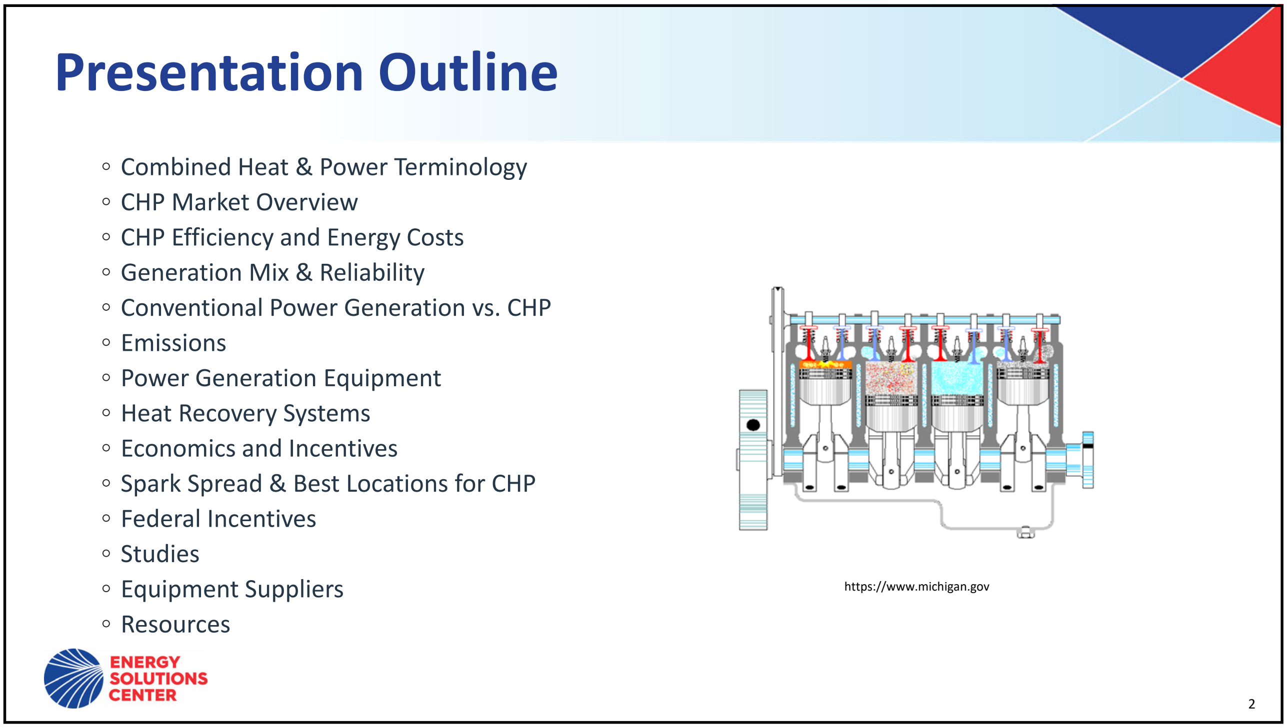
Track: Commercial Gas I
Unit #6: CHP Technologies

An overview of CHP Technologies for Commercial Facilities

Eric Burgis, Energy Solutions Center



Presentation Outline

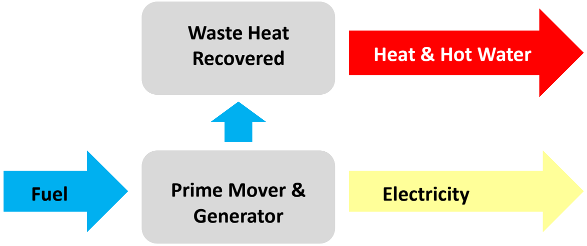
- Combined Heat & Power Terminology
- CHP Market Overview
- CHP Efficiency and Energy Costs
- Generation Mix & Reliability
- Conventional Power Generation vs. CHP
- Emissions
- Power Generation Equipment
- Heat Recovery Systems
- Economics and Incentives
- Spark Spread & Best Locations for CHP
- Federal Incentives
- Studies
- Equipment Suppliers
- Resources

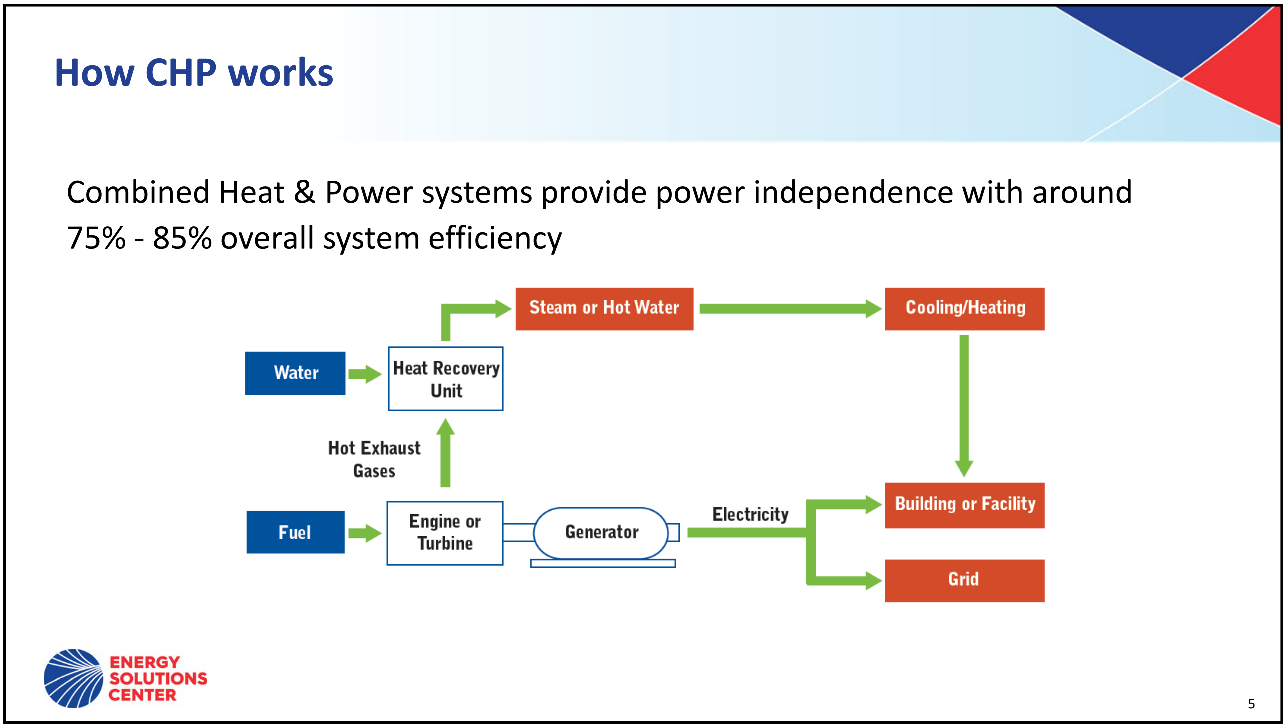
https://www.michigan.gov

Terms & Market Overview

What is CHP?

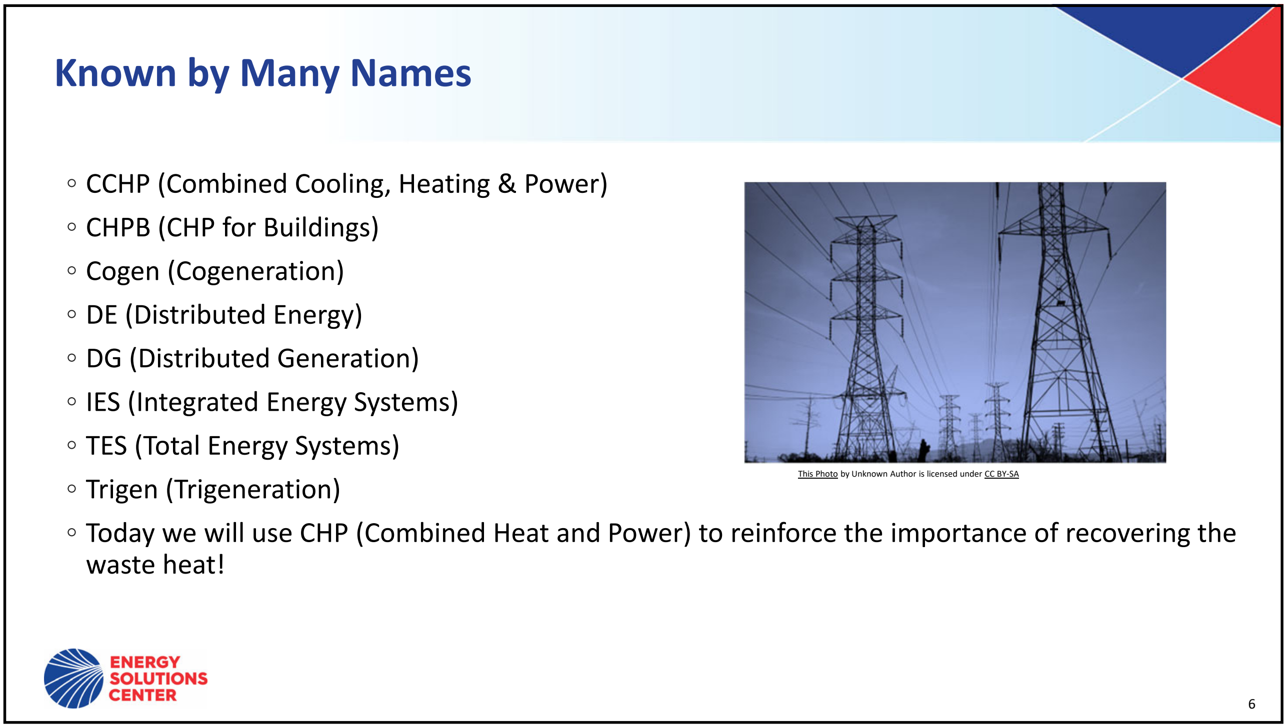
Combined Heat and Power (CHP) by definition is the generation of two forms of energy from one common source of fuel also known as Cogeneration.





How CHP works

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



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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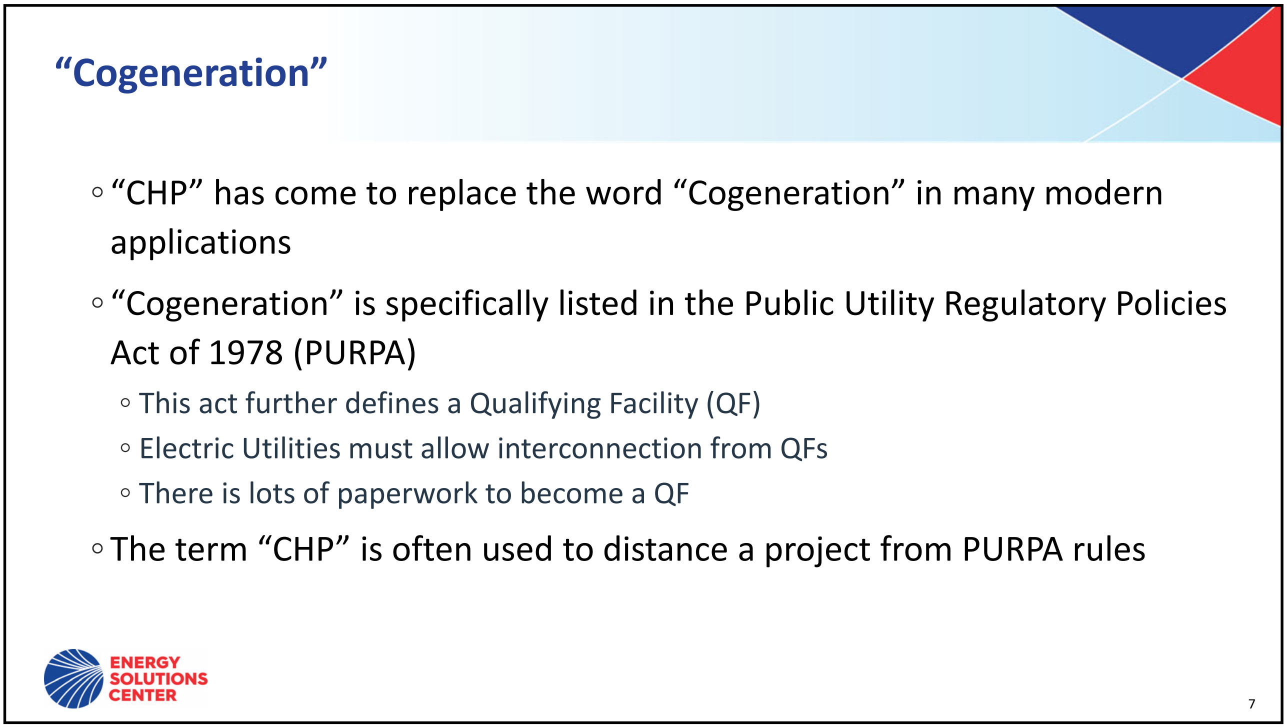
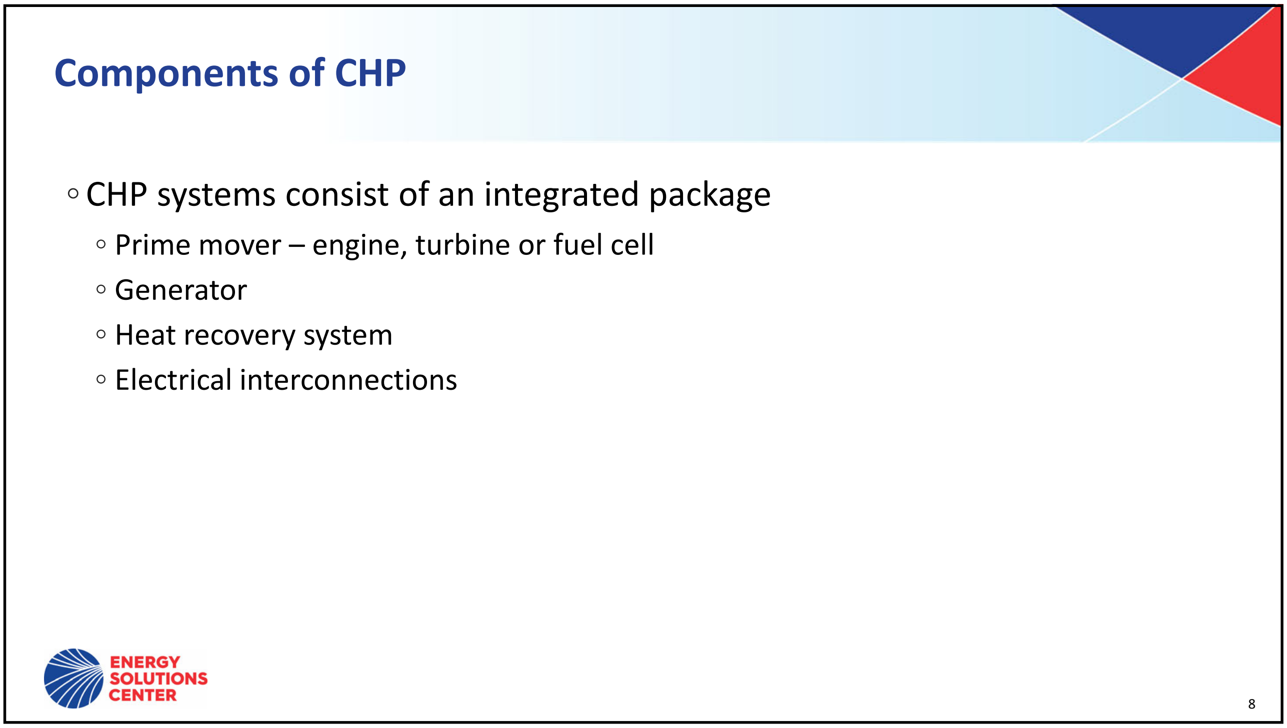


“Cogeneration”

- “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

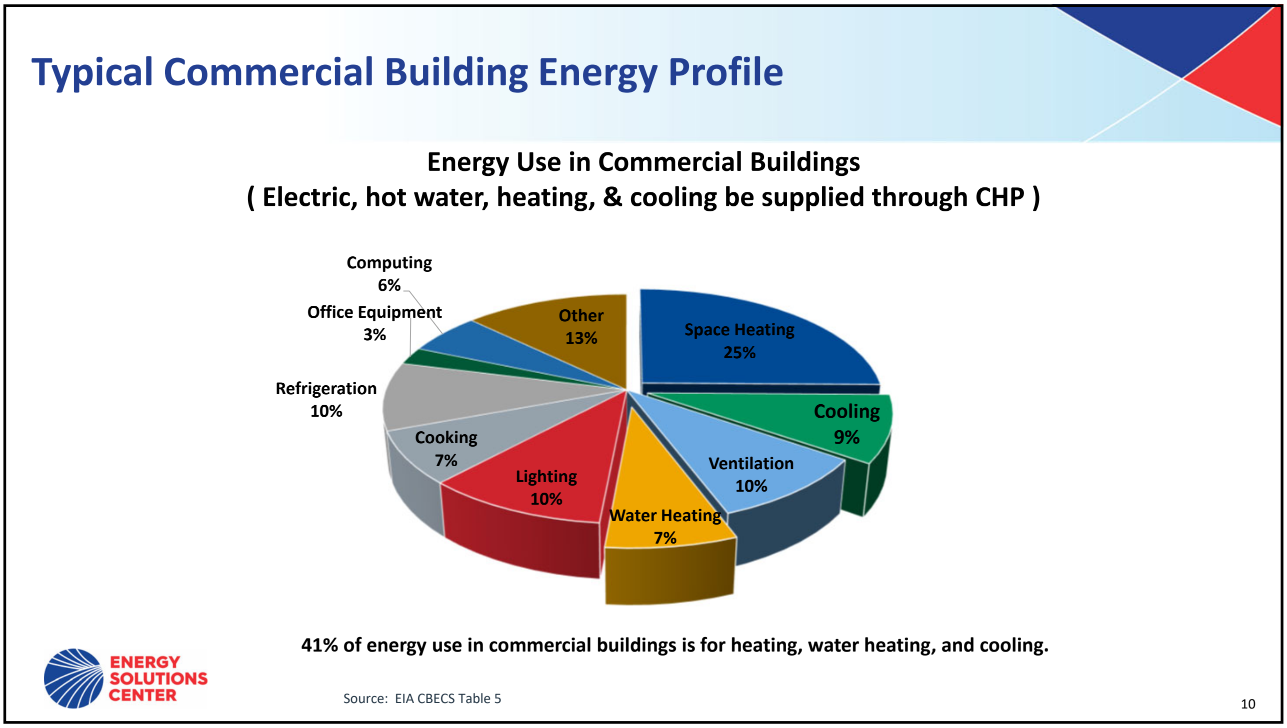


Components of CHP

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

Combined Heat and Power

Market Overview

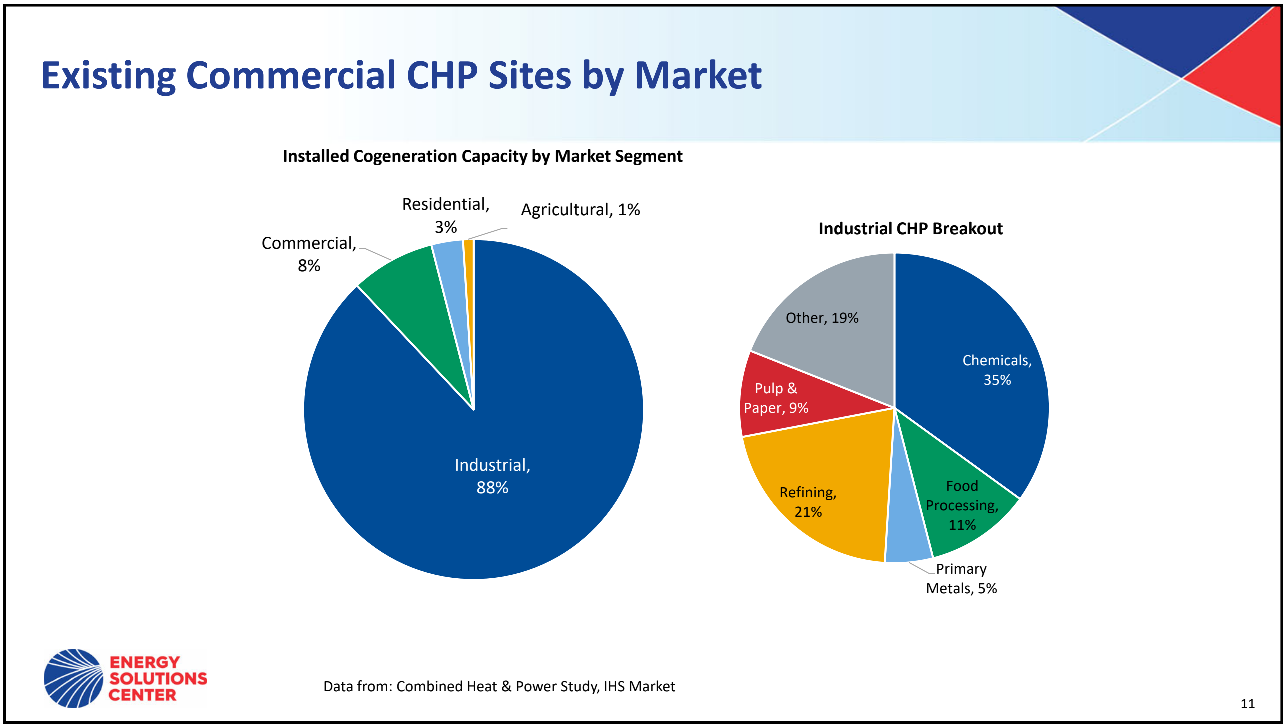


Typical Commercial Building Energy Profile

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

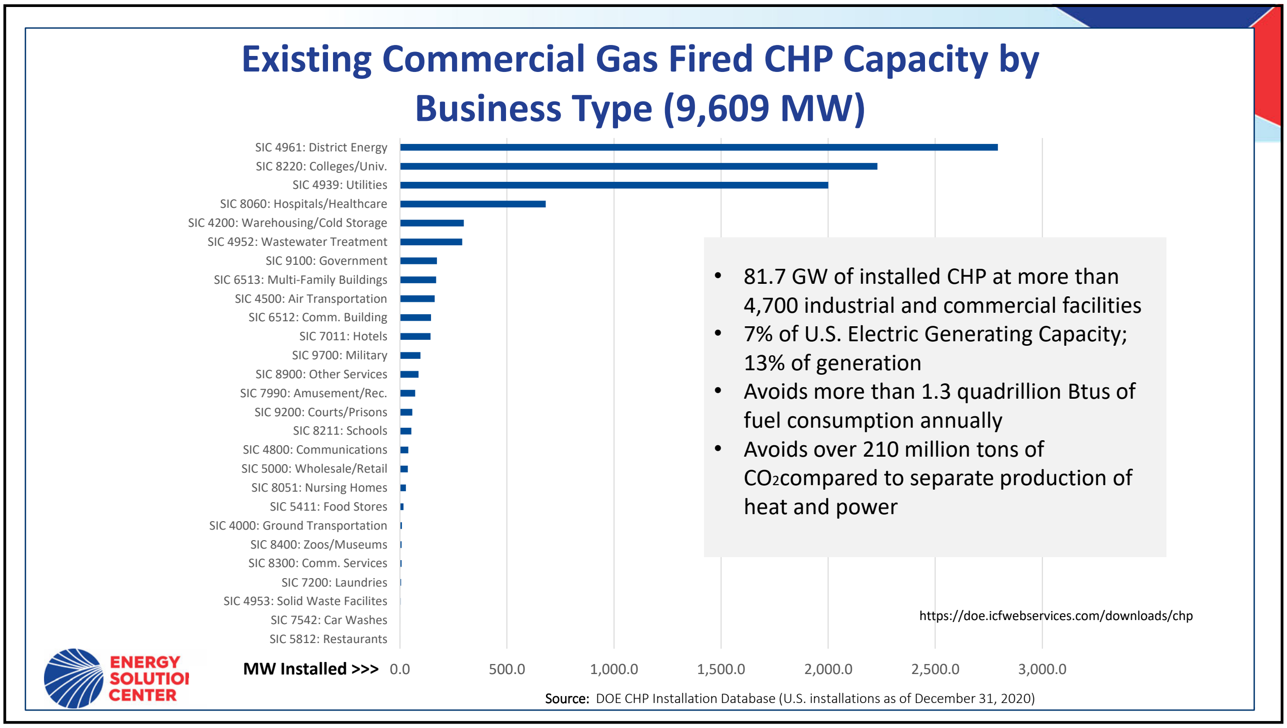
41% of energy use in commercial buildings is for heating, water heating, and cooling.

Source: EIA CBECS Table 5



Existing Commercial CHP Sites by Market

Data from: Combined Heat & Power Study, IHS Market



Existing Commercial Gas Fired CHP Capacity by Business Type (9,609 MW)

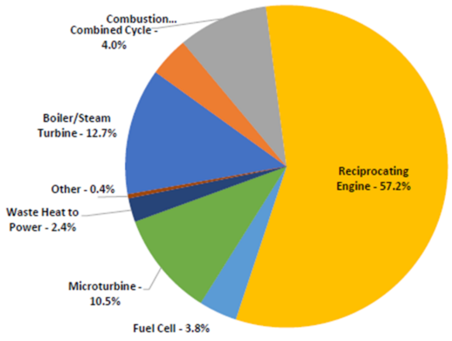
- 81.7 GW of installed CHP at more than 4,700 industrial and commercial facilities
- 7% of U.S. Electric Generating Capacity; 13% of generation
- Avoids more than 1.3 quadrillion Btus of fuel consumption annually
- Avoids over 210 million tons of CO_2compared to separate production of heat and power

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

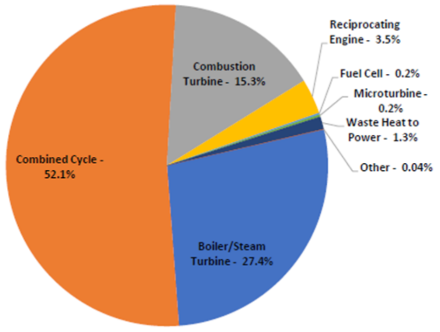
Source: DOE CHP Installation Database (U.S. installations as of December 31, 2020)

CHP Installations by Technology

By Site – 4,733 Sites

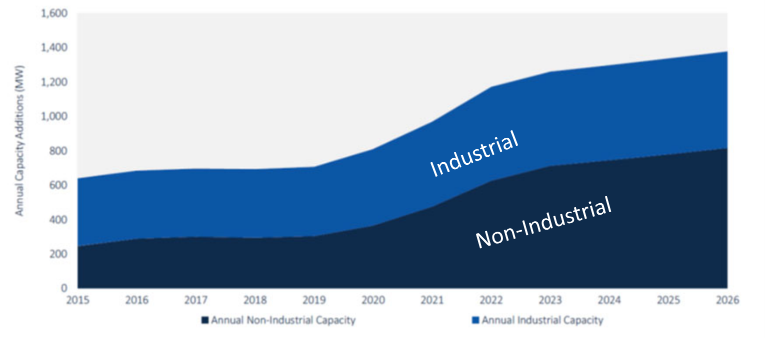


By Capacity – 81.7 GW



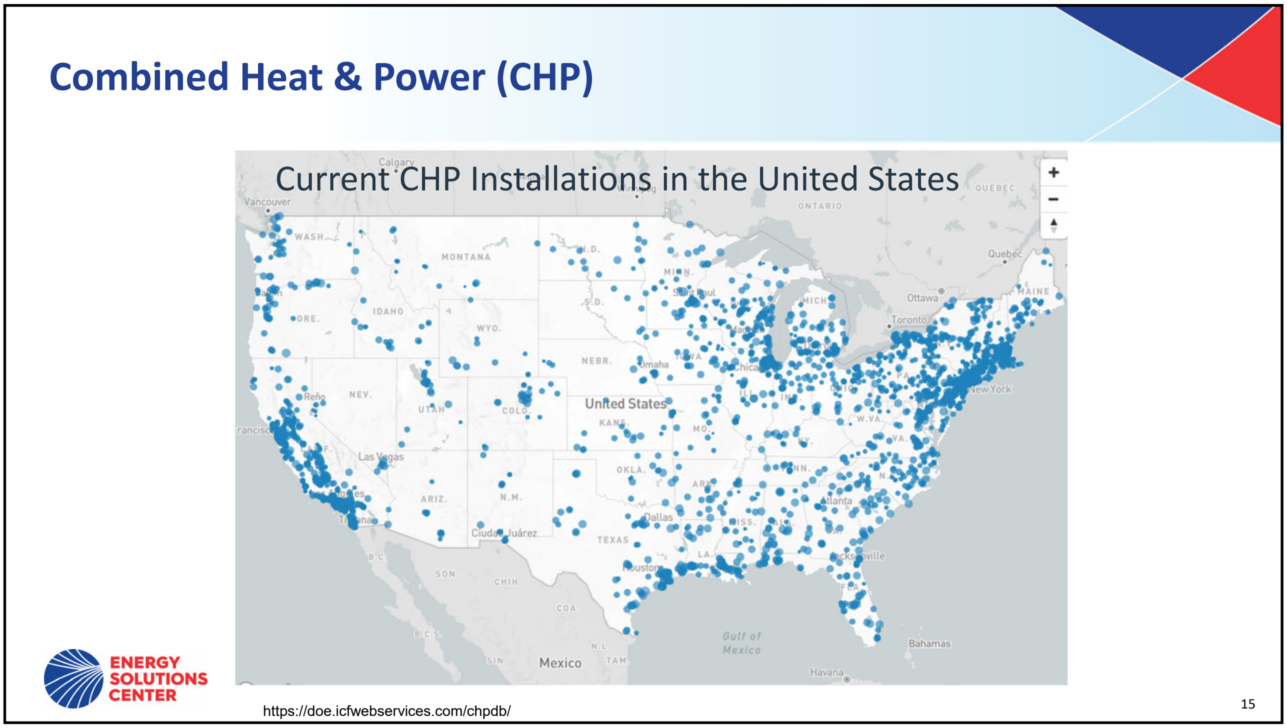
Source: DOE CHP Installation Database (U.S. installations as of December 31, 2020)

Most Growth Expected to be Non-Industrial



Year	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
Annual Non-Industrial Capacity	246	289	300	294	303	365	476	626	712	745	779	816
Annual Industrial Capacity	393	395	395	399	402	444	492	544	548	552	557	561

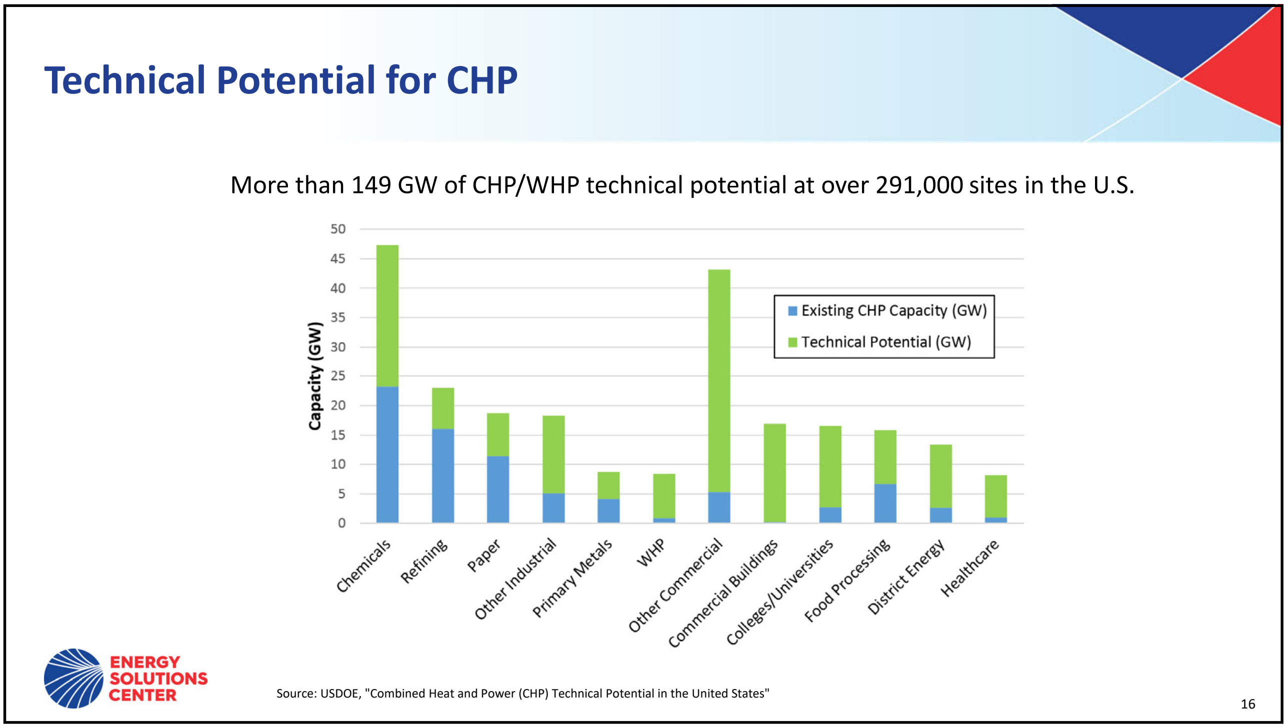
GTM Research, https://www.greentechmedia.com/research#gs.EaWfqxk



Combined Heat & Power (CHP)

Current CHP Installations in the United States

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



Technical Potential for CHP

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

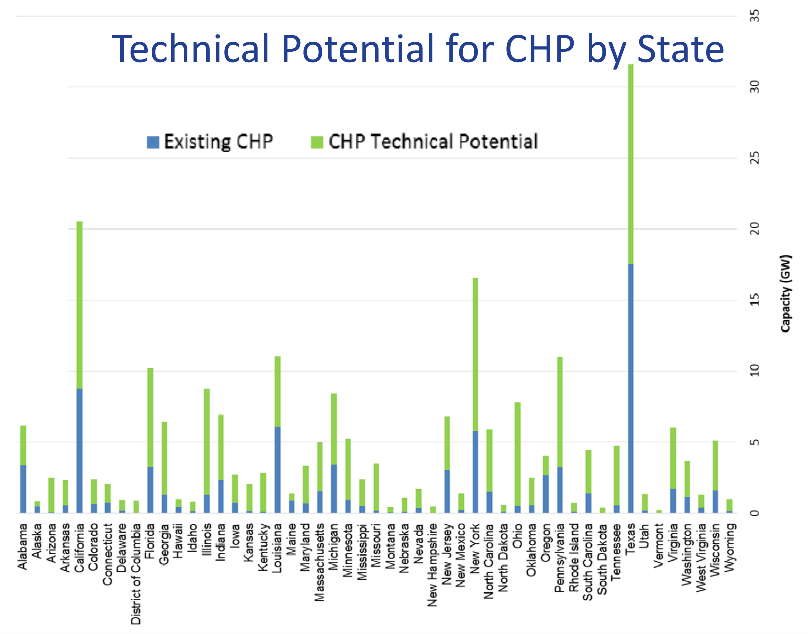
Source: USDOE, "Combined Heat and Power (CHP) Technical Potential in the United States"

Technical Potential for CHP by State

State	Total On-site Potential (MW)	Total Export Potential (MW)	Total CHP Technical Potential	State	Total On-site Potential (MW)	Total Export Potential (MW)	Total CHP Technical Potential
Alabama	2,777	1,001	3,777	Montana	377	441	818
Alaska	408	242	650	Nebraska	984	520	1,504
Arizona	2,320	533	2,853	Nevada	1,254	360	1,614
Arkansas	1,795	892	2,686	New Hampshire	447	136	584
Califomia	11,542	7,280	18,822	New Jersey	3,761	1,674	5,435
Colorado	1,665	433	2,098	New Mexico	1,140	457	1,597
Connecticut	1,214	455	1,670	New York	6,908	5,559	12,466
Delaware	747	786	1,533	North Carolina	4,352	1,164	5,516
District of Columbia	762	146	908	North Dakota	445	417	862
Florida	6,917	1,484	8,401	Ohio	7,005	4,082	11,087
Georgia	5,110	2,355	7,464	Oklahoma	1,805	1,387	3,192
Hawaii	563	237	799	Oregon	1,337	816	2,153
Idaho	659	304	962	Pennsylvania	7,025	3,872	10,896
Illinois	7,161	5,664	12,825	Rhode Island	616	180	796
Indiana	4,145	2,084	6,229	South Carolina	3,063	1,536	4,599
Iowa	1,993	1,675	3,668	South Dakota	378	222	600
Kansas	1,909	1,007	2,916	Tennessee	3,981	3,005	6,986
Kentucky	2,721	1,796	4,517	Texas	13,675	12,151	25,826
Louisiana	4,903	7,074	11,977	Utah	1,119	416	1,535
Maine	494	250	743	Vermont	228	153	381
Maryland	2,282	809	3,091	Virginia	4,308	1,633	5,941
Massachusetts	3,028	1,040	4,068	Washington	2,387	1,971	4,357
Michigan	4,291	2,021	6,312	West Virginia	929	449	1,378
Minnesota	3,260	3,671	6,931	Wisconsin	3,187	2,622	5,809
Mississippi	1,833	1,512	3,345	Wyoming	847	254	1,101
Missouri	2,882	1,482	4,364	Total	148,936	91,709	240,644

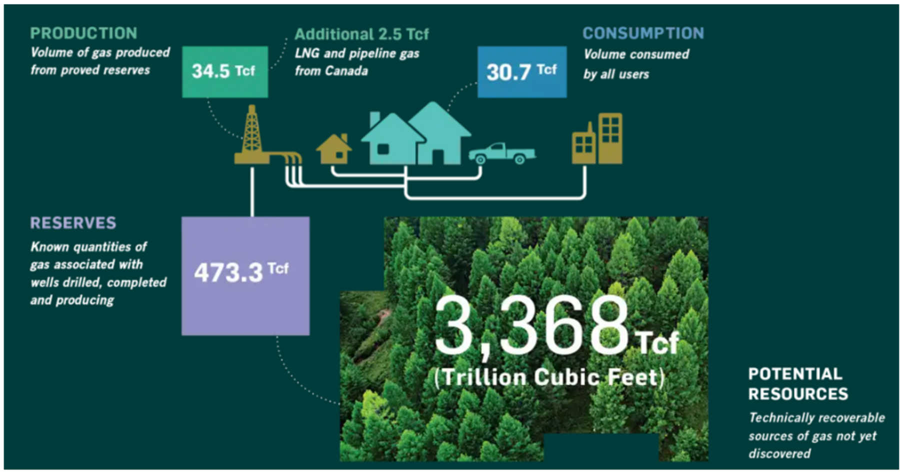
Source: USDOE, "Combined Heat and Power (CHP) Technical Potential in the United States"

Technical Potential for CHP by State



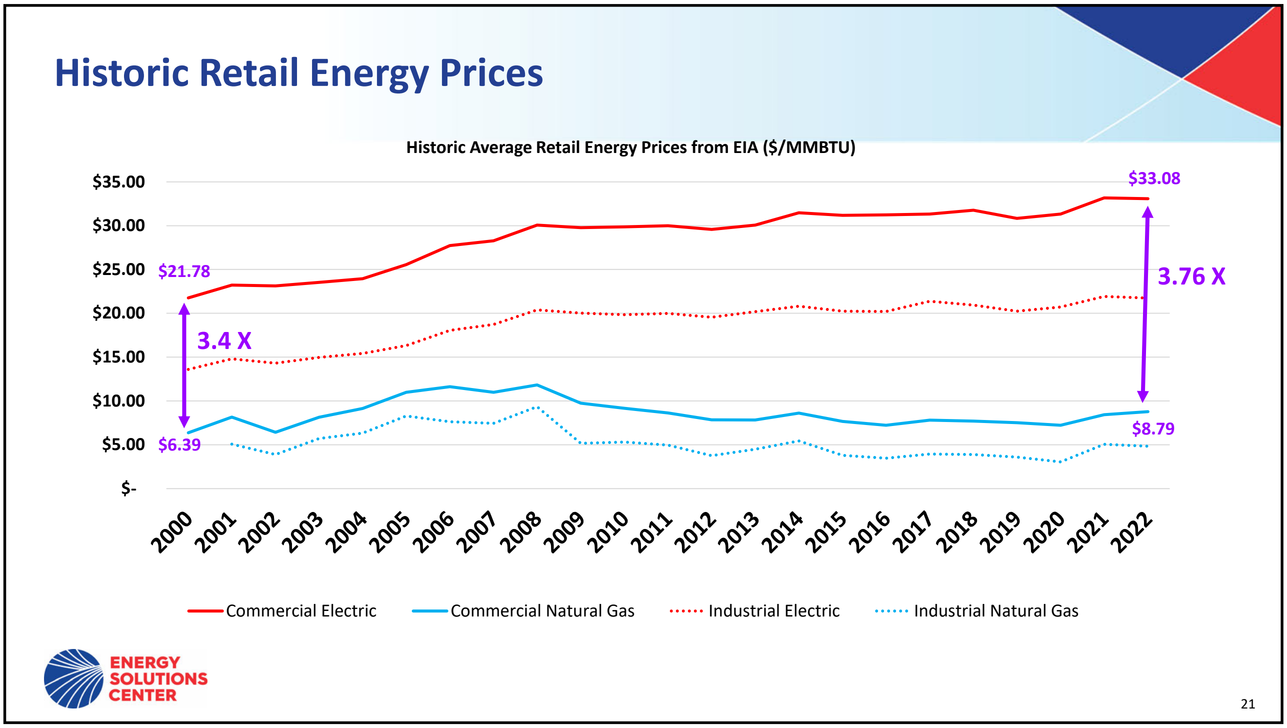
Source: USDOE, "Combined Heat and Power (CHP) Technical Potential in the United States"

More than 100 Years of Natural Gas Supply

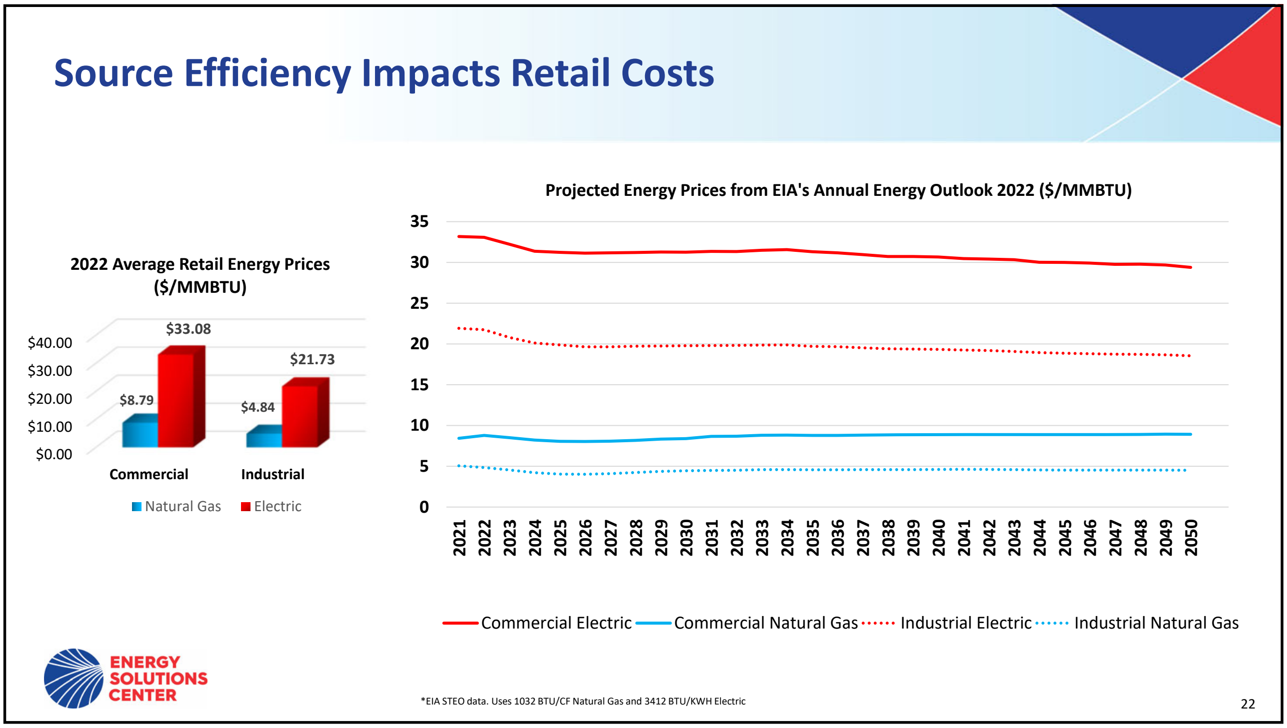


2023 AGA Playbook, https://playbook.aga.org/natural-gas-data

CHP Efficiency & Energy Costs



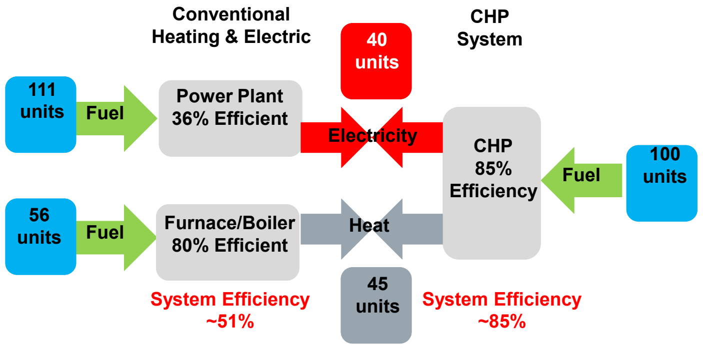
Historic Retail Energy Prices



Source Efficiency Impacts Retail Costs

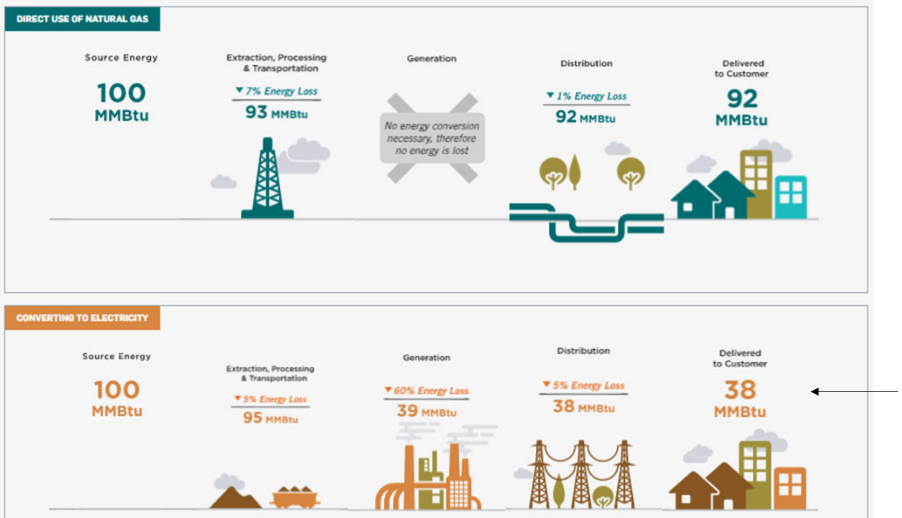
*EIA STEO data. Uses 1032 BTU/CF Natural Gas and 3412 BTU/KWH Electric

CHP is more Efficient



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

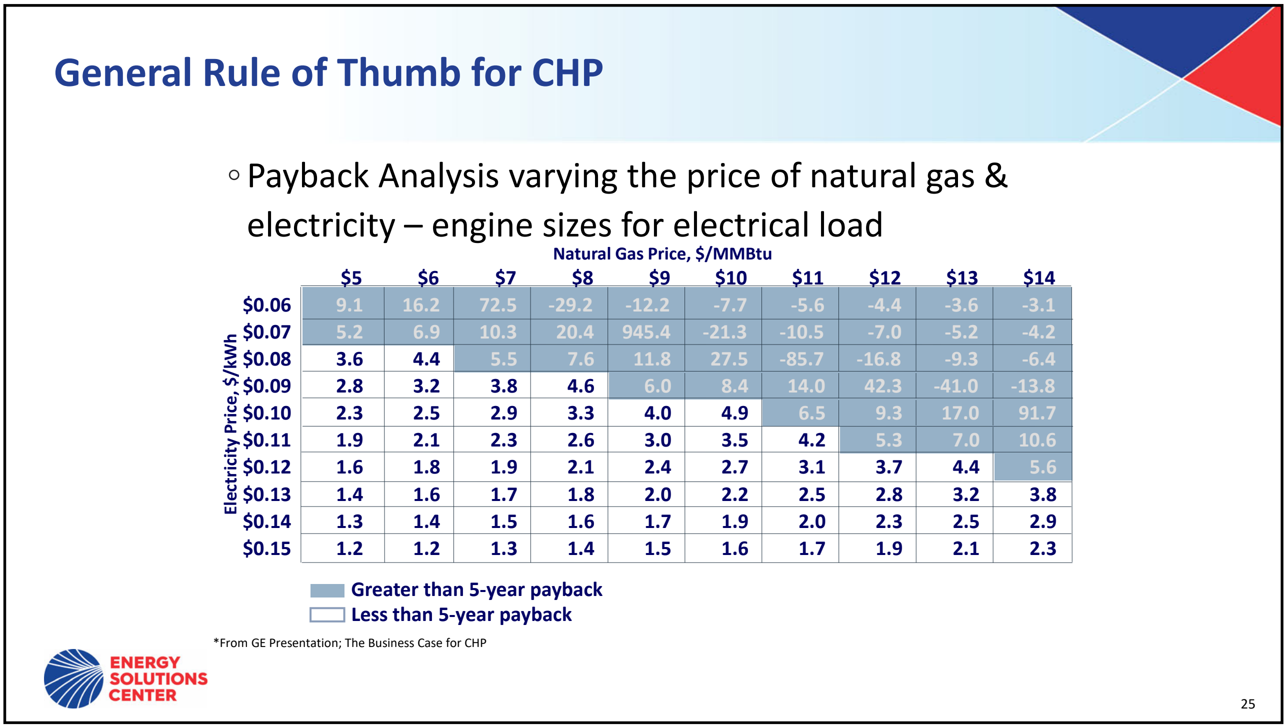
Source to Site Efficiency



Overall electrical efficiency has increased over past several years as combined cycle gas plants replace old coal plants.

Reduce Generation Losses and T&D Line Losses with CHP

2023 AGA Policy Handbook



General Rule of Thumb for CHP

- Payback Analysis varying the price of natural gas & electricity – engine sizes for electrical load

Natural Gas Price, $/MMBtu

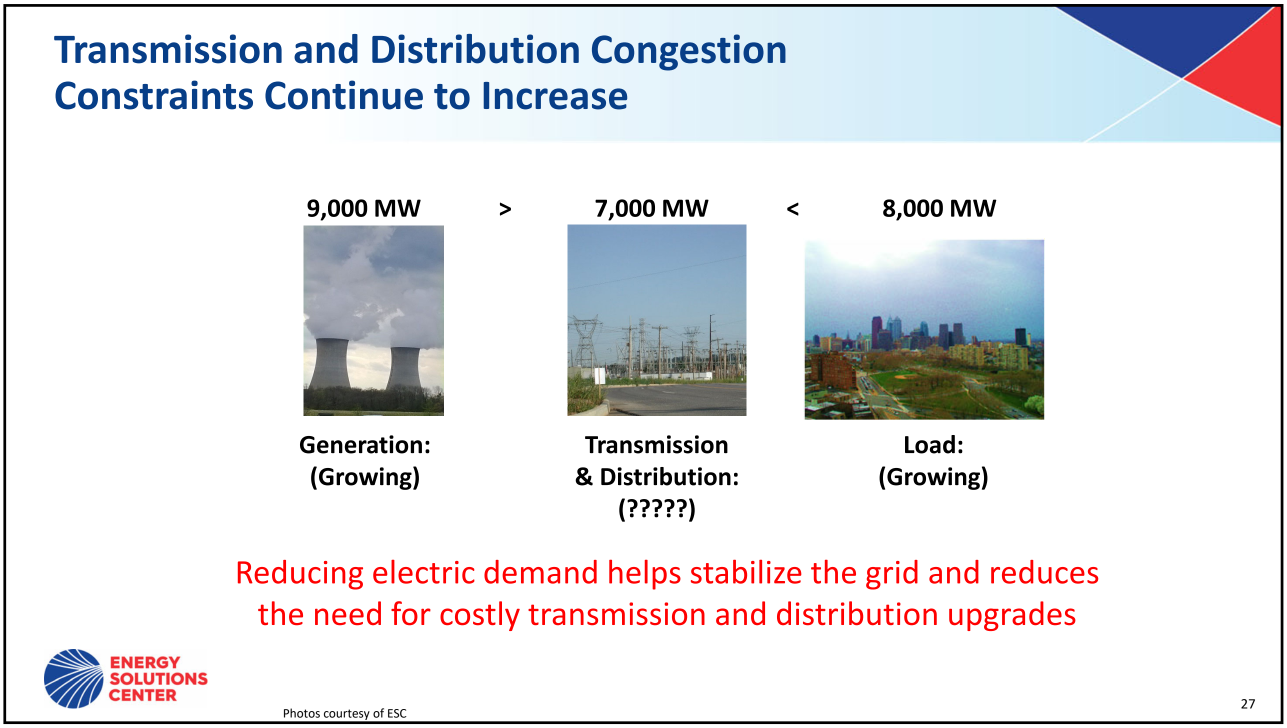
Electricity Price, $/kWh

	$5	$6	$7	$8	$9	$10	$11	$12	$13	$14
$0.06	▨ 9.1	▨ 16.2	▨ 72.5	▨ -29.2	▨ -12.2	▨ -7.7	▨ -5.6	▨ -4.4	▨ -3.6	▨ -3.1
$0.07	▨ 5.2	▨ 6.9	▨ 10.3	▨ 20.4	▨ 945.4	▨ -21.3	▨ -10.5	▨ -7.0	▨ -5.2	▨ -4.2
$0.08	3.6	4.4	▨ 5.5	▨ 7.6	▨ 11.8	▨ 27.5	▨ -85.7	▨ -16.8	▨ -9.3	▨ -6.4
$0.09	2.8	3.2	3.8	4.6	▨ 6.0	▨ 8.4	▨ 14.0	▨ 42.3	▨ -41.0	▨ -13.8
$0.10	2.3	2.5	2.9	3.3	4.0	4.9	▨ 6.5	▨ 9.3	▨ 17.0	▨ 91.7
$0.11	1.9	2.1	2.3	2.6	3.0	3.5	4.2	▨ 5.3	▨ 7.0	▨ 10.6
$0.12	1.6	1.8	1.9	2.1	2.4	2.7	3.1	3.7	4.4	▨ 5.6
$0.13	1.4	1.6	1.7	1.8	2.0	2.2	2.5	2.8	3.2	3.8
$0.14	1.3	1.4	1.5	1.6	1.7	1.9	2.0	2.3	2.5	2.9
$0.15	1.2	1.2	1.3	1.4	1.5	1.6	1.7	1.9	2.1	2.3

▨ Greater than 5-year payback
☐ Less than 5-year payback

*From GE Presentation; The Business Case for CHP

Generation Mix & Reliability



Transmission and Distribution Congestion Constraints Continue to Increase

9,000 MW > **7,000 MW** < **8,000 MW**

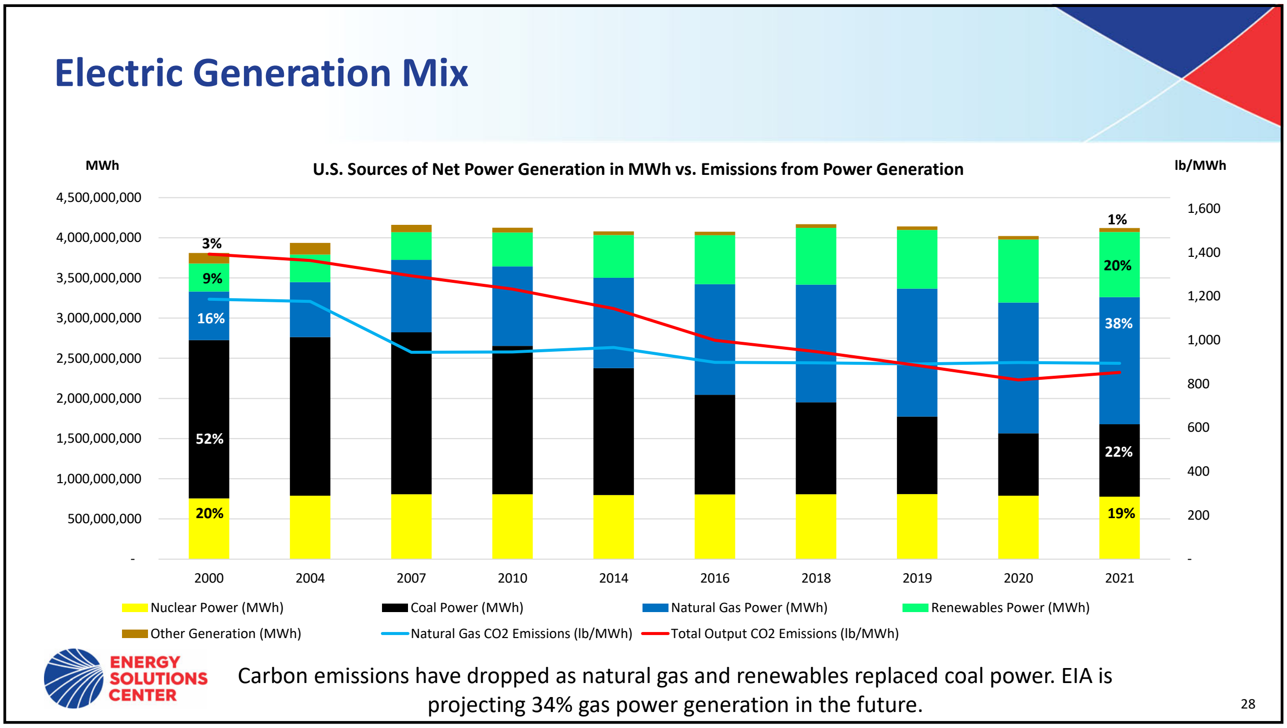
Generation: (Growing)

Transmission & Distribution: (?????)

Load: (Growing)

Reducing electric demand helps stabilize the grid and reduces the need for costly transmission and distribution upgrades

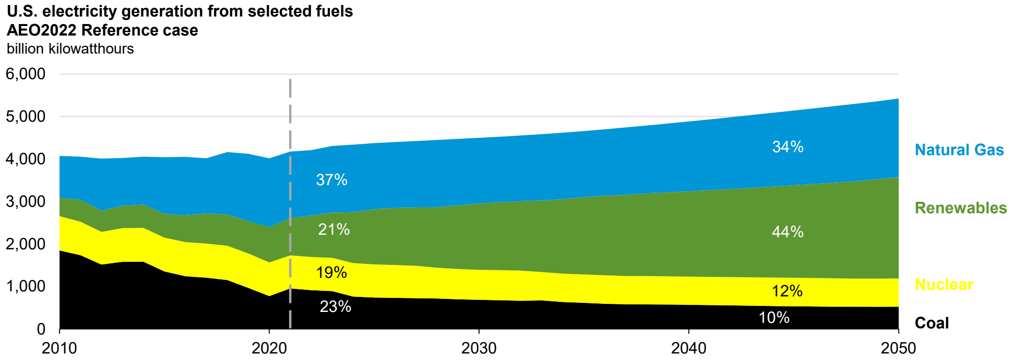
Photos courtesy of ESC



Electric Generation Mix

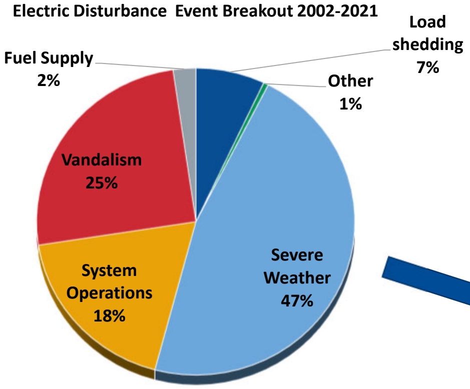
Carbon emissions have dropped as natural gas and renewables replaced coal power. EIA is projecting 34% gas power generation in the future.

Expected Electric Generation Mix into the Future

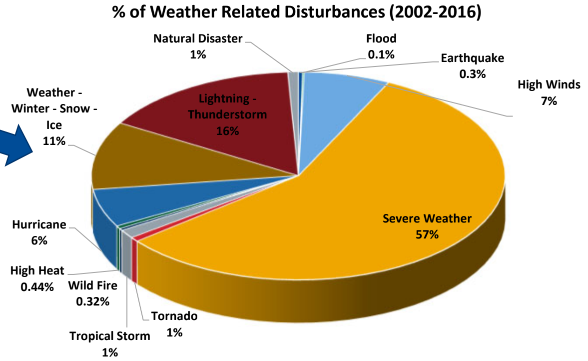


Carbon emissions have dropped as natural gas and renewables replaced coal power. EIA is projecting 34% gas power generation in the future.

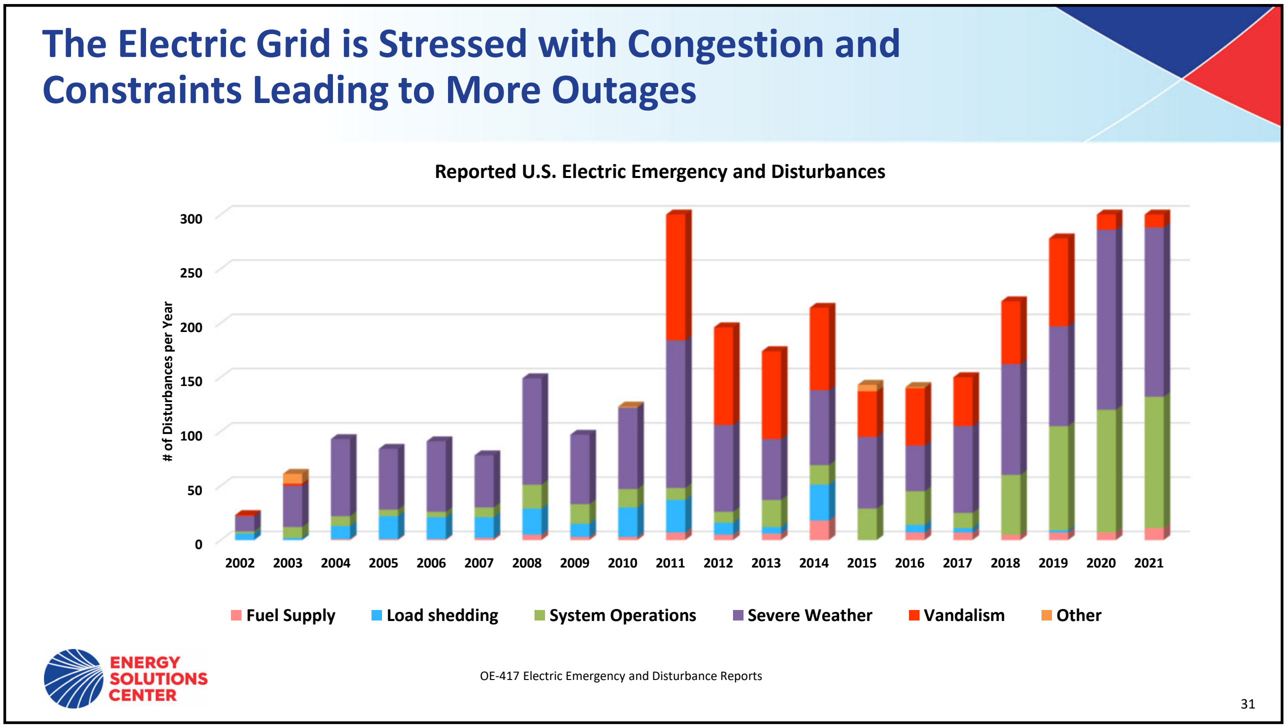
Electric Disturbance Breakout



CHP won't stop weather related electric disturbances but does help stabilize the grid and allows those facilities with CHP to continue operations during a black out.

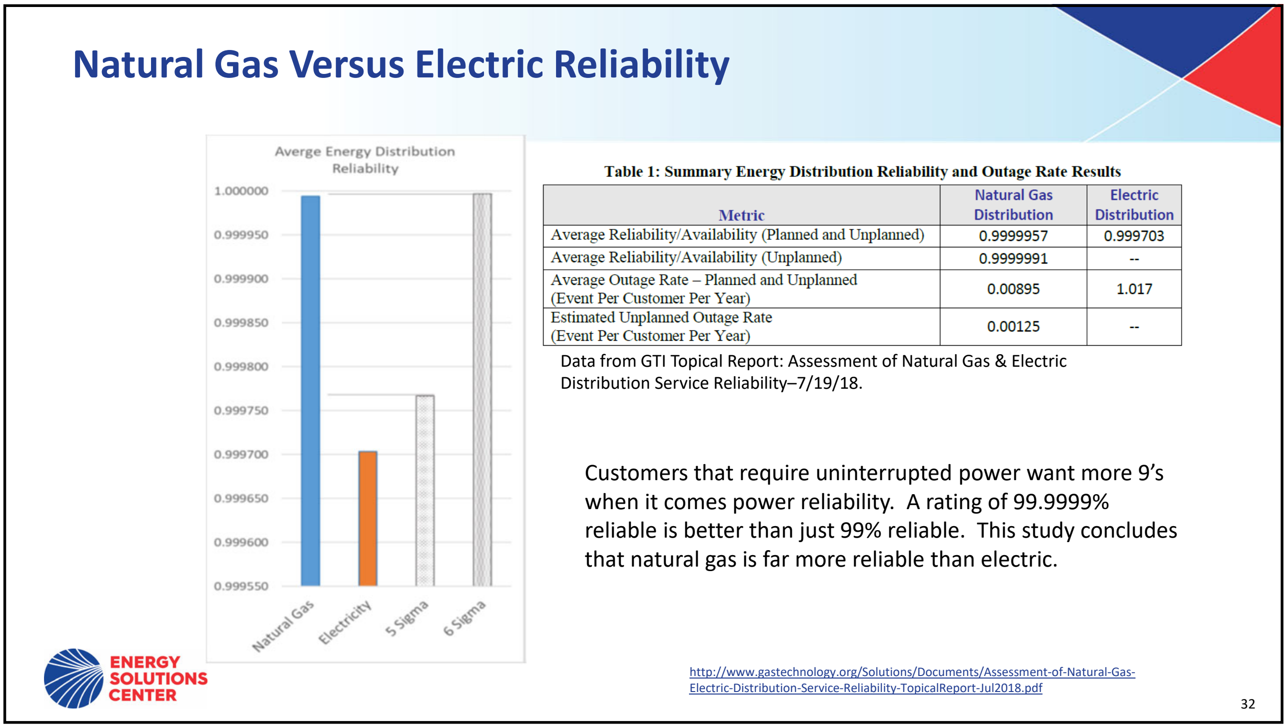


OE-417 Electric Emergency and Disturbance Reports



The Electric Grid is Stressed with Congestion and Constraints Leading to More Outages

OE-417 Electric Emergency and Disturbance Reports



Natural Gas Versus Electric Reliability

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	--

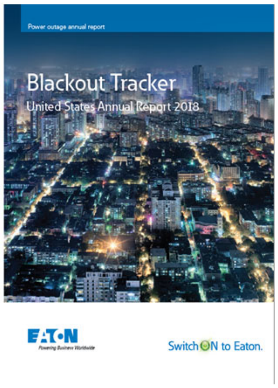
Data from GTI Topical Report: Assessment of Natural Gas & Electric Distribution Service Reliability–7/19/18.

Customers that require uninterrupted power want more 9's when it comes power reliability. A rating of 99.9999% reliable is better than just 99% reliable. This study concludes that natural gas is far more reliable than electric.

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

U.S. Average Annual Blackouts Over Past Decade

- An average of **3,215** blackouts occur in the U.S. each year.
- The average blackout lasts 98 minutes
- Average of 21,249,127 people are impacted by blackouts each year


Power outage annual report

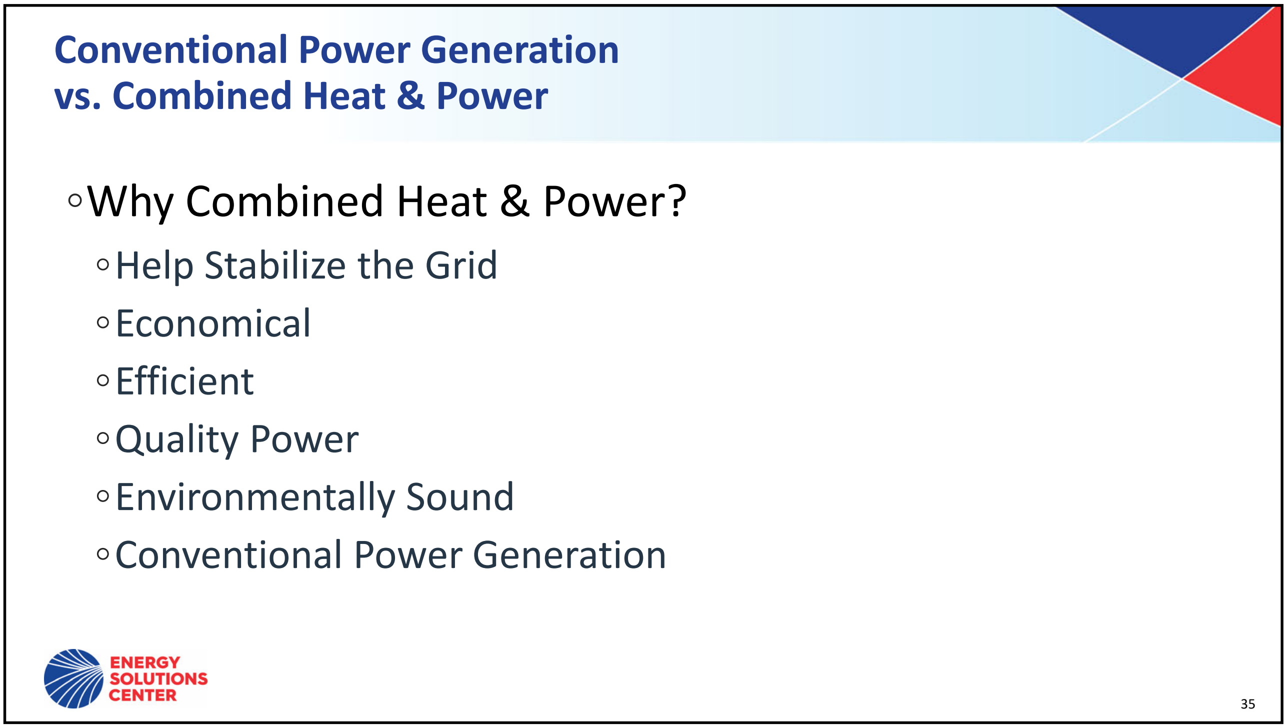
Blackout Tracker
United States Annual Report 2018

EATON
Powering Business Worldwide

Switch ON to Eaton.

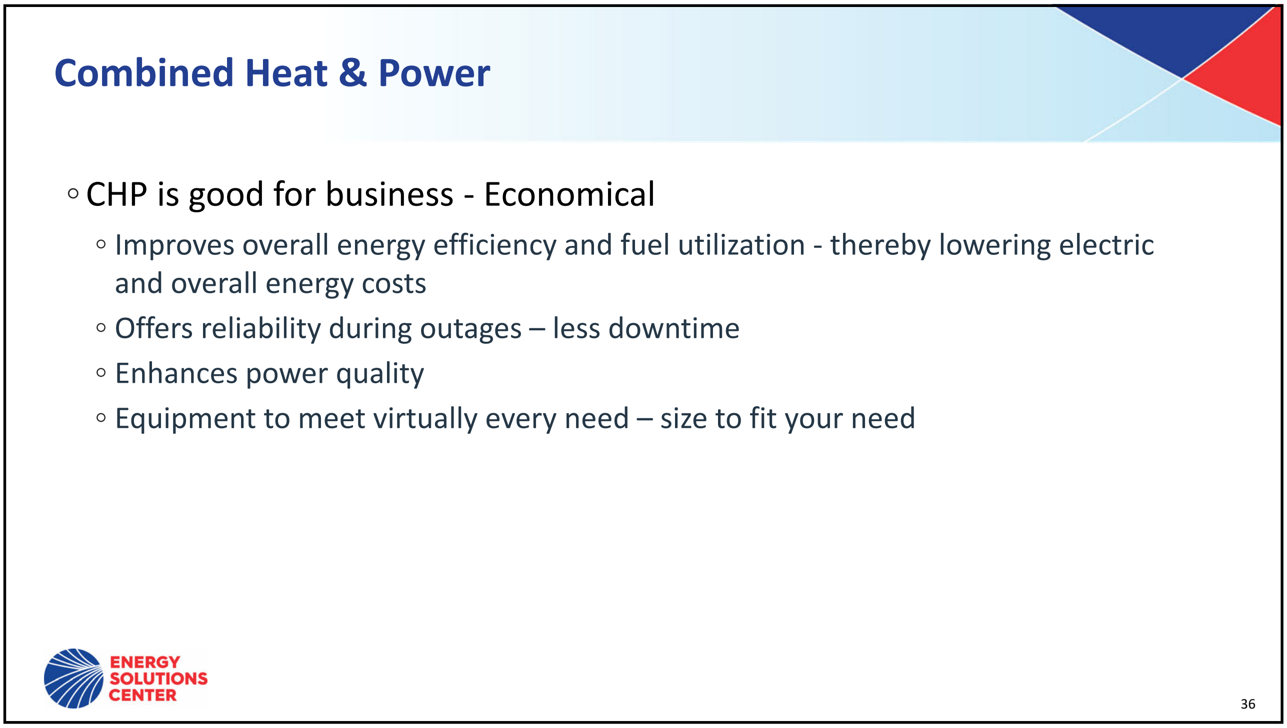
Data from Eaton Blackout Tracker Report 2018

CHP Compared to Conventional Power



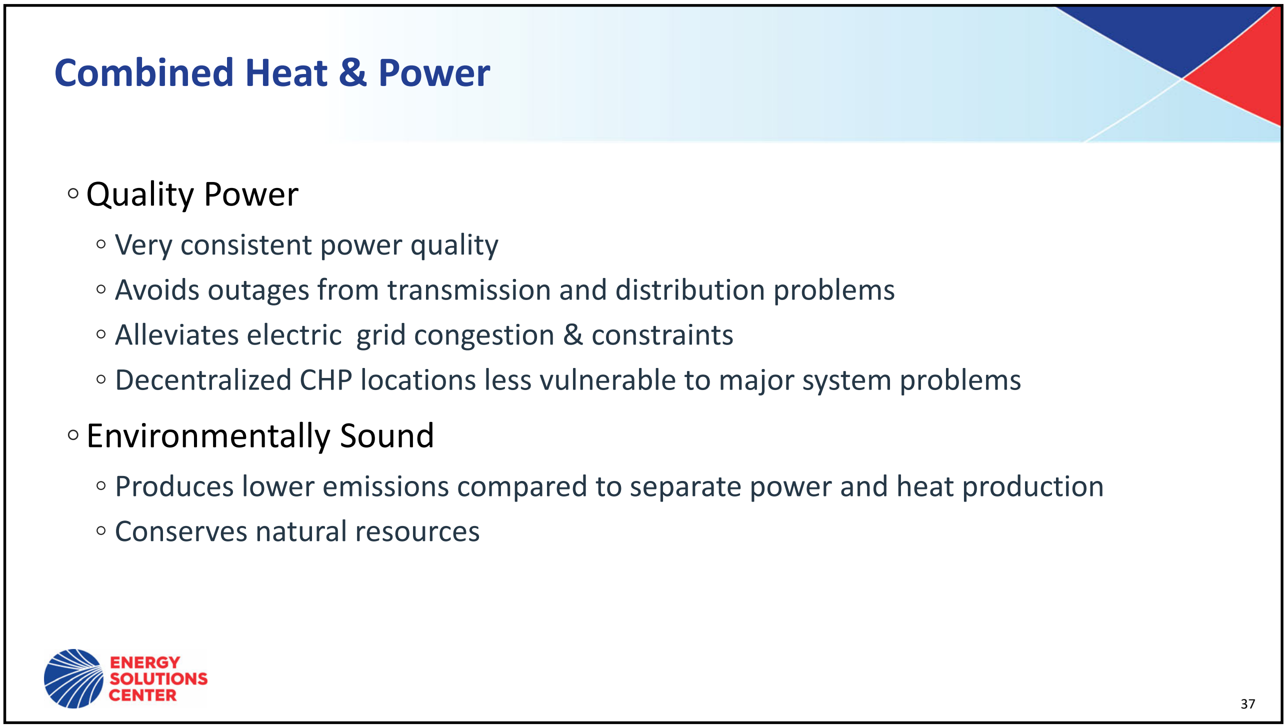
Conventional Power Generation vs. Combined Heat & Power

- Why Combined Heat & Power?
  - Help Stabilize the Grid
  - Economical
  - Efficient
  - Quality Power
  - Environmentally Sound
  - Conventional Power Generation



Combined Heat & Power

- CHP is good for business - Economical
  - Improves overall energy efficiency and fuel utilization - thereby lowering electric and overall energy costs
  - Offers reliability during outages – less downtime
  - Enhances power quality
  - Equipment to meet virtually every need – size to fit your need



Combined Heat & Power

- Quality Power
  - 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
- Environmentally Sound
  - Produces lower emissions compared to separate power and heat production
  - Conserves natural resources

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

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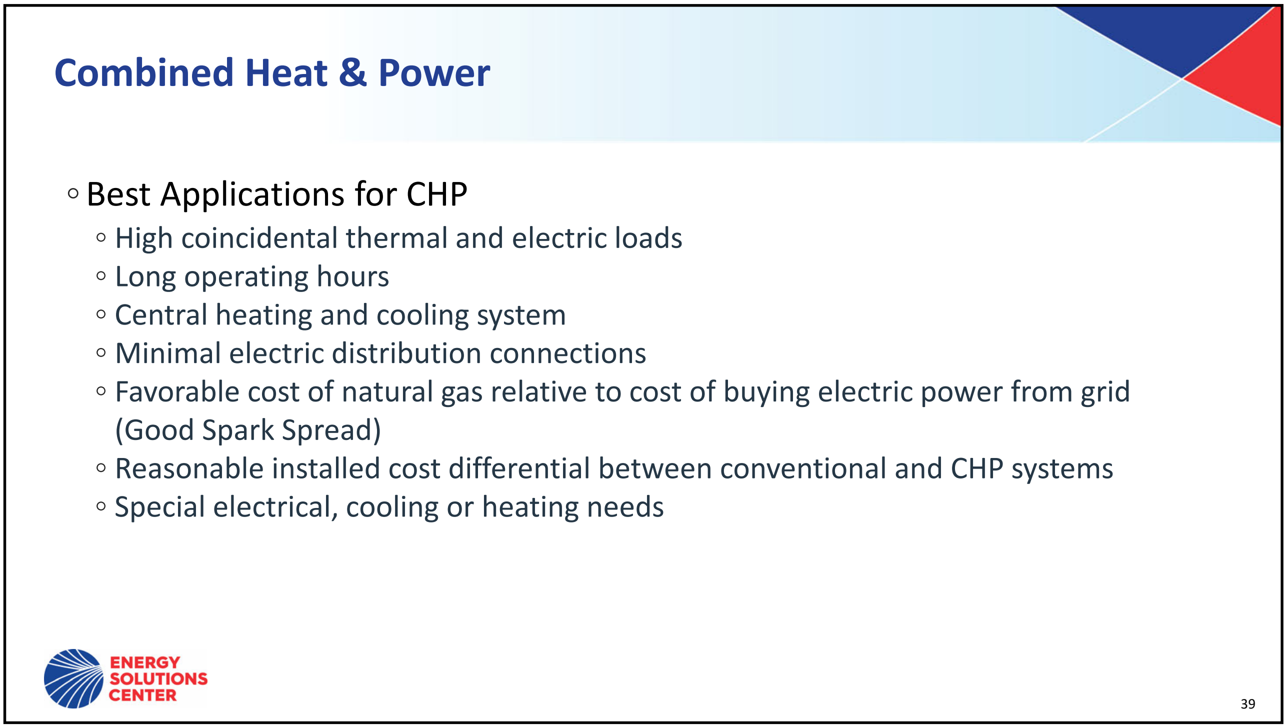
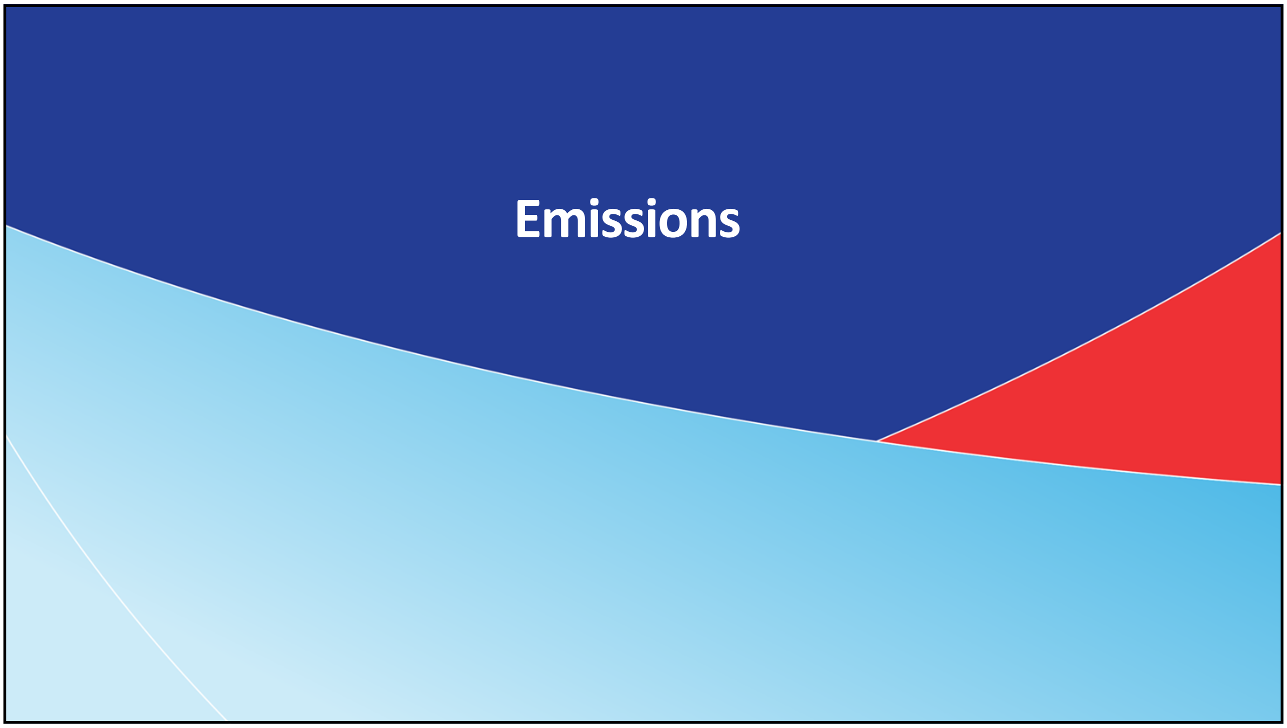
Neighbors don't generally challenge a business looking to install CHP.

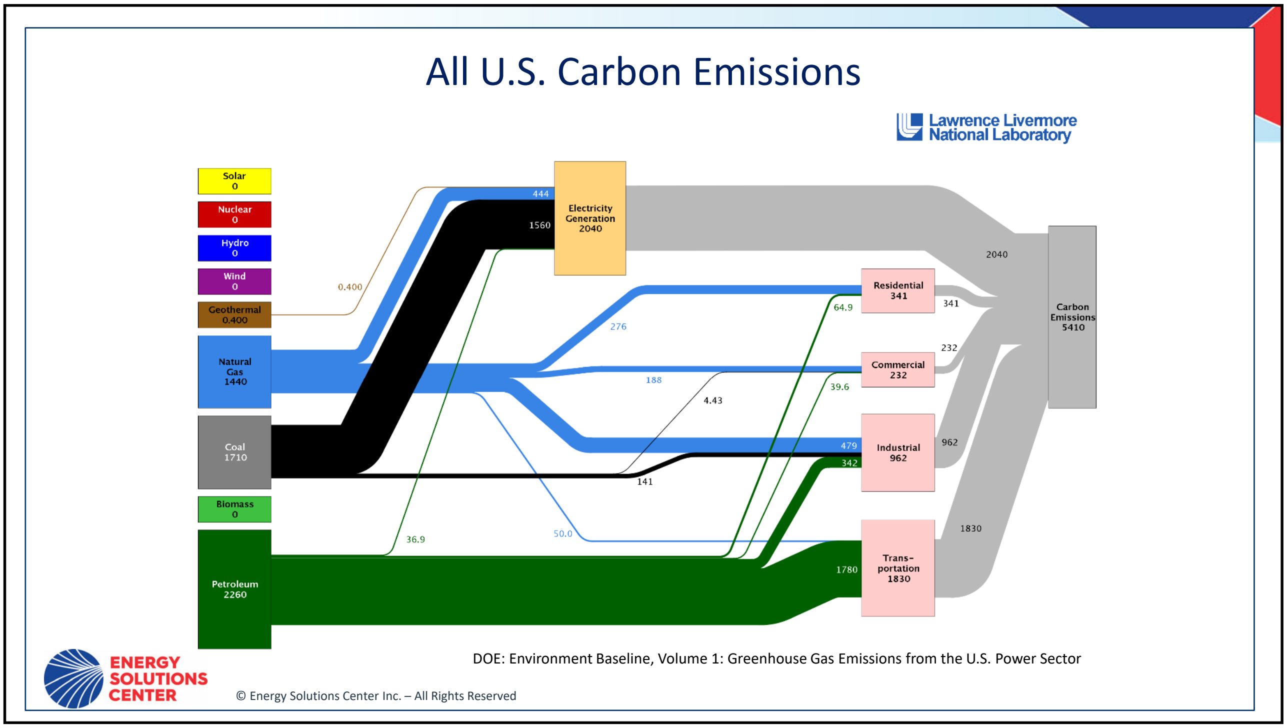


Combined Heat & Power

- 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

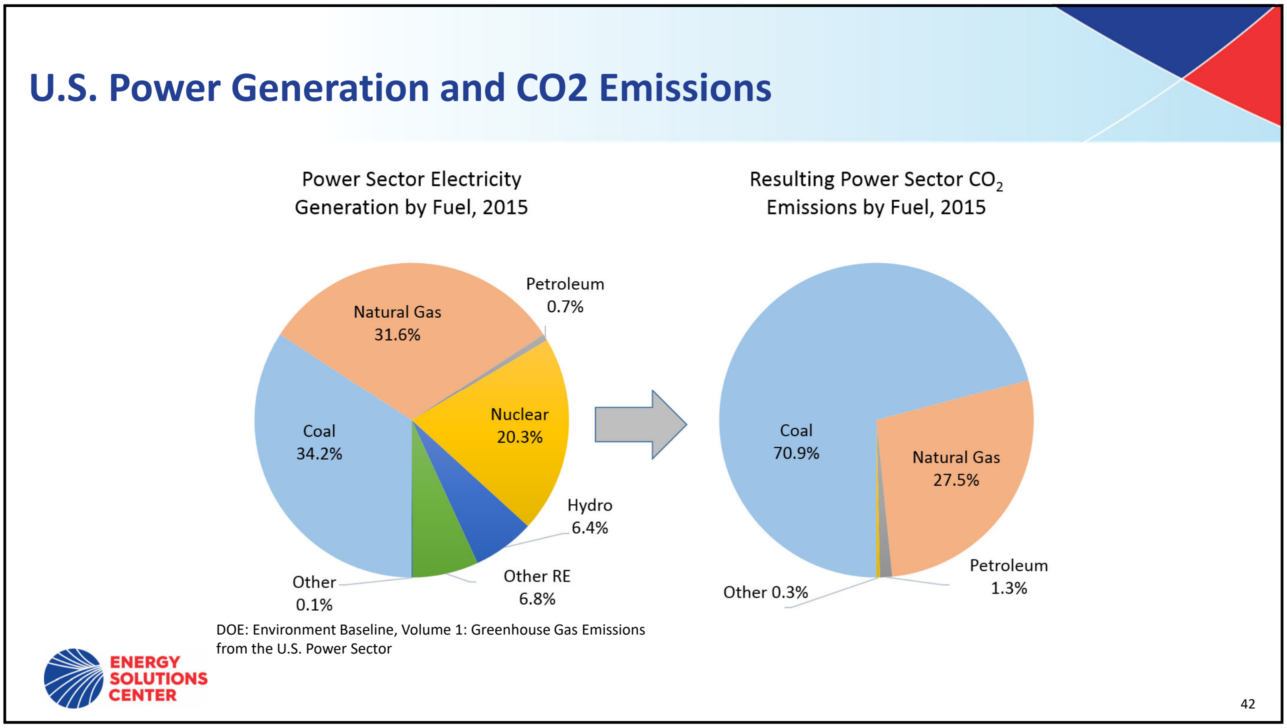


Emissions



All U.S. Carbon Emissions

DOE: Environment Baseline, Volume 1: Greenhouse Gas Emissions from the U.S. Power Sector



U.S. Power Generation and CO2 Emissions

Power Sector Electricity Generation by Fuel, 2015

Resulting Power Sector CO_2 Emissions by Fuel, 2015

DOE: Environment Baseline, Volume 1: Greenhouse Gas Emissions from the U.S. Power Sector

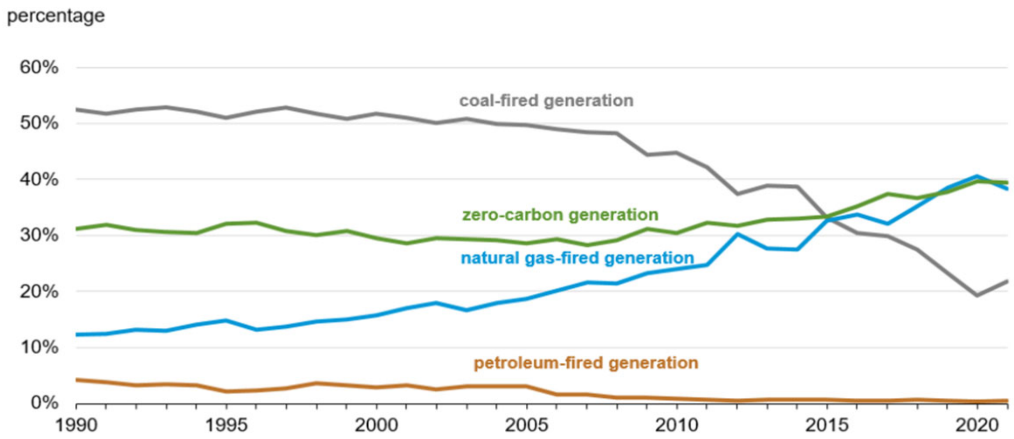
Average Emissions

	CO_2 Emissions Factor (kg CO_2/Btu)	Heat Rate (Btu/kWh)	Emission rate (kg CO_2/MWh)
Coal, steam generator	95.3	10,080	960.6
Petroleum, steam generator	73.2	10,156	743.4
Natural Gas, combustion turbine	53.1	11,378	604.2
Natural gas, combined cycle	53.1	7,658	406.6

Table 3. Average Emissions Factors, Heat Rates, and Emission Rates of the U.S. Fossil Fuel Generation Fleet, 2014 (EIA).[38 39] The emission rate of electricity generation is a key indicator of the climate impact of the power sector, and varies significantly by fuel and technology.

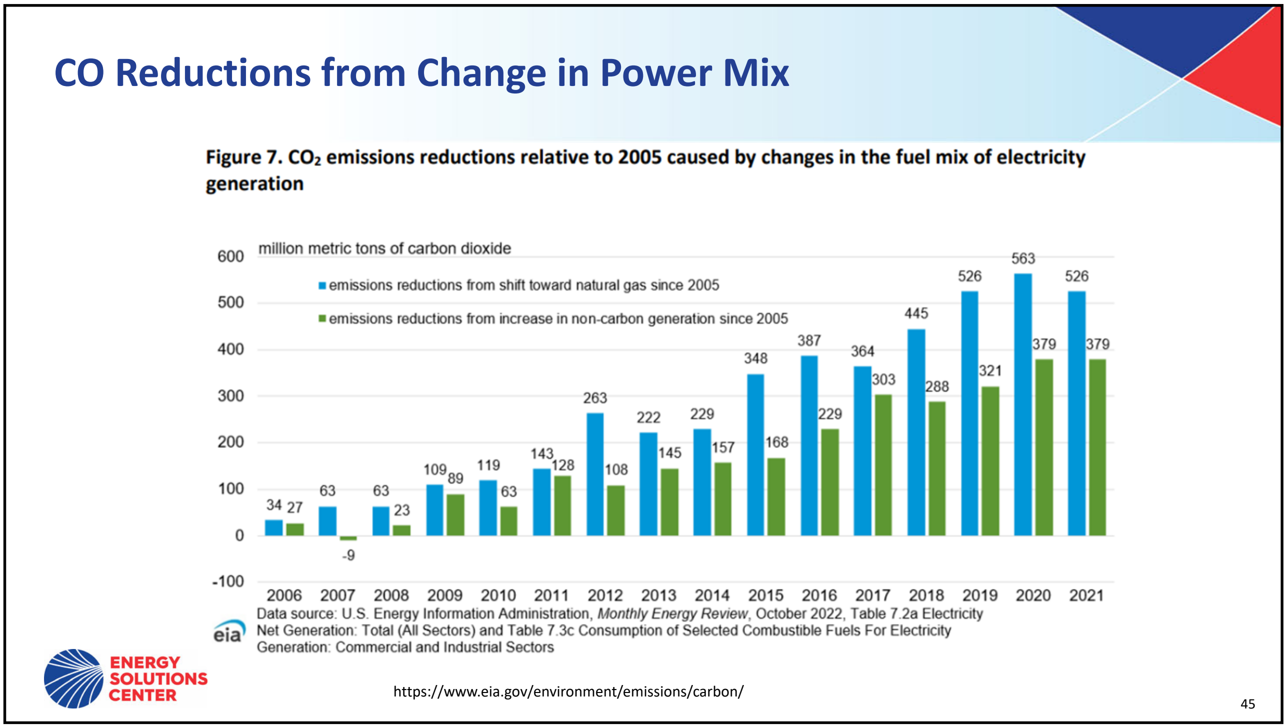
DOE: Environment Baseline, Volume 1: Greenhouse Gas Emissions from the U.S. Power Sector

Annual share of electricity generation by source (table 5)



eia Data source: U.S. Energy Information Administration, *Monthly Energy Review*, October 2022, Table 7.2a Electricity Net Generation Total (All Sectors) and Table 10.6 Solar Electricity Net Generation

https://www.eia.gov/environment/emissions/carbon/



CO Reductions from Change in Power Mix

Figure 7. CO_2 emissions reductions relative to 2005 caused by changes in the fuel mix of electricity generation

Data source: U.S. Energy Information Administration, *Monthly Energy Review*, October 2022, Table 7.2a Electricity Net Generation: Total (All Sectors) and Table 7.3c Consumption of Selected Combustible Fuels For Electricity Generation: Commercial and Industrial Sectors

https://www.eia.gov/environment/emissions/carbon/

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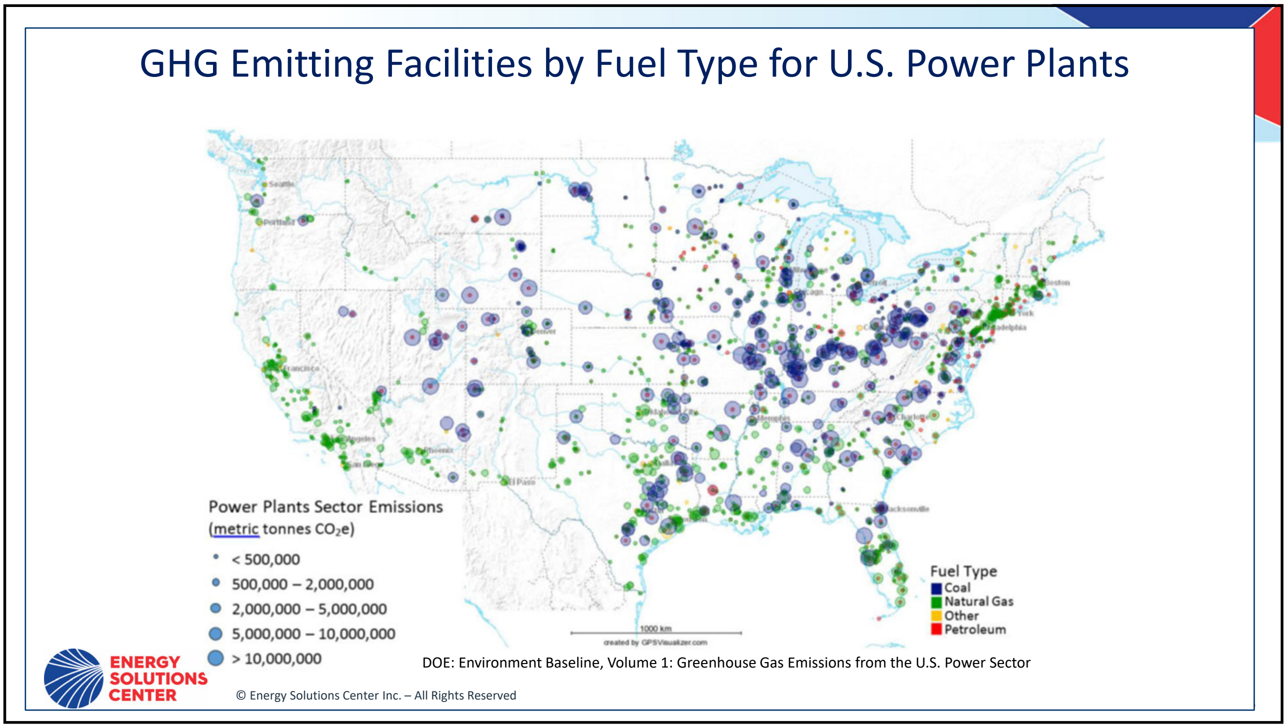

GHG Emitting Facilities by Fuel Type for U.S. Power Plants

DOE: Environment Baseline, Volume 1: Greenhouse Gas Emissions from the U.S. Power Sector

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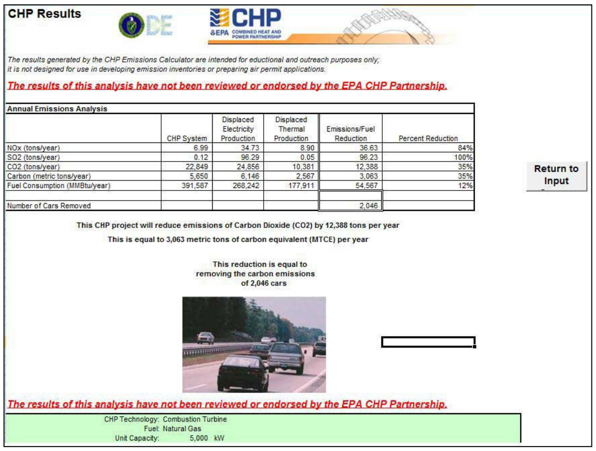
U.S. EPA CHP Emissions Calculator

Excel spreadsheet available at:

https://www.epa.gov/chp/chp-emissions-calculator



CHP Results

The results generated by the CHP Emissions Calculator are intended for eductional and outreach purposes only; it is not designed for use in developing emission inventories or preparing air permit applications.

The results of this analysis have not been reviewed or endorsed by the EPA CHP Partnership.

Annual Emissions Analysis

	CHP System	Displaced Electricity Production	Displaced Thermal Production	Emissions/Fuel Reduction	Percent Reduction
NOx (tons/year)	6.99	34.73	8.90	36.63	84%
SO2 (tons/year)	0.12	96.29	0.05	96.23	100%
CO2 (tons/year)	22,849	24,856	10,381	12,388	35%
Carbon (metric tons/year)	5,650	6,146	2,567	3,063	35%
Fuel Consumption (MMBtu/year)	391,587	268,242	177,911	54,567	12%
Number of Cars Removed				2,046	

This CHP project will reduce emissions of Carbon Dioxide (CO2) by 12,388 tons per year

This is equal to 3,063 metric tons of carbon equivalent (MTCE) per year

This reduction is equal to
removing the carbon emissions
of 2,046 cars

The results of this analysis have not been reviewed or endorsed by the EPA CHP Partnership.

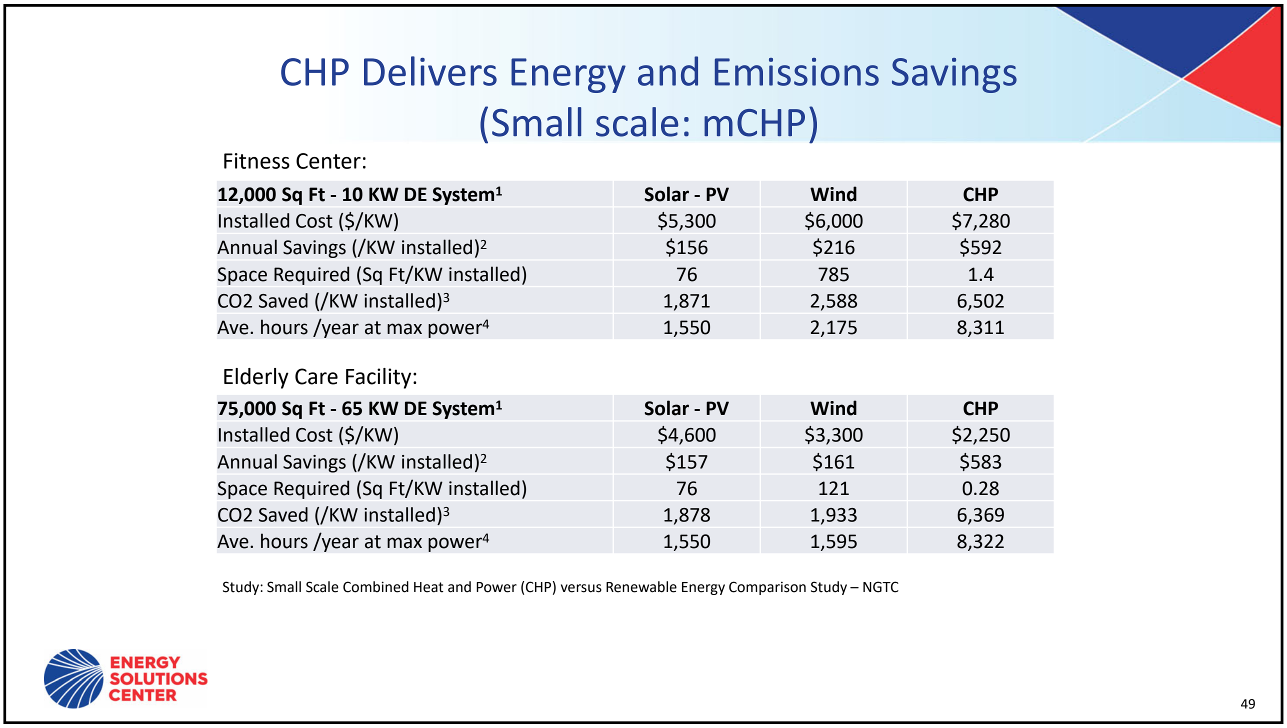
CHP Technology: Combustion Turbine
Fuel: Natural Gas
Unit Capacity: 5,000 kW

CHP Delivers Energy and Emissions Savings (Large scale)

Category	10 MW CHP	10 MW PV	10 MW Wind
Annual Capacity Factor	85%	22%	34%
Annual Electricity, MWh	74,446	19,272	29,784
Annual Useful Heat Provided, MWh_{th}	114,544	None	None
Annual Energy Savings, MMBtu	317,981	196,400	303,527
Annual CO_2 Savings, Tons	43,227	17,857	27,598

Based on: 10 MW Gas Turbine CHP - 27% electric efficiency, 69% total efficiency
Electricity displaces National All Fossil Average Generation (eGRID 2010) -
9,572 Btu/kWh, 1,745 lbs CO_2/MWh,, 6% T&D losses
Thermal displaces 80% efficient on-site natural gas boiler

*CHP Market Status, Bruce Hedman, Institute for Industrial Productivity



CHP Delivers Energy and Emissions Savings
(Small scale: mCHP)

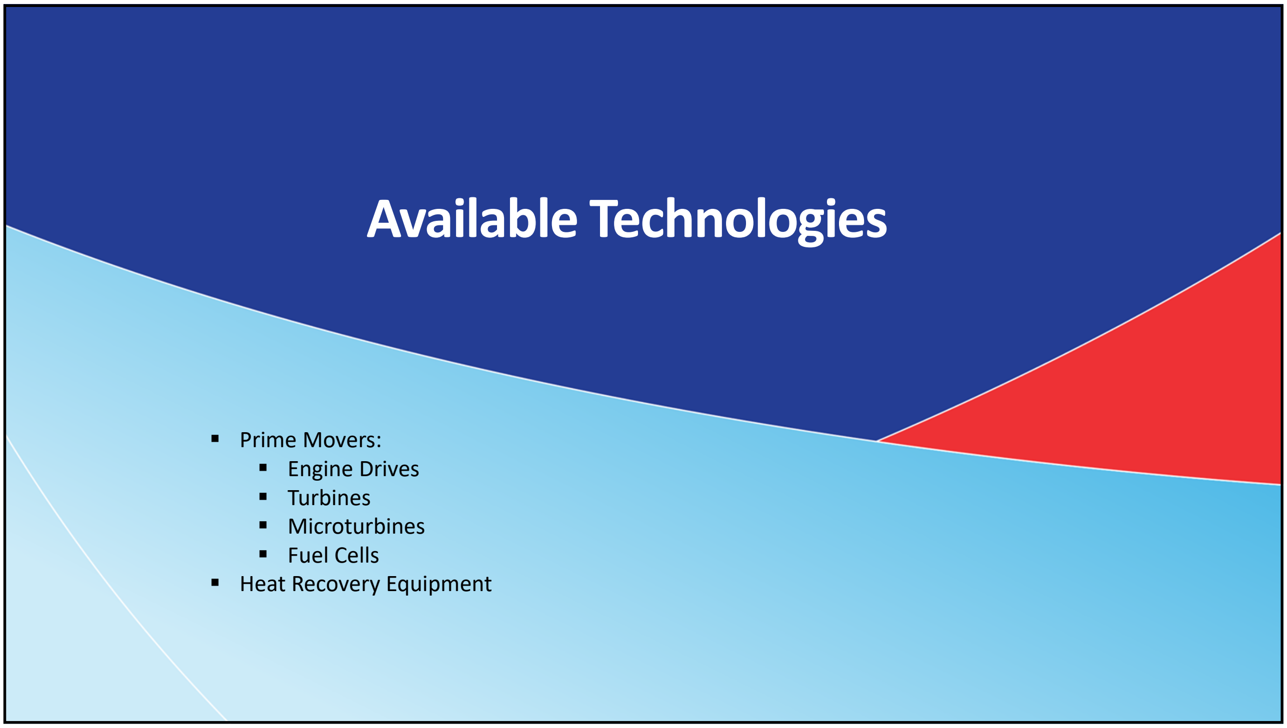
Fitness Center:

12,000 Sq Ft - 10 KW DE System[1]	**Solar - PV**	**Wind**	**CHP**
Installed Cost ($/KW)	$5,300	$6,000	$7,280
Annual Savings (/KW installed)[2]	$156	$216	$592
Space Required (Sq Ft/KW installed)	76	785	1.4
CO2 Saved (/KW installed)[3]	1,871	2,588	6,502
Ave. hours /year at max power[4]	1,550	2,175	8,311

Elderly Care Facility:

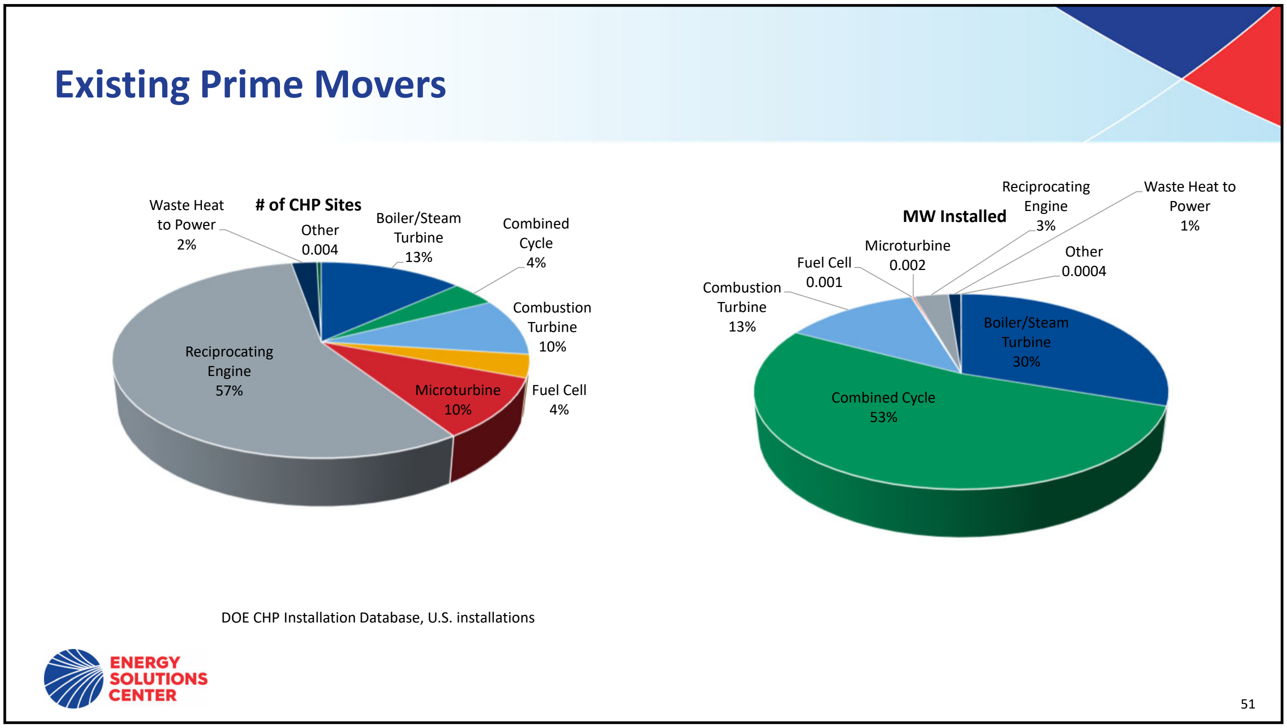
75,000 Sq Ft - 65 KW DE System[1]	**Solar - PV**	**Wind**	**CHP**
Installed Cost ($/KW)	$4,600	$3,300	$2,250
Annual Savings (/KW installed)[2]	$157	$161	$583
Space Required (Sq Ft/KW installed)	76	121	0.28
CO2 Saved (/KW installed)[3]	1,878	1,933	6,369
Ave. hours /year at max power[4]	1,550	1,595	8,322

Study: Small Scale Combined Heat and Power (CHP) versus Renewable Energy Comparison Study – NGTC



Available Technologies

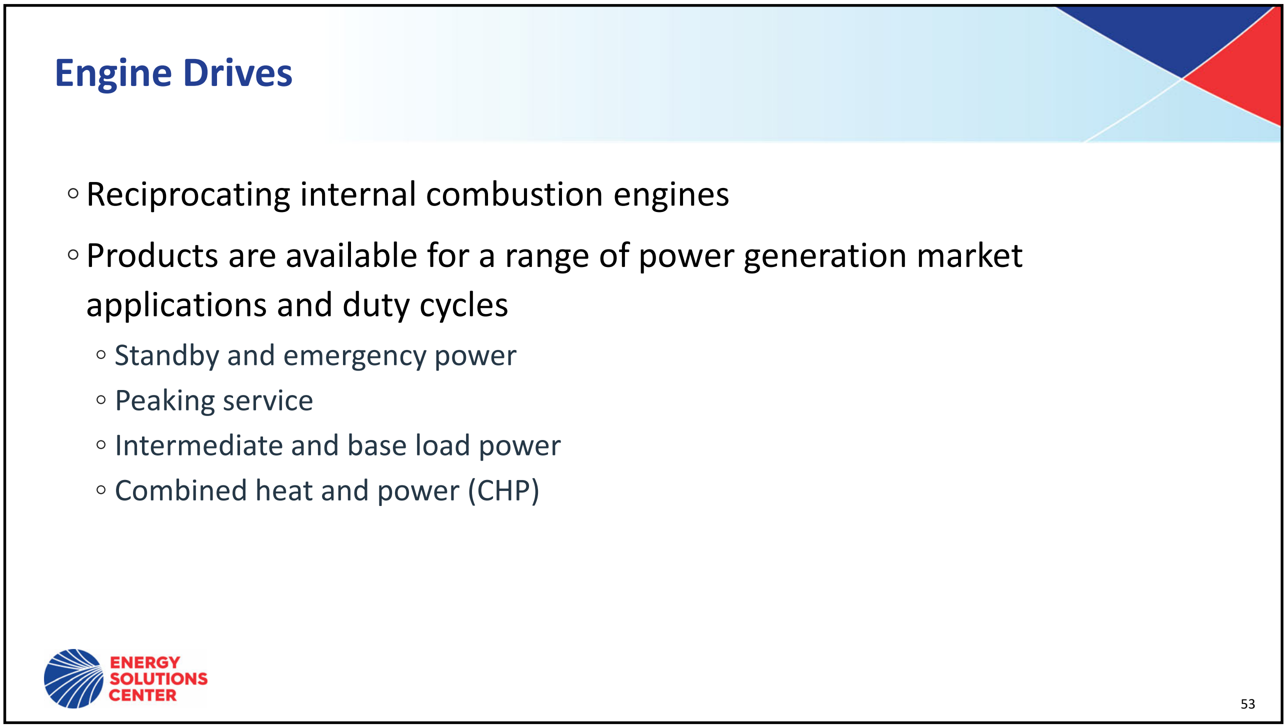
- Prime Movers:
  - Engine Drives
  - Turbines
  - Microturbines
  - Fuel Cells
- Heat Recovery Equipment



Existing Prime Movers

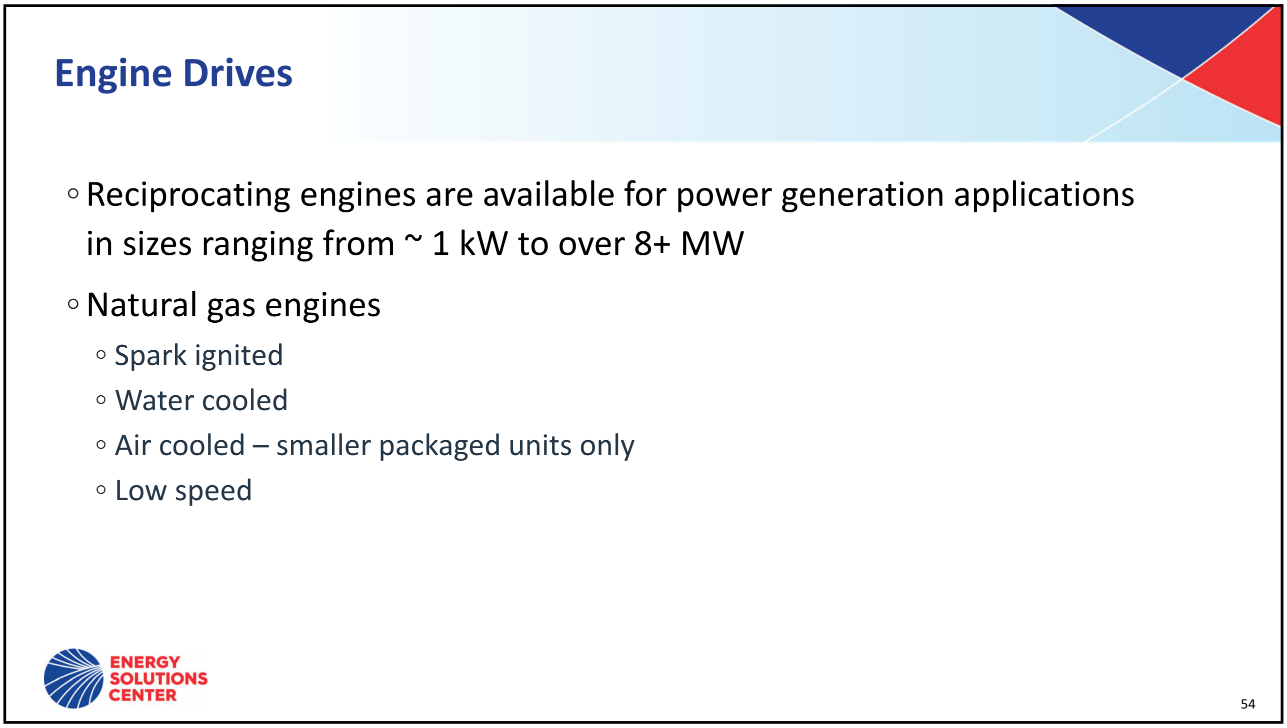
DOE CHP Installation Database, U.S. installations

Engine Driven Generators



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)



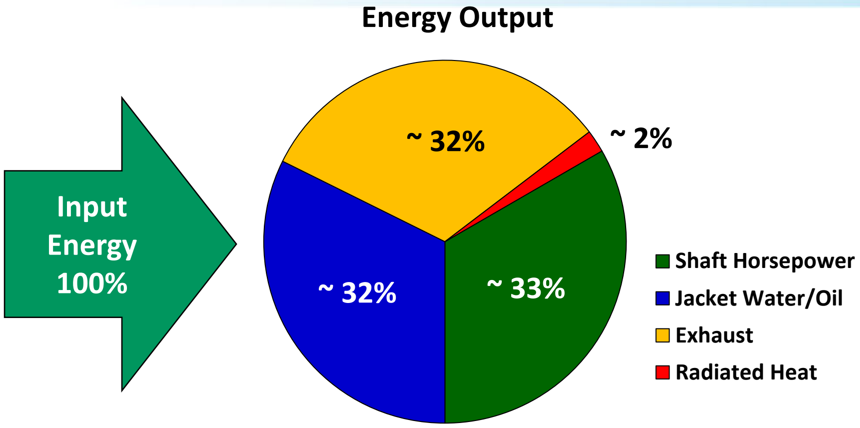
Engine Drives

- Reciprocating engines are available for power generation applications in sizes ranging from ~ 1 kW to over 8+ MW
- Natural gas engines
  - Spark ignited
  - Water cooled
  - Air cooled – smaller packaged units only
  - Low speed

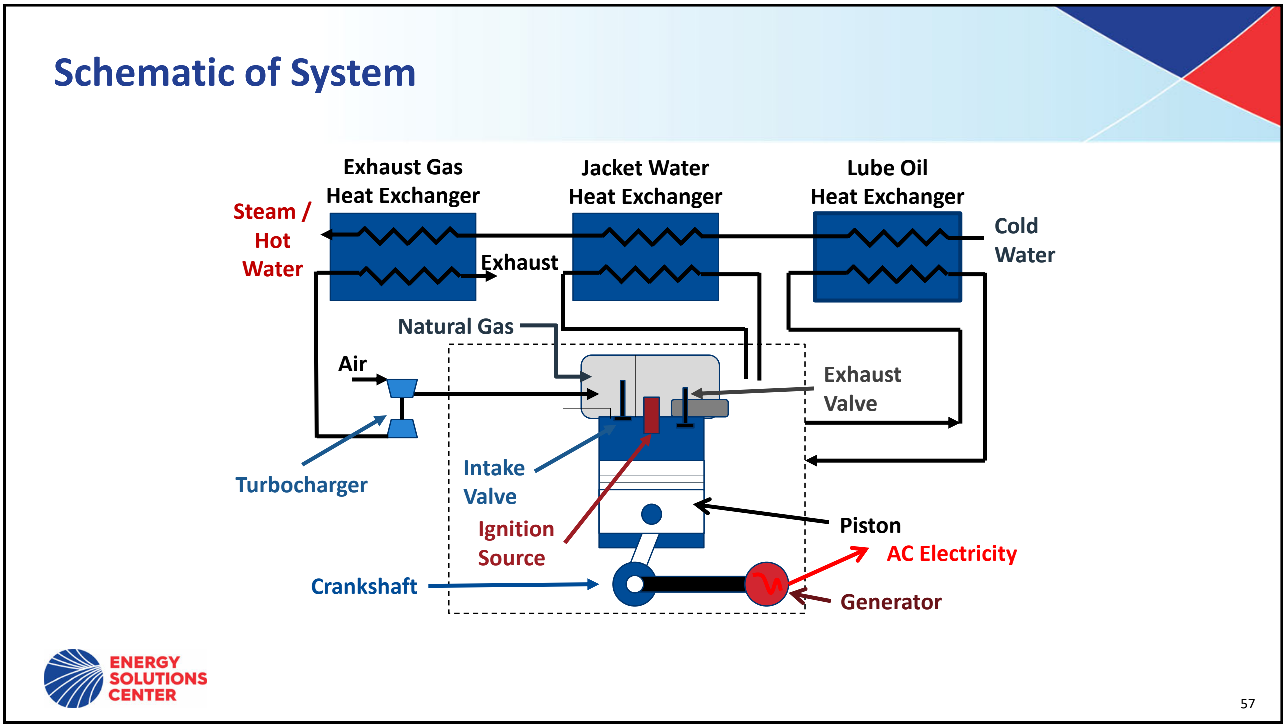
Engine Drives – Facts

- 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

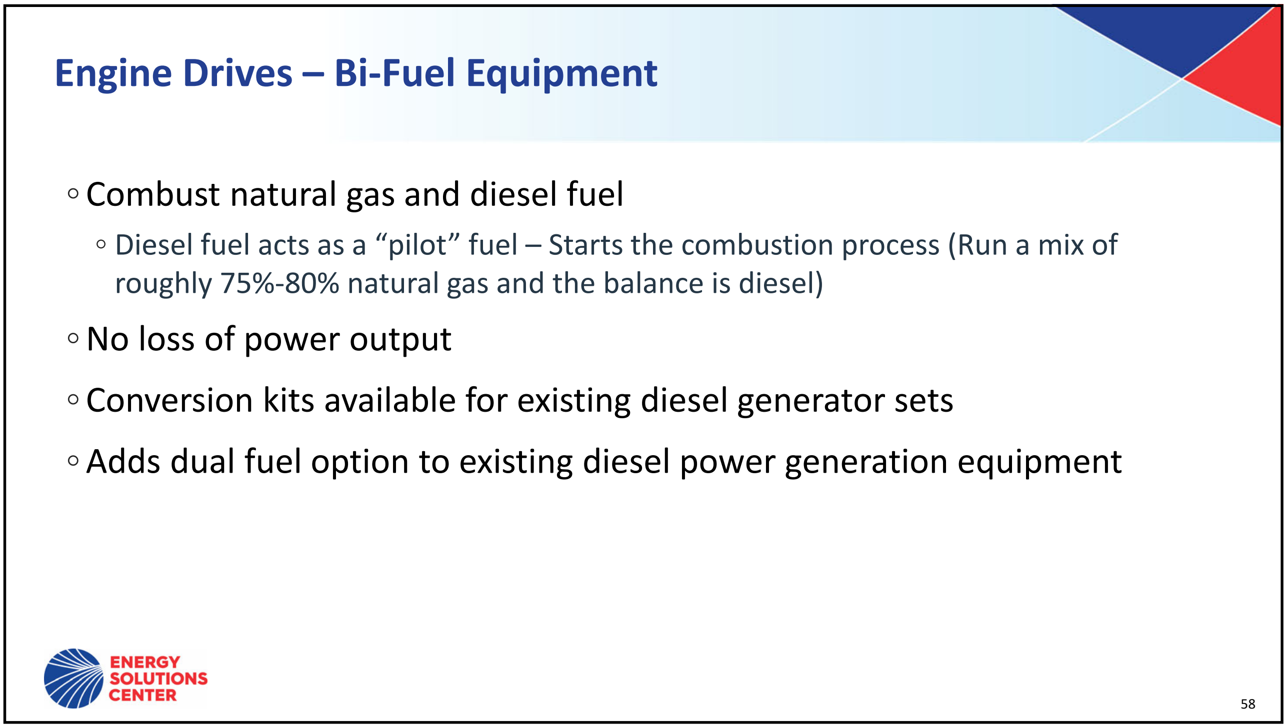
Engine Drive Energy Use



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



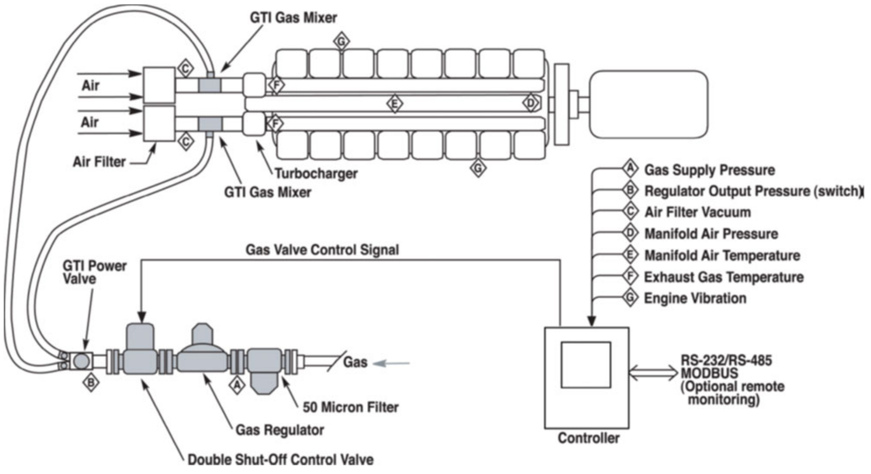
Schematic of System



Engine Drives – Bi-Fuel Equipment

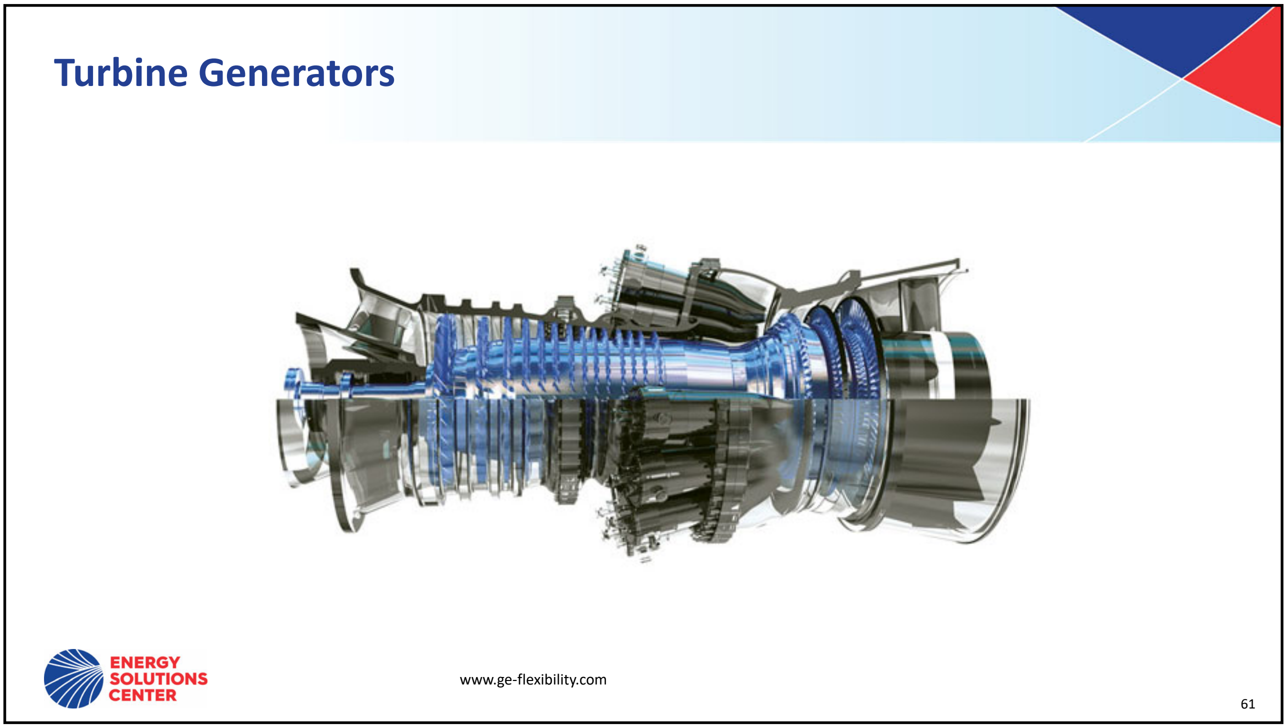
- Combust natural gas and diesel fuel
  - Diesel fuel acts as a "pilot" fuel – Starts the combustion process (Run a mix of roughly 75%-80% natural gas and the balance is diesel)
- No loss of power output
- Conversion kits available for existing diesel generator sets
- Adds dual fuel option to existing diesel power generation equipment

Bi-Fuel System



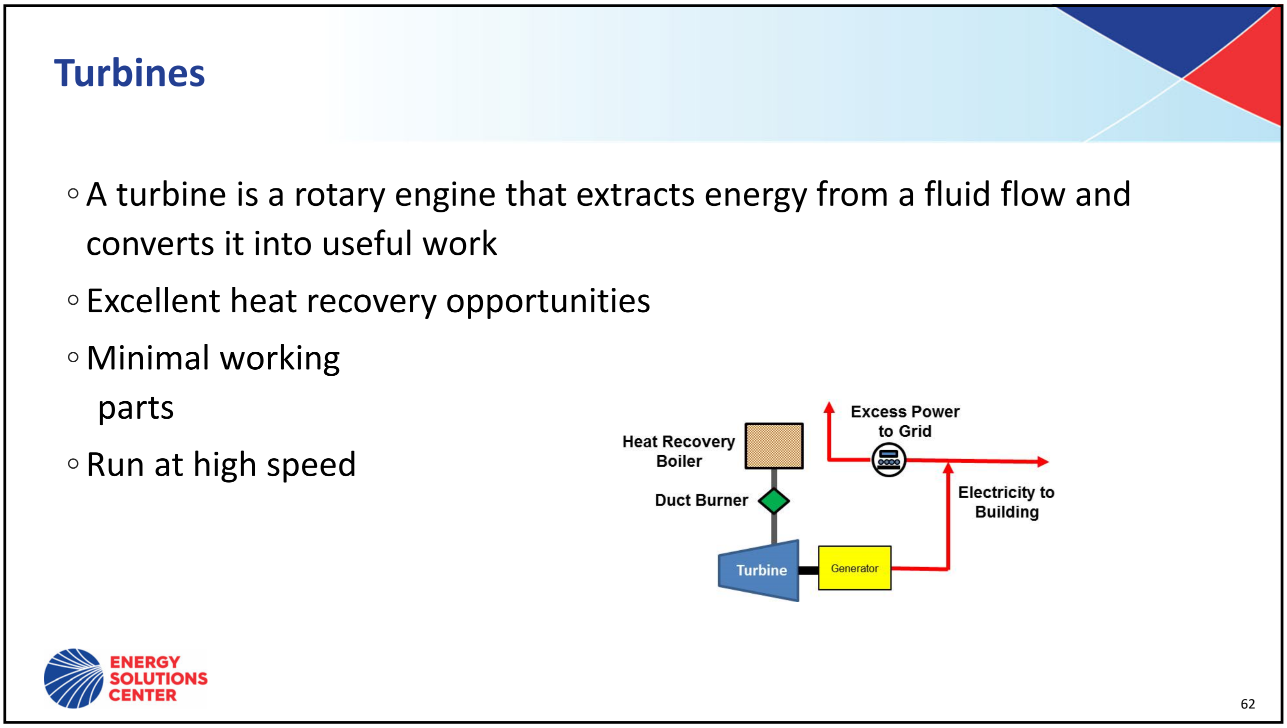
Black Start Capability

- 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 on line when the utility grid is down
  - Generator units without "black-start" capability can only operate when the electric utility is on line.
  - Provides the facility with "supplemental/stand-by" generation during utility outages



Turbine Generators

www.ge-flexibility.com

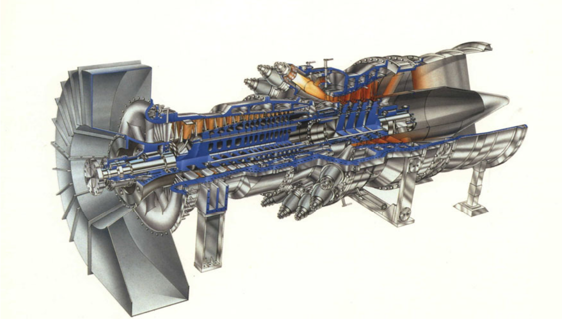


Turbines

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

Turbine Types

- Natural Gas Combustion Turbines
- Steam Turbines
- Microturbines



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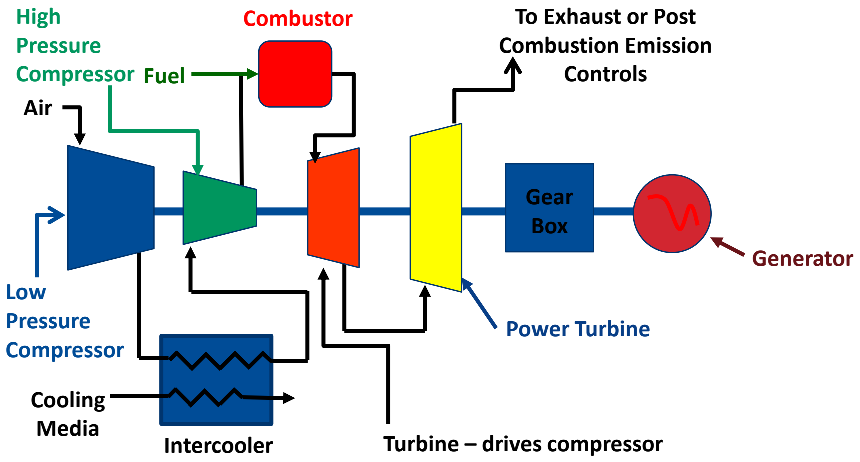
Natural Gas Turbine Generator

One large packaged unit will provide power and engineered heat recovery

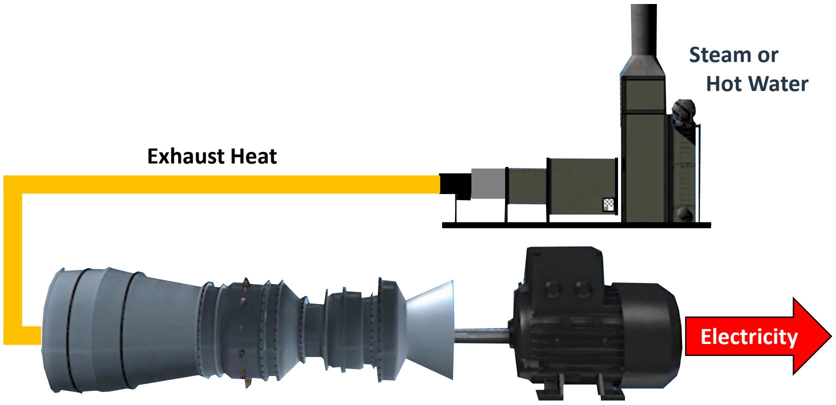
Gas Turbine

- 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



Turbine CHP – Simple Cycle



Use Natural gas and produce electricity and hot water or steam

Gas Turbines

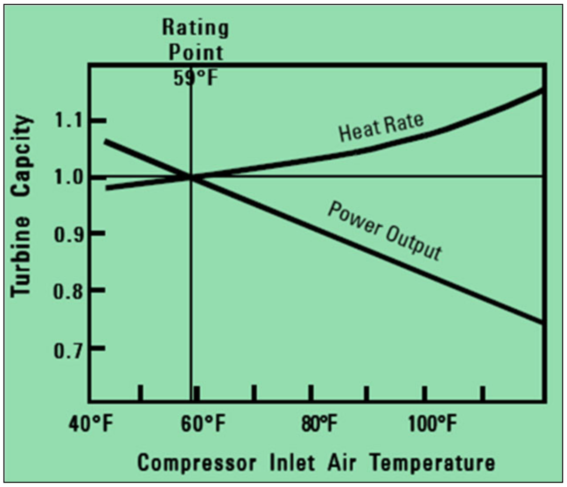
- High reliability
- Low emissions
- Able to produce high quality steam for:
  - Building heat or absorption chillers and process heating/consumption
  - District heating steam
  - Steam turbines in combined-cycle plant configurations
- Well suited for larger continuous duty CHP applications
- No cooling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

Gas Turbines – Efficiency Gains

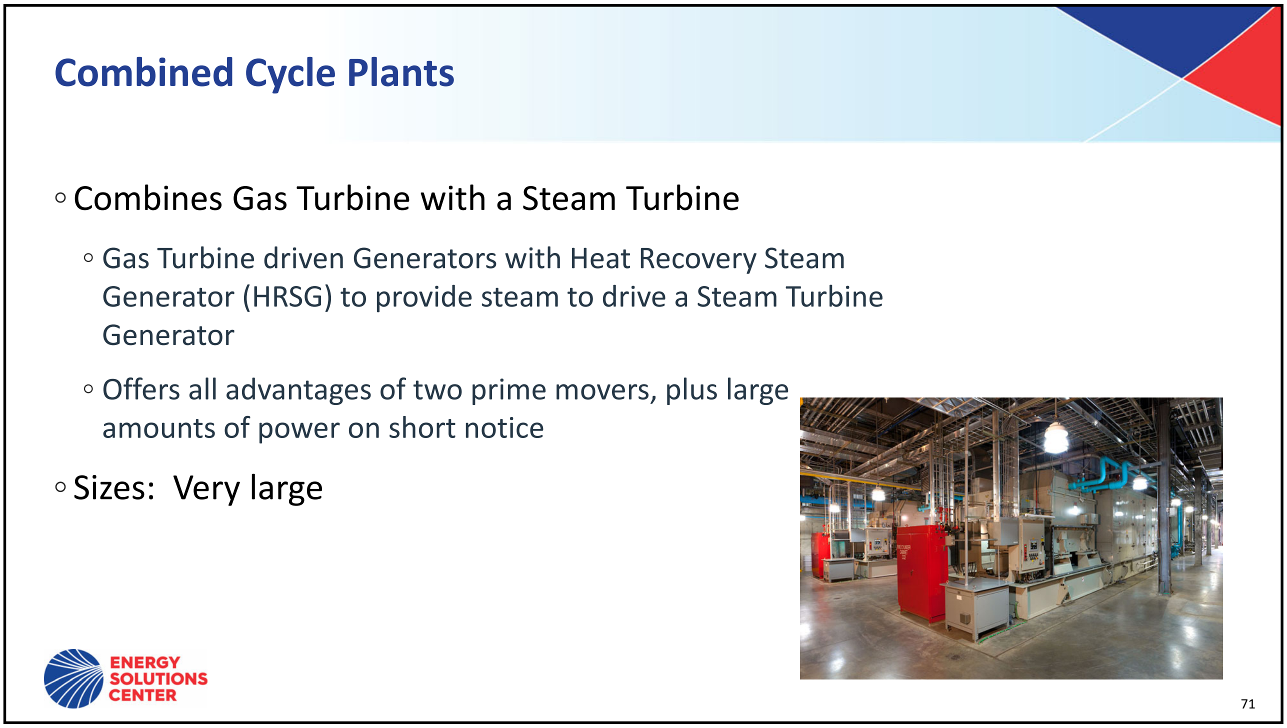
- Turbine inlet cooling
- Cooling the turbine inlet air -- even by a few degrees – increases power output
  - Cooled air is denser, giving the turbine a higher mass-flow rate
  - Produces increased turbine output and efficiency -- as much as 0.4% per degree Fahrenheit

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

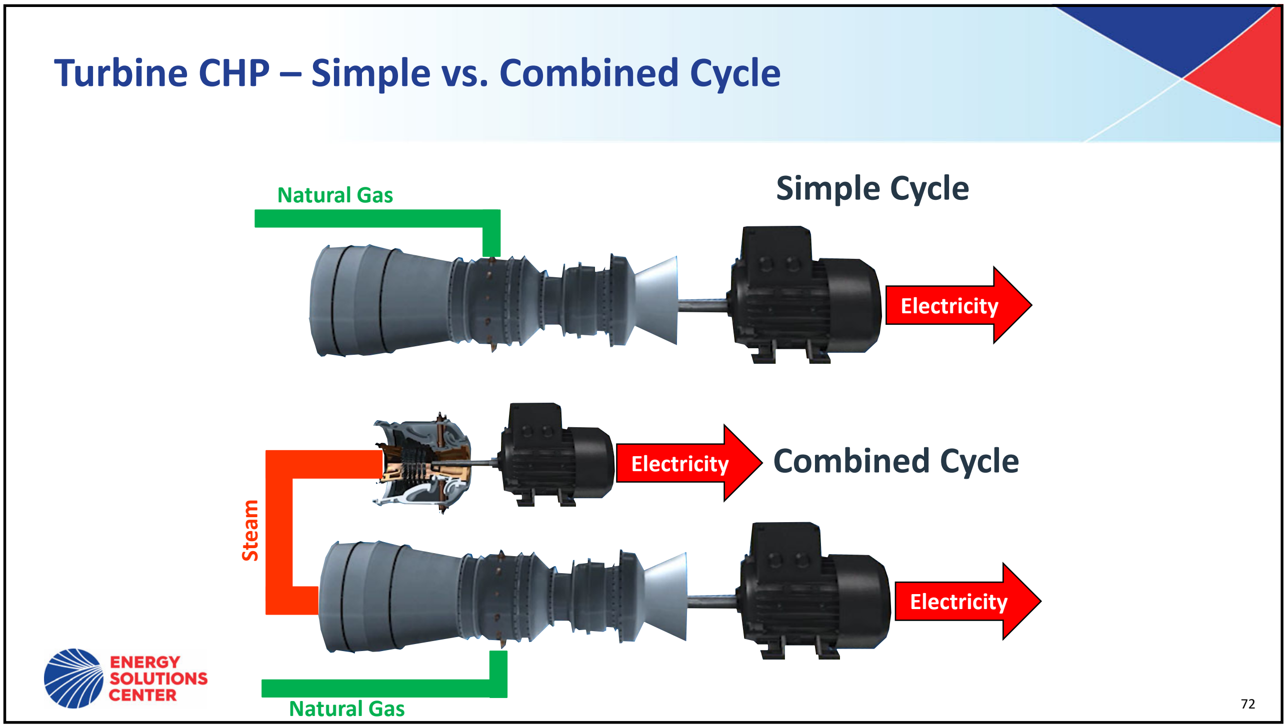


Source: ASHRAE, Donaldson Co.

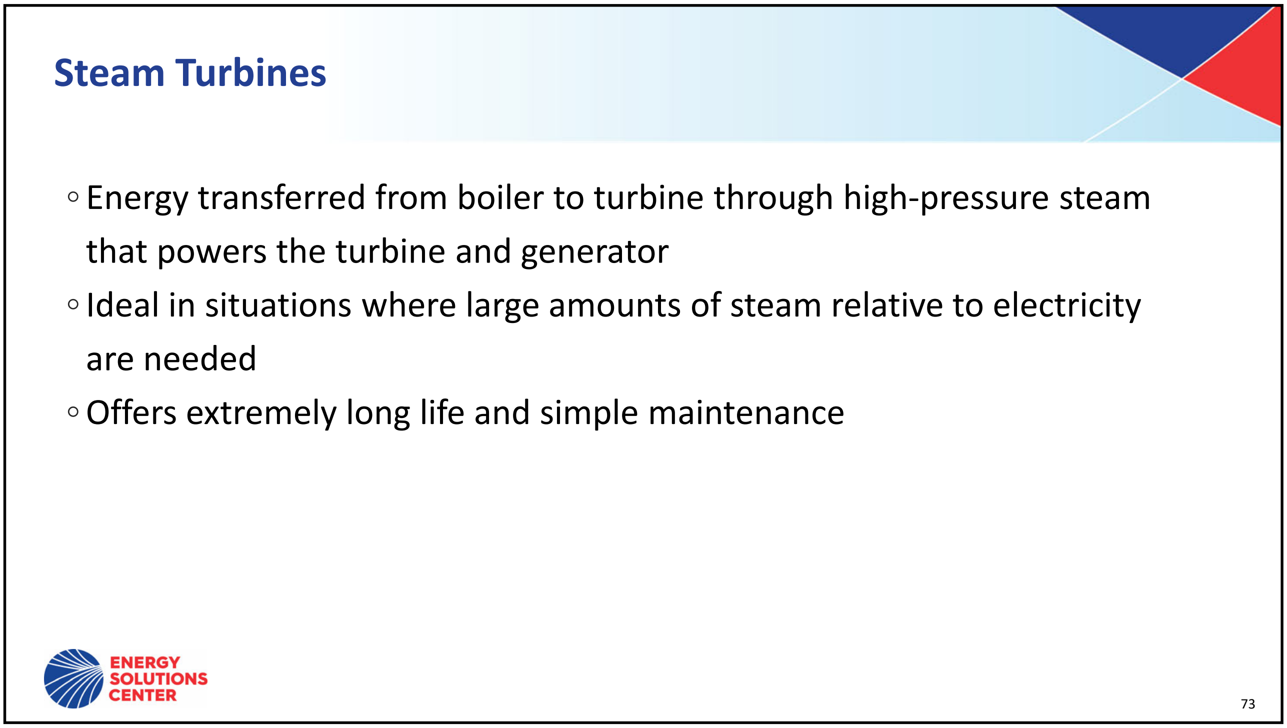


Combined Cycle Plants

- 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

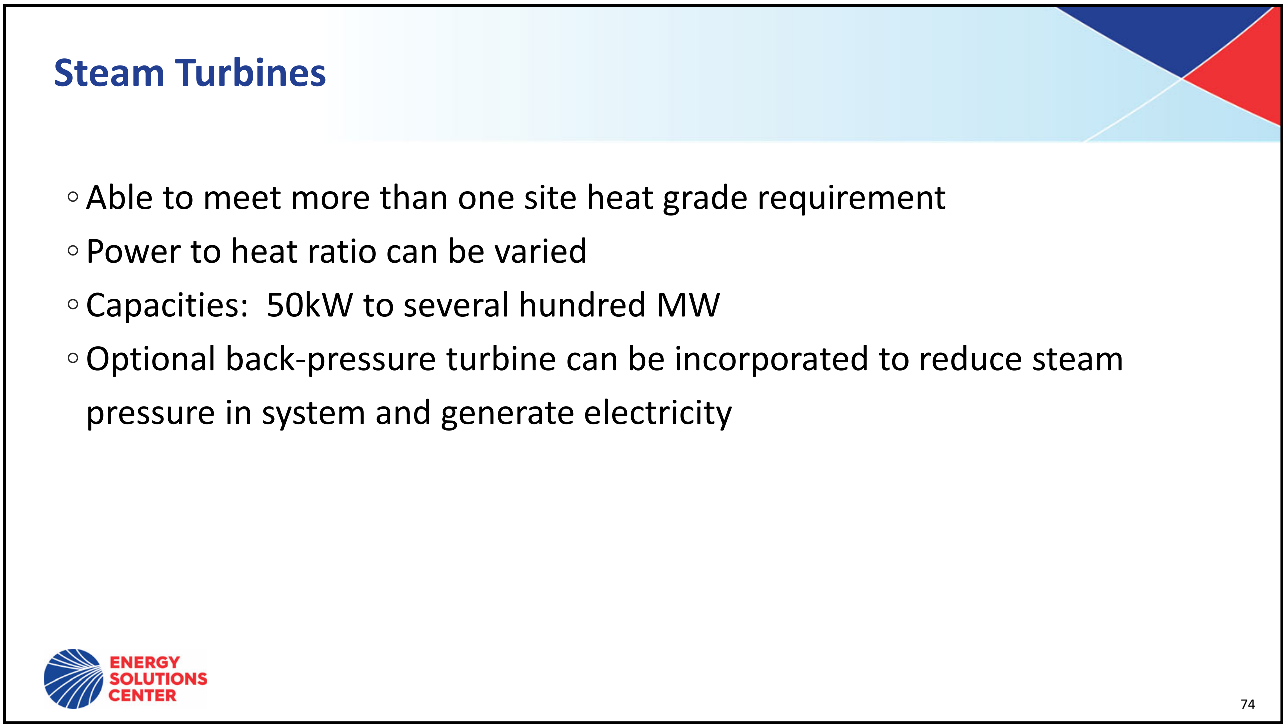


Turbine CHP – Simple vs. Combined Cycle



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

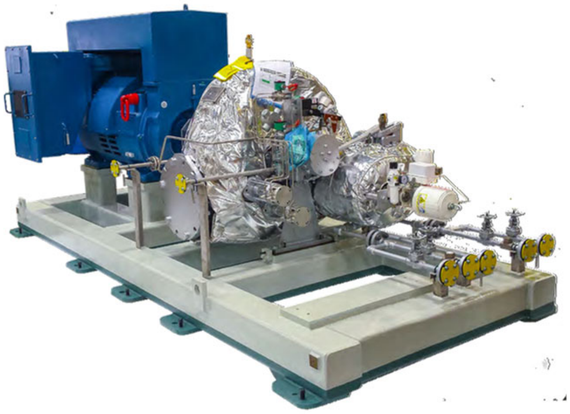


Steam Turbines

- Able to meet more than one site heat grade requirement
- Power to heat ratio can be varied
- Capacities: 50kW to several hundred MW
- Optional back-pressure turbine can be incorporated to reduce steam pressure in system and generate electricity

Steam Turbine Generator

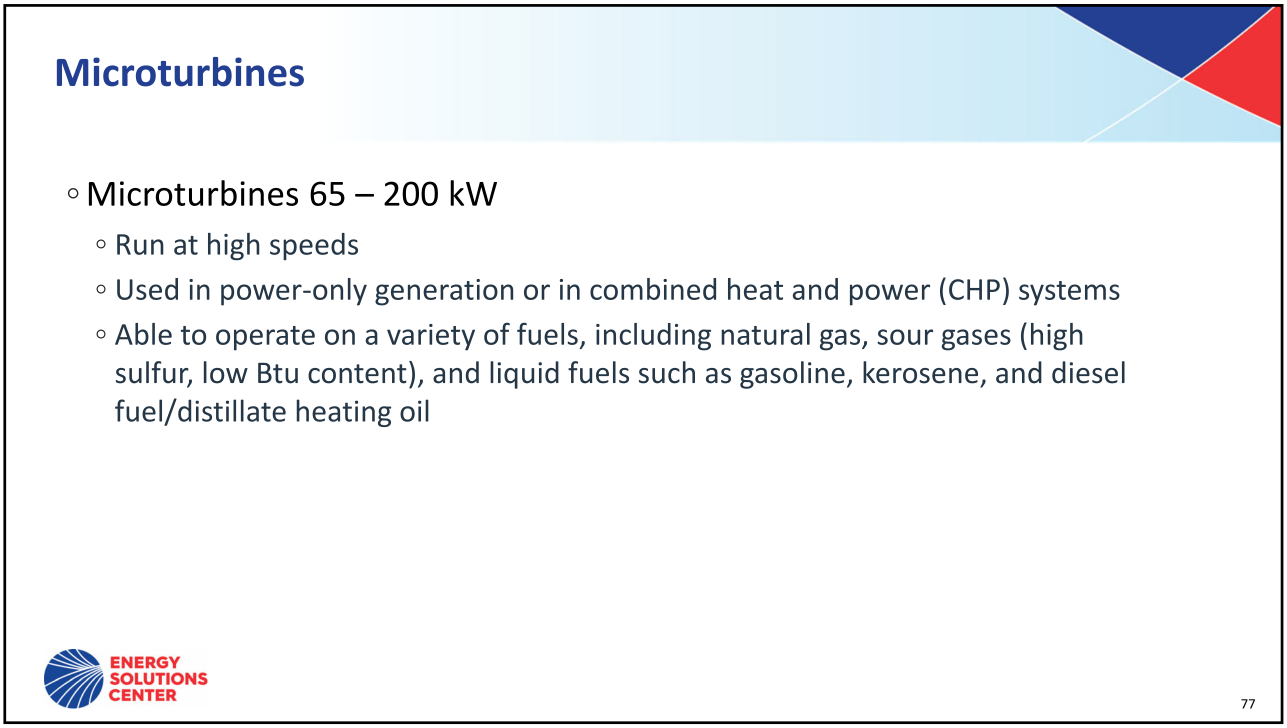
- Power range from 50 kW to 50 MW
- Synchronous or induction generator options



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

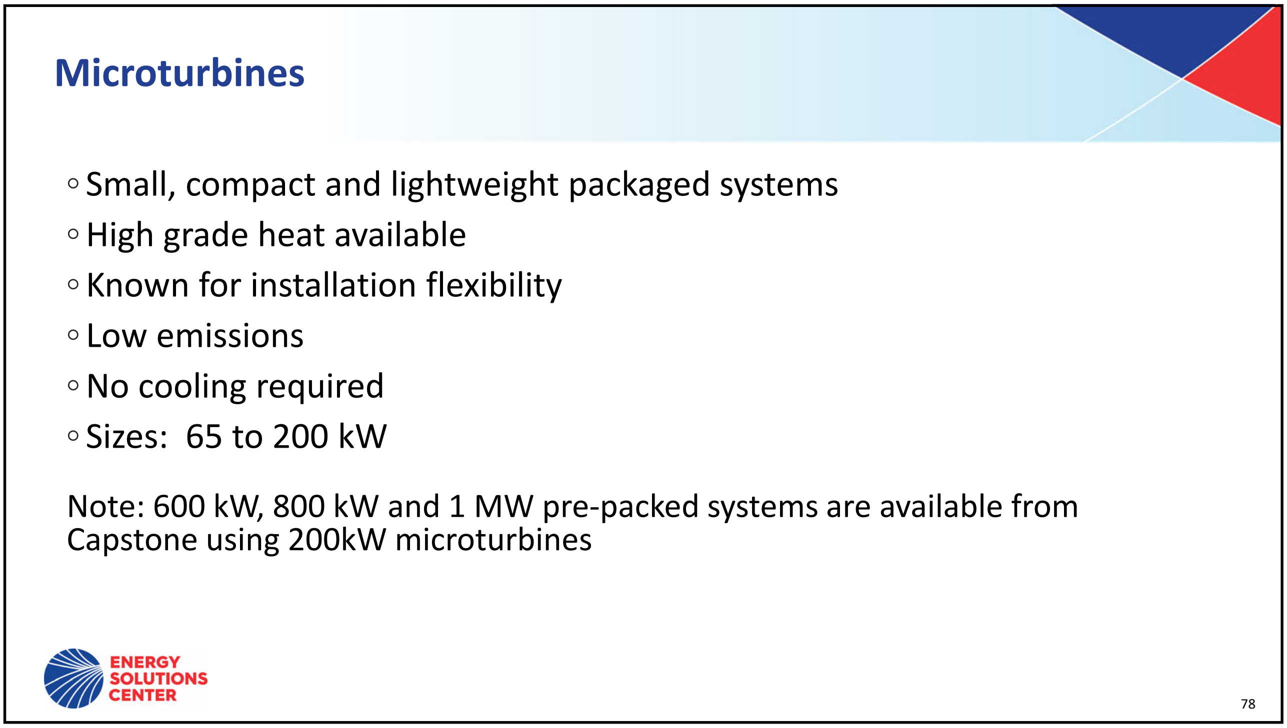
Microturbines

Several small units will provide power and engineered heat recovery



Microturbines

- Microturbines 65 – 200 kW
  - Run at high speeds
  - Used in power-only generation or in combined heat and power (CHP) systems
  - 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

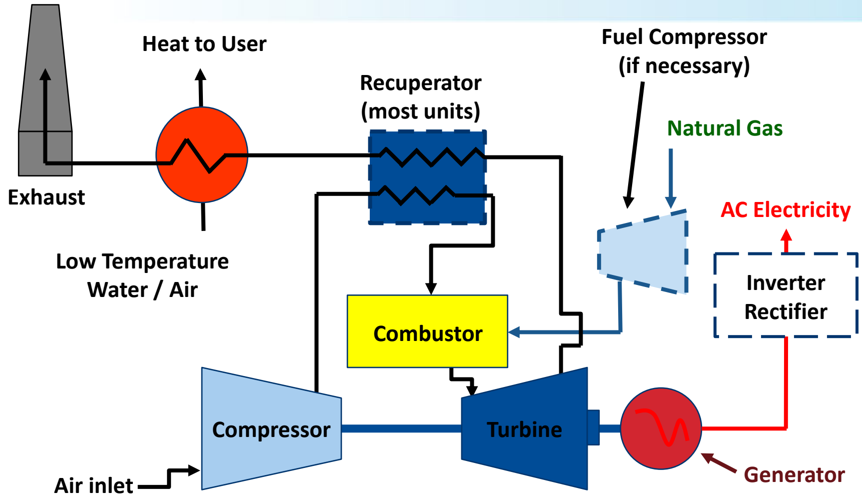


Microturbines

- Small, compact and lightweight packaged systems
- High grade heat available
- Known for installation flexibility
- Low emissions
- No cooling required
- Sizes: 65 to 200 kW

Note: 600 kW, 800 kW and 1 MW pre-packed systems are available from Capstone using 200kW microturbines

Schematic of Microturbine System



Heat to User

Recuperator
(most units)

Fuel Compressor
(if necessary)

Natural Gas

AC Electricity

Exhaust

Low Temperature
Water / Air

Inverter
Rectifier

Combustor

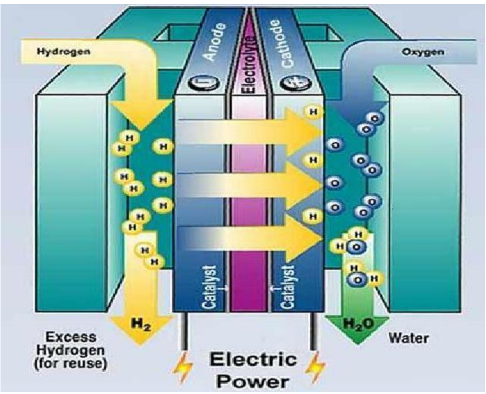
Compressor

Turbine

Air inlet

Generator

Fuel Cells



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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

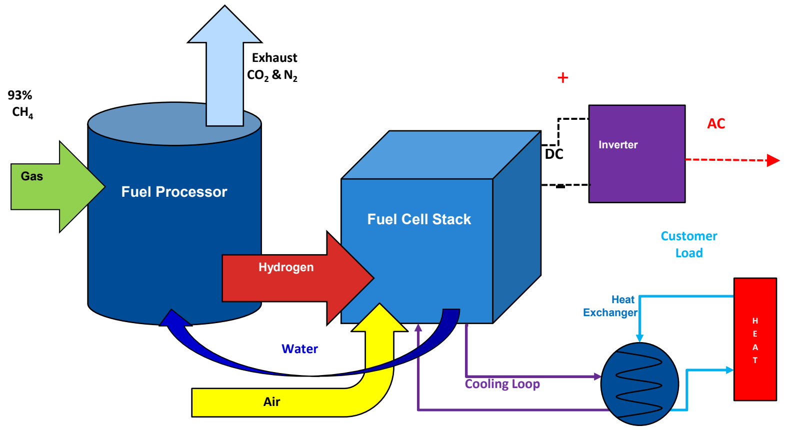
Fuel Cell Technologies

- 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)

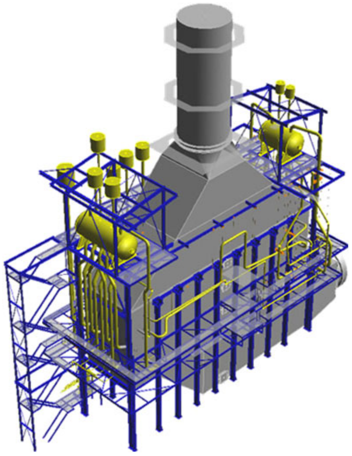
Micro CHP (mCHP)

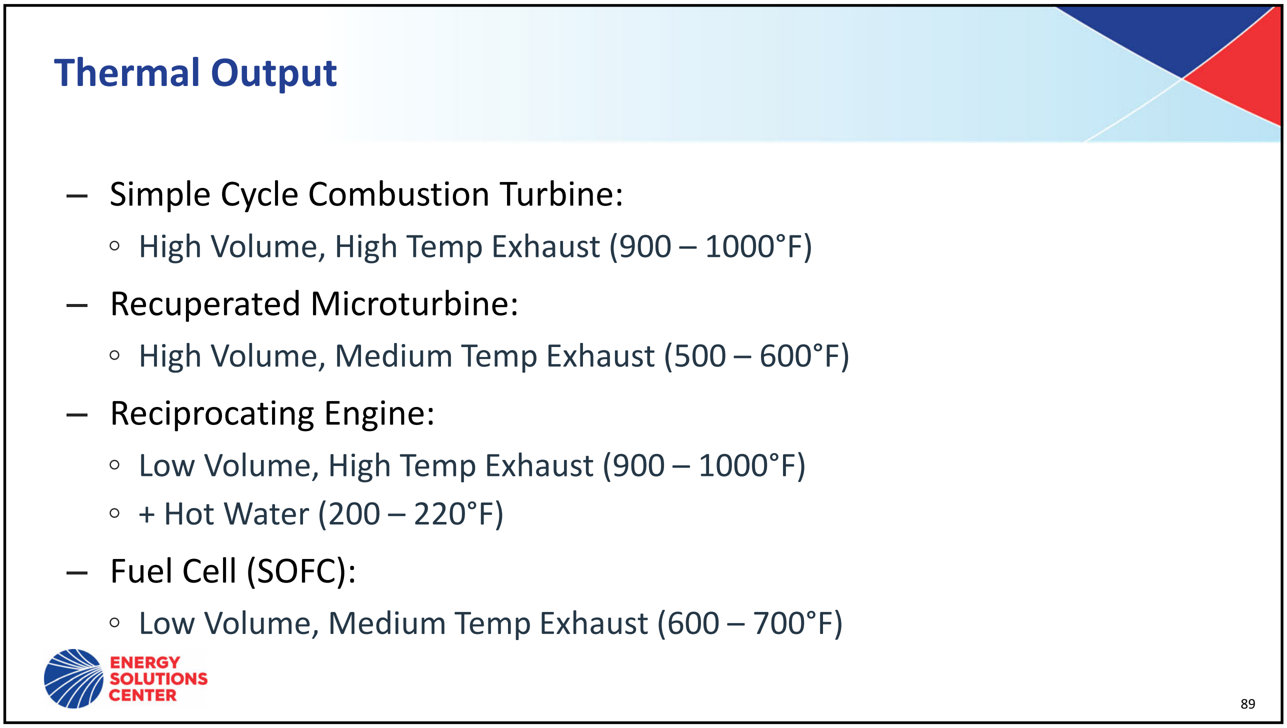
- Small scale cogeneration system for small commercial use
- Converts fuel to heat and electricity
- Micro-CHP units are sized up to 50 kWe
- Types Available
  - Engine driven
  - Fuel Cell
- Under Development: ORC, Stirling Engine, TAC

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

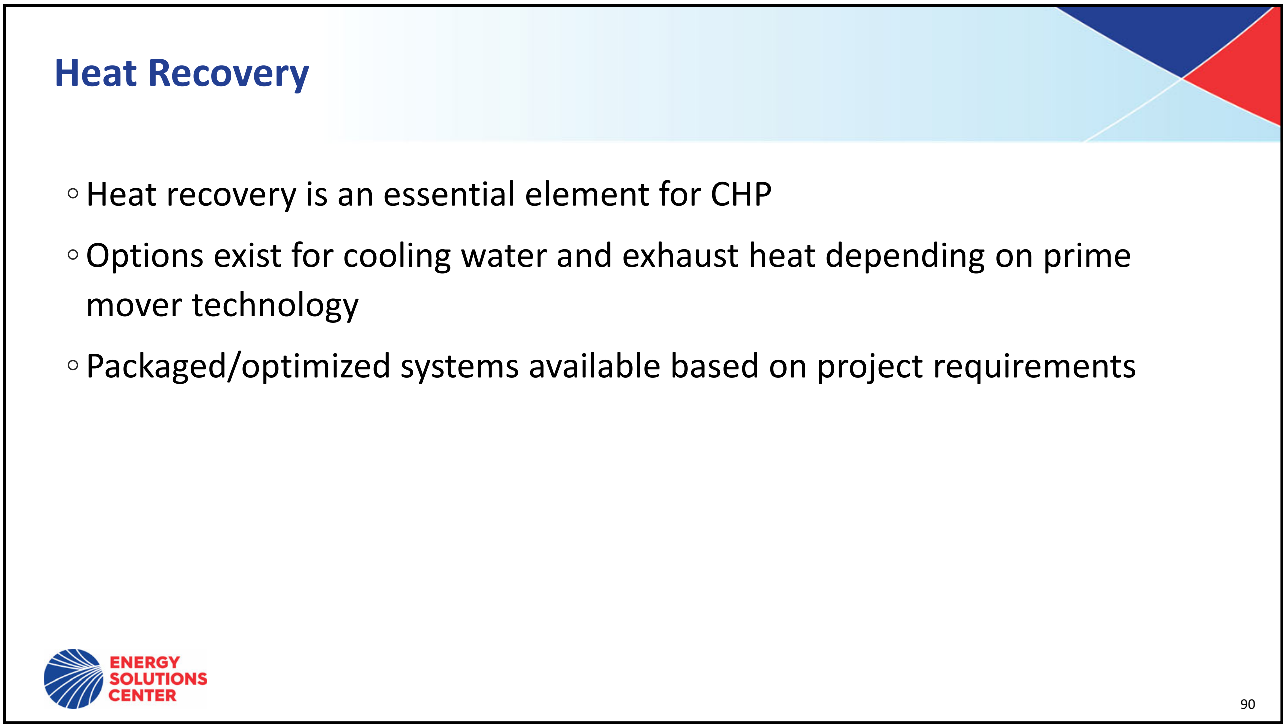
Heat Recovery





Thermal Output

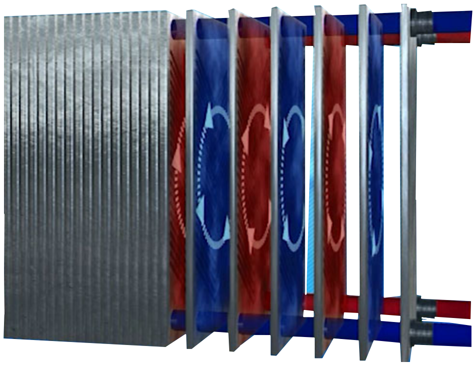
- Simple Cycle Combustion Turbine:
    - High Volume, High Temp Exhaust (900 – 1000°F)
- Recuperated Microturbine:
    - High Volume, Medium Temp Exhaust (500 – 600°F)
- Reciprocating Engine:
    - Low Volume, High Temp Exhaust (900 – 1000°F)
    - + Hot Water (200 – 220°F)
- Fuel Cell (SOFC):
    -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



Heat Recovery

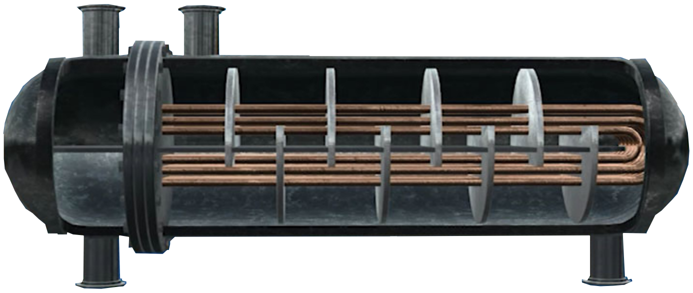
- Heat recovery is an essential element for CHP
- Options exist for cooling water and exhaust heat depending on prime mover technology
- Packaged/optimized systems available based on project requirements

Heat Recovery
Plate and Frame Heat Exchanger

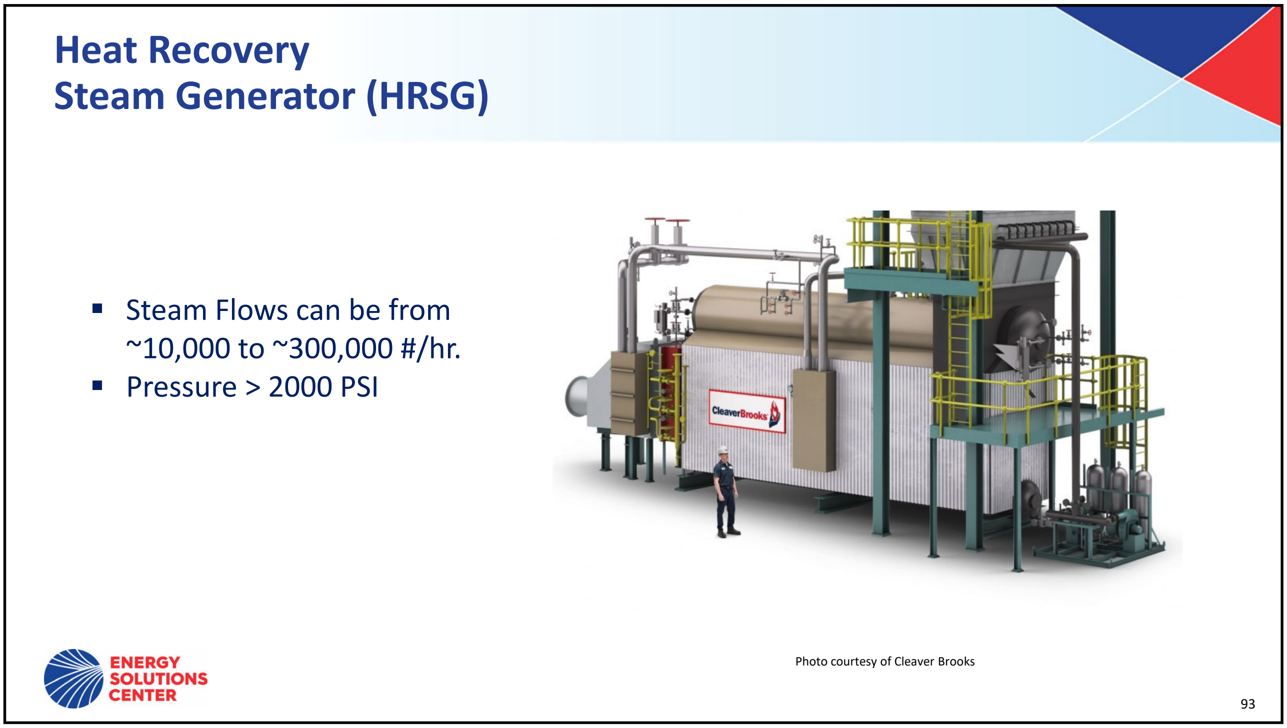


- Multiple thin slightly separated plates
- Large surface area
- Fluid flow passages allow heat transfer between two fluids

Heat Recovery
Shell & Tube Heat Exchanger



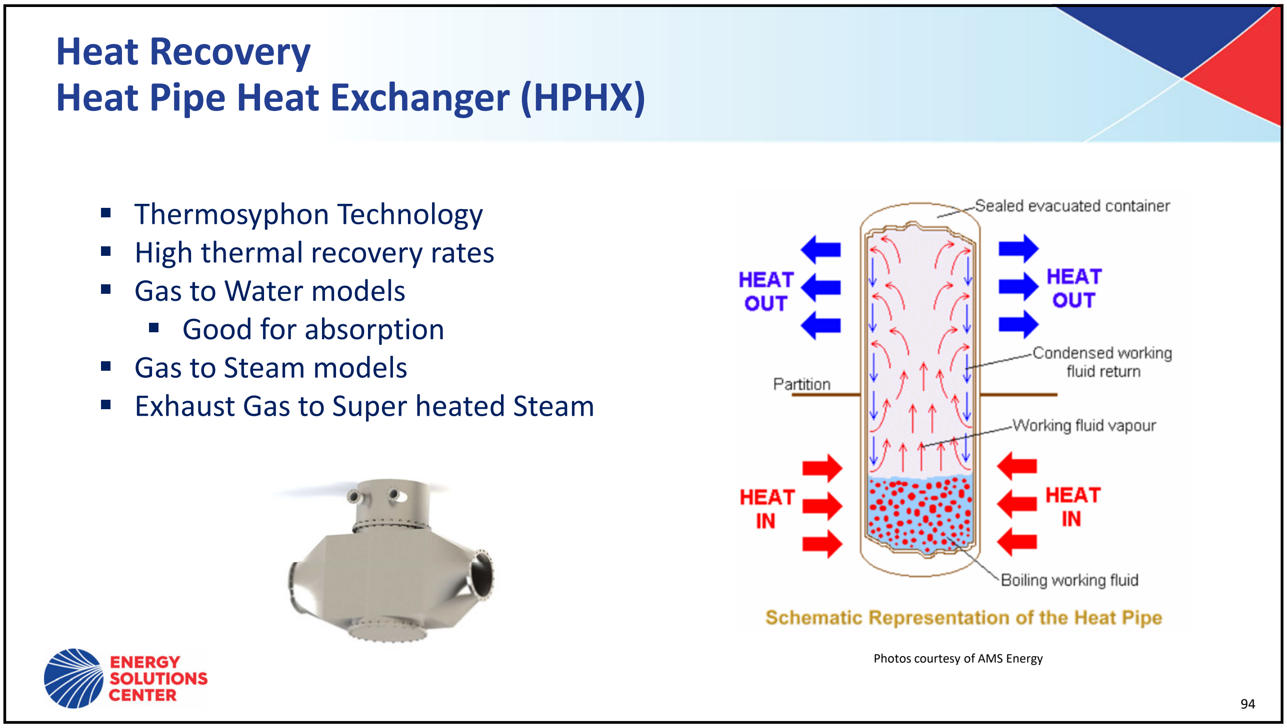
- Series of tubes that contain fluid to be heated
- Second fluid is located in shell and pumped around tubes transferring heat to fluid in tubes



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)

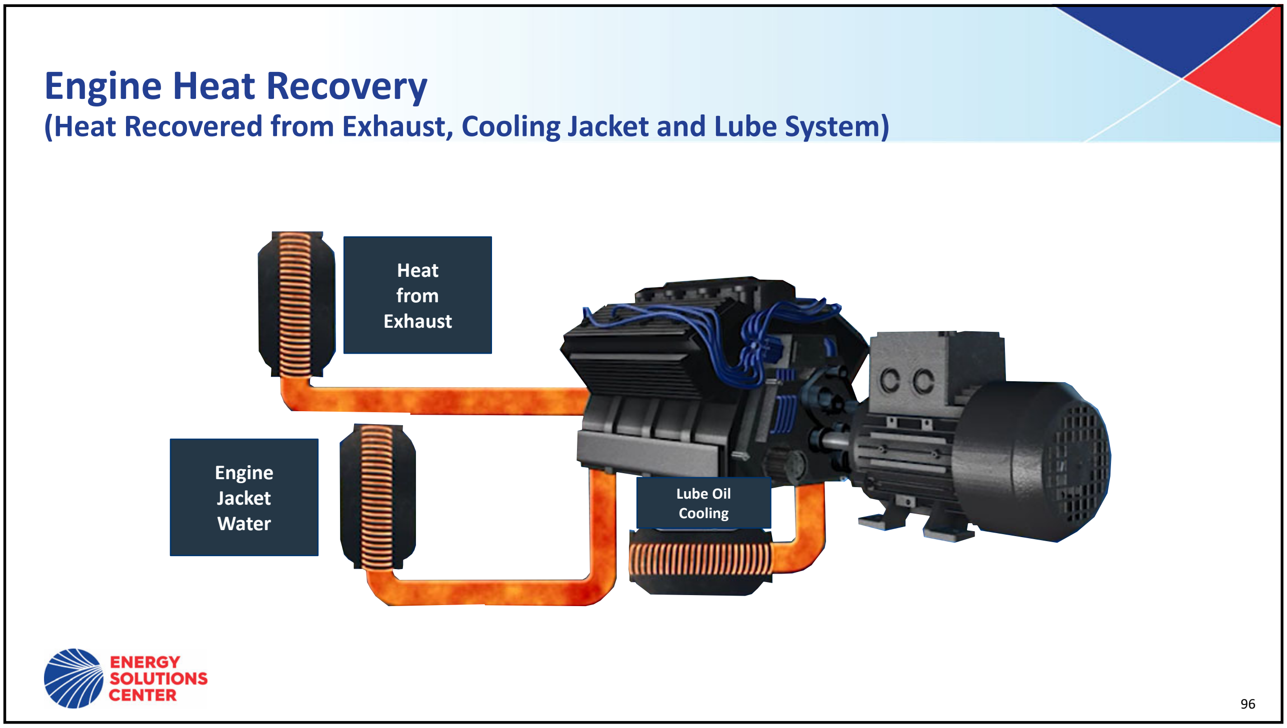
- Thermosyphon Technology
- High thermal recovery rates
- Gas to Water models
  - Good for absorption
- Gas to Steam models
- Exhaust Gas to Super heated Steam

Schematic Representation of the Heat Pipe

Photos courtesy of AMS Energy

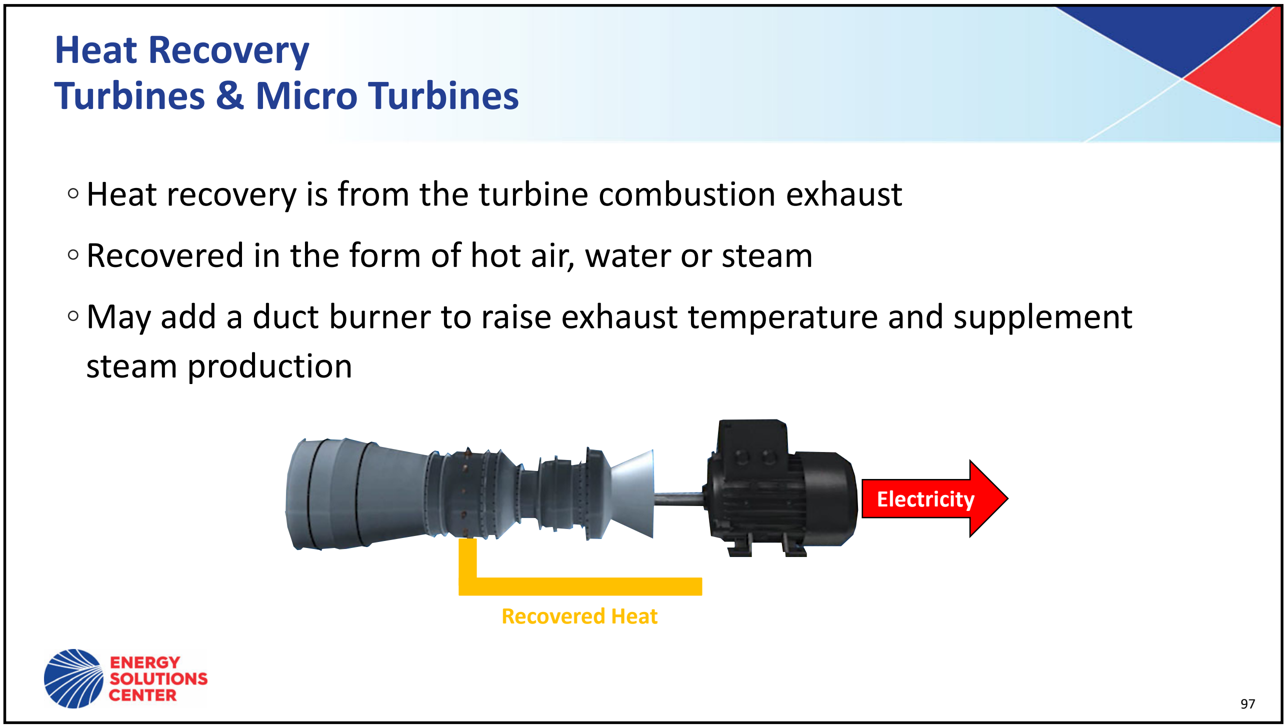
Heat Recovery on Engines

- 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



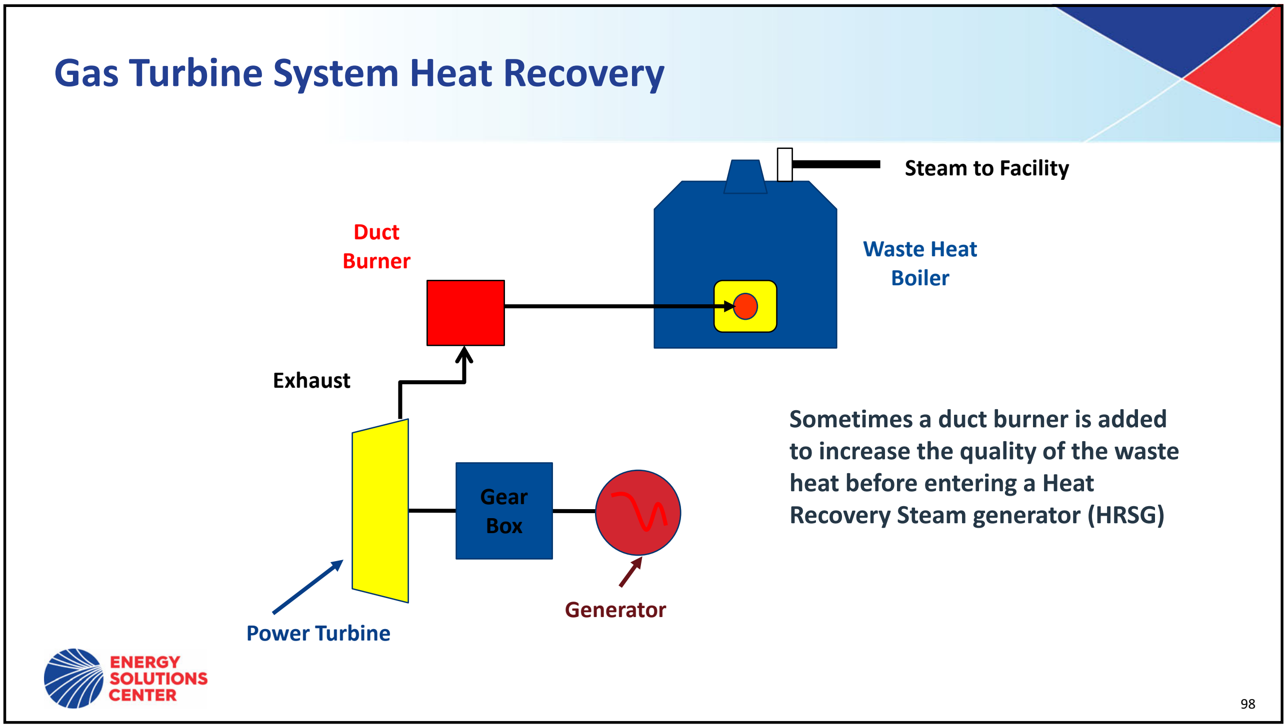
Engine Heat Recovery

(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

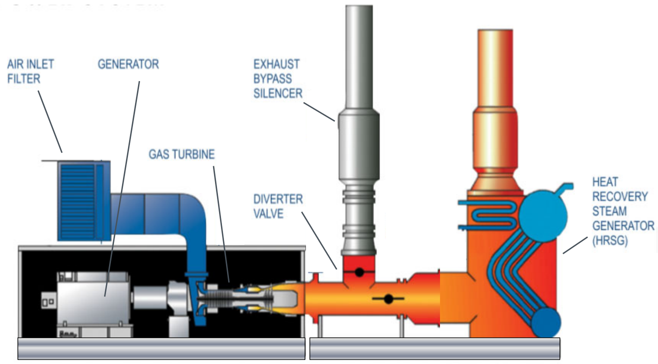


Gas Turbine System Heat Recovery

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

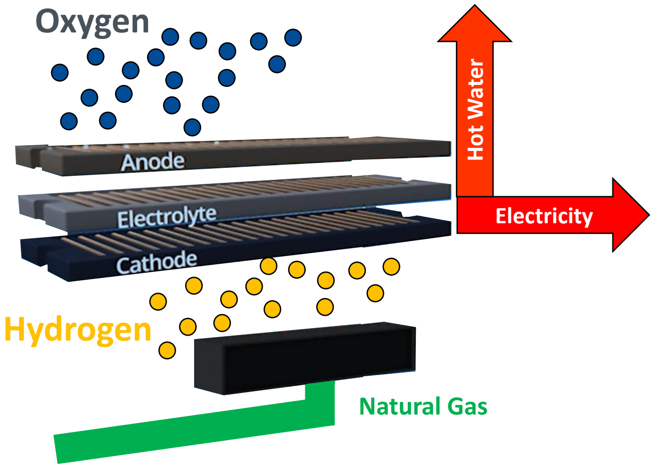
Heat Recovery – Turbines Produce Steam

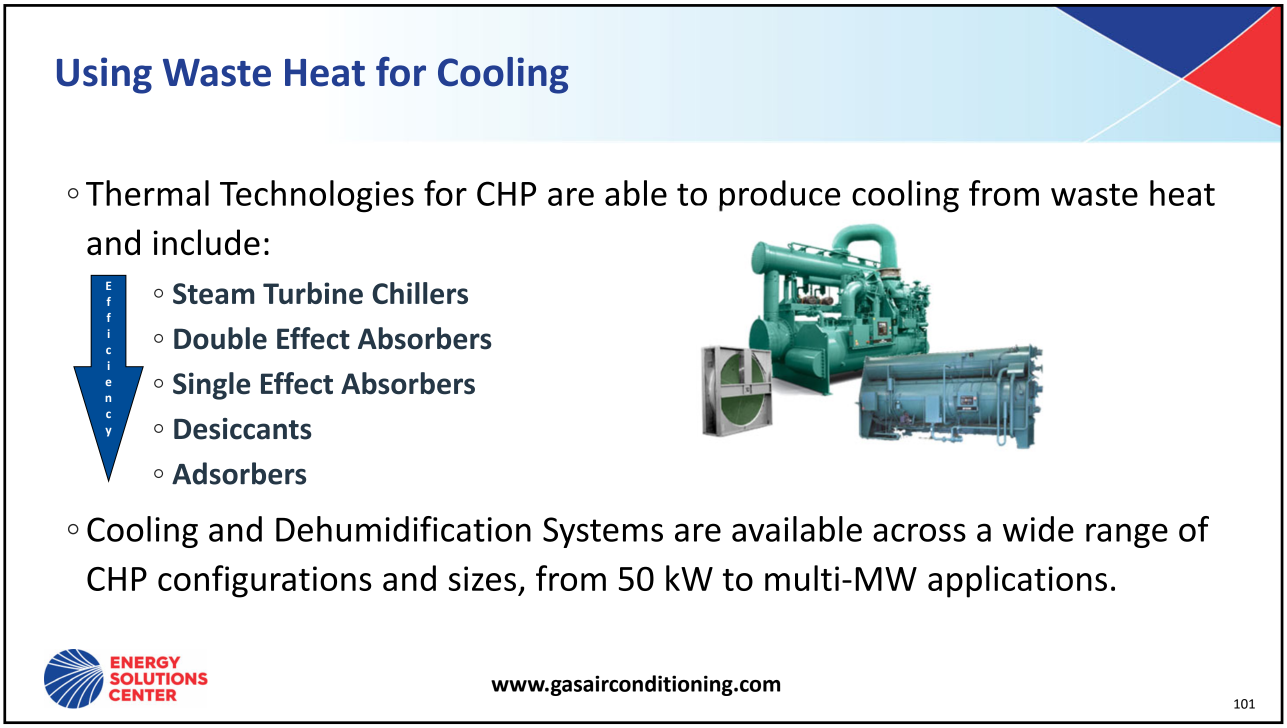
- Hot exhaust gases from the turbine pass through the HRSG - producing steam for steam turbine drives, heating, cooling, or process uses
- Can add supplemental firing if exhaust does not provide enough heat



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

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





Using Waste Heat for Cooling

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

www.gasairconditioning.com

Economics and Incentives

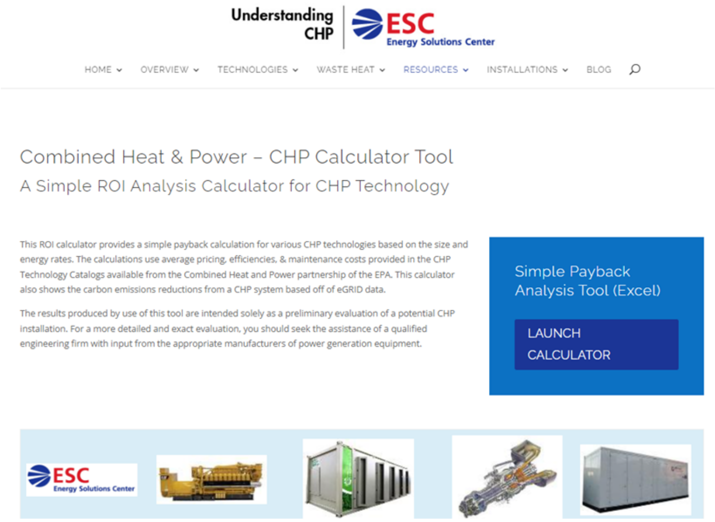
A detailed Life Cycle Cost Analysis is essential for evaluating a CHP project at any facility

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.

Life Cycle Cost & Emissions Calculator



Combined Heat & Power – CHP Calculator Tool

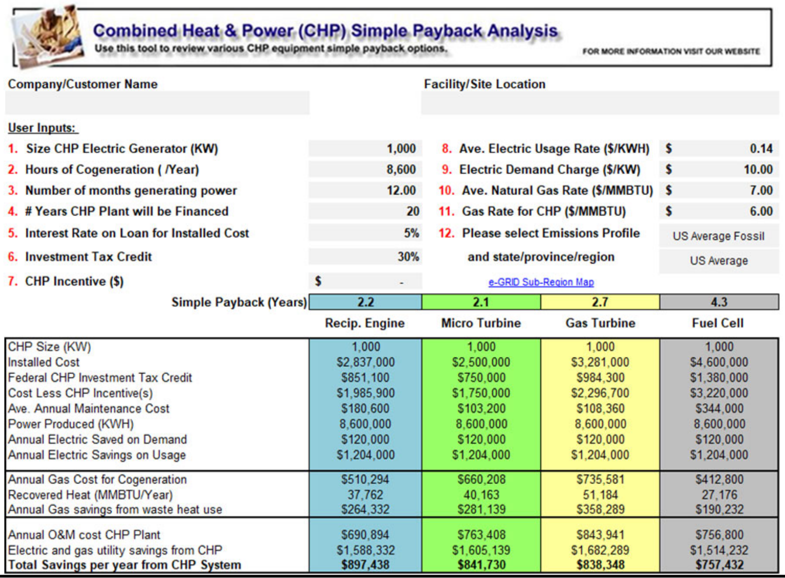
A Simple ROI Analysis Calculator for CHP Technology

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.

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

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

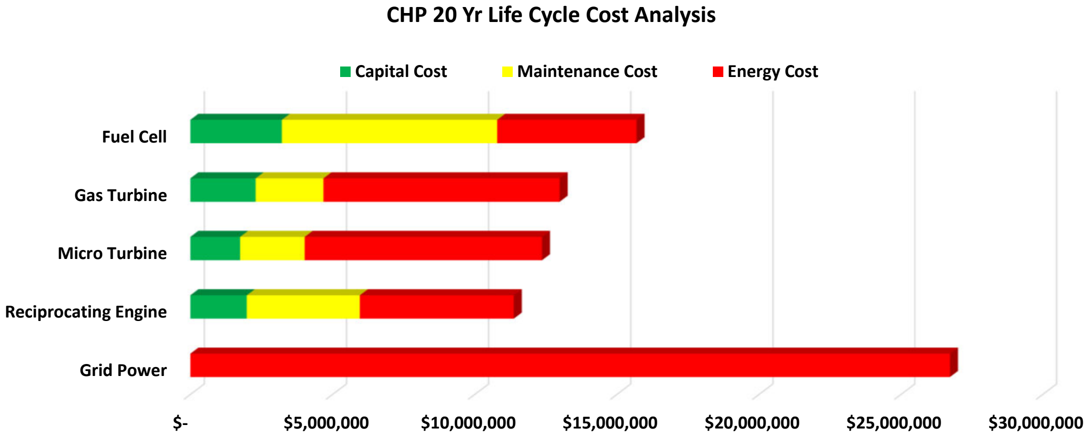
Facility/Site Location

User Inputs:

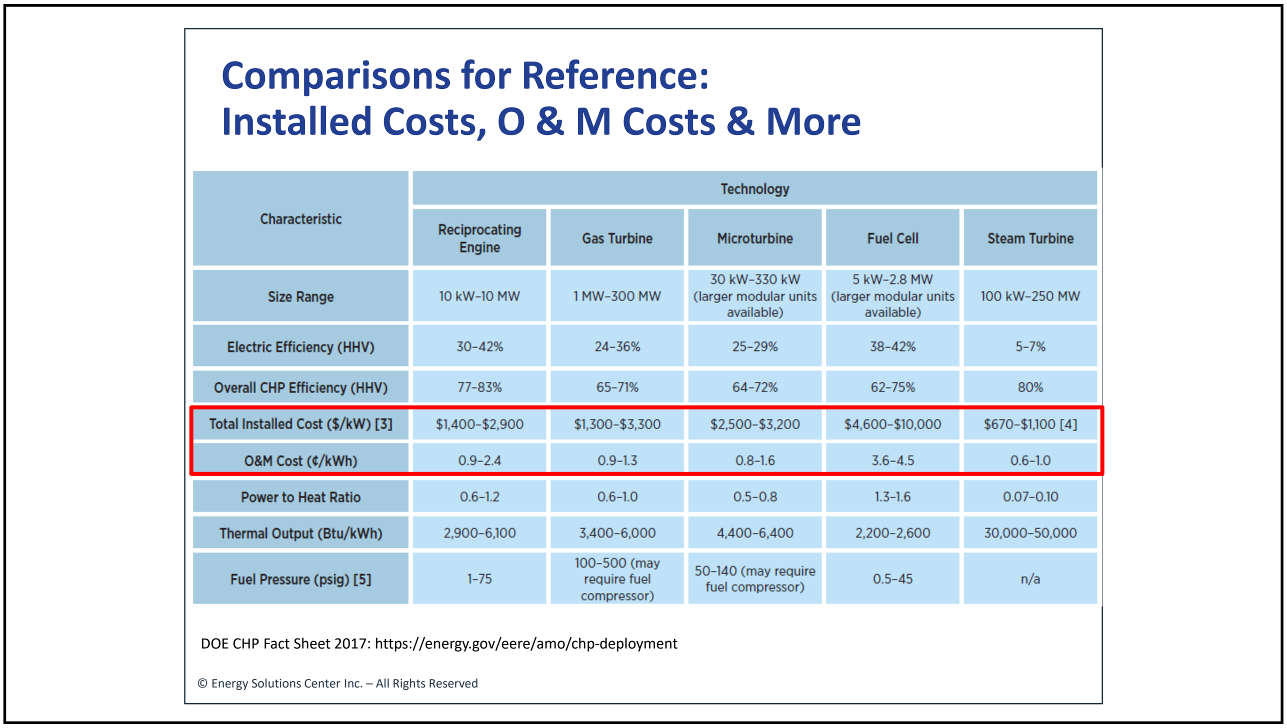
1. Size CHP Electric Generator (KW)	1,000	8. Ave. Electric Usage Rate ($/KWH)	$ 0.14
2. Hours of Cogeneration (/Year)	8,600	9. Electric Demand Charge ($/KW)	$ 10.00
3. Number of months generating power	12.00	10. Ave. Natural Gas Rate ($/MMBTU)	$ 7.00
4. # Years CHP Plant will be Financed	20	11. Gas Rate 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	

Simple Payback (Years)	2.2	2.1	2.7	4.3
	Recip. Engine	**Micro Turbine**	**Gas Turbine**	**Fuel Cell**
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



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



Comparisons for Reference: Installed Costs, O & M Costs & More

Characteristic	Technology				
	Reciprocating Engine	Gas Turbine	Microturbine	Fuel Cell	Steam Turbine
Size Range	10 kW–10 MW	1 MW–300 MW	30 kW–330 kW (larger modular units available)	5 kW–2.8 MW (larger modular units available)	100 kW–250 MW
Electric Efficiency (HHV)	30–42%	24–36%	25–29%	38–42%	5–7%
Overall CHP Efficiency (HHV)	77–83%	65–71%	64–72%	62–75%	80%
Total Installed Cost ($/kW) [3]	$1,400–$2,900	$1,300–$3,300	$2,500–$3,200	$4,600–$10,000	$670–$1,100 [4]
O&M Cost (¢/kWh)	0.9–2.4	0.9–1.3	0.8–1.6	3.6–4.5	0.6–1.0
Power to Heat Ratio	0.6–1.2	0.6–1.0	0.5–0.8	1.3–1.6	0.07–0.10
Thermal Output (Btu/kWh)	2,900–6,100	3,400–6,000	4,400–6,400	2,200–2,600	30,000–50,000
Fuel Pressure (psig) [5]	1–75	100–500 (may require fuel compressor)	50–140 (may require fuel compressor)	0.5–45	n/a

DOE CHP Fact Sheet 2017: https://energy.gov/eere/amo/chp-deployment

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Spark Spread & Best Locations for CHP

Spark Spread

Definition: Spark spread is the relative difference between the price of fuel and the price of power. Spark spread is highly dependent on the efficiency of conversion. For a CHP system, spark spread is the difference between the cost of fuel for the CHP system to produce power and heat on site and the offset cost of purchased grid power.

Spark Spread = Cost of Electricity from the grid – Cost of electricity from CHP

- If the spark spread is negative, then it is cheaper to buy electricity from the grid
- If it is positive, then it is advisable to run the CHP system

Spark Spreads

2020 Average Retail Commercial Energy prices from EIA converted to $/MMBTU using 1030 BTU/CF and 3412 BTU/KWH.

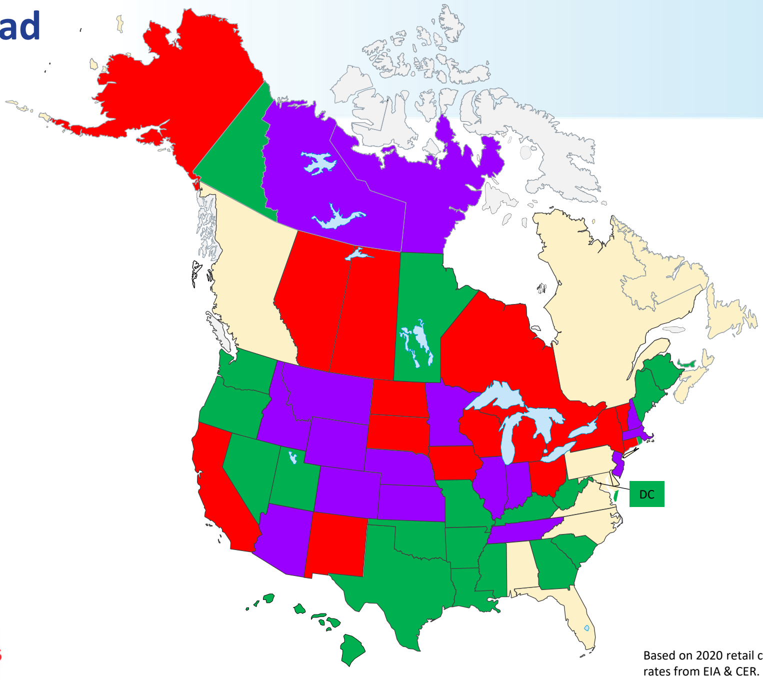
Average Commercial Retail Pricing	Gas $/MMBTU	Electric $/MMBTU	Spark Spread
U.S.	$ 7.27	$ 31.04	4.27
Alabama	$ 11.58	$ 33.85	2.92
Alaska	$ 9.62	$ 57.39	5.96
Arizona	$ 6.71	$ 29.63	4.42
Arkansas	$ 7.43	$ 25.23	3.40
California	$ 9.50	$ 51.38	5.41
Colorado	$ 6.05	$ 30.16	4.99
Connecticut	$ 9.11	$ 48.59	5.34
Delaware	$ 10.47	$ 26.91	2.57
District of Columbia	$ 10.27	$ 34.73	3.38
Florida	$ 11.17	$ 25.94	2.32
Georgia	$ 7.49	$ 29.54	3.95
Hawaii	$ 25.79	$ 83.26	3.23
Idaho	$ 5.43	$ 22.71	4.19
Illinois	$ 6.64	$ 26.82	4.04
Indiana	$ 6.66	$ 32.85	4.93
Iowa	$ 5.68	$ 29.19	5.14
Kansas	$ 7.27	$ 30.48	4.19
Kentucky	$ 8.39	$ 30.30	3.61
Louisiana	$ 8.13	$ 25.94	3.19
Maine	$ 11.03	$ 36.81	3.34
Maryland	$ 10.31	$ 28.49	2.76
Massachusetts	$ 10.87	$ 46.98	4.32
Michigan	$ 6.66	$ 34.32	5.15
Minnesota	$ 6.20	$ 30.57	4.93
Mississippi	$ 8.42	$ 30.42	3.61

Average Commercial Retail Pricing	Gas $/MMBTU	Electric $/MMBTU	Spark Spread
Missouri	$ 7.14	$ 26.17	3.67
Montana	$ 6.78	$ 30.80	4.55
Nebraska	$ 5.30	$ 26.06	4.92
Nevada	$ 7.04	$ 21.83	3.10
New Hampshire	$ 10.96	$ 45.16	4.12
New Jersey	$ 8.53	$ 36.20	4.24
New Mexico	$ 4.62	$ 30.13	6.52
New York	$ 6.68	$ 42.67	6.39
North Carolina	$ 8.75	$ 25.47	2.91
North Dakota	$ 5.11	$ 26.44	5.18
Ohio	$ 5.47	$ 27.93	5.11
Oklahoma	$ 6.73	$ 22.92	3.41
Oregon	$ 8.01	$ 26.38	3.29
Pennsylvania	$ 8.83	$ 24.91	2.82
Rhode Island	$ 11.95	$ 46.72	3.91
South Carolina	$ 8.36	$ 30.33	3.63
South Dakota	$ 5.12	$ 28.28	5.53
Tennessee	$ 7.50	$ 30.95	4.12
Texas	$ 6.33	$ 22.27	3.52
Utah	$ 6.37	$ 24.24	3.81
Vermont	$ 5.25	$ 48.04	9.15
Virginia	$ 7.88	$ 22.36	2.84
Washington	$ 8.50	$ 26.14	3.07
West Virginia	$ 7.92	$ 27.55	3.48
Wisconsin	$ 5.57	$ 31.51	5.65
Wyoming	$ 6.39	$ 28.28	4.43

Canada Energy Regulator – 2020 Macro Indicators

Commercial Retail Pricing	Gas C $/GJ	Electric C $/GJ	Spark Spread
Alberta	$ 3.30	$ 23.79	7.2
British Columbia	$ 10.91	$ 29.21	2.7
Manitoba	$ 7.10	$ 22.39	3.2
New Brunswick	$ 10.75	$ 37.52	3.5
Newfoundland & Labrador	$ 12.00	$ 28.89	2.4
Northwest Territories	$ 9.43	$ 43.79	4.6
Nova Scotia	$ 16.84	$ 41.28	2.5
Nunavut	$ 9.43	$ 43.79	4.6
Ontario	$ 6.56	$ 49.98	7.6
Prince Edward Island	$ 12.00	$ 43.71	3.6
Quebec	$ 12.80	$ 25.99	2.0
Saskatchewan	$ 7.02	$ 37.36	5.3
Yukon	$ 9.43	$ 36.80	3.9

Spark Spread



🟥 Spark Spread > 5

🟪 Spark Spread 4-5

🟩 Spark Spread 3-4

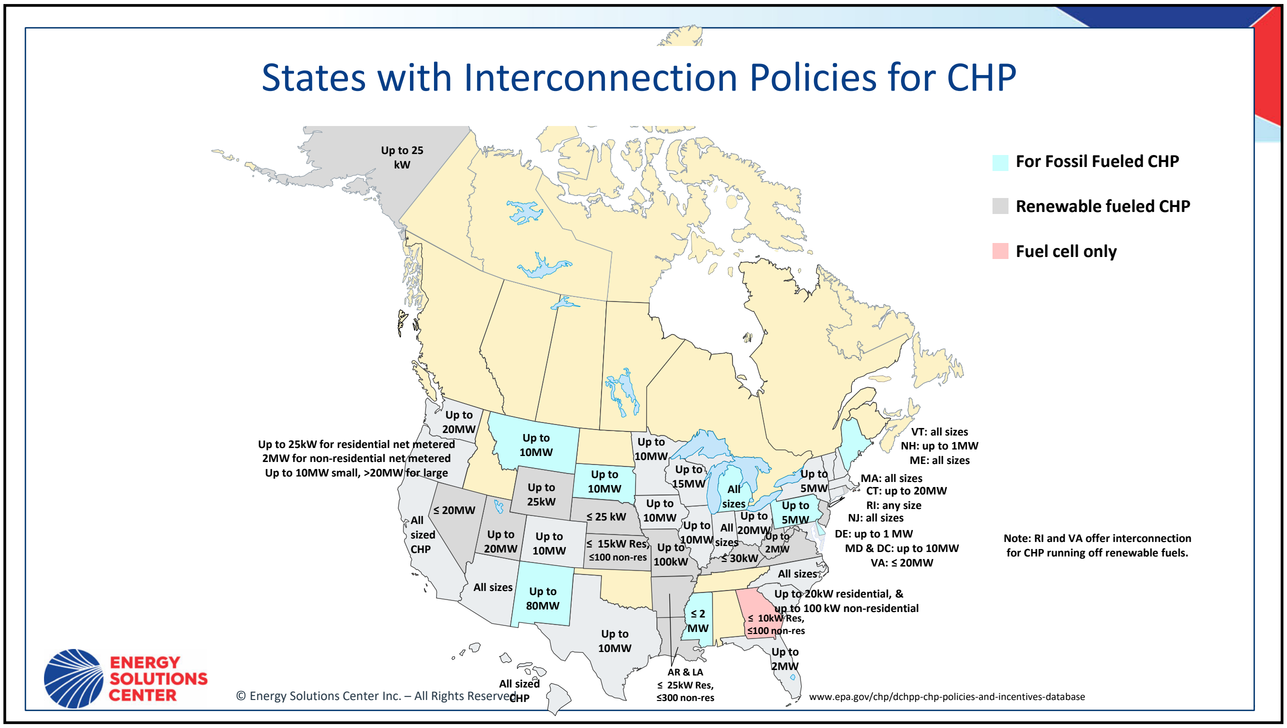
🟨 Spark Spread 2-3

A 3 or higher on a scale from 1-5 is a good spark spread. Most states and provinces have a spark spread >3.

Based on 2020 retail commercial energy rates from EIA & CER.

Interconnection

- Interconnection standards includes the technical requirements and the legal procedures whereby a customer-sited generator interfaces with the electric grid.
- Generally, the electric distribution utility must review and approve a proposed DG system within a framework established by the state's public utilities commission.
- Utilities traditionally have determined which systems may connect to the grid and under what circumstances. This arrangement presents a conflict of interest that can result in significant barriers to customer-sited CHP.
- Interconnection can be a deal killer.
- For CHP to be successful it is critical that interconnection policies are in place to allow for an easy interconnection.
- For example, a utility might apply a complicated set of procedures which are better suited to a 1,000 MW nuclear power plant than to a 100 kilowatt (kW) commercial system, or impose steep fees, redundant safety requirements and other obstacles.



States with Interconnection Policies for CHP

Note: RI and VA offer interconnection for CHP running off renewable fuels.

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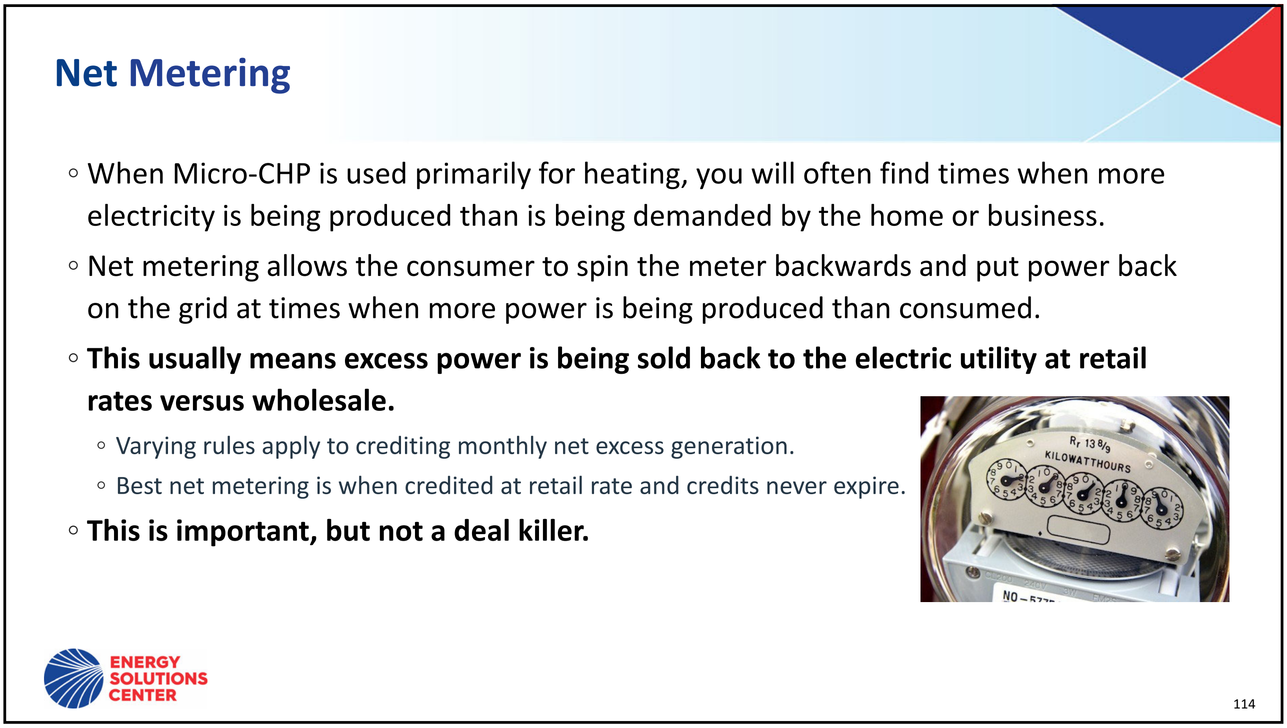
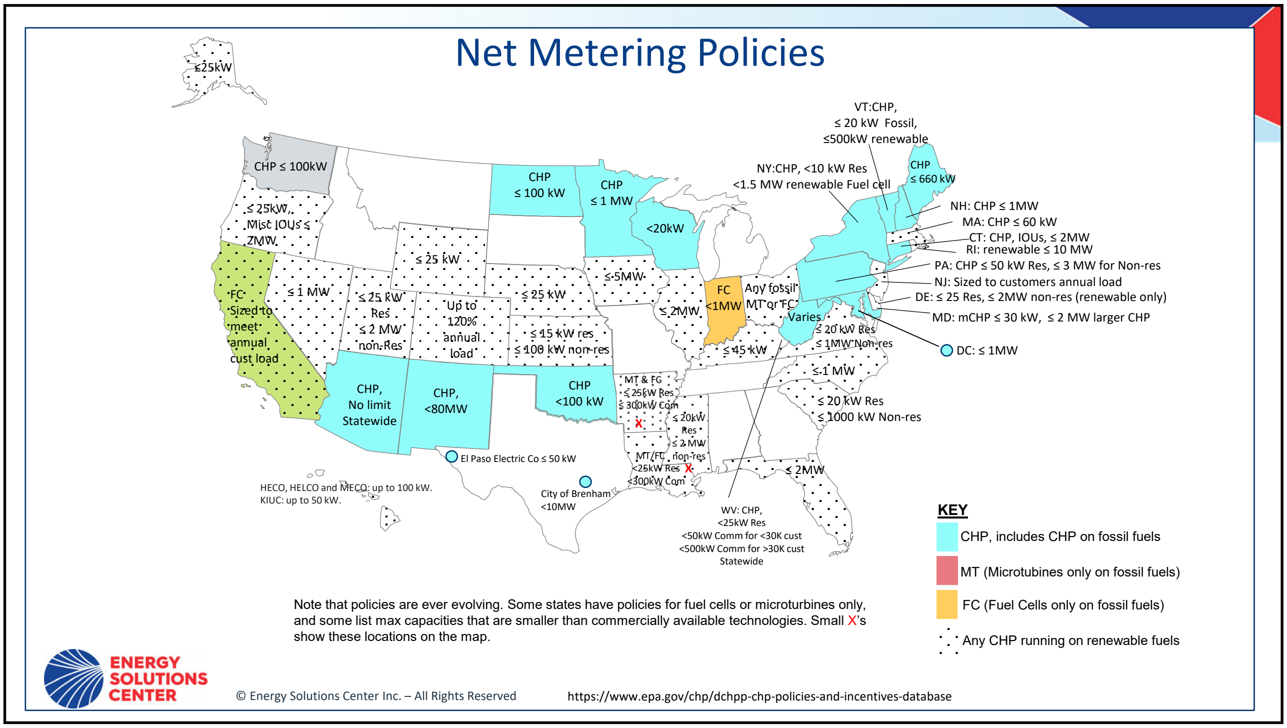
www.epa.gov/chp/dchpp-chp-policies-and-incentives-database



Net Metering

- When Micro-CHP is used primarily for heating, you will often find times when more electricity is being produced than is being demanded by the home or business.
- Net metering allows the consumer to spin the meter backwards and put power back on the grid at times when more power is being produced than consumed.
- **This usually means excess power is being sold back to the electric utility at retail rates versus wholesale.**
  - Varying rules apply to crediting monthly net excess generation.
  - Best net metering is when credited at retail rate and credits never expire.
- **This is important, but not a deal killer.**



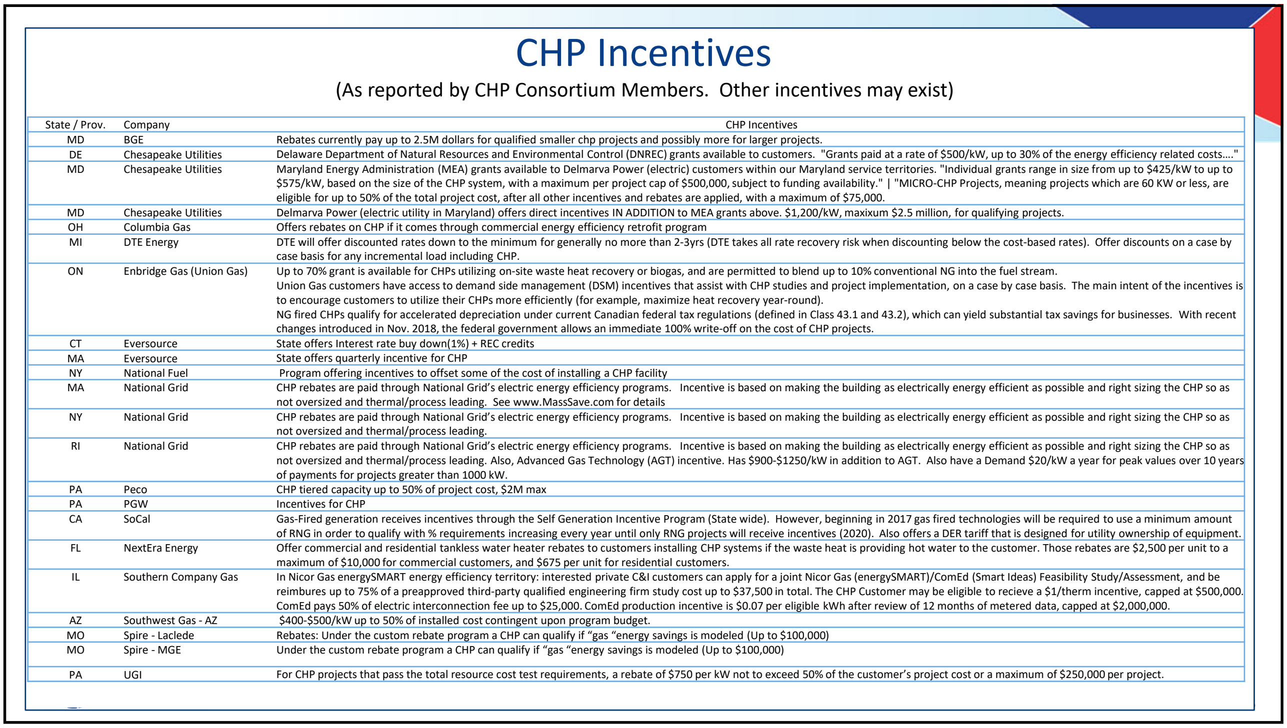
Net Metering Policies

KEY

- 🟦 CHP, includes CHP on fossil fuels
- 🟥 MT (Microtubines only on fossil fuels)
- 🟧 FC (Fuel Cells only on fossil fuels)
- ⁘ Any CHP running on renewable fuels

Note that policies are ever evolving. Some states have policies for fuel cells or microturbines only, and some list max capacities that are smaller than commercially available technologies. Small X's show these locations on the map.

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



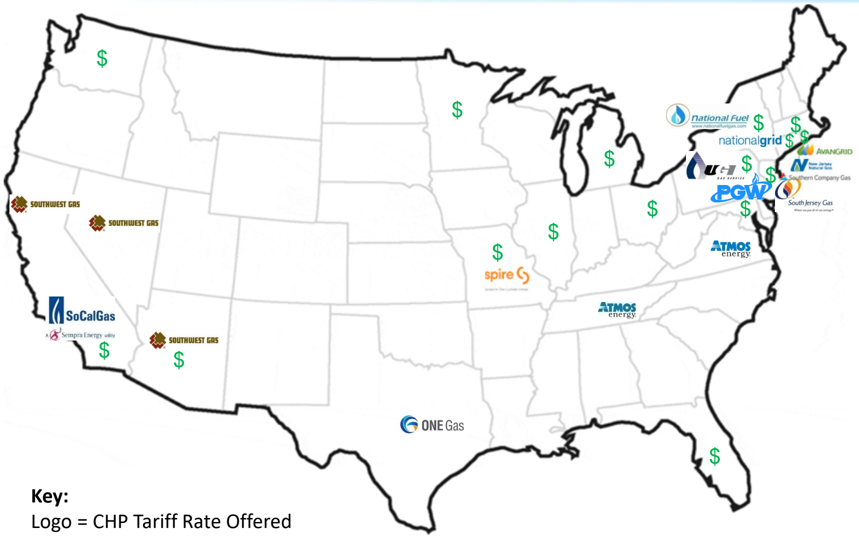
CHP Incentives

(As reported by CHP Consortium Members. Other incentives may exist)

State / Prov.	Company	CHP Incentives
MD	BGE	Rebates currently pay up to 2.5M dollars for qualified smaller chp projects and possibly more for larger projects.
DE	Chesapeake Utilities	Delaware Department of Natural Resources and Environmental Control (DNREC) grants available to customers. "Grants paid at a rate of $500/kW, up to 30% of the energy efficiency related costs…."
MD	Chesapeake Utilities	Maryland Energy Administration (MEA) grants available to Delmarva Power (electric) customers within our Maryland service territories. "Individual grants range in size from up to $425/kW to up to $575/kW, based on the size of the CHP system, with a maximum per project cap of $500,000, subject to funding availability." | "MICRO-CHP Projects, meaning projects which are 60 KW or less, are eligible for up to 50% of the total project cost, after all other incentives and rebates are applied, with a maximum of $75,000.
MD	Chesapeake Utilities	Delmarva Power (electric utility in Maryland) offers direct incentives IN ADDITION to MEA grants above. $1,200/kW, maxixum $2.5 million, for qualifying projects.
OH	Columbia Gas	Offers rebates on CHP if it comes through commercial energy efficiency retrofit program
MI	DTE Energy	DTE will offer discounted rates down to the minimum for generally no more than 2-3yrs (DTE takes all rate recovery risk when discounting below the cost-based rates). Offer discounts on a case by case basis for any incremental load including CHP.
ON	Enbridge Gas (Union Gas)	Up to 70% grant is available for CHPs utilizing on-site waste heat recovery or biogas, and are permitted to blend up to 10% conventional NG into the fuel stream. Union Gas customers have access to demand side management (DSM) incentives that assist with CHP studies and project implementation, on a case by case basis. The main intent of the incentives is to encourage customers to utilize their CHPs more efficiently (for example, maximize heat recovery year-round). NG fired CHPs qualify for accelerated depreciation under current Canadian federal tax regulations (defined in Class 43.1 and 43.2), which can yield substantial tax savings for businesses. With recent changes introduced in Nov. 2018, the federal government allows an immediate 100% write-off on the cost of CHP projects.
CT	Eversource	State offers Interest rate buy down(1%) + REC credits
MA	Eversource	State offers quarterly incentive for CHP
NY	National Fuel	Program offering incentives to offset some of the cost of installing a CHP facility
MA	National Grid	CHP rebates are paid through National Grid's electric energy efficiency programs. Incentive is based on making the building as electrically energy efficient as possible and right sizing the CHP so as not oversized and thermal/process leading. See www.MassSave.com for details
NY	National Grid	CHP rebates are paid through National Grid's electric energy efficiency programs. Incentive is based on making the building as electrically energy efficient as possible and right sizing the CHP so as not oversized and thermal/process leading.
RI	National Grid	CHP rebates are paid through National Grid's electric energy efficiency programs. Incentive is based on making the building as electrically energy efficient as possible and right sizing the CHP so as not oversized and thermal/process leading. Also, Advanced Gas Technology (AGT) incentive. Has $900-$1250/kW in addition to AGT. Also have a Demand $20/kW a year for peak values over 10 years of payments for projects greater than 1000 kW.
PA	Peco	CHP tiered capacity up to 50% of project cost, $2M max
PA	PGW	Incentives for CHP
CA	SoCal	Gas-Fired generation receives incentives through the Self Generation Incentive Program (State wide). However, beginning in 2017 gas fired technologies will be required to use a minimum amount of RNG in order to qualify with % requirements increasing every year until only RNG projects will receive incentives (2020). Also offers a DER tariff that is designed for utility ownership of equipment.
FL	NextEra Energy	Offer commercial and residential tankless water heater rebates to customers installing CHP systems if the waste heat is providing hot water to the customer. Those rebates are $2,500 per unit to a maximum of $10,000 for commercial customers, and $675 per unit for residential customers.
IL	Southern Company Gas	In Nicor Gas energySMART energy efficiency territory: interested private C&I customers can apply for a joint Nicor Gas (energySMART)/ComEd (Smart Ideas) Feasibility Study/Assessment, and be reimbures up to 75% of a preapproved third-party qualified engineering firm study cost up to $37,500 in total. The CHP Customer may be eligible to recieve a $1/therm incentive, capped at $500,000. ComEd pays 50% of electric interconnection fee up to $25,000. ComEd production incentive is $0.07 per eligible kWh after review of 12 months of metered data, capped at $2,000,000.
AZ	Southwest Gas - AZ	$400-$500/kW up to 50% of installed cost contingent upon program budget.
MO	Spire - Laclede	Rebates: Under the custom rebate program a CHP can qualify if "gas "energy savings is modeled (Up to $100,000)
MO	Spire - MGE	Under the custom rebate program a CHP can qualify if "gas "energy savings is modeled (Up to $100,000)
PA	UGI	For CHP projects that pass the total resource cost test requirements, a rebate of $750 per kW not to exceed 50% of the customer's project cost or a maximum of $250,000 per project.

Gas Utility Tariff Rates & Rebates for CHP

(This is not a comprehensive list of all CHP Tariffs or Incentives. Rates and rebates are constantly changing.)

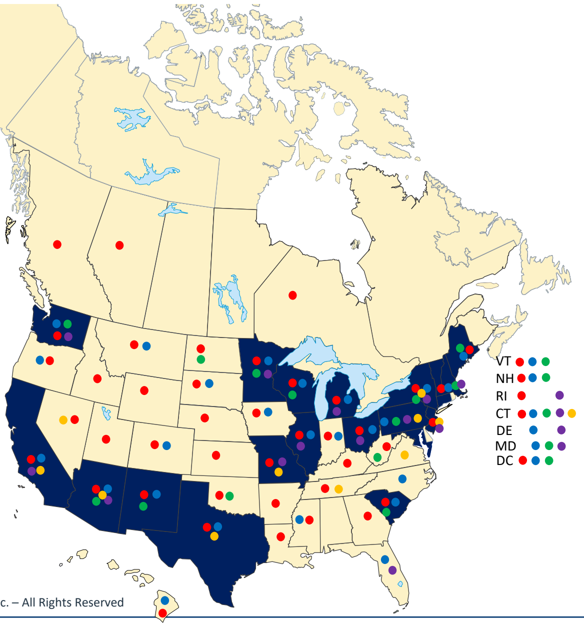


Key:
Logo = CHP Tariff Rate Offered
$ = Utility or state incentives for CHP

Best Locations for CHP

The 'Best' locations for CHP have at least 3 of the following attributes:

<u>KEY</u>
- ● Spark Spread > 3
- ● Fossil Fueled CHP Interconnection Policies
- ● Net Metering for all CHP
- ● CHP Tariff Rate
- ● State or Local Incentives



Any location with a good spark spread can be a decent opportunity for CHP.

Federal Incentives

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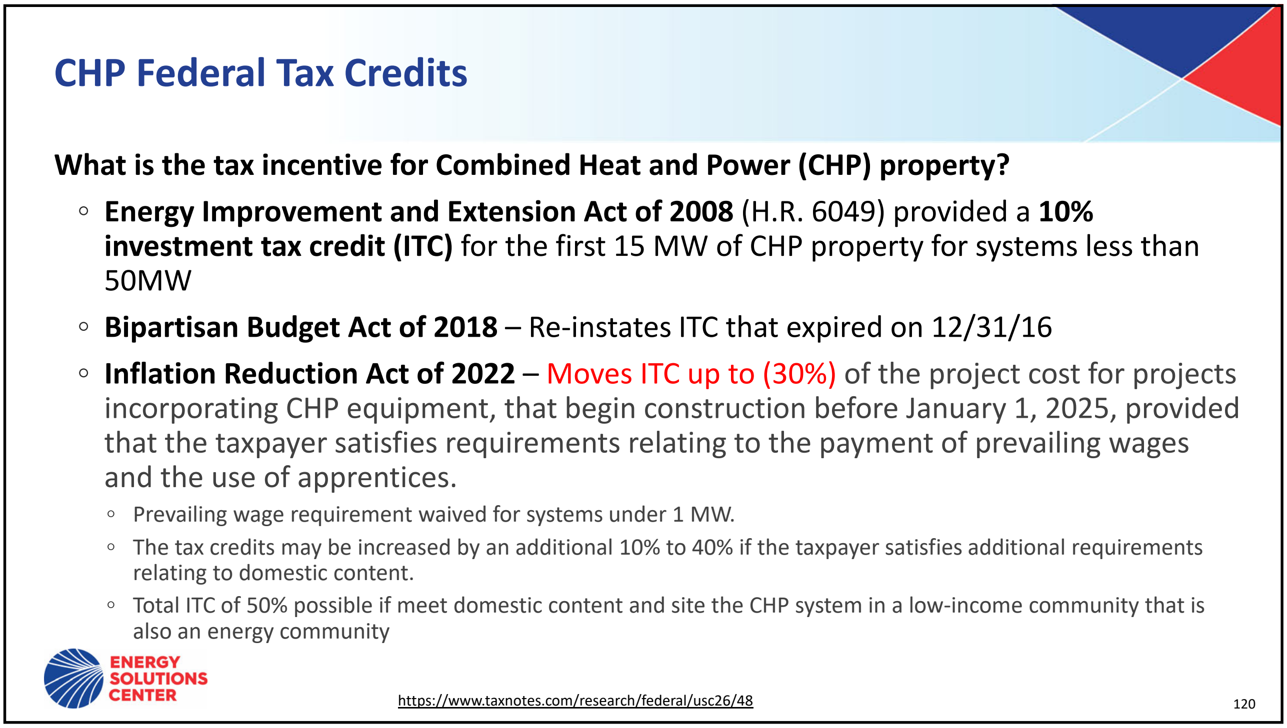
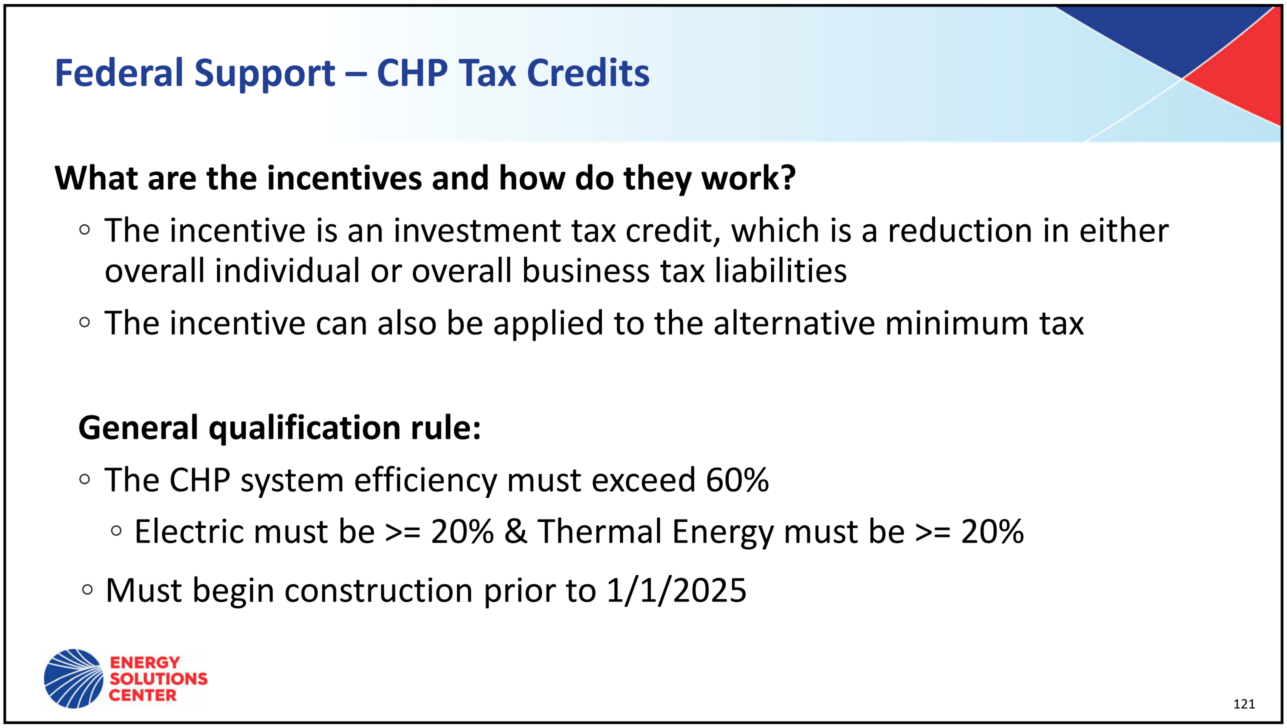


CHP Federal Tax Credits

What is the tax incentive for Combined Heat and Power (CHP) property?

- **Energy Improvement and Extension Act of 2008** (H.R. 6049) provided a **10% investment tax credit (ITC)** for the first 15 MW of CHP property for systems less than 50MW
- **Bipartisan Budget Act of 2018** – Re-instates ITC that expired on 12/31/16
- **Inflation Reduction Act of 2022** – Moves ITC up to (30%) of the project cost for projects incorporating CHP equipment, that begin construction before January 1, 2025, provided that the taxpayer satisfies requirements relating to the payment of prevailing wages and the use of apprentices.
  - Prevailing wage requirement waived for systems under 1 MW.
  - The tax credits may be increased by an additional 10% to 40% if the taxpayer satisfies additional requirements relating to domestic content.
  - Total ITC of 50% possible if meet domestic content and site the CHP system in a low-income community that is also an energy community

https://www.taxnotes.com/research/federal/usc26/48



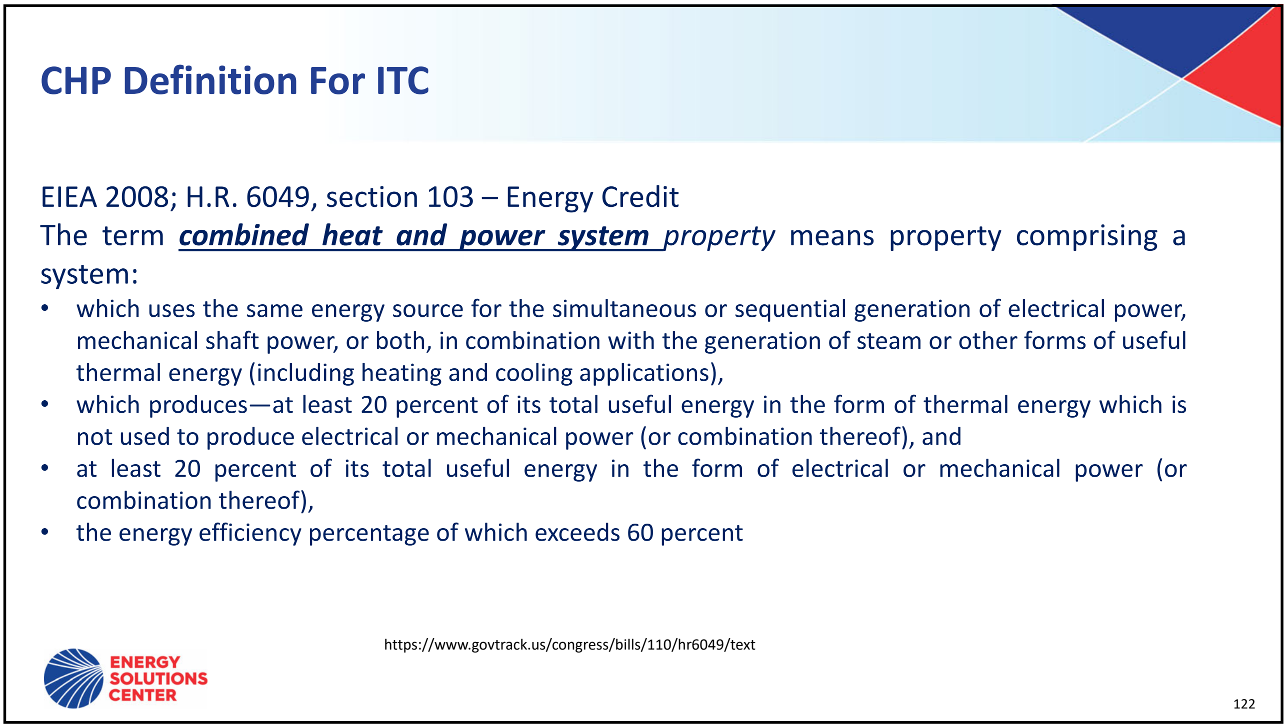
Federal Support – CHP Tax Credits

What are the incentives and how do they work?

- The incentive is an investment tax credit, which is a reduction in either overall individual or overall business tax liabilities
- The incentive can also be applied to the alternative minimum tax

General qualification rule:

- The CHP system efficiency must exceed 60%
  - Electric must be >= 20% & Thermal Energy must be >= 20%
- Must begin construction prior to 1/1/2025



CHP Definition For ITC

EIEA 2008; H.R. 6049, section 103 – Energy Credit

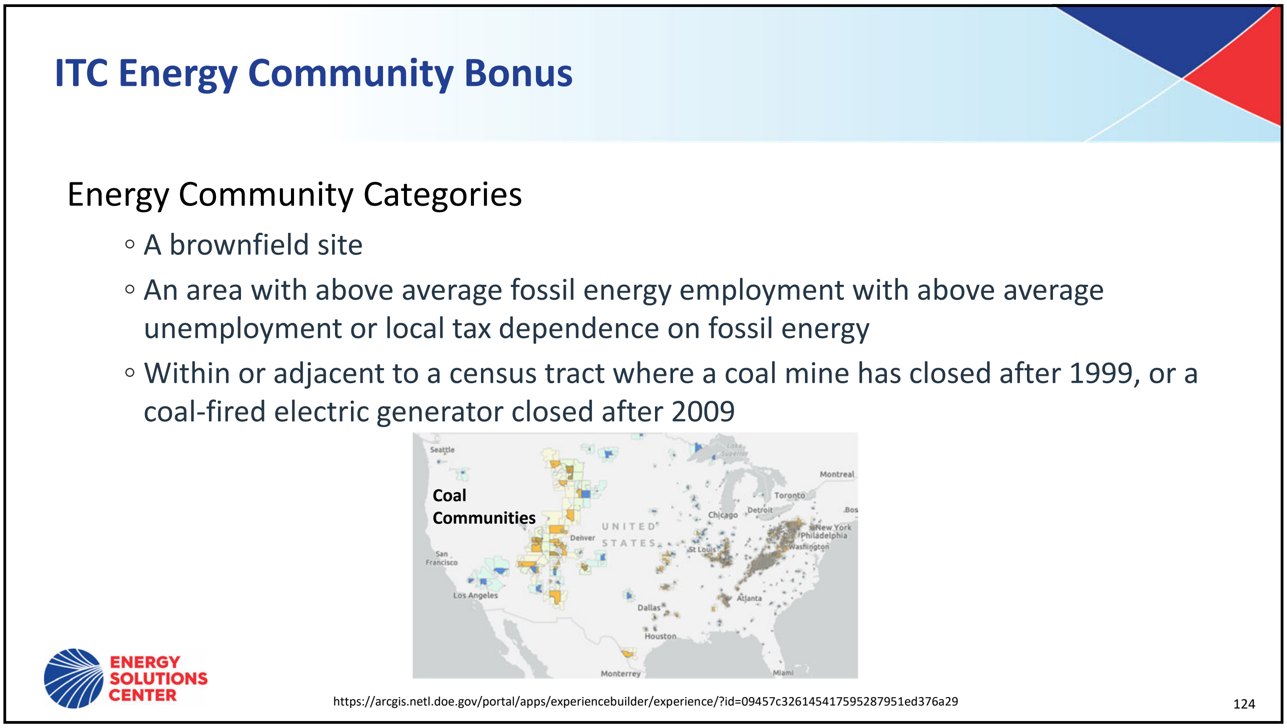
The term ***combined heat and power system*** *property* means property comprising a system:

- which uses the same energy source for the simultaneous or sequential generation of electrical power, mechanical shaft power, or both, in combination with the generation of steam or other forms of useful thermal energy (including heating and cooling applications),
- which produces—at least 20 percent of its total useful energy in the form of thermal energy which is not used to produce electrical or mechanical power (or combination thereof), and
- at least 20 percent of its total useful energy in the form of electrical or mechanical power (or combination thereof),
- the energy efficiency percentage of which exceeds 60 percent

https://www.govtrack.us/congress/bills/110/hr6049/text

ITC Wage & Apprentice Requirments

- Base rate ITC is 6% and bonus is 5X the Base rate = 30%
  - Bonus is for meeting prevailing wages and apprentice requirements.
  - Projects under 1 MW are exempt from prevailing wage and apprentice requirements
- Prevailing Wage Requirements
  - Taxpayers must ensure project workers are paid at prevailing locality wages.
- Apprentice Requirements
  - Taxpayers must ensure the applicable % of labor hours are filled by qualified apprentices:1/1/23: 10%, begins in 2023: 12.5% & begins in 2024 or later: 15%

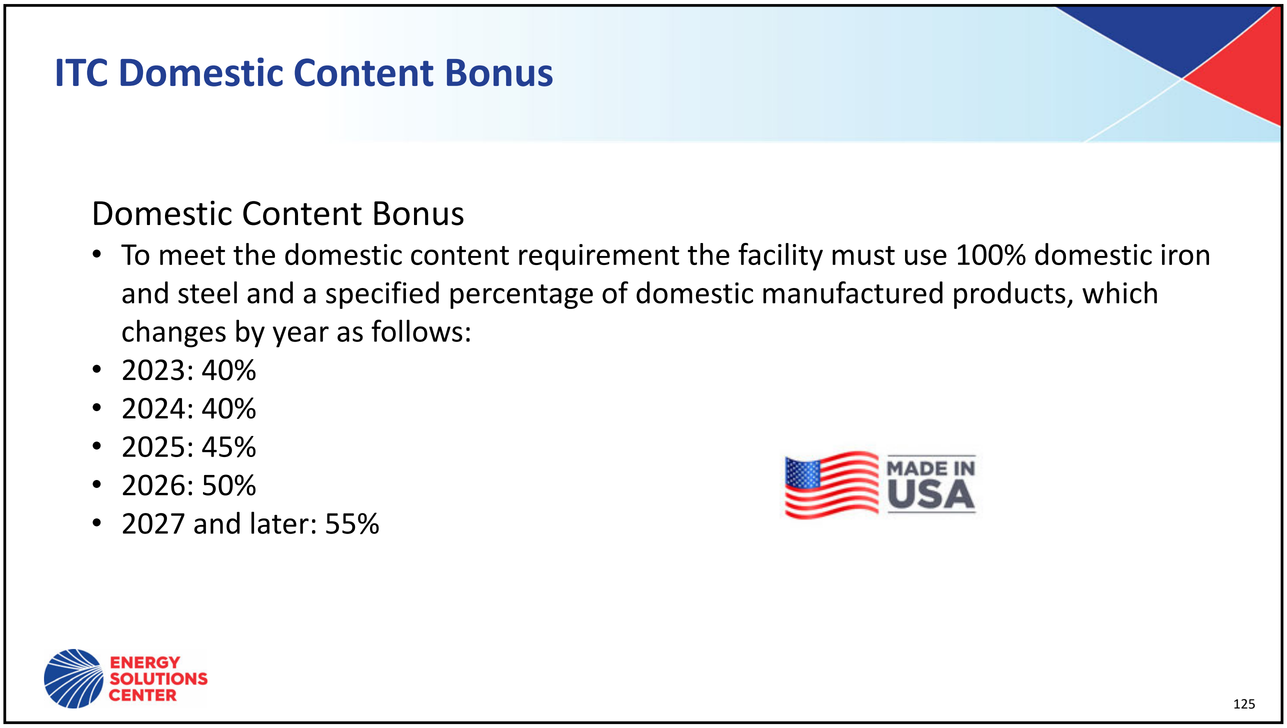


ITC Energy Community Bonus

Energy Community Categories

- A brownfield site
- An area with above average fossil energy employment with above average unemployment or local tax dependence on fossil energy
- Within or adjacent to a census tract where a coal mine has closed after 1999, or a coal-fired electric generator closed after 2009

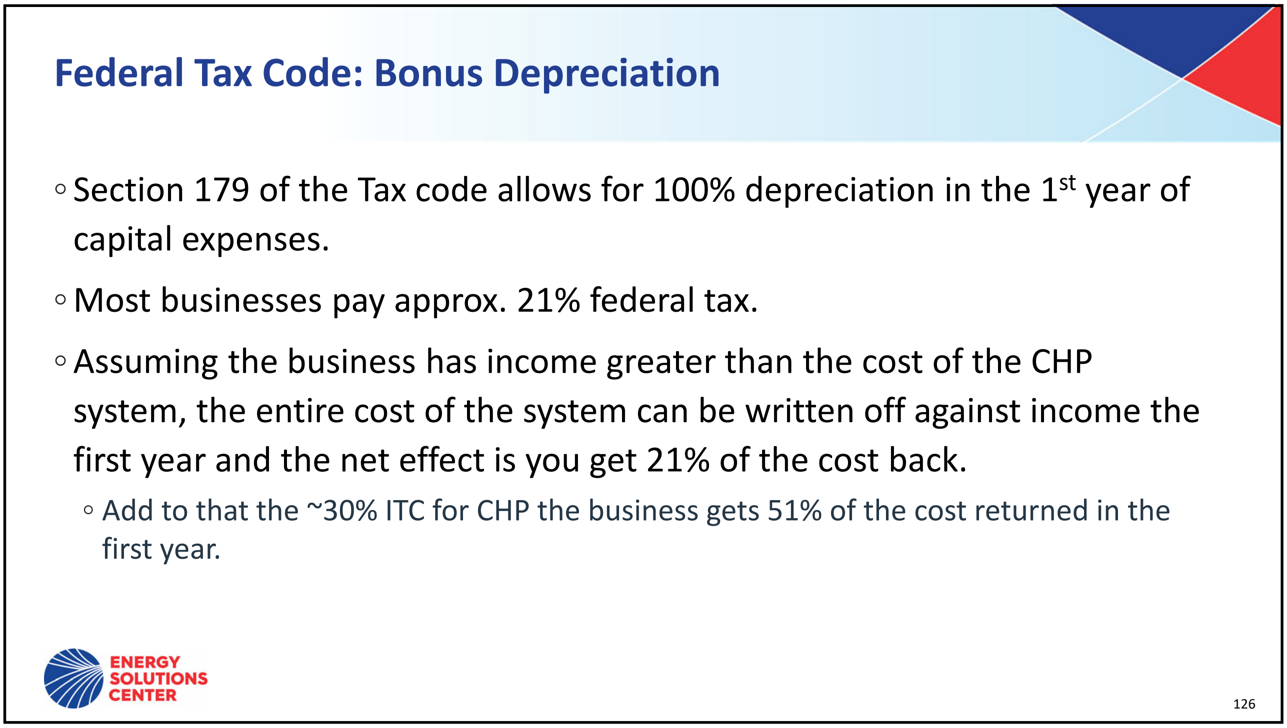
https://arcgis.netl.doe.gov/portal/apps/experiencebuilder/experience/?id=09457c326145417595287951ed376a29



ITC Domestic Content Bonus

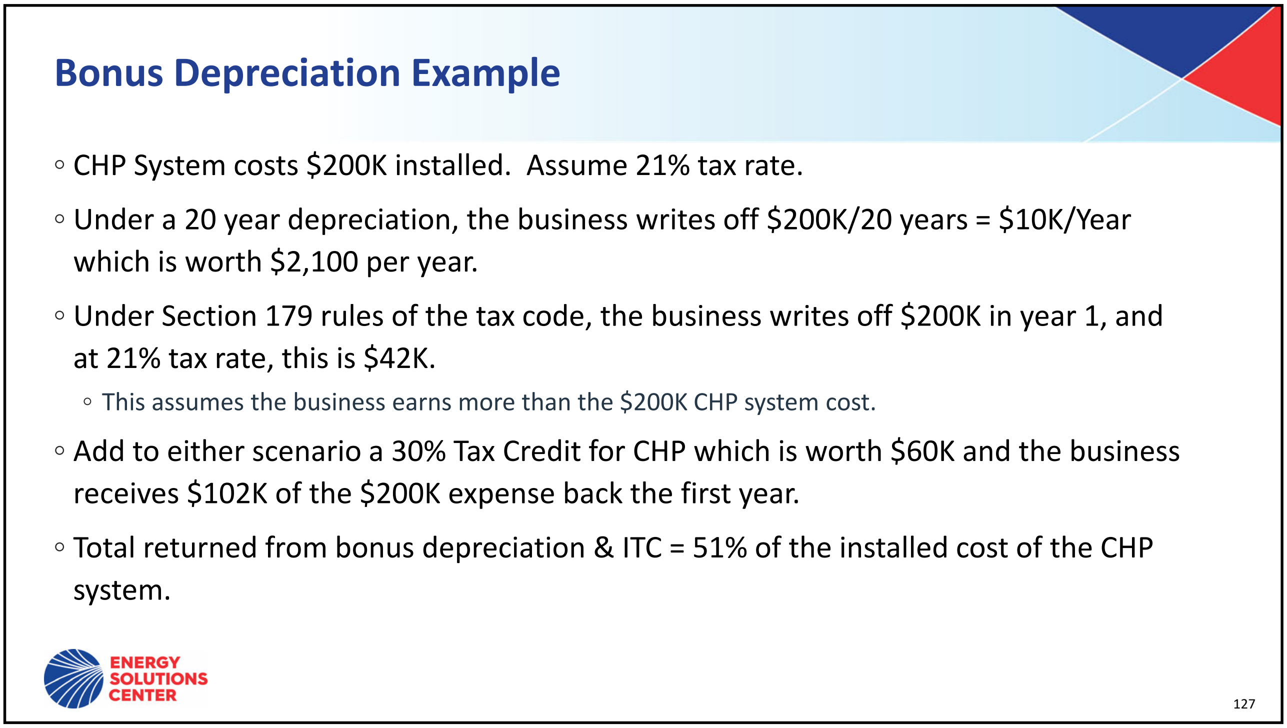
Domestic Content Bonus

- To meet the domestic content requirement the facility must use 100% domestic iron and steel and a specified percentage of domestic manufactured products, which changes by year as follows:
- 2023: 40%
- 2024: 40%
- 2025: 45%
- 2026: 50%
- 2027 and later: 55%



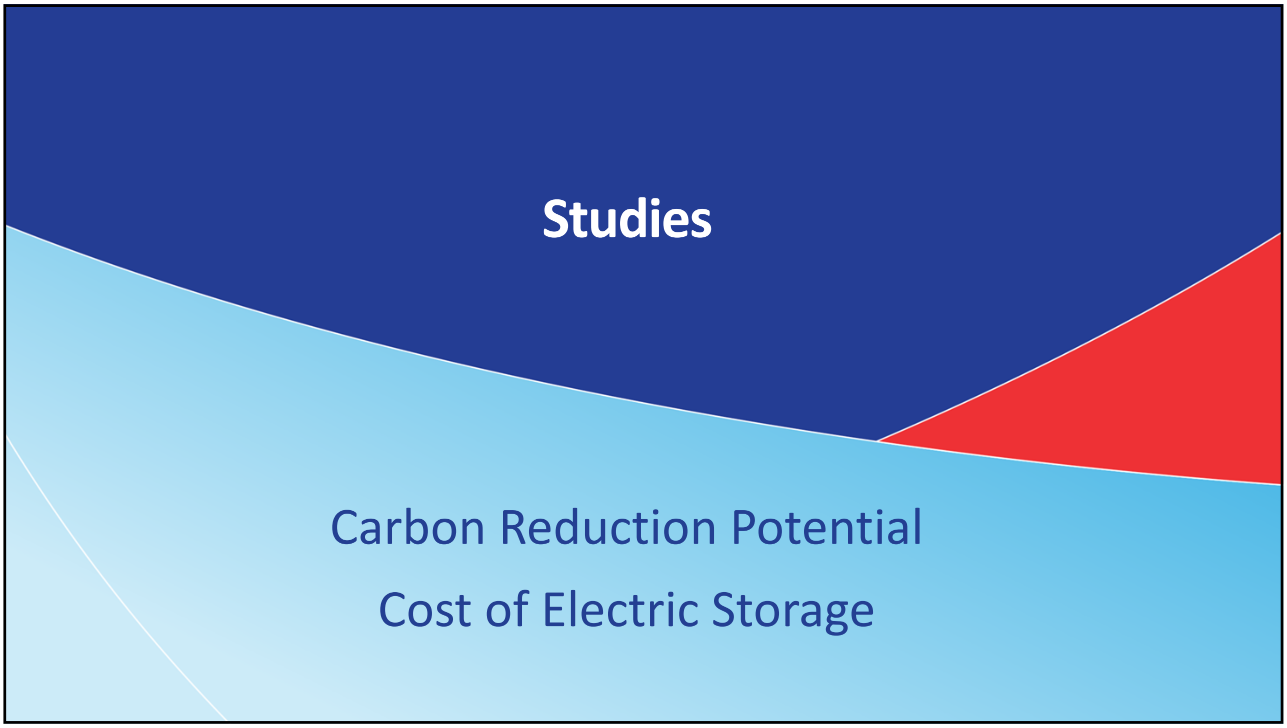
Federal Tax Code: Bonus Depreciation

- 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.



Bonus Depreciation Example

- CHP System costs $200K installed. Assume 21% tax rate.
- Under a 20 year depreciation, the business writes off $200K/20 years = $10K/Year which is worth $2,100 per year.
- Under Section 179 rules of the tax code, the business writes off $200K in year 1, and at 21% tax rate, this is $42K.
  - This assumes the business earns more than the $200K CHP system cost.
- Add to either scenario a 30% Tax Credit for CHP which is worth $60K and the business receives $102K of the $200K expense back the first year.
- Total returned from bonus depreciation & ITC = 51% of the installed cost of the CHP system.

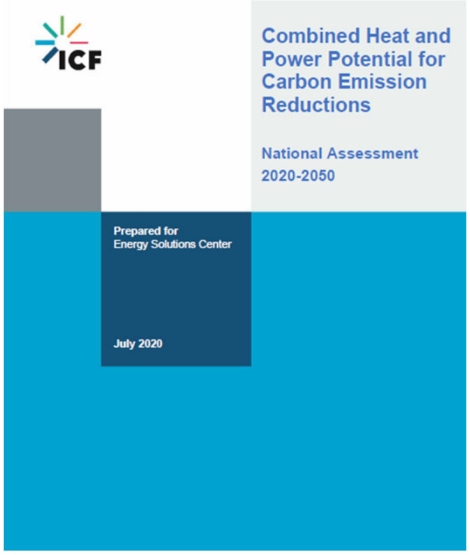


Studies

Carbon Reduction Potential

Cost of Electric Storage

CHP Carbon Reduction Potential Study



ICF

Combined Heat and Power Potential for Carbon Emission Reductions

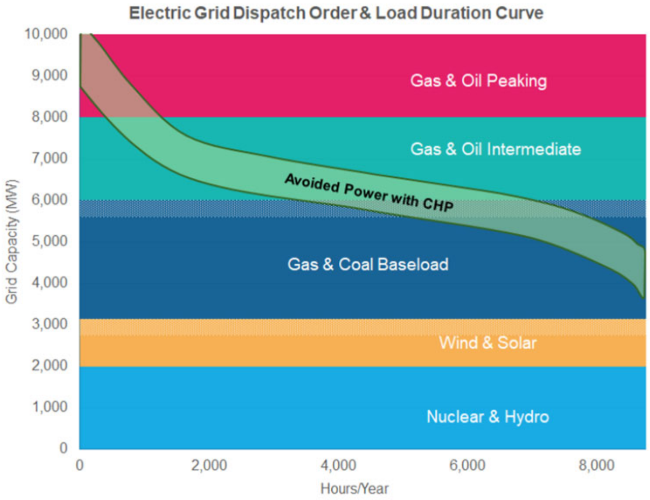
National Assessment
2020-2050

Prepared for
Energy Solutions Center

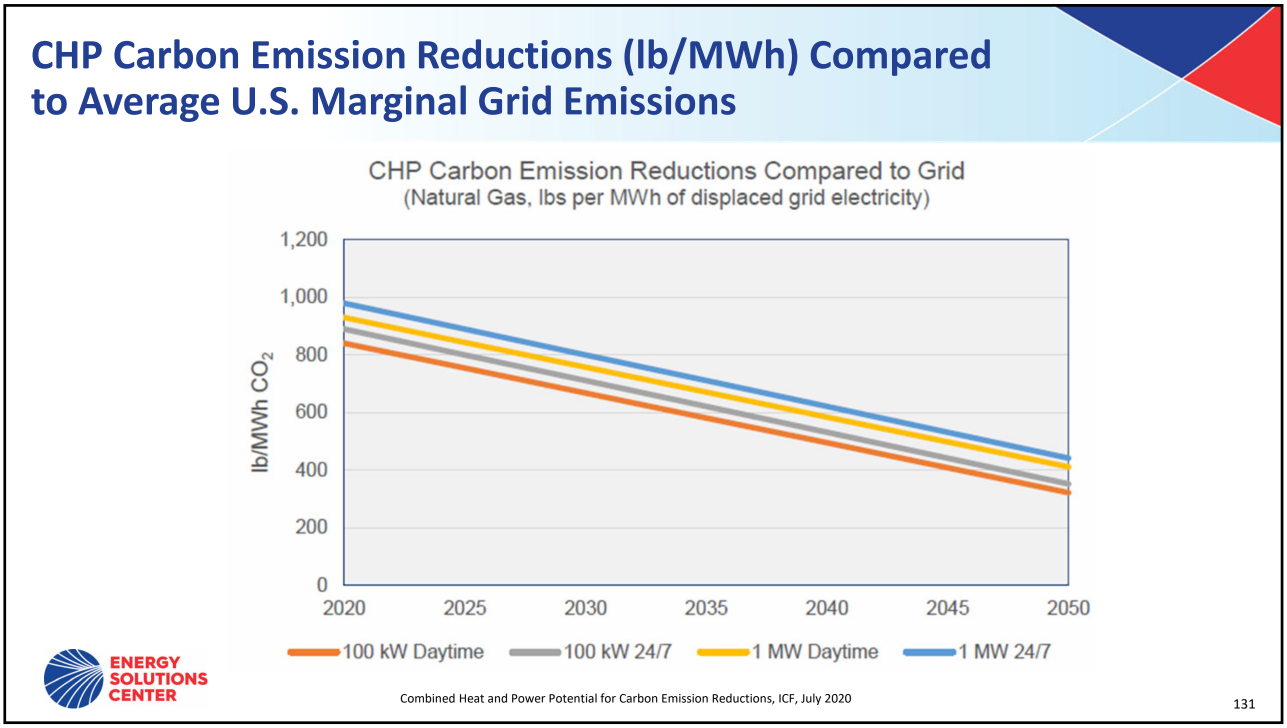
July 2020

Study for ESC by
ICF, July 2020

Avoided Power with CHP Example

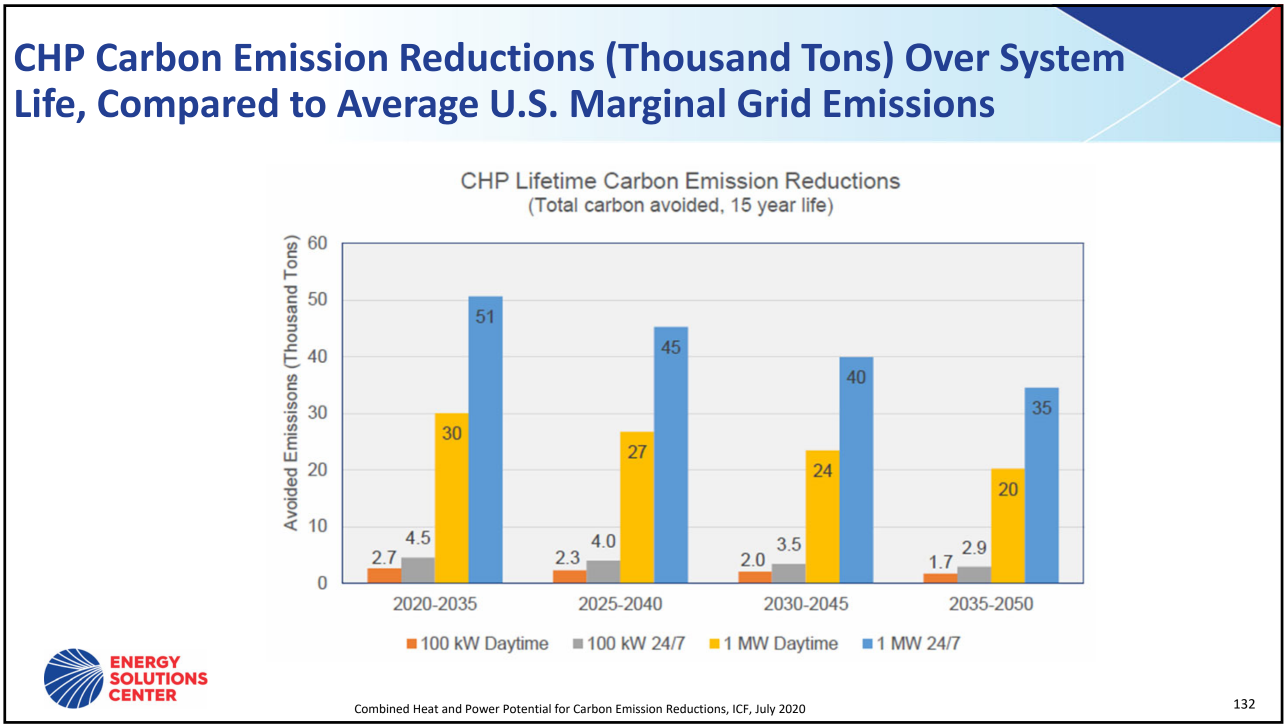


Combined Heat and Power Potential for Carbon Emission Reductions, ICF, July 2020



CHP Carbon Emission Reductions (lb/MWh) Compared to Average U.S. Marginal Grid Emissions

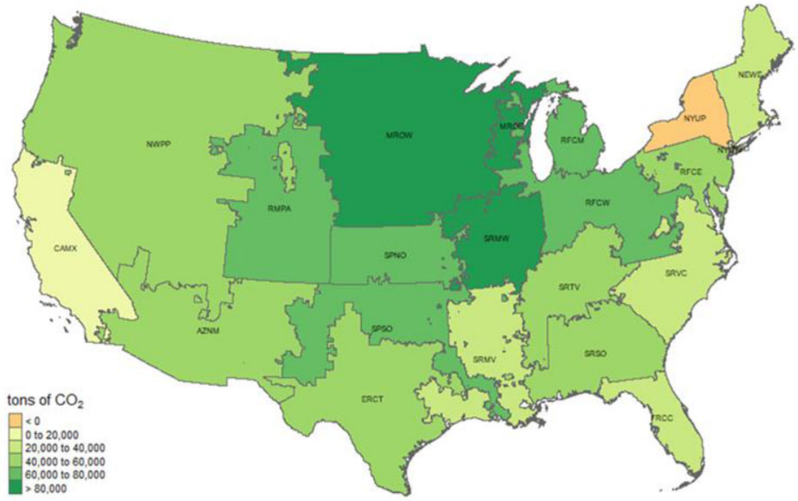
Combined Heat and Power Potential for Carbon Emission Reductions, ICF, July 2020



CHP Carbon Emission Reductions (Thousand Tons) Over System Life, Compared to Average U.S. Marginal Grid Emissions

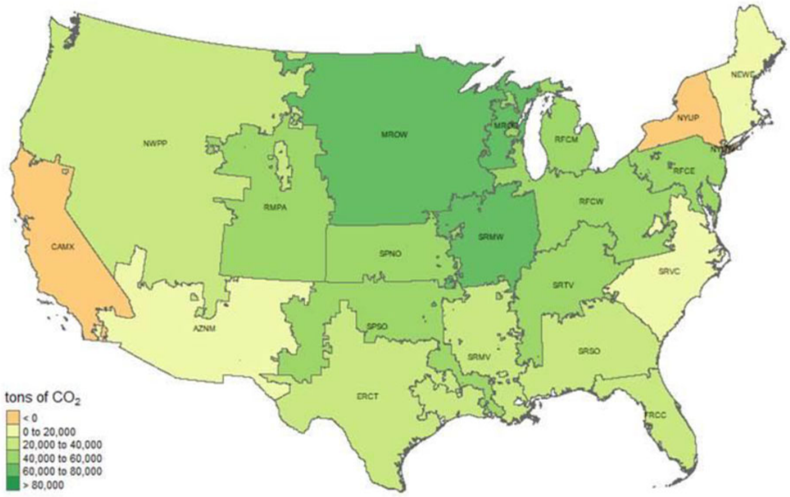
Combined Heat and Power Potential for Carbon Emission Reductions, ICF, July 2020

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

Lifetime Carbon Emission Reductions for 1 MW 24/7 CHP System on Natural Gas, installed in 2035 and retired in 2050



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

Energy Storage Cost Comparison

ICF

Energy Storage Comparison Analysis with Gas-Fueled Technologies

Prepared for
Energy Solutions Center

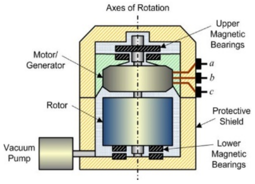
August 2020

Study for ESC by ICF,
September 2020

Short-Duration Technologies

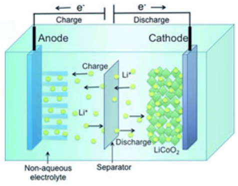
Flywheel Energy Storage

- Kinetic energy stored in rotating mass, released for short duration (minutes to ~2 hours)
- Near-instant dispatch response time, multiple daily cycles
- Used for: Grid frequency and voltage stabilization, Uninterruptable power supply (UPS)



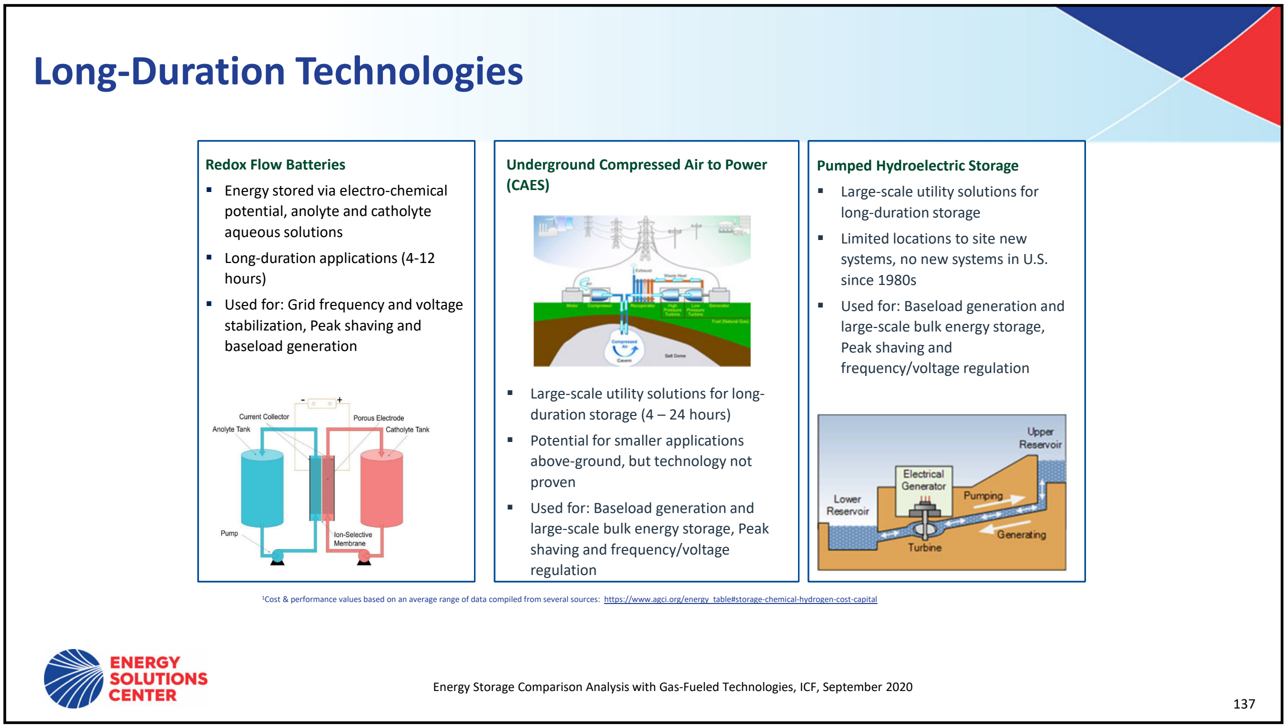
Lithium-Ion Batteries

- Energy stored via electro-chemical potential
- Improving cost and performance, with installed costs reduced 50% by 2030
- Used for: Grid frequency and voltage stabilization, Demand response, ancillary services, backup power



[1] Cost & performance values based on an average range of data compiled from several sources: https://www.agci.org/energy_table#storage-chemical-hydrogen-cost-capital

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



Long-Duration Technologies

Redox Flow Batteries

- Energy stored via electro-chemical potential, anolyte and catholyte aqueous solutions
- Long-duration applications (4-12 hours)
- Used for: Grid frequency and voltage stabilization, Peak shaving and baseload generation

Underground Compressed Air to Power (CAES)

- Large-scale utility solutions for long-duration storage (4 – 24 hours)
- Potential for smaller applications above-ground, but technology not proven
- Used for: Baseload generation and large-scale bulk energy storage, Peak shaving and frequency/voltage regulation

Pumped Hydroelectric Storage

- Large-scale utility solutions for long-duration storage
- Limited locations to site new systems, no new systems in U.S. since 1980s
- Used for: Baseload generation and large-scale bulk energy storage, Peak shaving and frequency/voltage regulation

[1] Cost & performance values based on an average range of data compiled from several sources: https://www.agci.org/energy_table#storage-chemical-hydrogen-cost-capital

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

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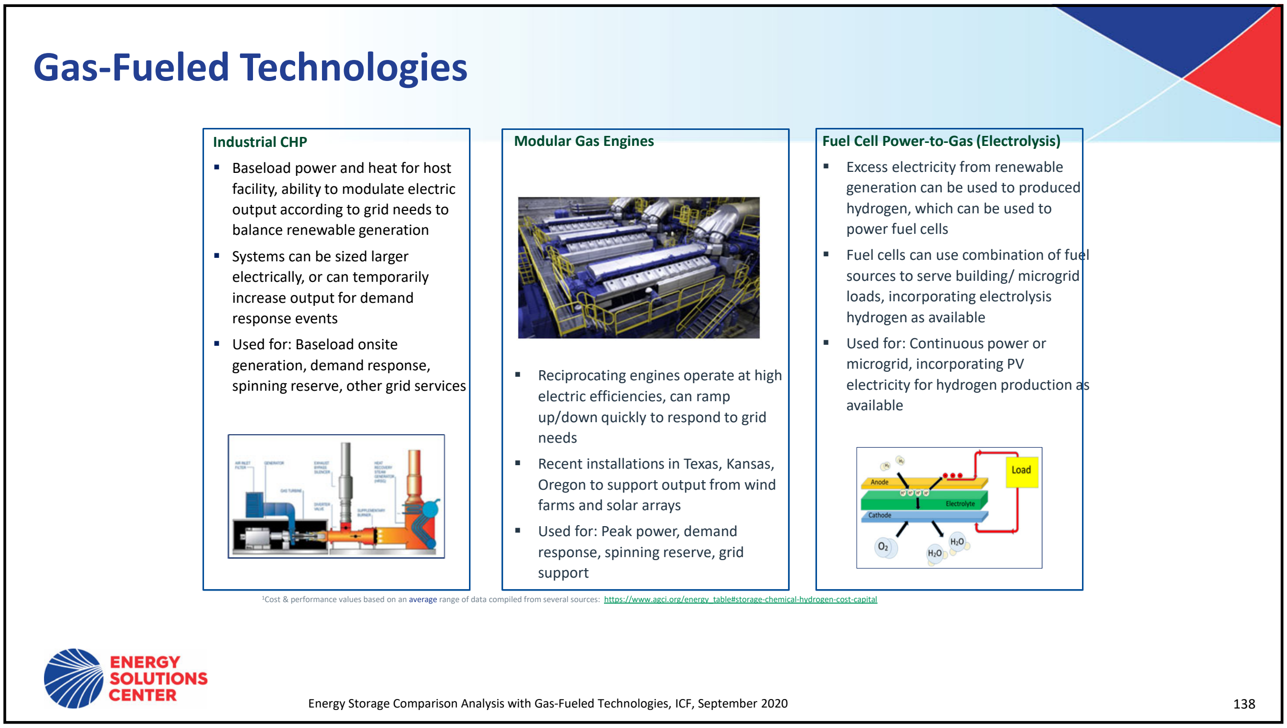

Gas-Fueled Technologies

Industrial CHP

- Baseload power and heat for host facility, ability to modulate electric output according to grid needs to balance renewable generation
- Systems can be sized larger electrically, or can temporarily increase output for demand response events
- Used for: Baseload onsite generation, demand response, spinning reserve, other grid services

Modular Gas Engines

- Reciprocating engines operate at high electric efficiencies, can ramp up/down quickly to respond to grid needs
- Recent installations in Texas, Kansas, Oregon to support output from wind farms and solar arrays
- Used for: Peak power, demand response, spinning reserve, grid support

Fuel Cell Power-to-Gas (Electrolysis)

- Excess electricity from renewable generation can be used to produced hydrogen, which can be used to power fuel cells
- Fuel cells can use combination of fuel sources to serve building/ microgrid loads, incorporating electrolysis hydrogen as available
- Used for: Continuous power or microgrid, incorporating PV electricity for hydrogen production as available

[1] Cost & performance values based on an average range of data compiled from several sources: https://www.agci.org/energy_table#storage-chemical-hydrogen-cost-capital

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

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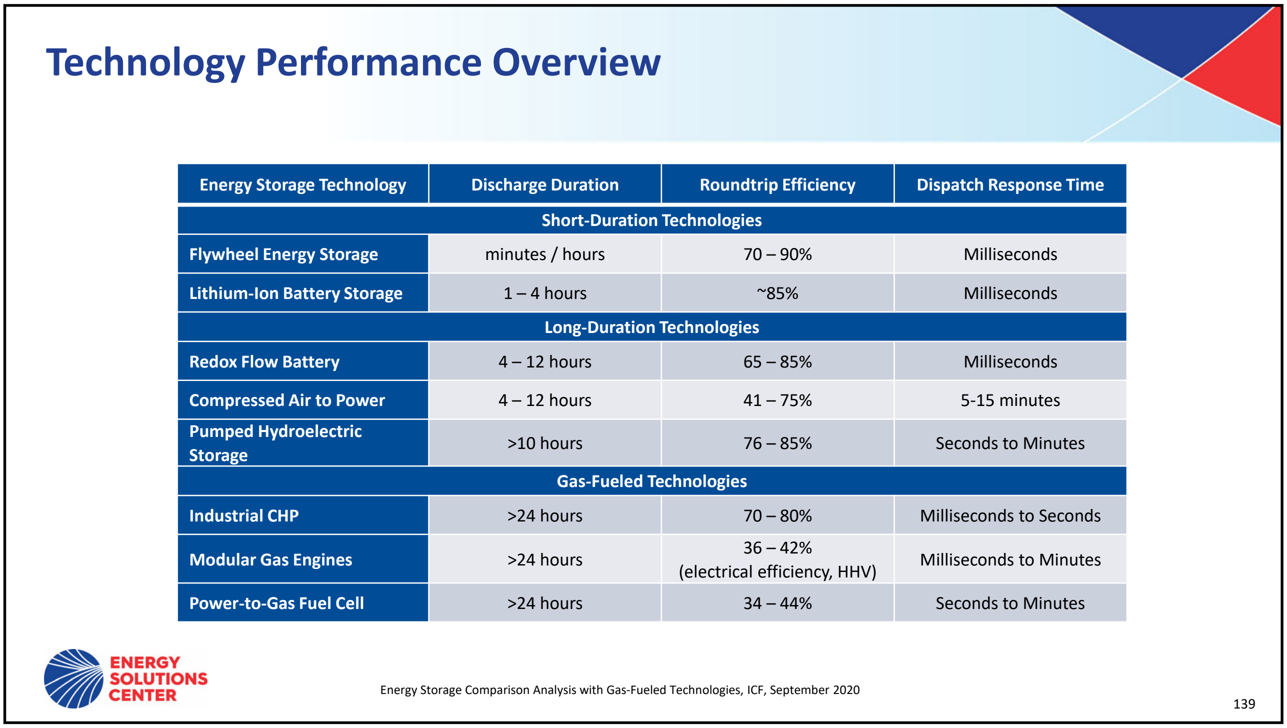
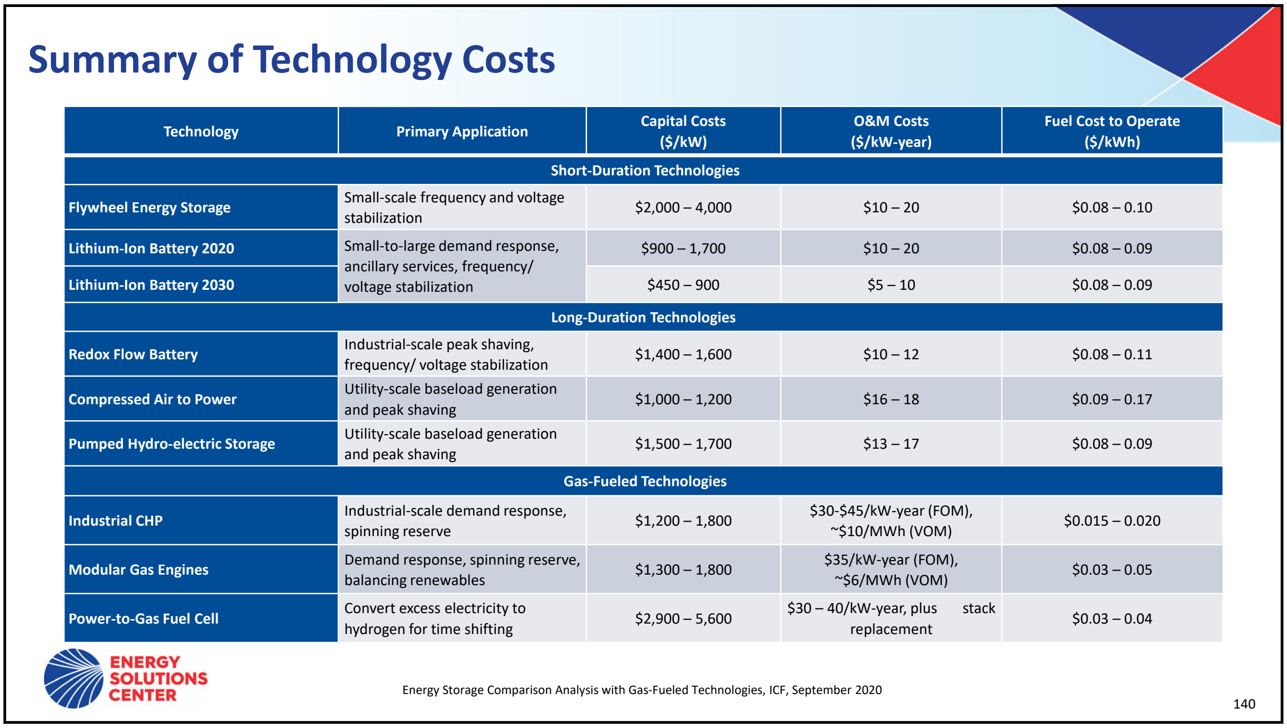


Technology Performance Overview

Energy Storage Technology	Discharge Duration	Roundtrip Efficiency	Dispatch Response Time
Short-Duration Technologies			
Flywheel Energy Storage	minutes / hours	70 – 90%	Milliseconds
Lithium-Ion Battery Storage	1 – 4 hours	~85%	Milliseconds
Long-Duration Technologies			
Redox Flow Battery	4 – 12 hours	65 – 85%	Milliseconds
Compressed Air to Power	4 – 12 hours	41 – 75%	5-15 minutes
Pumped Hydroelectric Storage	>10 hours	76 – 85%	Seconds to Minutes
Gas-Fueled Technologies			
Industrial CHP	>24 hours	70 – 80%	Milliseconds to Seconds
Modular Gas Engines	>24 hours	36 – 42% (electrical efficiency, HHV)	Milliseconds to Minutes
Power-to-Gas Fuel Cell	>24 hours	34 – 44%	Seconds to Minutes

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

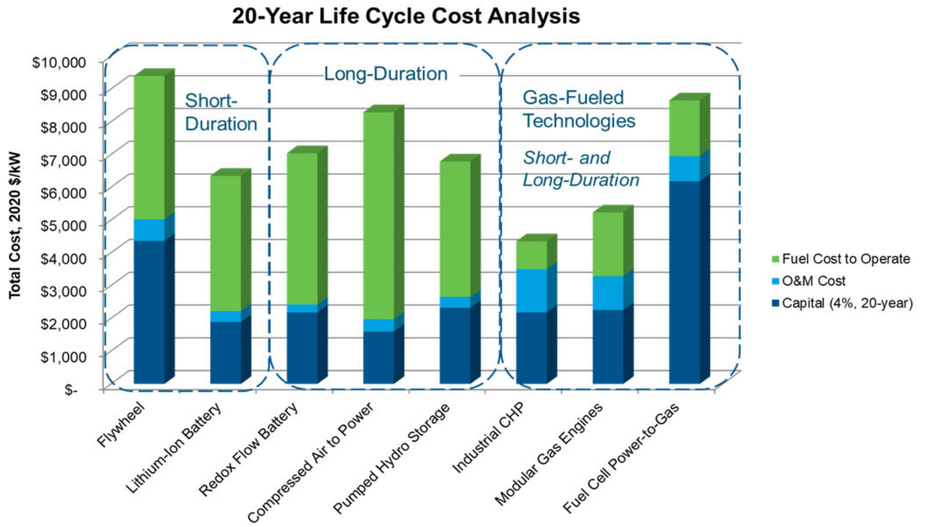


Summary of Technology Costs

Technology	Primary Application	Capital Costs ($/kW)	O&M Costs ($/kW-year)	Fuel Cost to Operate ($/kWh)
Short-Duration Technologies				
Flywheel Energy Storage	Small-scale frequency and voltage stabilization	$2,000 – 4,000	$10 – 20	$0.08 – 0.10
Lithium-Ion Battery 2020	Small-to-large demand response, ancillary services, frequency/ voltage stabilization	$900 – 1,700	$10 – 20	$0.08 – 0.09
Lithium-Ion Battery 2030		$450 – 900	$5 – 10	$0.08 – 0.09
Long-Duration Technologies				
Redox Flow Battery	Industrial-scale peak shaving, frequency/ voltage stabilization	$1,400 – 1,600	$10 – 12	$0.08 – 0.11
Compressed Air to Power	Utility-scale baseload generation and peak shaving	$1,000 – 1,200	$16 – 18	$0.09 – 0.17
Pumped Hydro-electric Storage	Utility-scale baseload generation and peak shaving	$1,500 – 1,700	$13 – 17	$0.08 – 0.09
Gas-Fueled Technologies				
Industrial CHP	Industrial-scale demand response, spinning reserve	$1,200 – 1,800	$30-$45/kW-year (FOM), ~$10/MWh (VOM)	$0.015 – 0.020
Modular Gas Engines	Demand response, spinning reserve, balancing renewables	$1,300 – 1,800	$35/kW-year (FOM), ~$6/MWh (VOM)	$0.03 – 0.05
Power-to-Gas Fuel Cell	Convert excess electricity to hydrogen for time shifting	$2,900 – 5,600	$30 – 40/kW-year, plus stack replacement	$0.03 – 0.04

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

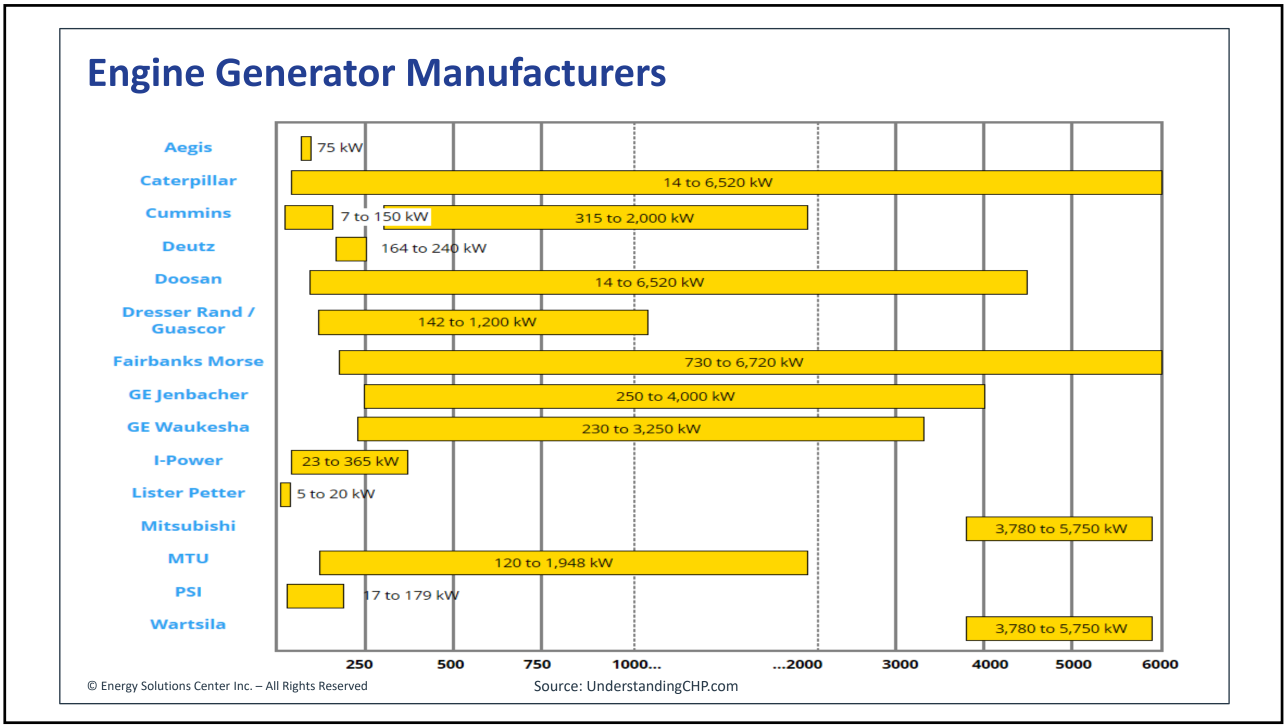
Technology Comparison



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

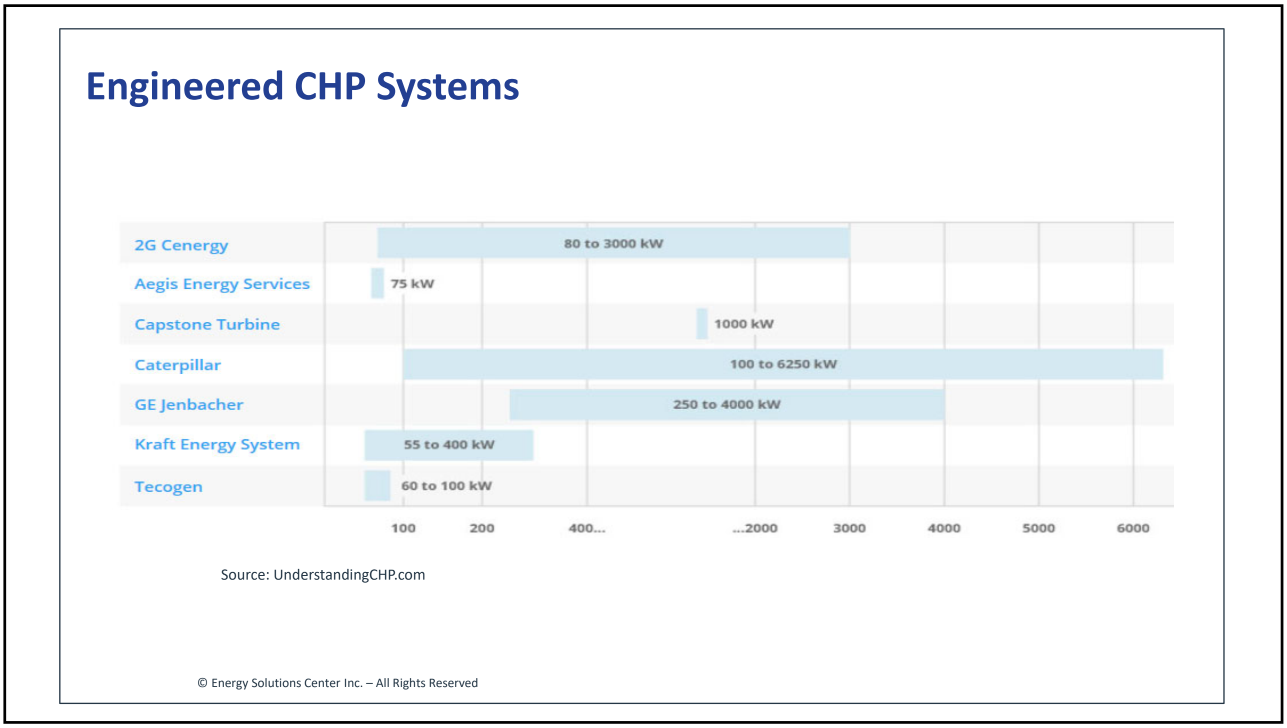
Equipment Supplier Resources

Numerous manufacturers offer equipment to supply electricity and thermal heat. Refer to the following listing or visit the ESC website for an additional listing of vendors.



Engine Generator Manufacturers

Source: UnderstandingCHP.com



Engineered CHP Systems

Source: UnderstandingCHP.com

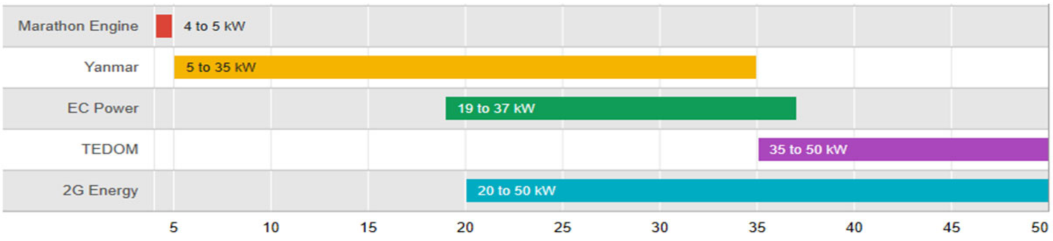
Microturbine Manufacturers

Source: UnderstandingCHP.com

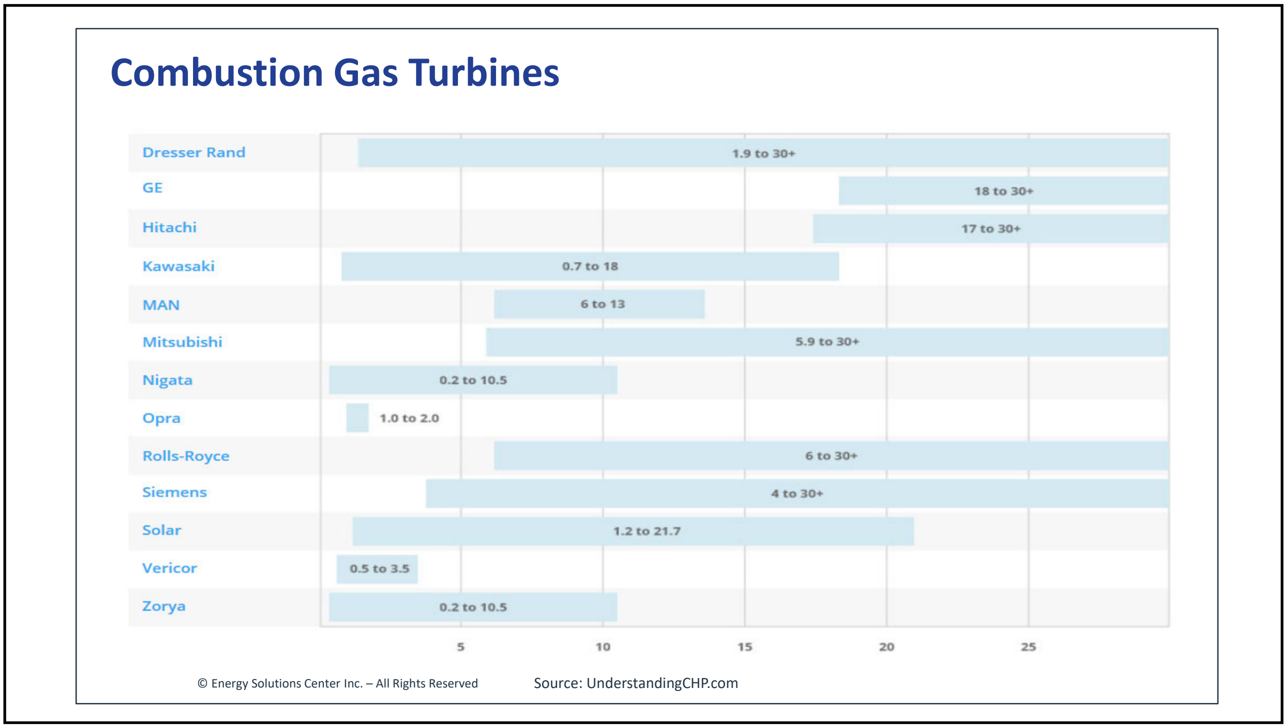
Micro CHP

Micro CHP Systems Manufacturers

This section of our website provides information on the manufacturers of **Micro CHP Systems**. *Click on the company name to be redirected to the company website.*



Source: UnderstandingCHP.com



Combustion Gas Turbines

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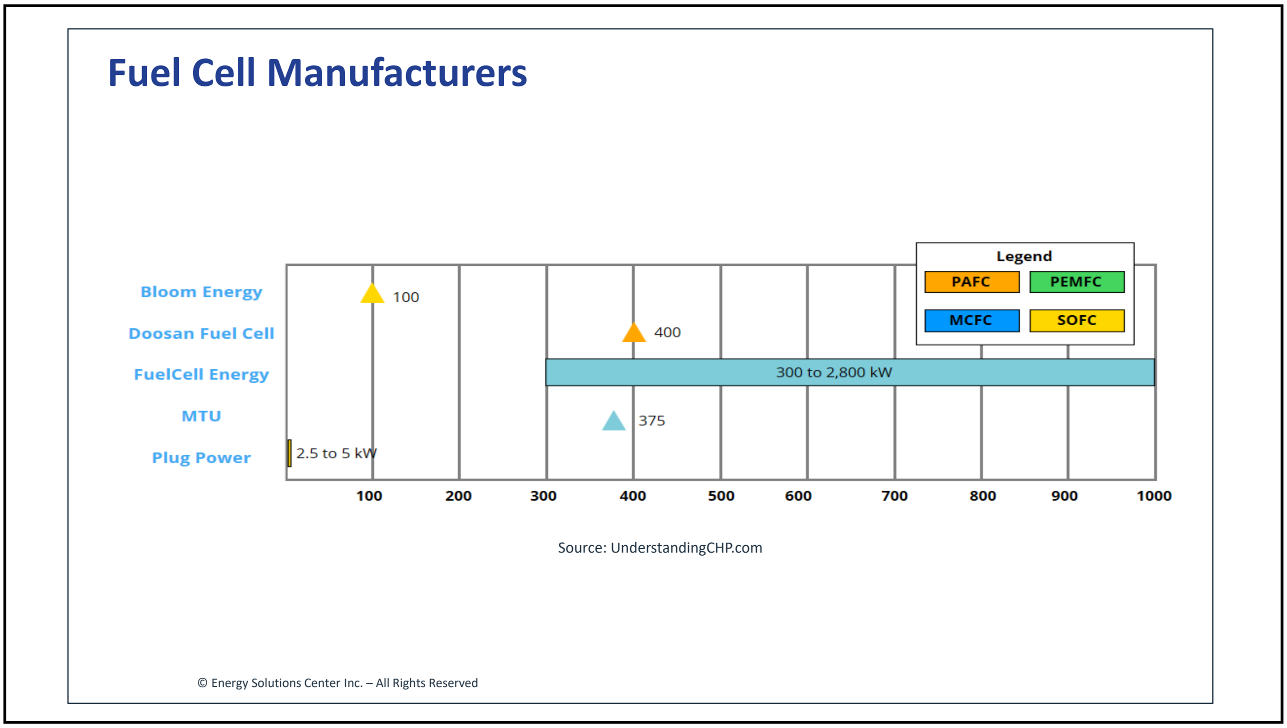
Source: UnderstandingCHP.com



Fuel Cell Manufacturers

Source: UnderstandingCHP.com

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Other CHP Resources

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

CHP Resources

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.

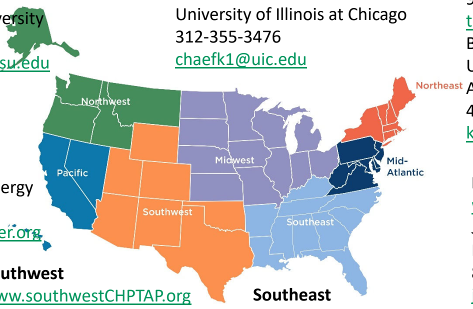
This form of power generation is known today by many names and acronyms. Cogeneration, or combined heat and power (CHP) are two. CHP is not a single technology, but an integrated energy system that can be modified depending upon the needs of the energy end user. These systems simply capture and utilize 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

DOE CHP Technical Assistance Partnerships for CHP (CHP TAPs)



Northwest
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Beka Kosanovic, Ph.D.
University of Massachusetts Amherst
413-545-0684
kosanovi@ecs.umass.edu

Mid-Atlantic
www.midatlanticCHPTAP.org
Jim Freihaut, Ph.D.
Pennsylvania State University
814-863-0083
jdf11@psu.edu

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

Regional Application Centers: Technical Assistance

Feasibility Steps

- Phone and Meeting Inquiries
- Site Data Collection
- Level I – Screening Analysis
- Level II – Conceptual / Financial Analysis
- Level III – Investment Grade Study
- Procurement / Installation / Operation

RAC Capabilities

- **Analysis Performance thru Level II**
- **Consulting Expertise thru all Steps**
- **Bringing customers and CHP engineering community together**

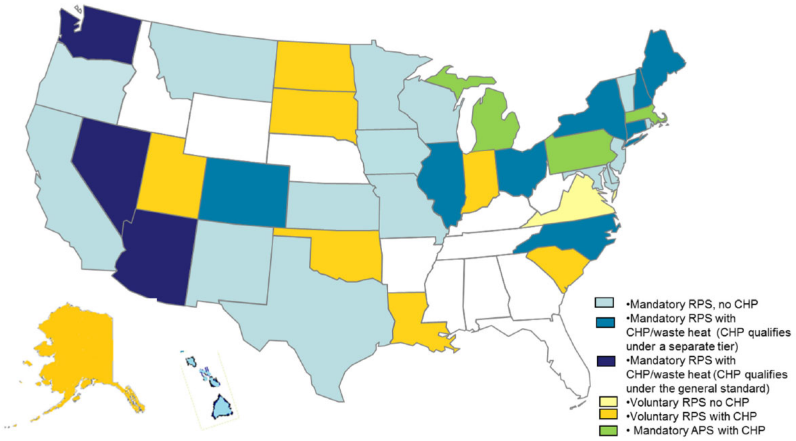
RAC Accomplishments

- **Over 285 assessments and over 1,000 technical support activities**
- **Represents over 1.8 GW installed and / or in development**

Courtesy PEA/U.S. DOE

State Support – CHP

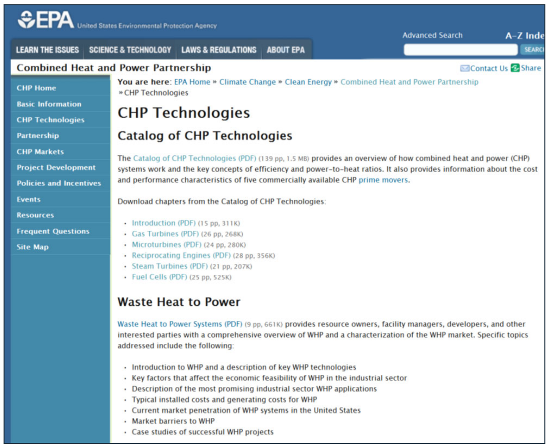
- Many states include CHP or waste heat recovery in Renewable Portfolio Standards (RPS) and/or Alternative Energy Portfolio Standards (APS)



Source: ICF International, C2ES, and the DSIRE database, 2015.
CHP partnership: Portfolio Standards and the Promotion of Combined Heat And Power, March 2016

EPA Web Site – CHP Information

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



Combined Heat and Power Partnership

You are here: EPA Home » Climate Change » Clean Energy » Combined Heat and Power Partnership » CHP Technologies

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.

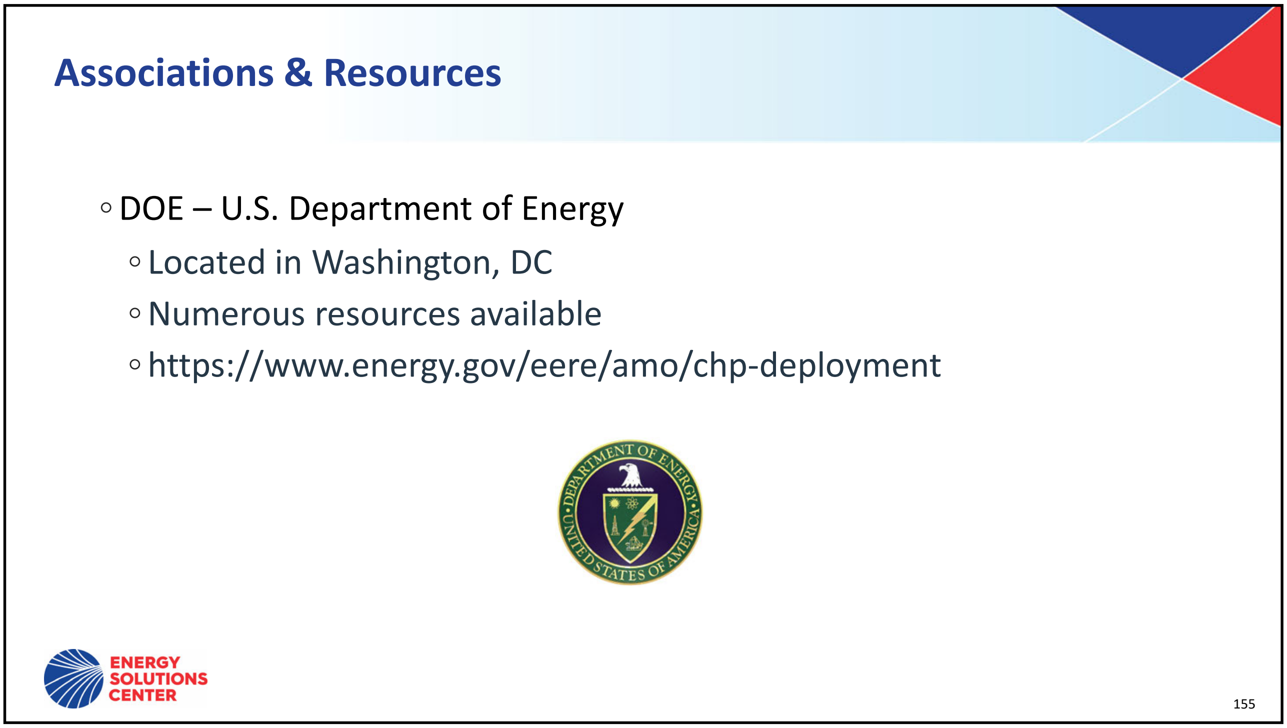
Download chapters from the Catalog of CHP Technologies:

- 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

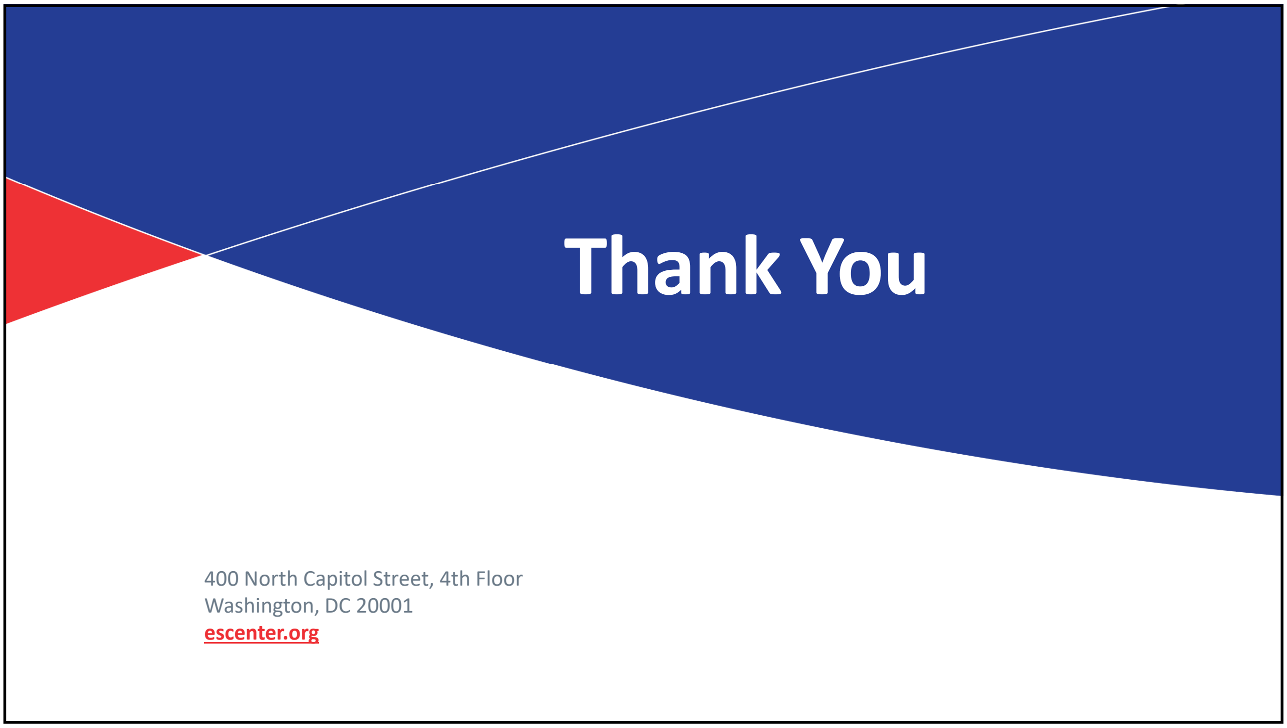
Waste Heat to Power Systems (PDF) (9 pp, 661K) provides resource owners, facility managers, developers, and other interested parties with a comprehensive overview of WHP and a characterization of the WHP market. Specific topics addressed include the following:

- 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



Associations & Resources

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



Thank You

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