ENERGY SOLUTIONS CENTER

Track: Commercial Natural Gas I
Unit #1: Commercial Technologies

Eric Burgis, Energy Solutions Center

Presentation Outline

- Market Overview
- Heating Technologies
  - Warm Air
  - Boilers
  - Gas Heat Pumps
  - Infrared
- Water Heating
- Gas Cooling
- Humidity Control
- Combined Heat & Power
- Back Up Power Generation
- Natural Gas Vehicles
- Food Service Technologies

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Commercial Building Market Data

	Number of buildings (thousand)	Total floor space (million square feet)	Sum of major fuel consumption (trillion Btu)	Natural Gas (trillion Btu)	Site Electricity[1] (trillion Btu)	Primary Electricity[2] (trillion Btu)
All buildings	**5,918**	**96,423**	**6787**	**2,300**	**4,081**	**11,834**
Building floorspace (square feet)					**Note: Source electricity uses about 3X the site electricity delivered.**	
1,001 to 5,000	2,833	8,025	576	**183**	**371**	**1,075**
5,001 to 10,000	1,359	10,204	597	**209**	**367**	**1,064**
10,001 to 25,000	981	15,838	921	**320**	**563**	**1,631**
25,001 to 50,000	386	13,957	960	**365**	**571**	**1,657**
50,001 to 100,000	218	15,302	1,075	**385**	**627**	**1,817**
100,001 to 200,000	93	13,003	959	**321**	**582**	**1,689**
200,001 to 500,000	40	11,776	1,004	**320**	**597**	**1,732**
Over 500,000	9	8,317	696	**197**	**403**	**1,169**

Source: EIA CBECS Table C1

1 Site electricity is the amount of electricity that enters a building
2 Primary electricity, which is not included in the sum of major fuels, is the site electricity plus the energy used to produce and deliver that electricity

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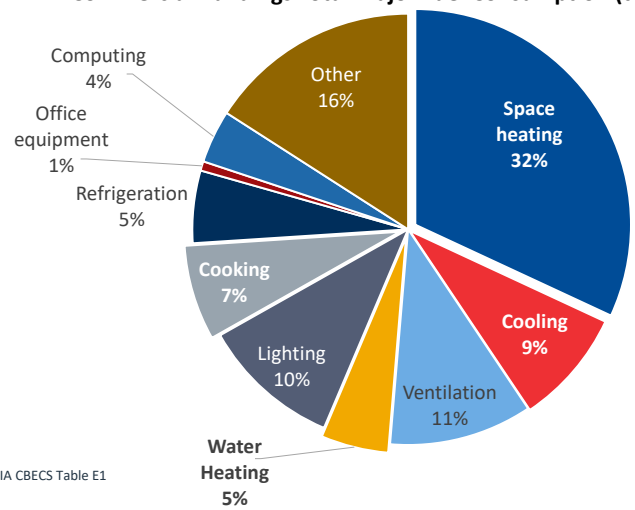
Energy Use in U.S. Commercial Buildings

Commercial Buildings Total Major Fuel Consumption (trillion Btu)



Source: EIA CBECS Table E1

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53% of energy use in commercial buildings is for heating, water heating, cooling, and cooking.

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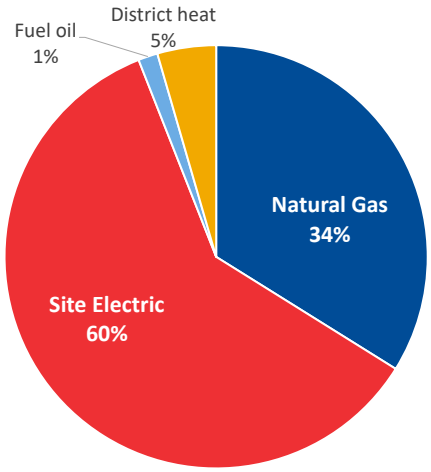
Commercial Energy Use

Commercial Building Consumption by Energy Source



Source: EIA CBECS Table C1

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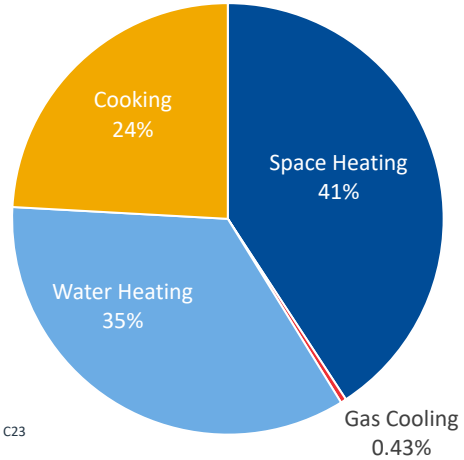
Natural Gas Usage in U.S. Commercial Buildings

Natural Gas Consumption for Total Commercial Market



Source: EIA CBECS Table C23

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Natural Gas Heating

Warm Air
Boilers
Gas Heat Pumps
Infrared

Natural Gas Heating

- **Forced Warm Air Systems**
  - The most common heating system is a forced-air system or furnace that uses a natural gas burner to heat air
  - Cool air is drawn into the system and moved into a heat exchanger where it is warmed by the gas burner and then circulated by a blower or fan through ductwork to the space being heated
  - Forced air system can also include items such as electronic air filters, electric cooling equipment and a humidifier or dehumidifier

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Natural Gas Heating

- **Boilers: Radiant Water-Based or Hydronic Systems**
  - Hydronic or hot water systems use a gas boiler that creates steam or hot water which is then circulated through pipes or tubes
  - These heating systems can incorporate radiators, radiant floor systems or baseboard units
  - Boilers or hydronic systems use the same type of venting as with forced air systems

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Natural Gas Heating

- **Heat Pump Systems**
  - Instead of warming the air by direct application of heat, a heat pump moves heat from the air, water or ground and transfers it to areas of cooler air
  - Uses a refrigerant gas or fluid that runs through pipes between two sets of coils
  - A heat pump works like a typical air conditioner, but runs in reverse
  - Heat pumps can use Natural Gas or Electric
  - Gas Heat Pumps (GHP) can use Vapor Compression, Absorption or Thermal compression cycles for high efficiencies.

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Natural Gas Heating

- Infrared Heaters
  - Has either a glowing panel or tube distribution system that warms people and surfaces in its direct path
  - Warms objects (not air) which then radiate heat upwards
  - Very energy efficient

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Available Heating Technologies

- Forced Warm Air Systems
- Make-Up Air Systems
- Unit Heaters
- PTACs
- Thru-The-Wall Furnace
- Heat Pumps
- Boilers
- Infrared Heaters
- Combo Heaters

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Forced Warm Air Heating

Rooftop Units

- Natural gas rooftop units are commonplace
- Usually purchased with gas heat and electric air conditioning in one unit
- New high efficiency designs employ modulating and condensing technology for higher efficiency

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Conventional Rooftop Units

- Conventional gas-fired rooftop heaters often have efficiency ratings between 80 and 82 percent
- Heating capacities range from under 100,000 to over 500,000 BTU/hr.

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High Efficiency Rooftop Units

- Condensing natural gas rooftop units provide comfort and efficiency (89-97%) offering:
  - Fast morning warm-up and response times
  - Lower operating and maintenance costs
  - Longer equipment life than heat pump units
  - Easily maintainable and replaceable systems
- These systems need to be designed properly in cold climates to deal with condensate.

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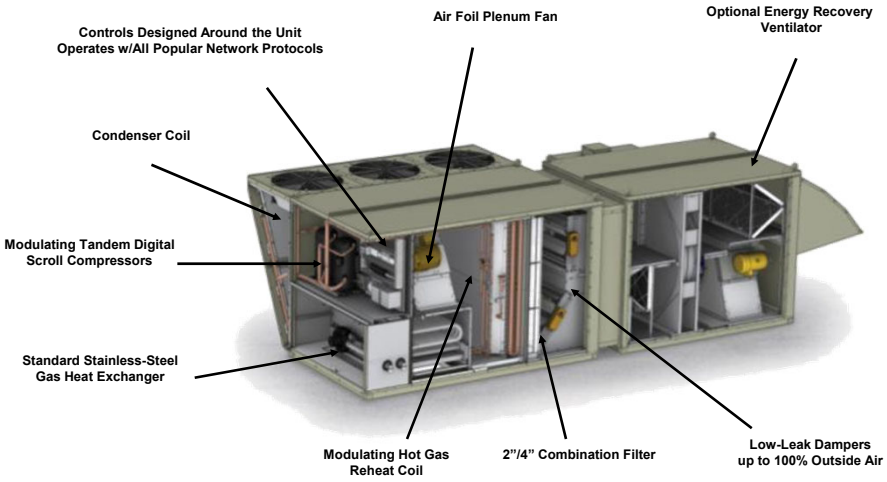
System Design



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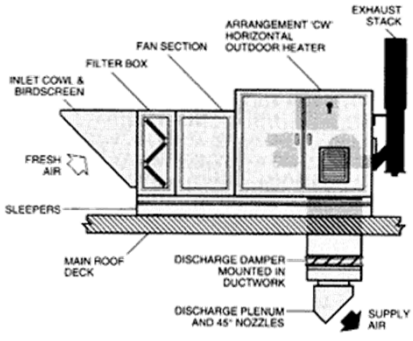
Make Up Air Systems

- Cost effective way to provide fresh tempered air to "make up" air leaving the building
- Sizes available 900 – 1,200,000 CFM
- Up to 100% outdoor air



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Unit Heaters

- Heat air in warm air closed combustion heat exchanger
- Blower moves air through heat exchanger providing warm air to the space
- Thermostatically controlled or can be tied into an energy management system
- Typically vented through the roof structure

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Unit Heaters

- Unit Heaters – 150,000 to 400,000 BTU/Hr
  - Forced Hot Air Systems
  - Standard Efficiency 78-82%
- High Efficiency Unit Heaters
  - Up to 93% AFUE
  - Power Vented Exhausts
  - Integrated Direct Spark Control

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Packaged Terminal Air Conditioner (PTAC)

- Single package containing all the components of an air-cooled air conditioner, furnace and air-handling system
- Require an outside wall and offers individual occupant control
- Units available with various heating options
  - Natural gas as well as hydronic options using gas fired boilers
  - Typical Efficiency – 80%

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PTACs

- Heating capacity is 12 - 25,000 BTUs and cooling capacity is 0.5 to 1.5 tons
- Typical applications include:
  - Motels, school classrooms, small office complexes, multifamily units & elder care facilities

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Thru-The-Wall Units

- Combine heating and cooling in one compact easy-to-install unit
- Each space has individual comfort controls
- Used in multifamily, eldercare facilities
- Sizes from 26,000 – 64,000 BTUh
- Efficiency – 80%

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Natural Gas Boilers

Types of Boilers

- Sectional Boilers – Plates (heating sections) are bolted together to make a system
- Fin Tube Boilers – Incorporate additional heat transfer surface using fins on the coils
- Fire Tube Boiler – gas flame contained inside tubes that heat water
- Water Tube Boiler – Water is heated inside of tubes in boiler furnace area

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Boiler Terminology

- Horsepower – How a boiler is sized
  - One boiler horsepower equals 33,475 Btu/hour
  - The energy rate required to evaporate 34.5 lb (15.65 kg) of water at 212°F (100°C) in an hour
- Low vs. High Pressure – operating pressure
  - Low pressure - below 15 psig or water at 250°F (121°C)
  - High pressure - above these conditions

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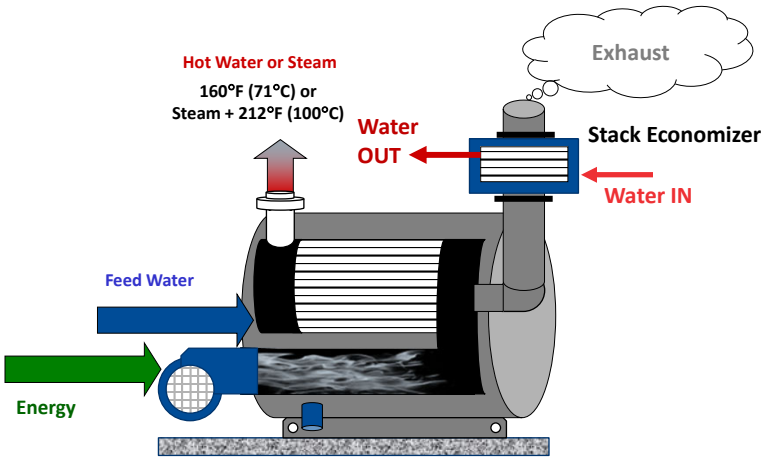
Typical Boiler Arrangement



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Boiler Efficiency Standards

§431.87—Commercial Packaged Boiler Energy Conservation Standards

Equipment category	Subcategory	Certified rated input	Efficiency level—effective date: March 2, 2012 *
Hot Water Commercial Packaged Boilers	Gas-fired	≥300,000 Btu/h and ≤2,500,000 Btu/h	80.0% E_T.
Hot Water Commercial Packaged Boilers	Gas-fired	>2,500,000 Btu/h	82.0% E_C.
Steam Commercial Packaged Boilers	Gas-fired, all, except natural draft	≥300,000 Btu/h and ≤2,500,000 Btu/h	79.0% E_T.
Steam Commercial Packaged Boilers	Gas-fired, all, except natural draft	>2,500,000 Btu/h	79.0% E_T.

Equipment category	Subcategory	Certified rated input	Efficiency level—effective date: March 2, 2022 *
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Steam Commercial Packaged Boilers	Gas-fired—natural draft	>2,500,000 Btu/h	79.0% E_T.

* Where E_C is combustion efficiency and E_T is thermal efficiency.

Code of Federal Regulations, Title 10 up to date as of 1/18/24

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Sectional Boilers

- Assembled using a number of cast sections
- Typically box shaped
- Packaged with circulator pump, electric box, and flue stub connected to the box
  - Ideal for multiple installations
- Unit sizing up to 150 hp
- Efficiency ranges from 80%-96%

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Copper Tube Boilers

- Water tube design – flows through pipe fitted with fins
  - Increased heat transfer surface
  - Compact design
- Sized from 45,000 -2,065,000 Btu/Hr
- Efficiency ranged from 82%-97%

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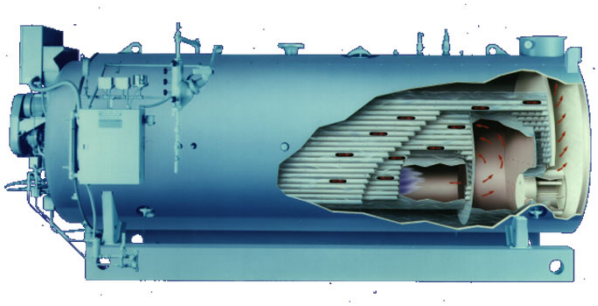
Fire Tube Boilers

- Combustion gases pass inside boiler tubes, and heat is transferred to water on the shell side
- Low initial cost
- Systems from 10 to 2,200 HP
- Incorporate 80-82%

  combustion efficiency

  burners and combustion controls



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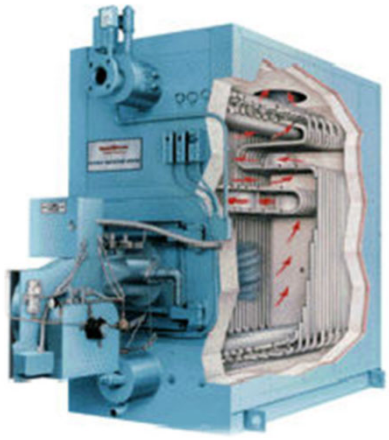
Water Tube Boilers



- Water passes through tubes
- 1.5 to 25.0 MMBTU/hr input
- Exhaust gases remain in the shell passing over the tube surfaces
- Can produce steam up to 3,000 psi
- Can generate saturated or superheated steam
- Capable of high efficiencies
- Incorporate high efficiency burners and combustion controls

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Improving Boiler Efficiency

- Boiler Replacement
- New Burners
- Add Controls

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Gas Heat Pumps

Heat Pumps

- What is a 'Heat Pump?'
  - Device that transfers thermal energy from a heat source to a heat sink
  - Move thermal energy in a direction which is opposite to the direction of spontaneous heat flow
  - A heat pump uses energy to accomplish the desired transfer of thermal energy from heat source to heat sink
    - Energy can be electric or natural gas

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Heat Pumps

- Various Types Available
  - Air to Air
  - Water Source
  - Ground Source (Geo-Thermal)
- Natural Gas
  - Absorption Technology
  - Engine Driven Technology (Vapor Compression)
  - Thermal Compression

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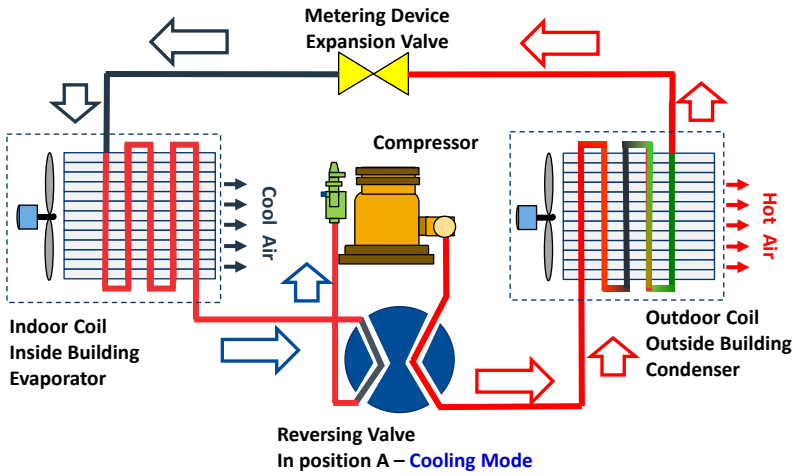
Cooling Mode (Regular Air Conditioning)



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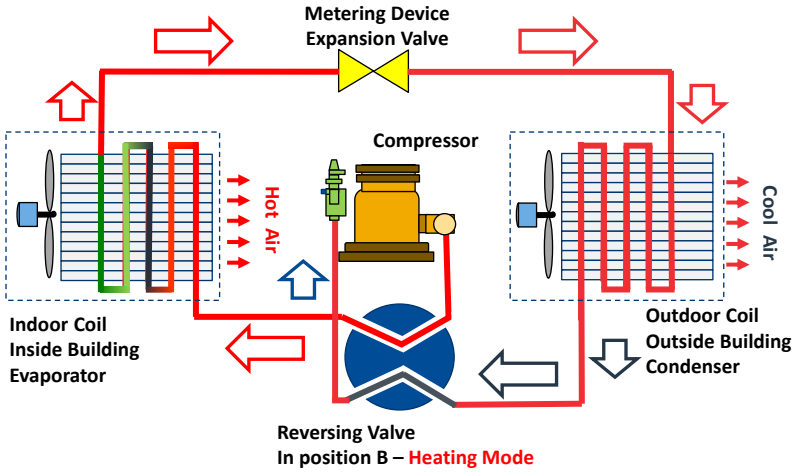
Heating Mode



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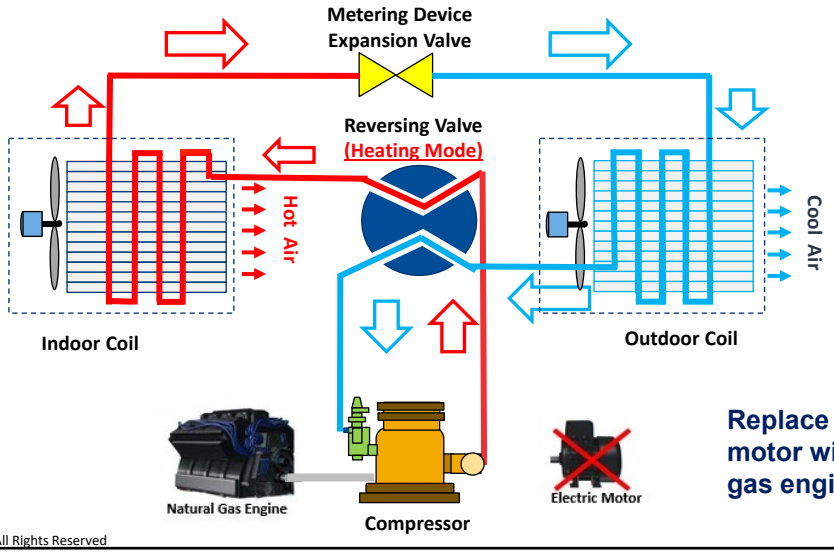
GHP: Engine Driven (Heating mode)



Replace electric motor with natural gas engine

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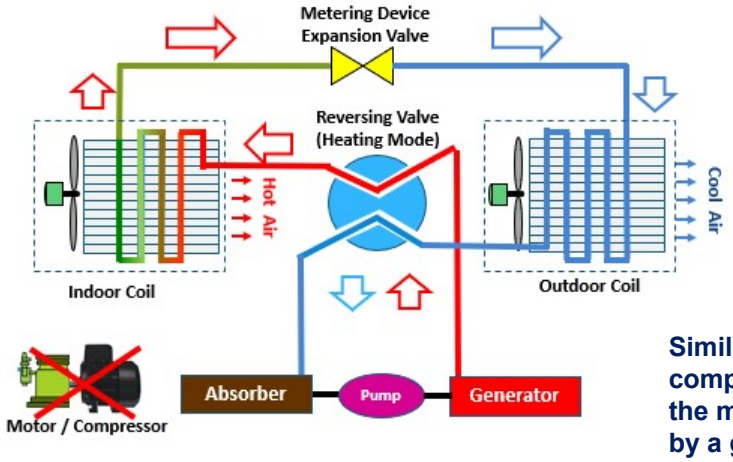
GHP: Absorption (Heating mode)



Similar to vapor compression, except the motor is replaced by a generator, pump, & absorber.

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IR Heating

Infra-Red Radiant Heating

- Types of systems
  - High intensity units
  - Low intensity tubular (black tube radiant heaters)
- Systems available from 25,000 to 200,000 BTUH
- Generate radiant energy that is converted into heat when absorbed by objects in its path
- 20-50% fuel savings over conventional forced air units

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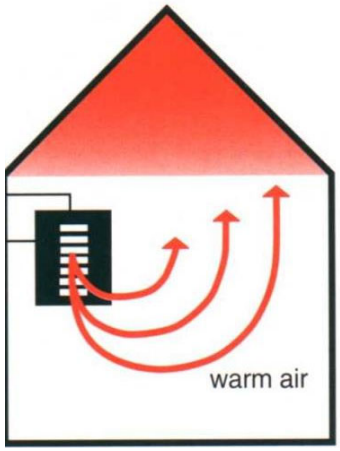
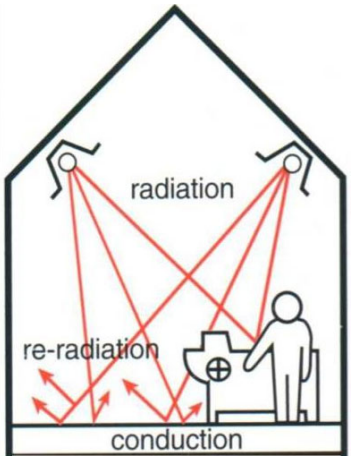
Infra-Red Heats the People & Objects – Not the Air



Forced Warm Air



Infrared Heating

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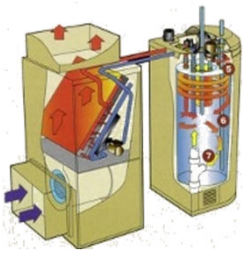
Combo Systems

Types of Combo Systems

- Water heater that also provides space heat
- Boiler for space heating that also makes hot water



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Natural Gas Heating Benefits

- Save Money over Other energy sources
- Faster Warm Up compared to Electric Heat
- Cleaner – Reduced Emissions
- Warmer than a Heat Pump – Less Drafty

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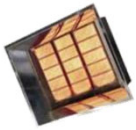
Natural Gas Space Heat Summary

Forced Warm Air Systems

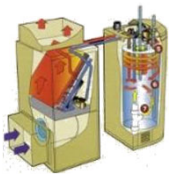
Unit Heaters



Infrared

Make Up Air Systems

Heat Pumps



Combo System
Space and Water Heat

Thru the Wall
Furnaces

Boilers for
Building Heat

Combine w/ Hydronic
Floor Heating

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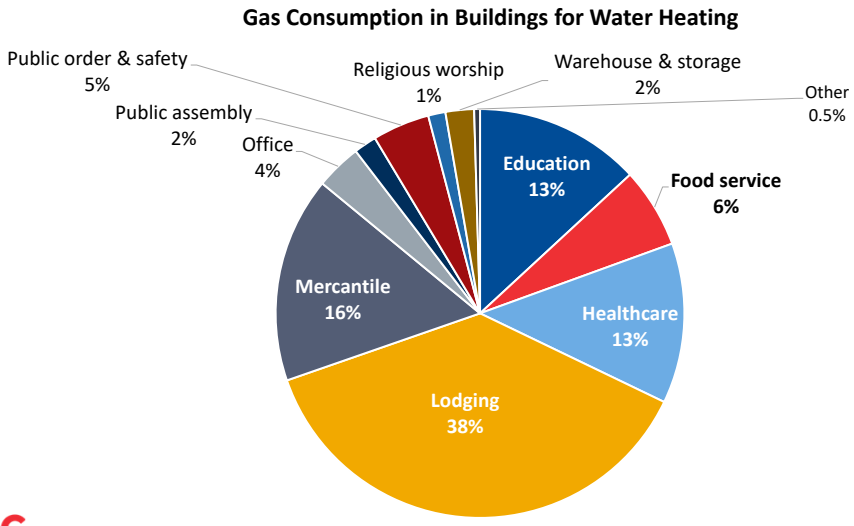
Natural Gas Water Heaters

Natural Gas Consumption for Water Heating by Business Activity



Source: EIA CBECS Table E7 (Total water heating natural gas consumption for all buildings = 230 trillion BTU)

Natural Gas Water Heating Options

Atmospheric Storage

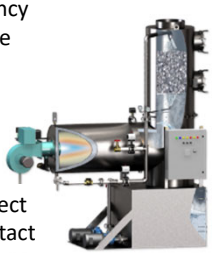
Boiler

Tankless

Booster Water Heater

High Efficiency Storage

Solar/Gas Hybrid



Direct Contact

Fire-Tube Condensing

Heat Pump Water Heater

Commercial Water Heaters

- Water heating is used in all commercial building applications
- Commercial water heaters are major energy consumers, accounting for about 10% of a building's total natural gas load on average
- Average natural gas energy intensity for water heating is 4,900 BTU/Square foot

Source: EIA CBECS Table E7

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Tank Water Heaters

- Commercialized versions of traditional residential unit
- Input ratings <= 199,999 BTUs/hour as many codes change at 200,000 BTUs/hour and above
- Storage capacity of about 100 gallons (378.5 liters)
- Heat water to about 180°F (82.2°C)
- Direct or power venting options

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Tankless Water Heaters

- Have no storage tank
- Heat water on demand with no tank standby-losses
- Standard efficiency units – 82%
- High efficiency units – 97%+
- Sizing done by GPM required but under 200,000 BTU input per unit
- Higher first cost – savings comes from elimination of standby losses

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Hybrid Systems – Solar/Gas

- Solar water heater with natural gas-fired back-up heat exchanger
- Internal solar heat exchanger for a solar panel
- Combines with a highly efficient all in one storage tank
- Provides approximately ½ of the water heating from solar

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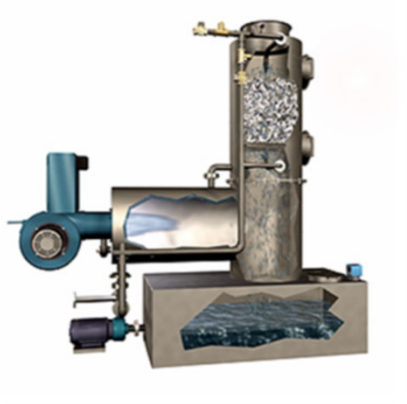
Direct Contact Water Heaters



- Have no tubes, tubing or coils
- Use heat transfer media such as spheres or cylinders and allow flue gases to come in direct contact with the water
- Up to 99% efficient
- 250,000 Btu/hr to 75,000,000 Btu/hr
- 4 GPM to 2000 GPM

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Booster Water Heaters

- Designed to heat rinse water for better cleaning with fewer spots – especially on glassware
- Heats hot water from 120°-140° up to 180°F (48.8°-60° up to 82.2°C) water
- Improves cleaning and sanitizing of dishes
- Shortens drying time
- Eliminates need for chemical rinse aids

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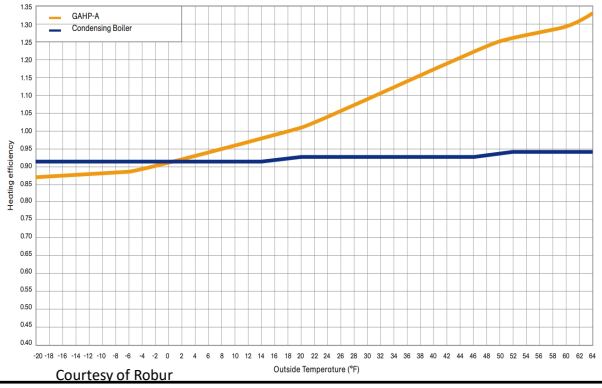
Commercial Heat Pump Water Heater

- Can be use for direct hot water heating
- Typical energy efficiency well over 100%
- Produce hot water temperatures ~ 140 °F



Courtesy of Robur

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Natural Gas Air Conditioners

Commercial Gas Cooling

- Space conditioning is a critical component in all commercial building applications
- Chillers/HVAC systems are major energy consumers, accounting for a large portion of a building's energy load

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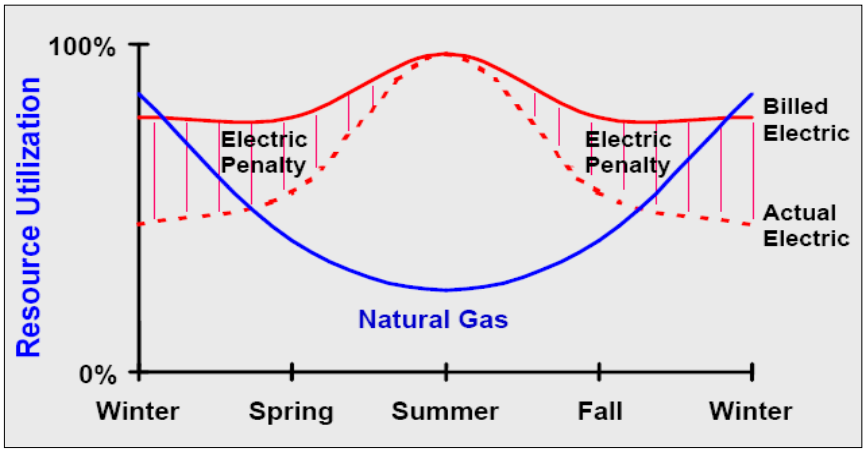
Commercial Gas Cooling



Gas air conditioning increases summer gas load while reducing peak summer electric.

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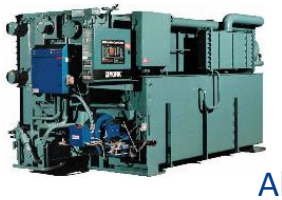
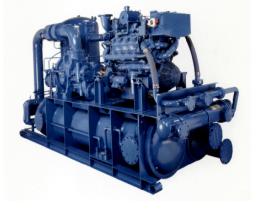
Natural Gas Cooling Options



Absorption Chillers

Gas Heat Pumps



Engine Driven Chillers

Steam Turbine Driven Chiller

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Measuring Efficiency

- Gas cooling systems are measured by the Coefficient of Performance (COP)
  - The ratio of heating or cooling provided to the energy consumed
  - The higher the COP – the more efficient the system
  - COP can be treated as an efficiency where a COP of 2.00 = 200% efficiency

$$\text{COP} = \frac{\text{Cooling Produced (Btus/Hr or kW)}}{\text{Heat Input (Btus/Hr or kW)}}$$

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Absorption Chillers

- Available as stand-alone chillers or chiller/heaters
- Single Effect (COP = ~.6), or Double Effect (COP = 1.2)
- Direct or Indirect fired (Hot water, steam, or waste heat)
- Sizes range from 5 to > 3000 tons
- Suitable for inclusion in a CHP system
- Smaller footprint than an electric chiller with boiler

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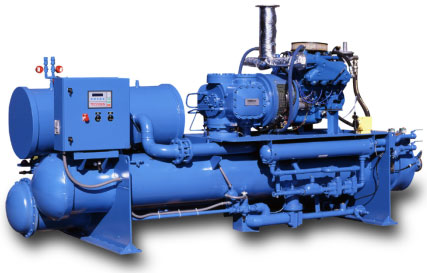
Engine Driven Chillers

- Sizes range from typically 150 - 400 tons
- Variable speed for efficient partial load operation
- Typical COP = 1.7 for water cooled unit, as high as COP = 2.4 with waste heat recovery
- Engine heat recovery for domestic hot water and other thermal energy needs
- Longer operating life
- Environmentally friendly



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Steam Turbine Chillers

- Uses medium pressure steam (usually 100 to 200 psig) to turn a compressor
- Applicable to large tonnage chiller loads (700 -2000 tons)
- COPs ~ 1.8
- Maximizes year-round use of boiler system
- Compact footprint
- Requires minimal maintenance

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Gas Heat Pumps (GHP)

- GHP Cycles include Absorption, Engine Drive, and Thermal Compression
- Wide range of cooling and heating capacities and temperatures with capacities from 5 to over 3000 tons
- Air source, water source or ground source

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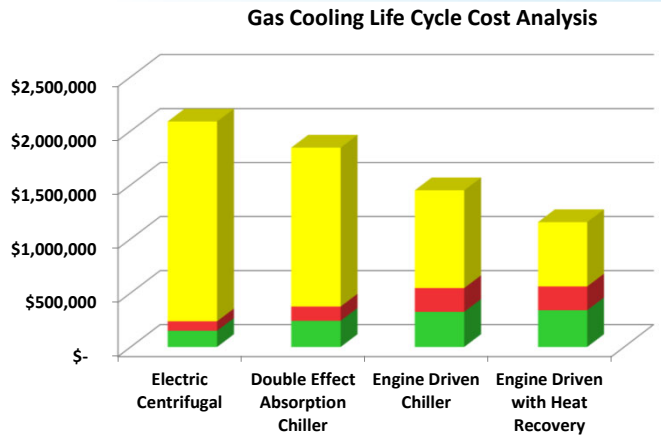
Gas Cooling 20 Year Life Cycle Cost Analysis



Compared to Electric Centrifugal Chiller	Simple Payback
Absorption - Double Effect	6.09
Engine Driven Chiller	4.74
Engine Driven w/ Heat Recovery	3.73

Example Only –500 Tons Cooling, 2000 operating hours/yr.
Energy Prices –Electricity @ $0.12 / KWH & Natural Gas @ $7.00 / MCF

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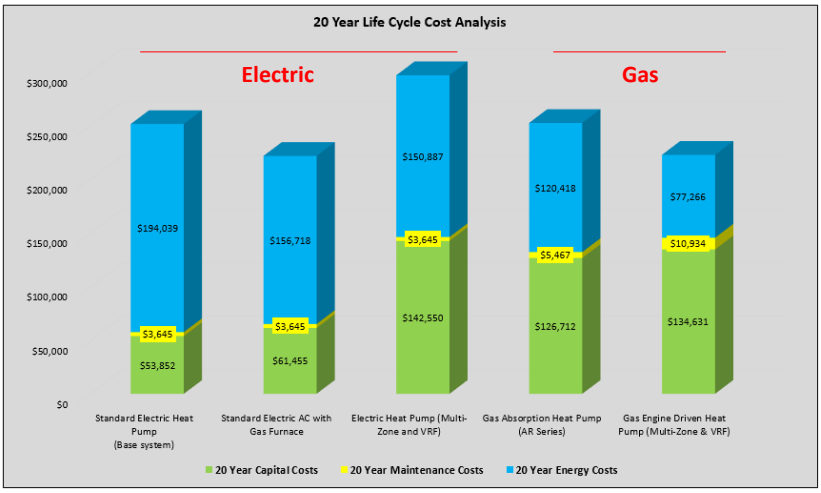
ESC Gas Heat Pump Consortium

Gas Heat Pump Life Cycle Cost Analysis



Assumptions:
Electric - $.15/KW, no demand charge, Gas = $.70/Therm
20 Tons of cooling for 6 months per year
1500 full load hours cooling & 1500 hours heating

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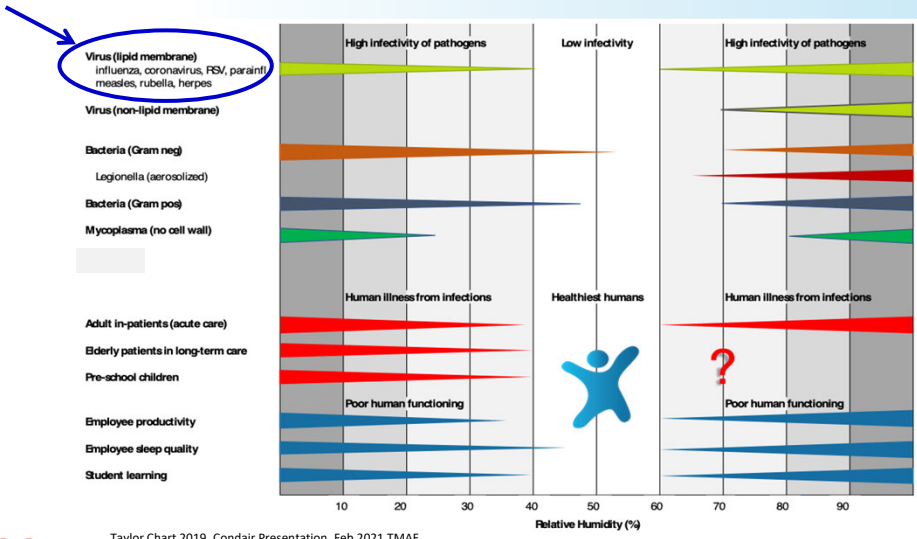
Humidity Control
Humidification & Dehumidification

Health Impact of Uncontrolled Humidity



Taylor Chart 2019, Condair Presentation, Feb 2021 TMAF

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Problems Using Conventional Air Conditioning to Dehumidify

- Not energy efficient
- Cool air to lower temperature, then Re-Heat back to desired temperature
- Cooling coils and condensate drain system are constantly wet
- Ideal for growth of bacteria, mold, etc.
- Dry or liquid desiccant systems available

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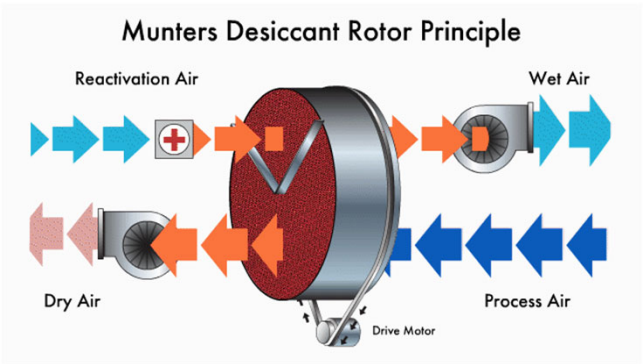
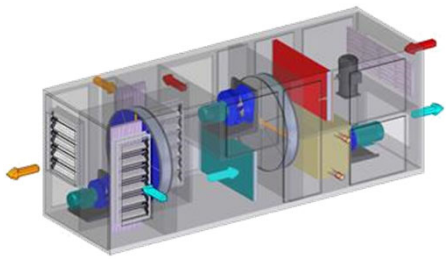
Dry Desiccant Dehumidification

- Commercial & Industrial sizes available
- Dry desiccant wheel or liquid desiccant systems





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https://www.munters.com/en/solutions/dehumidification/

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Humidifiers

- Steam humidifier
  - Uses a boiler
- Direct-Fired humidifier
  - Cost-effective when boiler not available
  - Boil water to steam and distribute via air handling system or remote blower
  - Designed to deal with scale left behind that can cause issues with a standard boiler.

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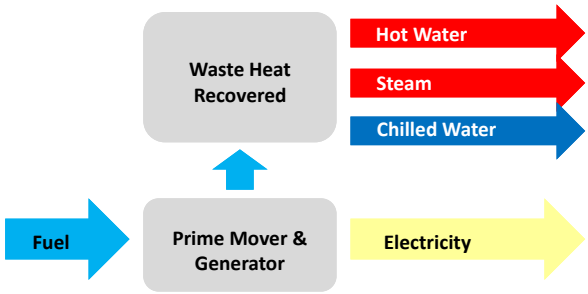
Combined Heat & Power (CHP)

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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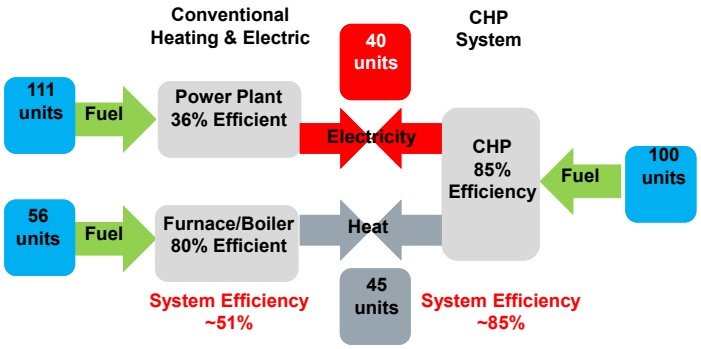
CHP is more Efficient



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.

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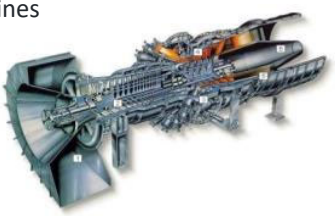
Combined Heat & Power

Power Generation Equipment Options

Reciprocating Engines
(~5 KW - 8 MW)

Microturbines
(~65 to - 200 KW)



Turbines
(1,000 KW – 40 MW)

Fuel Cells
(100 – 300 KW)

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Reciprocating Engine Driven CHP

- High fuel efficiency
- Sizes ranging from a few kilowatts to over 5 MW
- Lower Initial costs vs. larger turbines
- Best for variable load applications
- More tolerant to high ambient conditions and high elevations
- Lower fuel pressure requirement
- Accept low BTU fuels
- On line in less than 30 seconds
- May offer “black start” opportunity

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Combustion Turbine CHP

- Large heat to ekW ratio
- Sizes from several hundred kW to MegaWatts
- High exhaust temperatures: 480°C / 900°F
- Low weight & minimal space requirement
- Very simple design
- Lower emissions capabilities
- Ideal for 24/7 operation
- Accept high or low BTU fuels

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Microturbine CHP

- 65 – 200 kW sizes available
- Lightweight & small footprint
- Multi-fuel capability
- Air cooled
- Ultra low emissions
- High reliability
- Minimal scheduled maintenance

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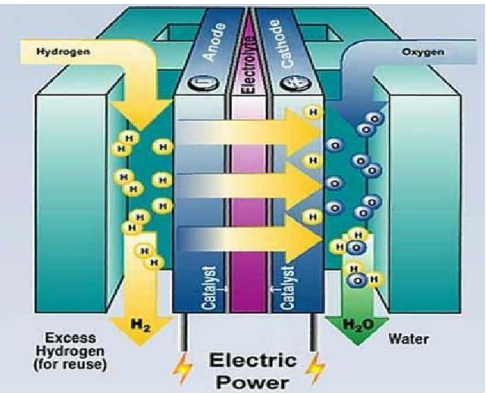
Fuel Cell CHP

- Grid-independent operation
- Typical Sizes from 100kW to 400 kW
  - 1.5 kW Residential systems
- Electric load following
- Multi-megawatt capacity
- Will operate on low pressure natural gas fuel
- Low noise and vibration
- Ultra-low emissions
- ~10 year cell stack life



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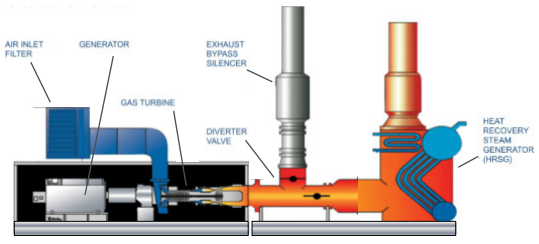
Heat Recovery - Technologies to Recover Heat



Heat Recovery Steam Generator

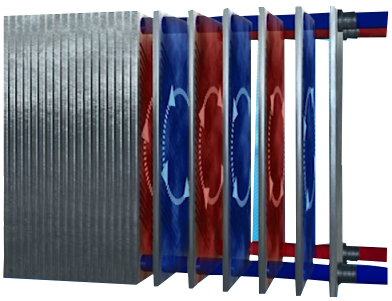
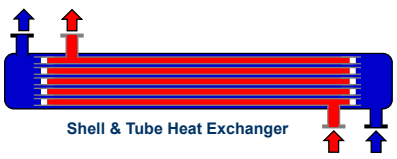


Plate & Frame Heat Exchanger



Shell & Tube Heat Exchanger

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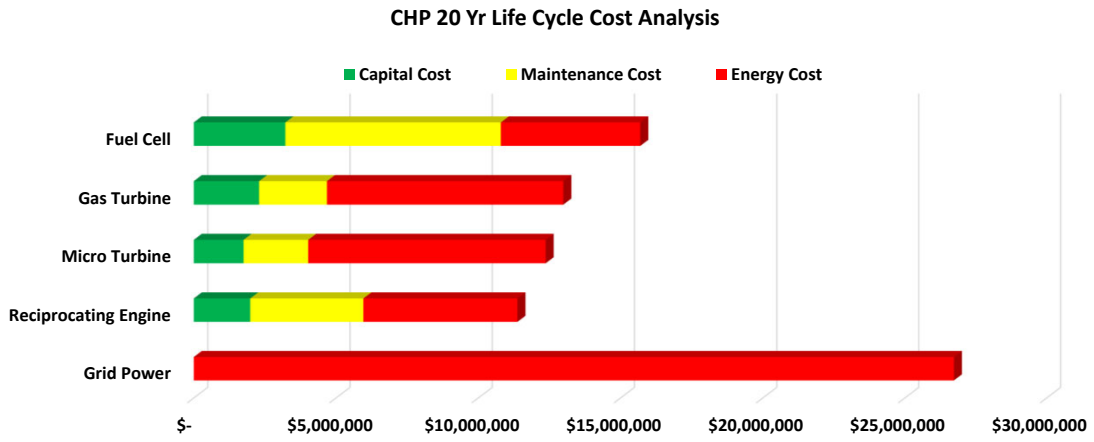
CHP Life Cycle Cost Analysis



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

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Combined Heat & Power Benefits

- More efficient use of energy
- Reduced emissions
- Reduced energy costs
- Not reliant on electric power grid
- For more information visit: www.understandingchp.com

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Backup Power Systems

Back Up Power Systems

From a few KW to a MW systems available

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Back Up Power Systems

- Operate with a dependable, efficient natural gas engine
- Designed to turn on automatically whenever electric service is interrupted
- Transfers the electric load back to the utility once power is restored
- Equipped with controls to handle even brief electric interruptions

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Back Up Power Systems

- Strengths
  - Numerous equipment types and providers available
  - Provides security/safety for customers
- Weakness
  - Not a large throughput per customer for LDCs
  - Cost to install a system, versus do nothing

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Natural Gas Vehicles (NGVs)

Available Natural Gas Vehicles

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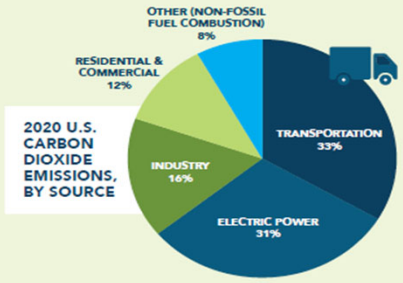
Natural Gas Vehicles

EMISSIONS BENEFITS OF NATURAL GAS VEHICLES (NGV)

One of the primary advantages of NGVs is that they produce significantly less tail pipe emissions than diesel vehicles. The adoption of NGVs can be an effective strategy to reduce transportation-related emissions and comply with stricter clean air regulations.

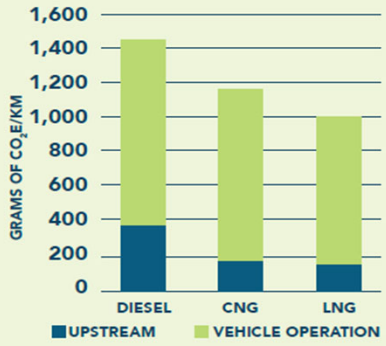


Source: https://www.epa.gov/ghgemissions/overview-greenhouse-gases

U.S. TRANSPORTATION SECTOR IS THE LARGEST SOURCE OF GREEN HOUSE GAS EMISSIONS IN THE COUNTRY.

NGVS PRODUCE 21% TO 30% LESS CO_2 COMPARED TO DIESEL-FUELED VEHICLES.[3]

RENEWABLE NATURAL GAS (RNG) CAN REDUCE EMISSIONS EVEN FURTHER.



Source: Natural Gas Use in Transportation Roundtable, "Natural Gas Use in the Canadian Transportation Sector"

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Compressed Natural Gas (CNG) Benefits

ADDITIONAL BENEFITS OF NATURAL GAS VEHICLES

CNG is estimated to cost **40% to 45% less** than gasoline and diesel.[4]

INCENTIVES FOR RNG MAY BRING DOWN PRICES EVEN MORE.

In 2020, **53 percent** of all on-road fuel used in NGVs was RNG.[5]

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Cooking

Natural Gas High Efficiency Cooking Equipment

- New Energy Star rated appliances provide innovative solutions for food service facilities
- Designed to meet needs of food service facilities
- Integrated systems
- Lower annual operating costs

Creative Commons photo

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NEW Natural Gas Energy Star Equipment Options for Cooking

- Low Oil Volume Fryers
- Steam Cookers
- Griddles
- Convection Ovens
- Combi Ovens

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Other Foodservice Technologies

- Booster Water Heaters
- Low Flow Spray Nozzles
- Demand Control Ventilation

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The Environmental Benefits of Natural Gas

- The cleanest burning fossil fuel
- It produces virtually no emissions of sulfur dioxide or particulate matter and far lower levels of "greenhouse" gases and nitrogen oxides than oil or coal
- Produces virtually no solid waste
- Natural gas is delivered to the customer with around 90% efficiency

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Thank You

Consider taking the on-line test while course material is fresh in your mind

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