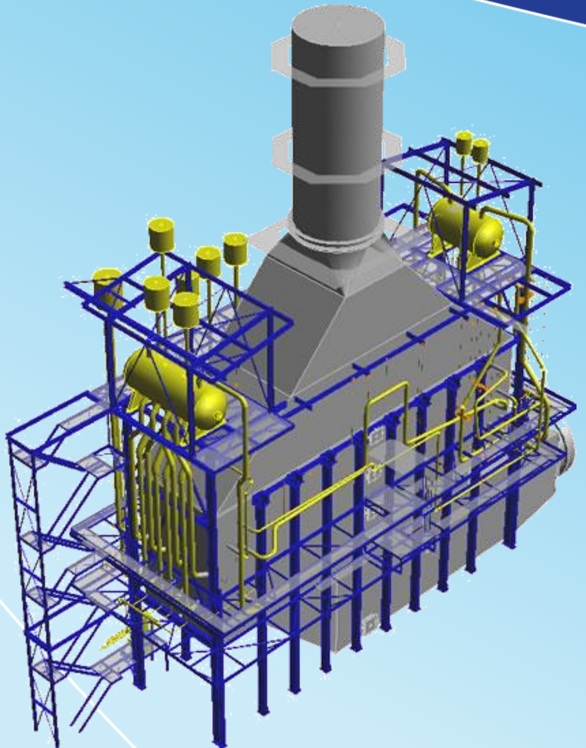
Heat Recovery



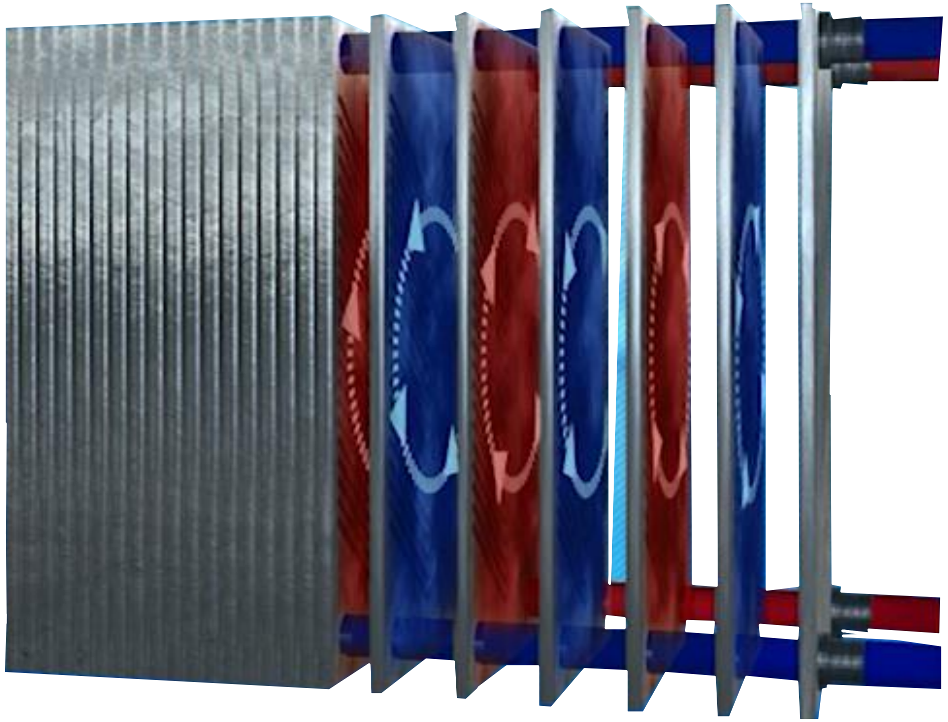
Thermal Output

- Simple Cycle Combustion Turbine:
  - High Volume, High Temp Exhaust (900 – 1000°F)
- Recuperated Microturbine:
  - High Volume, Medium Temp Exhaust (500 – 600°F)
- Reciprocating Engine:
  - Low Volume, High Temp Exhaust (900 – 1000°F)
  - + Hot Water (200 – 220°F)
- Fuel Cell (SOFC):
  - Low Volume, Medium Temp Exhaust (600 – 700°F)

Heat Recovery

- Heat recovery is an essential element for CHP
- Options exist for cooling water and exhaust heat depending on prime mover technology
- Packaged/optimized systems available based on project requirements

Heat Recovery
Plate and Frame Heat Exchanger



- Multiple thin slightly separated plates
- Large surface area
- Fluid flow passages allow heat transfer between two fluids

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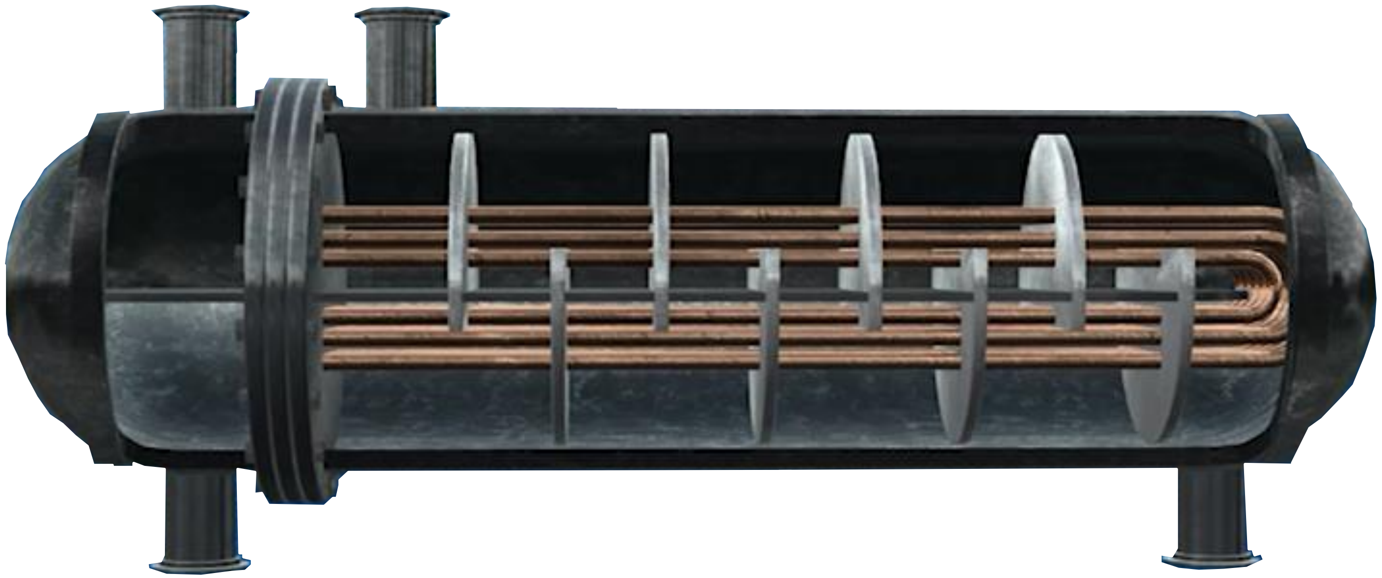
Heat Recovery
Shell & Tube Heat Exchanger



- Series of tubes that contain fluid to be heated
- Second fluid is located in shell and pumped around tubes transferring heat to fluid in tubes

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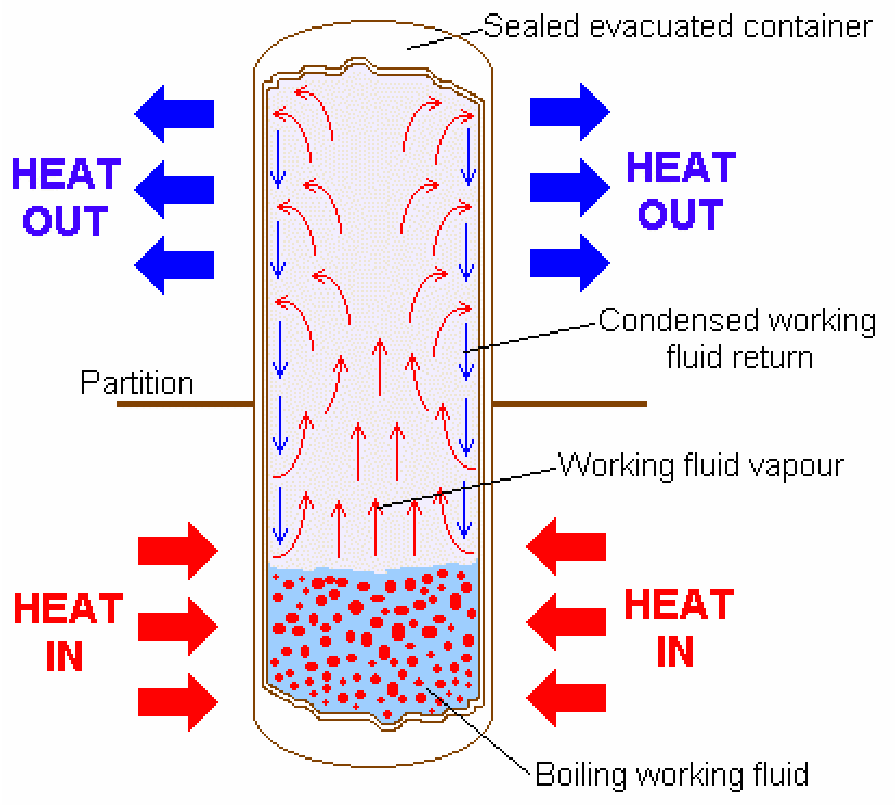
Heat Recovery Steam Generator (HRSG)

- Steam Flows can be from ~10,000 to ~300,000 #/hr.
- Pressure > 2000 PSI

Photo courtesy of Cleaver Brooks

Heat Recovery
Heat Pipe Heat Exchanger (HPHX)

- Thermosyphon Technology
- High thermal recovery rates
- Gas to Water models
  - Good for absorption
- Gas to Steam models
- Exhaust Gas to Super heated Steam



Schematic Representation of the Heat Pipe

Photos courtesy of AMS Energy

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Heat Recovery on Engines

- Four sources of usable waste heat from a reciprocating engine:
  - Exhaust gas
  - Engine jacket cooling water
  - Lube oil cooling water
  - Turbocharger cooling
- Heat can be recovered in the form of hot water or low pressure steam (<30 psig)
- Medium pressure steam (up to about 150 psig) can be generated from the engine's high temperature exhaust gas

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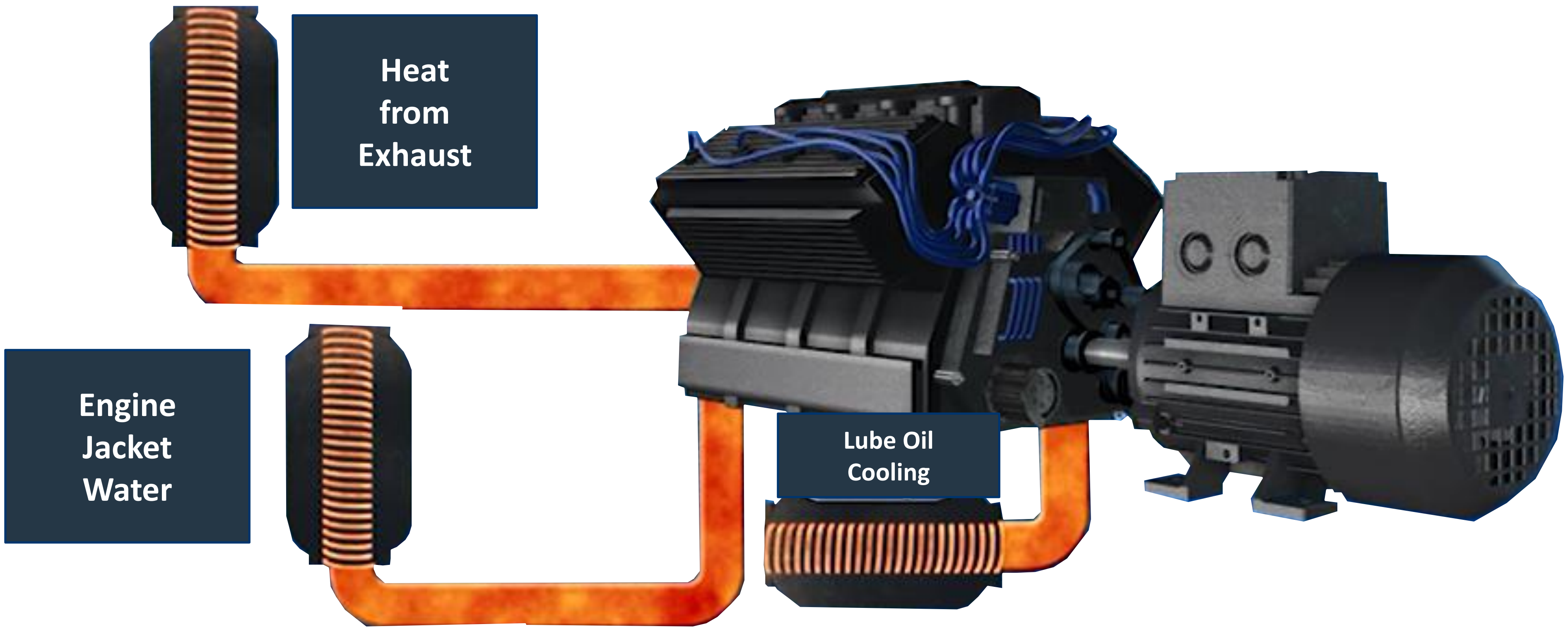
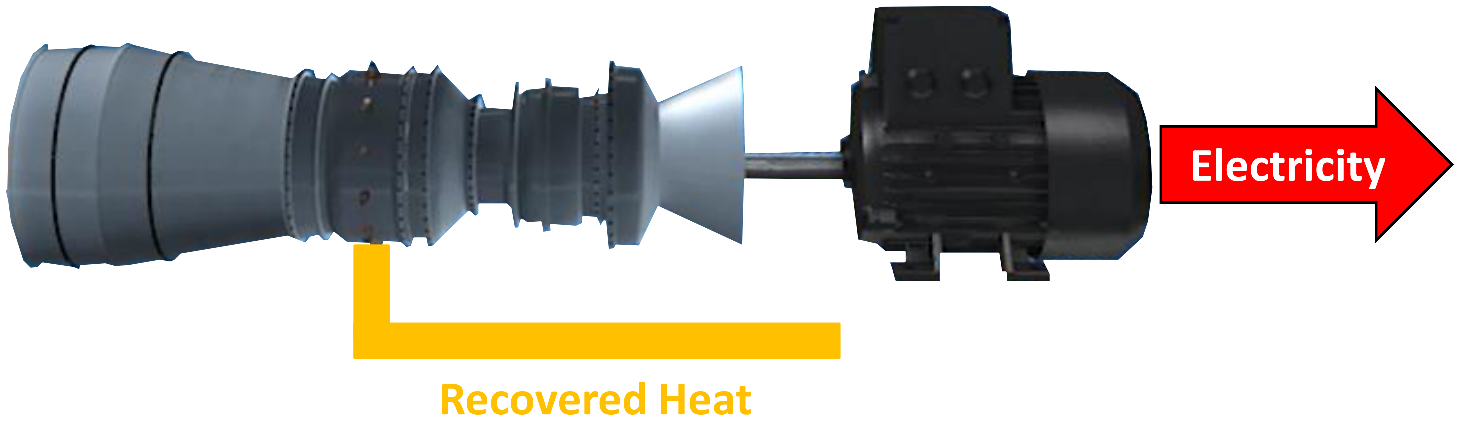
Engine Heat Recovery
(Heat Recovered from Exhaust, Cooling Jacket and Lube System)



Heat Recovery
Turbines & Micro Turbines

- Heat recovery is from the turbine combustion exhaust
- Recovered in the form of hot air, water or steam
- May add a duct burner to raise exhaust temperature and supplement steam production



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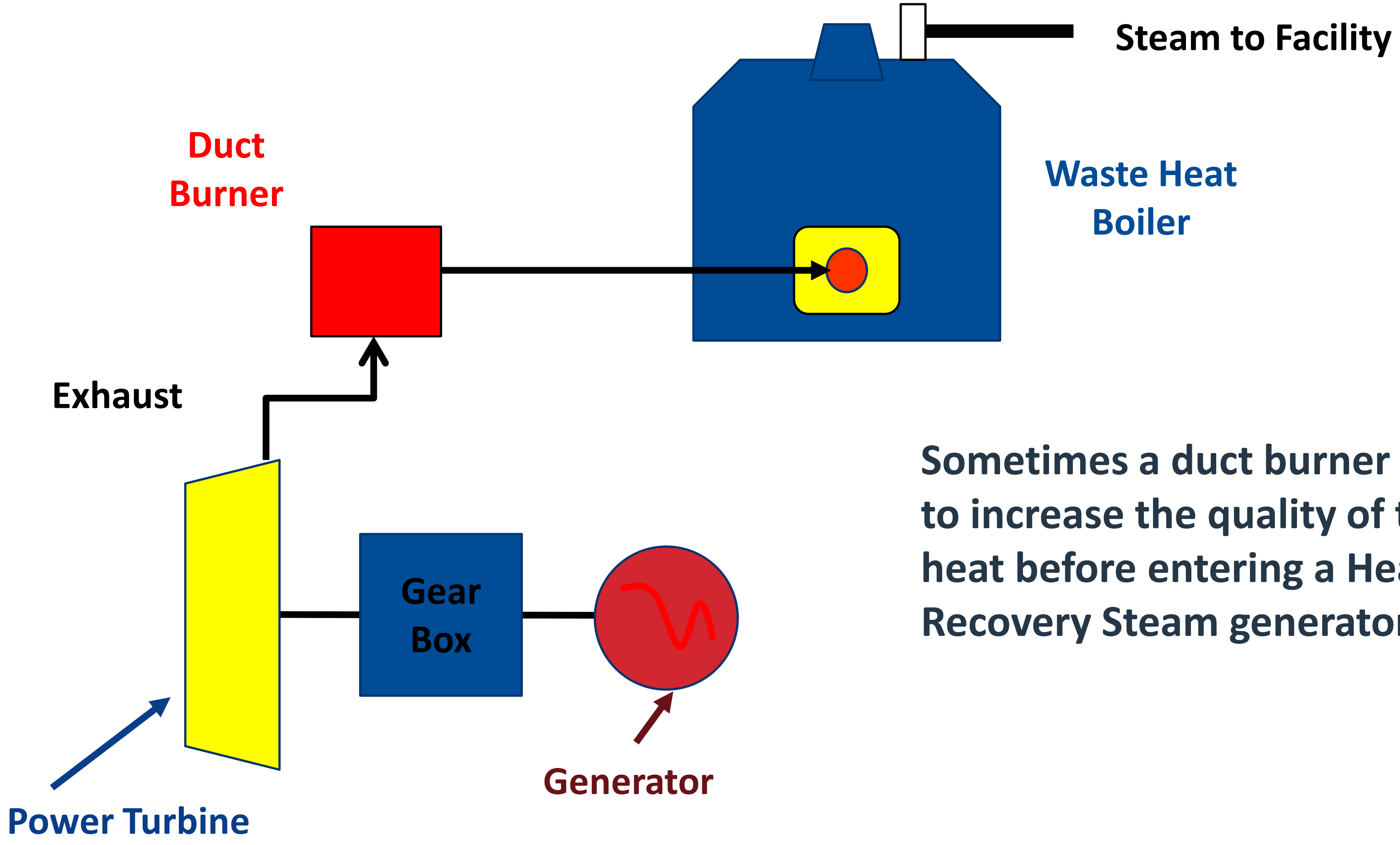
Gas Turbine System Heat Recovery



Sometimes a duct burner is added to increase the quality of the waste heat before entering a Heat Recovery Steam generator (HRSG)

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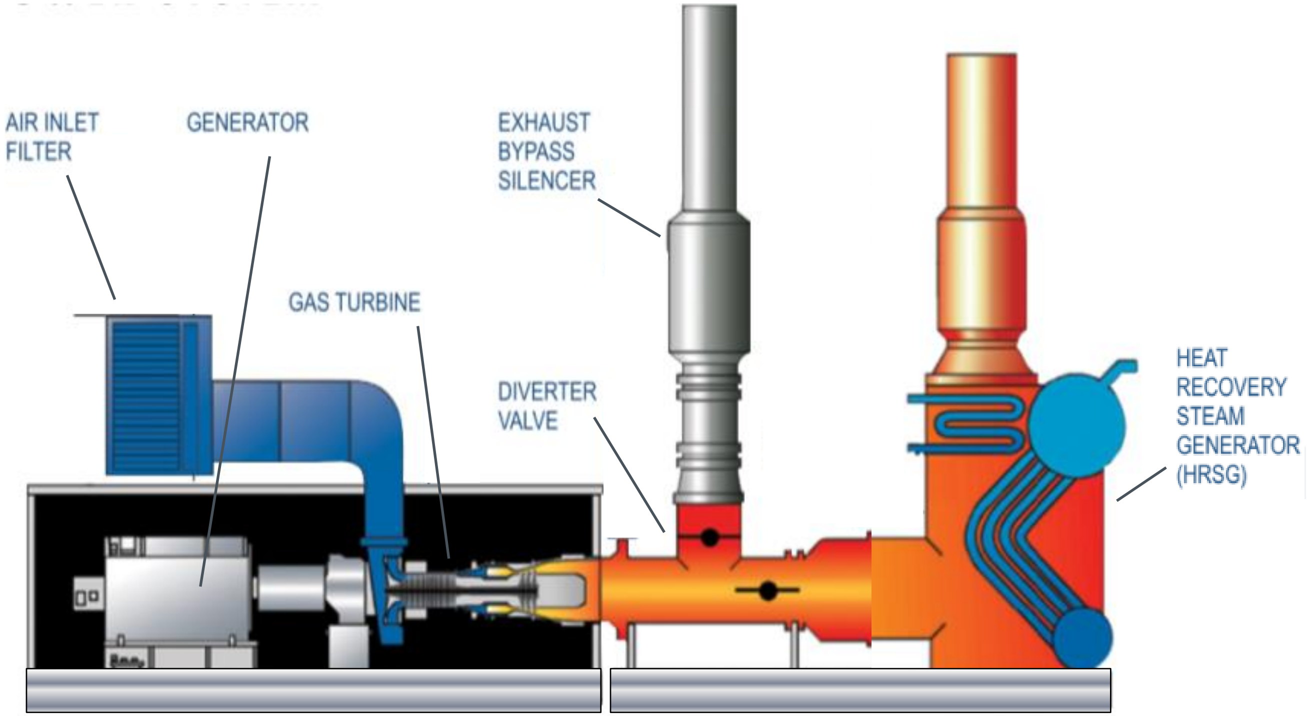
Heat Recovery – Turbines Produce Steam

- Hot exhaust gases from the turbine pass through the HRSG - producing steam for steam turbine drives, heating, cooling, or process uses
- Can add supplemental firing if exhaust does not provide enough heat



http://www.epa.gov/chp/documents/presentations/forum_wd/NCHPTTRFLyonsFinal.pdf

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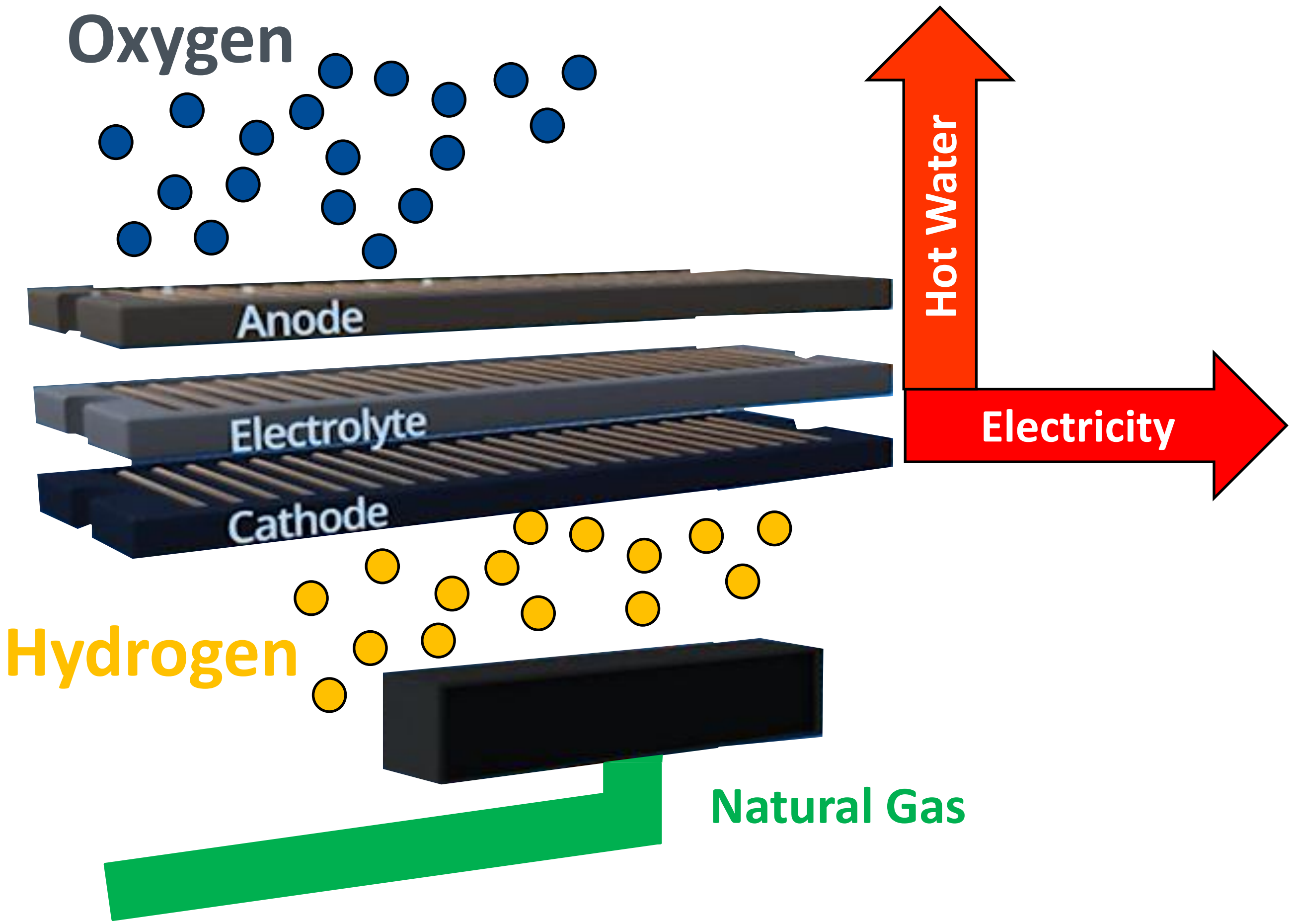
Fuel Cell Heat Recovery
(Hot water is byproduct of process)



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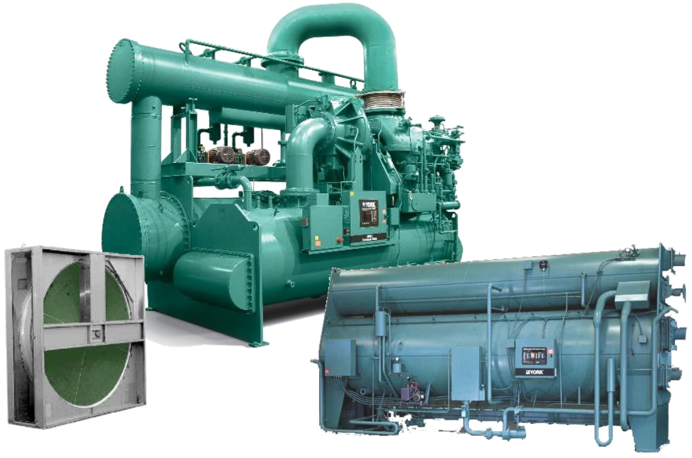
Using Waste Heat for Cooling

- Thermal Technologies for CHP are able to produce cooling from waste heat and include:

Efficiency

  - **Steam Turbine Chillers**
  - **Double Effect Absorbers**
  - **Single Effect Absorbers**
  - **Desiccants**
  - **Adsorbers**



- Cooling and Dehumidification Systems are available across a wide range of CHP configurations and sizes, from 50 kW to multi-MW applications.

Economics and Incentives

A detailed Life Cycle Cost Analysis is essential for evaluating a CHP project at any facility

Economic Analysis

Life cycle costing is the process that compiles all expected costs that the owner of an asset will incur over its lifespan of the equipment. These costs include the initial investment (capital cost for equipment & installation), Operating and Maintenances Costs and Energy Costs. When comparing the life cycle cost of two options, the one with the lower life cycle cost is recommended.

- Capital costs are amortized of the life of the equipment at the interest rate able to be obtained by the borrower.
- O&M costs are X on Day 1, and are expected to increase each year by some %.
- Energy Costs are expected to escalate or increase over time as well.

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Life Cycle Cost & Emissions Calculator

Understanding CHP | ESC Energy Solutions Center

HOME ⌄ OVERVIEW ⌄ TECHNOLOGIES ⌄ WASTE HEAT ⌄ RESOURCES ⌄ INSTALLATIONS ⌄ BLOG

Combined Heat & Power – CHP Calculator Tool

A Simple ROI Analysis Calculator for CHP Technology

This ROI calculator provides a simple payback calculation for various CHP technologies based on the size and energy rates. The calculations use average pricing, efficiencies, & maintenance costs provided in the CHP Technology Catalogs available from the Combined Heat and Power partnership of the EPA. This calculator also shows the carbon emissions reductions from a CHP system based off of eGRID data.

The results produced by use of this tool are intended solely as a preliminary evaluation of a potential CHP installation. For a more detailed and exact evaluation, you should seek the assistance of a qualified engineering firm with input from the appropriate manufacturers of power generation equipment.

Simple Payback Analysis Tool (Excel)

LAUNCH CALCULATOR

https://understandingchp.com/resources/payback-tool/

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Tool Assumptions & Simple Payback

Combined Heat & Power (CHP) Simple Payback Analysis

Use this tool to review various CHP equipment simple payback options.

FOR MORE INFORMATION VISIT OUR WEBSITE

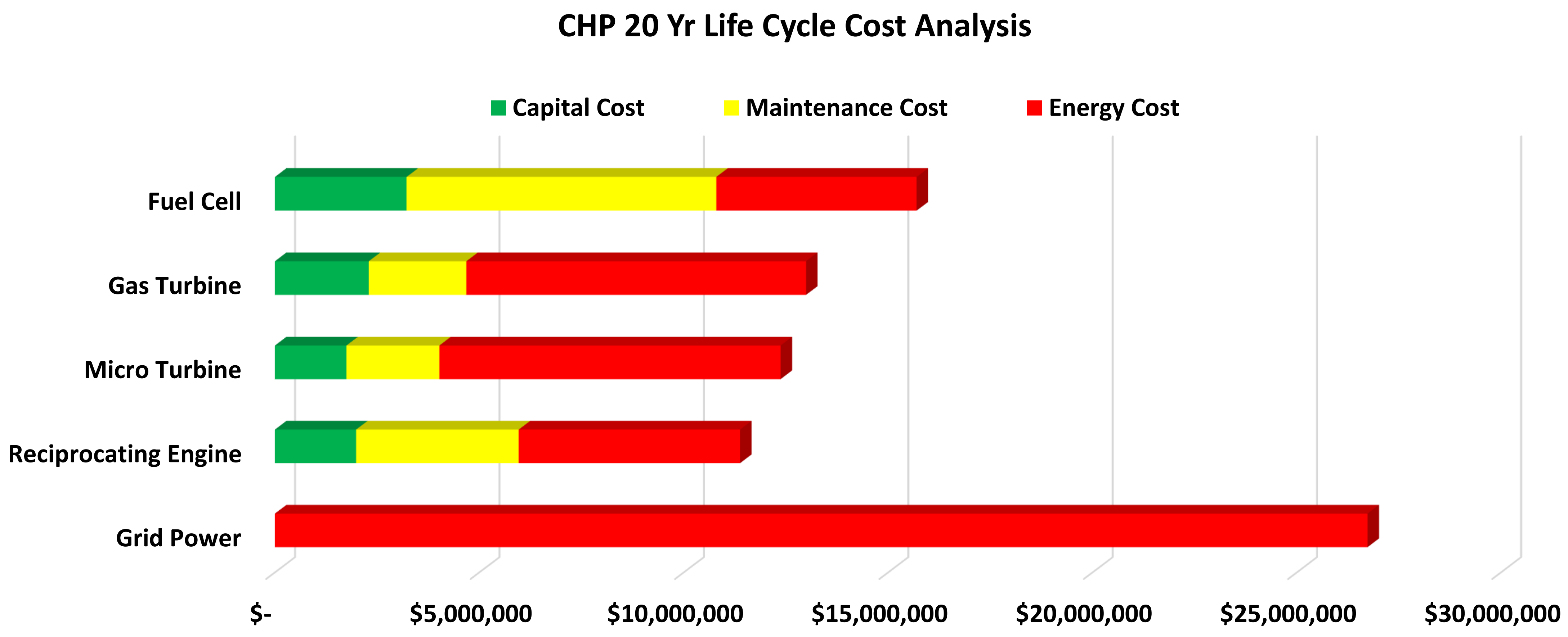
Company/Customer Name	Facility/Site Location

User Inputs:

1. Size CHP Electric Generator (KW)	1,000	8. Ave. Electric Usage Rate ($/KWH)	$ 0.14
2. Hours of Cogeneration (/Year)	8,600	9. Electric Demand Charge ($/KW)	$ 10.00
3. Number of months generating power	12.00	10. Ave. Natural Gas Rate ($/MMBTU)	$ 7.00
4. # Years CHP Plant will be Financed	20	11. Gas Rate for CHP ($/MMBTU)	$ 6.00
5. Interest Rate on Loan for Installed Cost	5%	12. Please select Emissions Profile	US Average Fossil
6. Investment Tax Credit	30%	and state/province/region	US Average
7. CHP Incentive ($)	$ -	e-GRID Sub-Region Map	

	Recip. Engine	Micro Turbine	Gas Turbine	Fuel Cell
Simple Payback (Years)	2.2	2.1	2.7	4.3
CHP Size (KW)	1,000	1,000	1,000	1,000
Installed Cost	$2,837,000	$2,500,000	$3,281,000	$4,600,000
Federal CHP Investment Tax Credit	$851,100	$750,000	$984,300	$1,380,000
Cost Less CHP Incentive(s)	$1,985,900	$1,750,000	$2,296,700	$3,220,000
Ave. Annual Maintenance Cost	$180,600	$103,200	$108,360	$344,000
Power Produced (KWH)	8,600,000	8,600,000	8,600,000	8,600,000
Annual Electric Saved on Demand	$120,000	$120,000	$120,000	$120,000
Annual Electric Savings on Usage	$1,204,000	$1,204,000	$1,204,000	$1,204,000
Annual Gas Cost for Cogeneration	$510,294	$660,208	$735,581	$412,800
Recovered Heat (MMBTU/Year)	37,762	40,163	51,184	27,176
Annual Gas savings from waste heat use	$264,332	$281,139	$358,289	$190,232
Annual O&M cost CHP Plant	$690,894	$763,408	$843,941	$756,800
Electric and gas utility savings from CHP	$1,588,332	$1,605,139	$1,682,289	$1,514,232
Total Savings per year from CHP System	**$897,438**	**$841,730**	**$838,348**	**$757,432**

CHP Life Cycle Cost Analysis



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https://understandingchp.com/resources/payback-tool/

U.S. CHP Tax Credit

Investment Tax Credit

- The incentive is an Investment Tax Credit, which is a reduction in either overall individual or overall business tax liabilities
- 30% of the project cost for projects incorporating CHP equipment, that begin construction before January 1, 2025.
- Possible 10% more if equipment meets domestic content requirements
- Possible 10% more if site is located in an Energy Community

General qualification rule:

- The CHP system efficiency must exceed 60%
  - Electric must be >= 20% & Thermal Energy must be >= 20%

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Federal Tax Code: Bonus Depreciation

- Section 179 of the Tax code allows for 100% depreciation in the 1st year of capital expenses.
- Most businesses pay approx. 21% federal tax.
- Assuming the business has income greater than the cost of the CHP system, the entire cost of the system can be written off against income the first year and the net effect is you get 21% of the cost back.
  - Add to that the ~30% ITC for CHP the business gets 51% of the cost returned in the first year.

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CHP Resources

Numerous Trade Associations and web resources are available to assist and provide you additional market information and resources

CHP Resources

Understanding CHP | ESC Energy Solutions Center

HOME OVERVIEW TECHNOLOGIES WASTE HEAT RESOURCES VENDORS INSTALLATIONS NEWS

Understanding Combined Heat and Power (CHP)

Distributed Generation is an efficient on-site power system that produces electric power and thermal energy for heat, steam or air conditioning.

This form of power generation is known today by many names and acronyms. Cogeneration, or combined heat and power (CHP) are two. CHP is not a single technology, but an integrated energy system that can be modified depending upon the needs of the energy end user. These systems simply capture and utilize excess heat generated during the production of electric power. CHP systems offer economic, environmental and reliability-related compared to power generation facilities that produce only electricity.

By capturing and using the waste heat, these systems normally consume 50 percent of the fuel burned by a central power station to provide an equivalent amount of energy. Because greenhouse gas emissions are related to the amount of fuel burned, CO2 production can also cut in half using a distributed generation system.
This website will provide you information on the various technologies available to produce your own power with recoverable heat. By making continuous use of both electricity and thermal energy, you can save up to 35 percent on overall energy costs.

The real key to an efficient and economical CHP system is having the need for simultaneous use of both electricity and heat.

www.understandingchp.com

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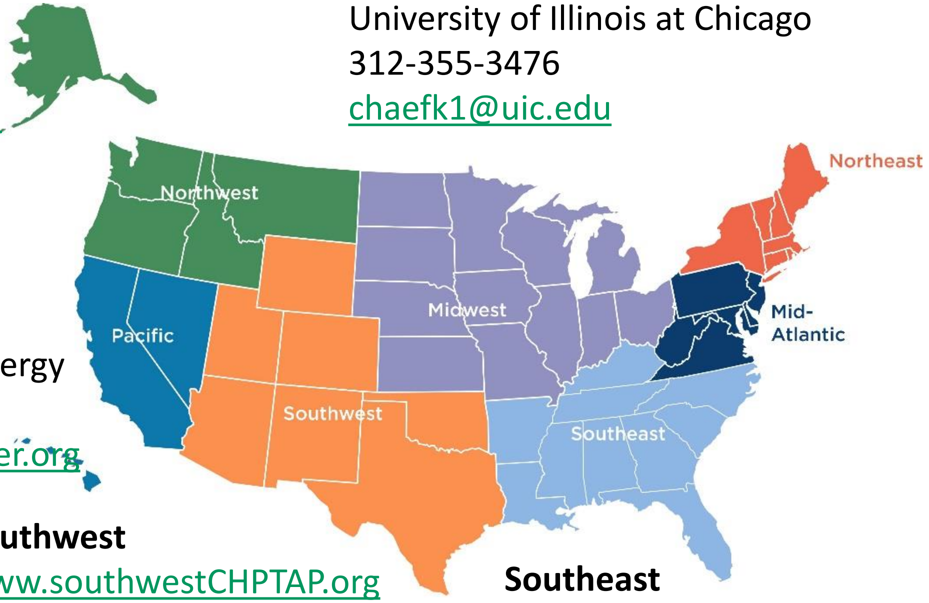
Department of Energy

- DOE – U.S. Department of Energy
  - Located in Washington, DC
  - Numerous resources available
  - https://www.energy.gov/eere/amo/chp-deployment

DOE CHP Technical Assistance Partnerships for CHP (CHP TAPs)



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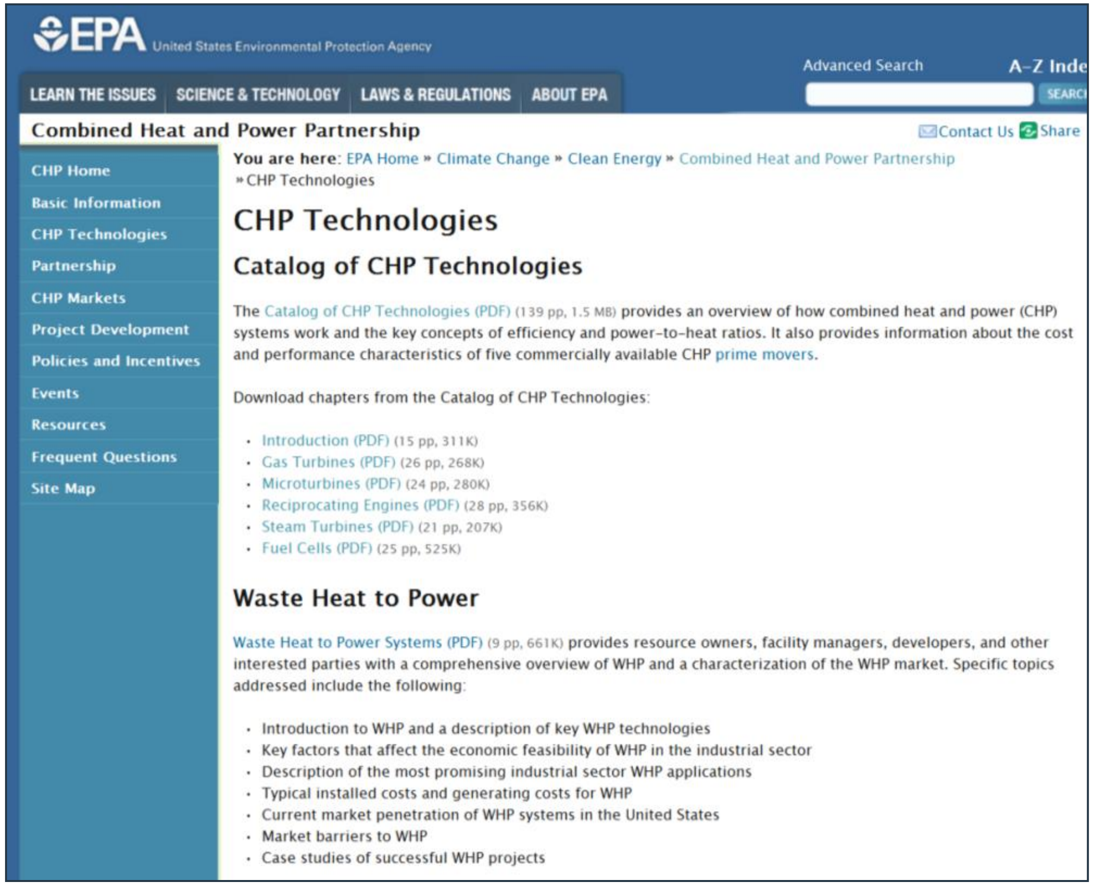
For more information visit https://energy.gov/eere/amo/chp-technical-assistance-partnerships-chp-taps

EPA Web Site – CHP Information

https://www.epa.gov/chp/chp-technologies


EPA United States Environmental Protection Agency

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Combined Heat and Power Partnership

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CHP Technologies

Catalog of CHP Technologies

The Catalog of CHP Technologies (PDF) (139 pp, 1.5 MB) provides an overview of how combined heat and power (CHP) systems work and the key concepts of efficiency and power-to-heat ratios. It also provides information about the cost and performance characteristics of five commercially available CHP prime movers.

Download chapters from the Catalog of CHP Technologies:

- Introduction (PDF) (15 pp, 311K)
- Gas Turbines (PDF) (26 pp, 268K)
- Microturbines (PDF) (24 pp, 280K)
- Reciprocating Engines (PDF) (28 pp, 356K)
- Steam Turbines (PDF) (21 pp, 207K)
- Fuel Cells (PDF) (25 pp, 525K)

Waste Heat to Power

Waste Heat to Power Systems (PDF) (9 pp, 661K) provides resource owners, facility managers, developers, and other interested parties with a comprehensive overview of WHP and a characterization of the WHP market. Specific topics addressed include the following:

- Introduction to WHP and a description of key WHP technologies
- Key factors that affect the economic feasibility of WHP in the industrial sector
- Description of the most promising industrial sector WHP applications
- Typical installed costs and generating costs for WHP
- Current market penetration of WHP systems in the United States
- Market barriers to WHP
- Case studies of successful WHP projects

CHPA

- Coalition of businesses, labor, contractors, non-profit organizations, and educational institutions with the common purpose to educate all Americans about CHP and WHP, and how CHP and WHP can make America's manufacturers and other businesses more competitive, reduce energy costs, enhance grid reliability, and reduce emissions.
- Located in Arlington, VA
- www.chpalliance.org

COMBINED HEAT AND POWER ALLIANCE

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Thank You

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escenter.org