ENERGY SOLUTIONS CENTER

Track: Commercial Natural Gas
Unit #3: Natural Gas Heating Equipment

An overview of Heating Technologies for Commercial Facilities

Mr. Eric Burgis, Energy Solutions Center

Presentation Outline

- Commercial Markets
- Sizing and Efficiency
- Available HVAC Technologies
- Associations & Resources

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Commercial Market Overview

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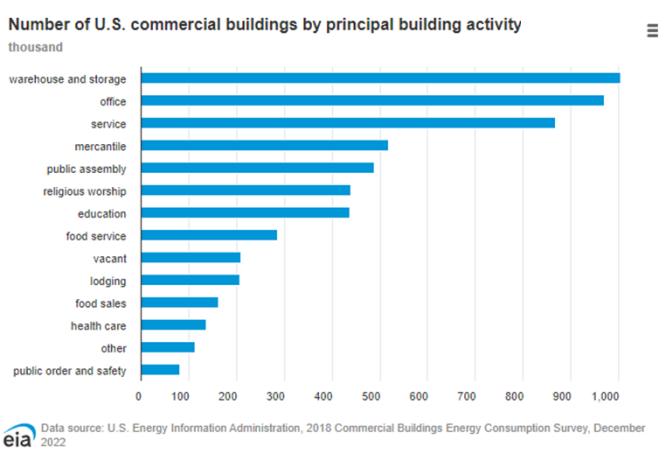
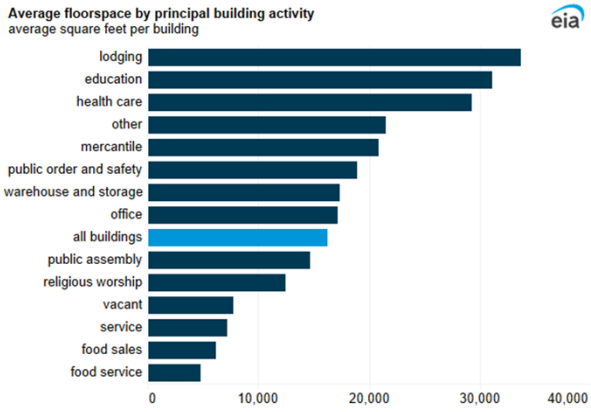
Commercial Building Make-up (U.S.)



Data source: U.S. Energy Information Administration, 2018 Commercial Buildings Energy Consumption Survey, December 2022

https://www.eia.gov/energyexplained/use-of-energy/commercial-buildings.php



Data source: U.S. Energy Information Administration, *Commercial Buildings Energy Consumption Survey*

https://www.eia.gov/consumption/commercial/pba/overview.php

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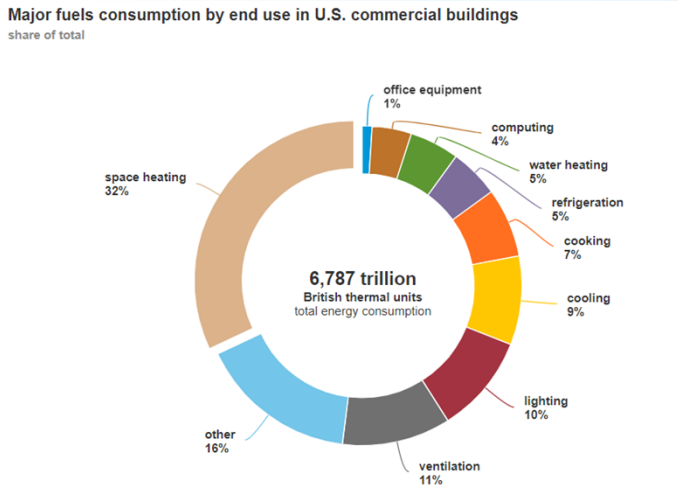
~1/3 of Energy Use is for Heating



Data source: U.S. Energy Information Administration, 2018 Commercial Buildings Energy Consumption Survey, December 2022
https://www.eia.gov/energyexplained/use-of-energy/commercial-buildings.php

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High Performance Buildings

High Performance Buildings set out to:

- Improve the energy efficiency
- Reduce the energy consumption and improve occupant comfort, and cost-effectiveness
- Achieve goals by using energy-efficiency and renewable energy technologies, recycled and sustainable materials, and site sensitive design to minimize environmental impacts

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Natural Gas Heating Technology in Commercial Buildings

- Provide environmental and energy savings benefits
- Offer financial savings for the building owner
- Improve building operations
- Reduce operating and maintenance costs

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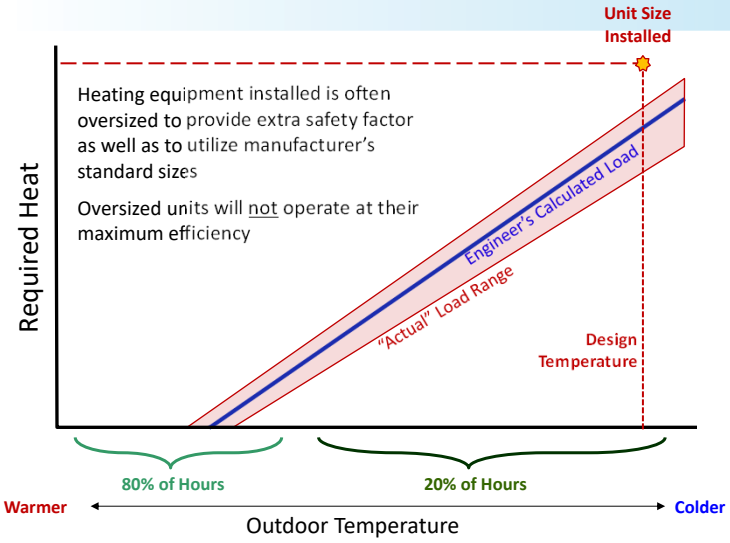
Heating Load



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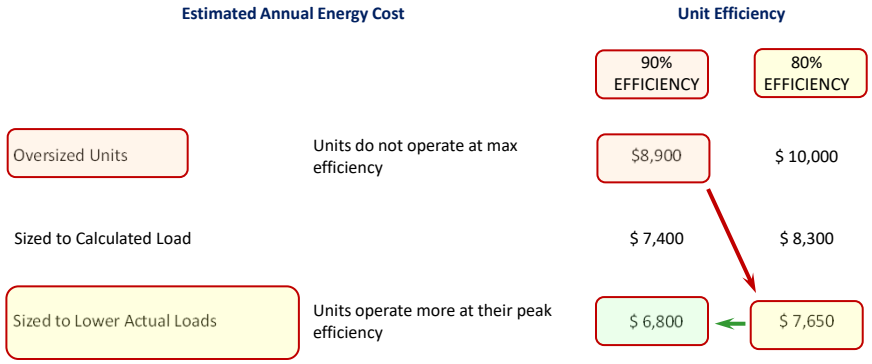
Impact on Energy Cost of Oversized Units Example



Annual Estimated Savings for Every $100 of Fuel Costs by Increasing Your Heating Equipment Efficiency *

Existing System AFUE	New / Upgraded System AFUE								
	55%	60%	65%	70%	75%	80%	85%	90%	95%
50%	$9.09	$16.76	$23.07	$28.57	$33.33	$37.50	$41.24	$44.24	$47.36
55%	----	$8.33	$15.38	$21.42	$26.66	$31.20	$35.29	$38.88	$42.10
60%	----	----	$7.69	$14.28	$20.00	$25.00	$29.41	$33.33	$37.80
65%	----	----	----	$7.14	$13.33	$18.75	$23.52	$27.77	$31.57
70%	----	----	----	----	$6.66	$12.50	$17.64	$22.22	$26.32
75%	----	----	----	----	----	$6.50	$11.76	$16.66	$21.10
80%	----	----	----	----	----	----	$5.88	$11.11	$15.80
85%	----	----	----	----	----	----	----	$5.55	$10.50
90%	----	----	----	----	----	----	----	----	$5.30

*Assuming the same heat output

Example **Replace your 70% Heating System with a 90% System and save $22.22 for every $100 / yr of energy for heating**

http://energy.gov/energysaver/articles/furnaces-and-boilers

Heating Technologies

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Available HVAC Technologies

- Forced Warm Air Systems
- Make-Up Air Systems
- Unit Heaters
- PTACs
- Thru-The-Wall Units
- Heat Pumps
- Boilers
- Infrared Heaters
- Combo Heaters
- Thermostats & Reset Controllers

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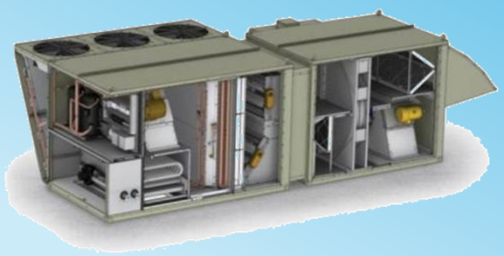
Forced Warm Air Systems



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Forced Warm Air Furnaces

- Basic Physics of Warm Air Systems:
  - Warm air rises
  - Air must be moved by mechanical means
  - Air loses heat rapidly to the surroundings
    - Heats the air first … then people

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Furnaces Efficiency

Standard Warm Air Furnace

- Seasonal efficiency of at least 78 – 80 percent
- Most have naturally aspirated burners
- Newer furnaces have electric ignition systems
  - Can consume 3 to 5 percent less energy than a furnace with a conventional standing pilot

High Efficiency

- Common Features of High Efficiency Furnaces:
  - Conventional or Condensing design with heating efficiencies of 90% - 97%+
  - Capability to provide up to 100% outside air for "free cooling" on mild days
  - Quiet and efficient plenum fans
  - Modulating hot gas reheat
  - Indoor or outdoor installation

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Rooftop Systems

- Natural gas rooftop units are the most commonly used HVAC systems for commercial buildings
- Usually purchased with gas heat and electric air conditioning in one unit
- Some designs employ modulating and/or condensing technology

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Rooftop Systems

- Natural gas rooftop units provide comfort and efficiency, offering:
  - Fast morning warm-up and response times
  - Lower operating and maintenance costs
  - Longer life than electric heat pump units
  - Easily maintainable and replaceable systems

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Rooftop Unit Efficiencies

Conventional Rooftops

- Often have efficiency ratings between 78 and 82 percent
- Heating capacities range from under 100,000 to over 500,000 BTU/hr.

High Efficiency Rooftops

- Designs employ modulating and condensing technology
- Efficiencies of 90% to 97% for condensing units
- Provide comfort and efficiency

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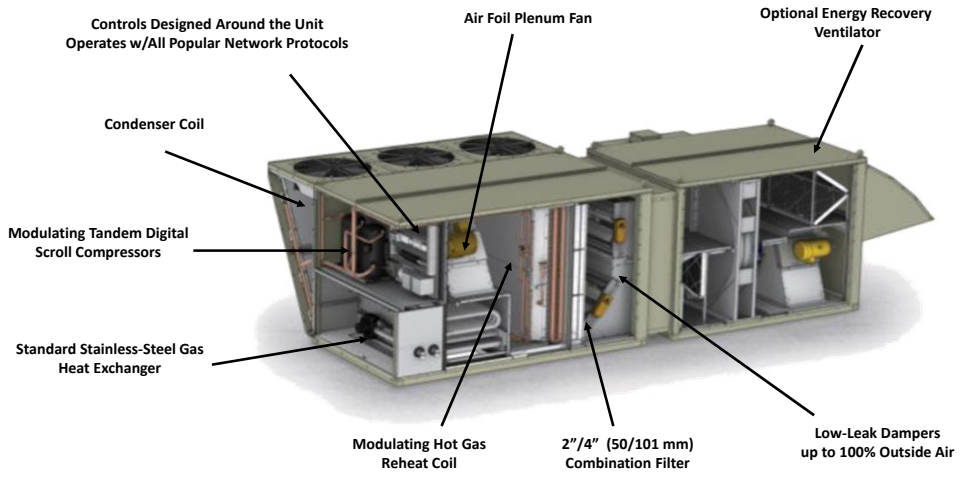
Design Features



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Make Up Air Systems (MUA)

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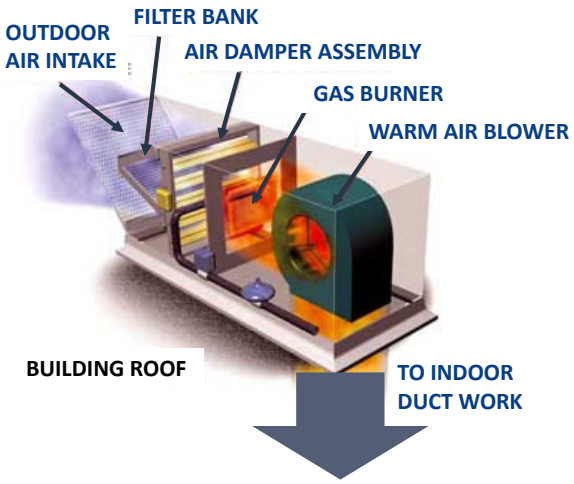
Make Up Air Heater



Make Up Air Systems

- Cost effective way to provide fresh tempered air to “make up” for air leaving the building:
  - Restaurants and Commercial Kitchens
  - Office Buildings
  - Gymnasiums and Indoor Sports Facilities
  - Automobile Service and Repair Facilities
  - Wastewater and Sewage Treatment Facilities
  - Parking Garages

Make Up Air Systems – Two Options

- **Direct Fired Units**
  - Gas is burned directly in the air stream being heated
  - 100% of the available heat is delivered to the building
- **Indirect Fired Units**
  - Gas is burned in a heat exchanger/furnace unit
  - Typically 80% efficient due to heat exchanger efficiency and heat lost up the flue

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Why Use Make Up Air

- Improved indoor air quality
- Improved equipment operation by supplying an adequate supply of combustion air
- Reduce cold air infiltration by heating outside air as it enters the building
- Reduce the infiltration of dust and dirt
- Improve occupant comfort and health by eliminating drafts
- Increase employee productivity and reduce absenteeism
- Improve overall building and systems efficiency and operation

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Energy Recovery Ventilators (ERV)

- An air-to-air heat exchanger that recovers energy from both heat and humidity
- ERV reduces the peak heating & cooling loads
- ERV systems can provide annual energy savings by reducing the amount of HVAC energy needed
- Allows capital reduction due to HVAC equipment downsizing

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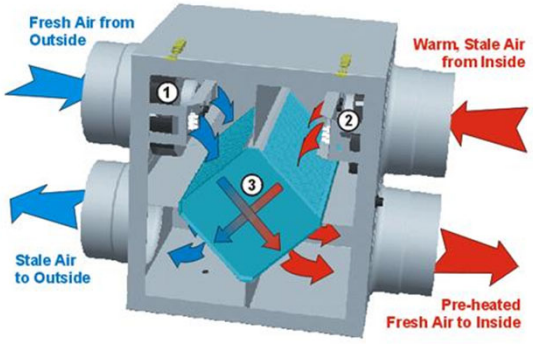
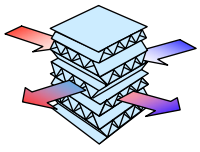
Energy Recovery Ventilators (ERV)





- Separate chambers allows for removal of contaminants from air flows
- Can be added to the air inlet of a rooftop system allowing the unit to be sized smaller
- Available in sizes from 100 to 20,000 CFM
- Easily installed on new or as a retrofit to an existing system

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Unit Heaters

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Unit Heaters

- Typically suspended from the ceiling
  - Factories, warehouses, garages
  - Big box stores or warehouses
- Unit heaters provide an excellent solution for
  - Doorway heating (entry)
  - Freeze protection (loading docks)
  - Space heating (retail or warehouse)
  - Summer time air circulation
- Typically 78-80% efficiency

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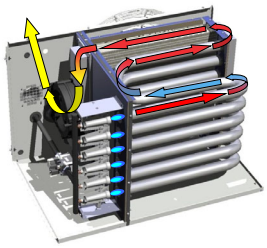
High Efficiency Unit Heaters

- Units Incorporate
  - Tubular heat exchanger
  - Power vented exhaust
  - Integrated Direct Spark Control
- Easy to install and control
- System design is necessary to provide maximum heating results
- Up to 97% Efficiency
- Outputs from 51,150 to 288,300 BTU/Hour



https://www.modinehvac.com/products/unit-heaters/commercial-gas-fired-heaters/effinity-with-building-management-system-integration-ptc-btc/

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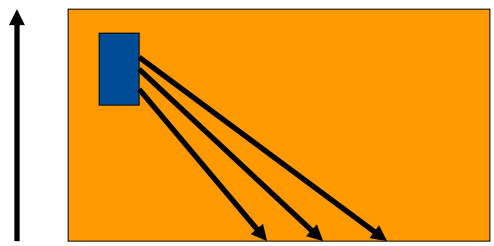
Unit Heater Example

- Mounted in Elevated Positions from which Heated Air is Directed Downward
- For Buildings with Low to Moderate Ceiling Heights



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Benefits of Unit Heaters

- Relatively Light Weight / Roof Load per Btu Output
- Only heat occupied areas as necessary (Zone Control)
- Doesn't Consume Productive Floor Space
- Multiple Unit Redundancy
- Air Circulation by Fans in Summer Mode
- Quick Response to Night Setback Temperatures
- Re-Cycles Warm Air Stratifying at the Ceiling

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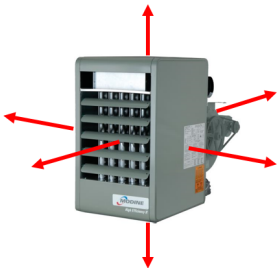
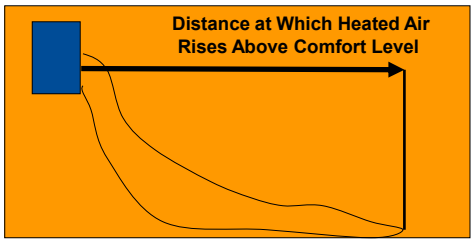
Unit Heater Considerations

- Piping to systems
- Roof penetrations for exhaust
- Condensate removal for H.E. models
- Clearances (Combustibles, Accessibility, Free flow of air)





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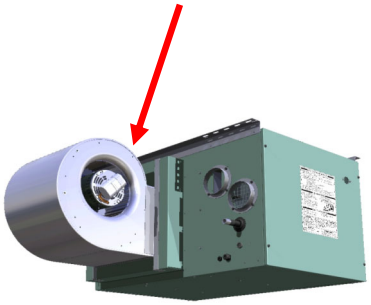
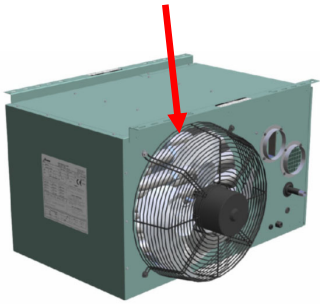
Unit Heater Types

Blower Unit Heater



Ductwork & Nozzles Acceptable
Quieter Than Propeller Units
Higher Cost Than Propeller Units
Power Vented

Propeller Unit Heater



Deflector Blades & Hoods Acceptable
Ductwork & Nozzles Not Acceptable
Lower Cost Than Blower Units

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PTACs

Packaged **T**erminal **A**ir **C**onditioner

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PTACs

- Single package containing all the components of an air-cooled air conditioner, furnace and air-handling system
- Used where individual zones have an outside wall and are conditioned separately with individual occupant control
- Well suited to hotels, motels, nursing homes, schools and apartments
- Units available with various heating options
- Natural gas as well as hydronic options using gas fired boilers
- Typical Efficiency – 80%

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Issues with PTACs

- Pro's:
  - Higher efficiency units now available
  - Replacement units available for older systems
  - Only heat/cool occupied areas as necessary
- Con's:
  - Noise
  - Piping to systems
  - Multiple units = more maintenance

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Thru the Wall Furnaces

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Thru-The-Wall Units

- Thru-The-Wall Units combine heating and cooling in one compact easy-to-install unit
  - For use in:
  - Apartments
  - Condominiums
  - Other multiple occupancy buildings
  - Efficiency – 80%
  - Each space has individual comfort controls providing tenants complete control over their comfort needs

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Thru-The-Wall Units

- Available in gas heating/electric cooling, heat pump and electric heating/cooling
- Easily installed with venting through side of building
- Great for multi-family

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Issues with Thru the Wall Units

- Pro's:
  - High efficiency units available
  - Replacement units available for older systems
  - Occupants heat/cool space as necessary
- Con's:
  - Gas piping and metering to systems
  - Individual units = more maintenance

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Heat Pumps

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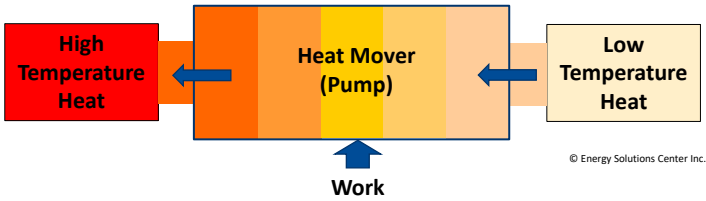
What is a "Heat Pump"

- 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 and vice versa based on winter or summer operation



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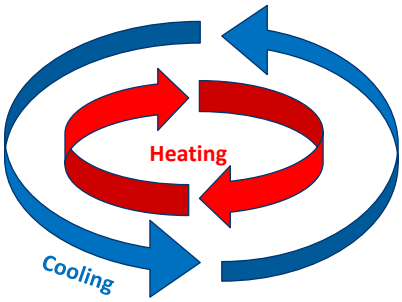
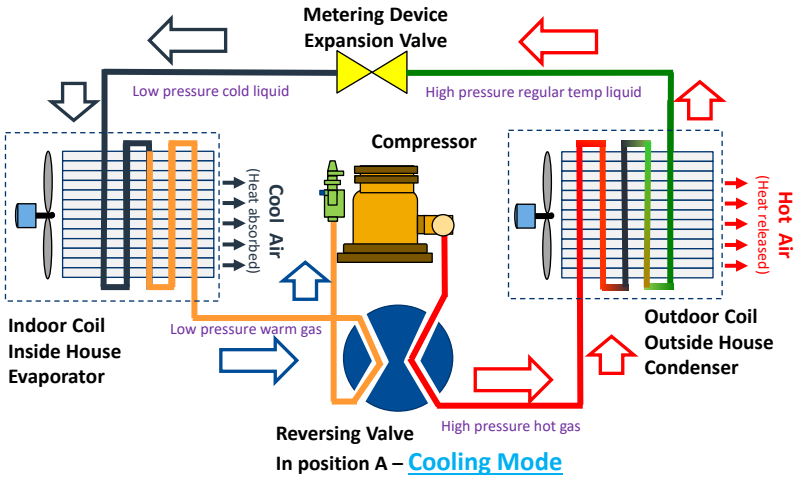
How it Works in Heating Mode
Vapor Compression for Electric and Gas Engine Heat Pumps

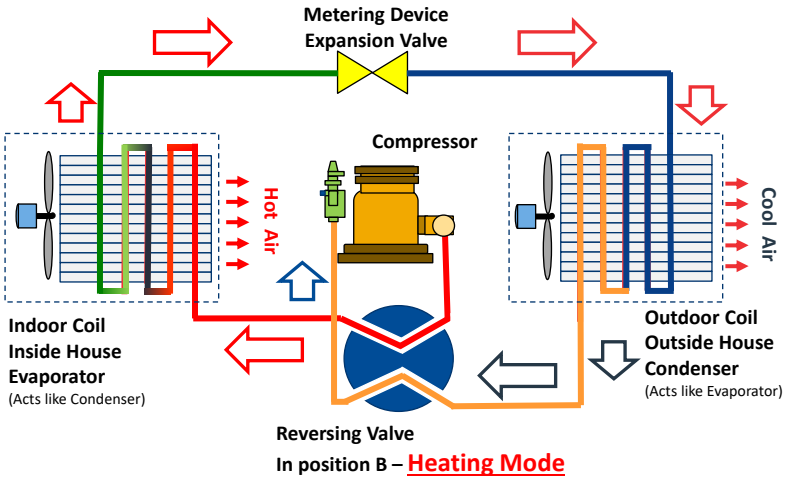
- Refrigerant flow is reversed via a valve in the system
  - Reversing valve rotates 90°
  - Changes the direction of the flow of the refrigerant
  - Flow is in the opposite direction – the reverse of the cooling cycle

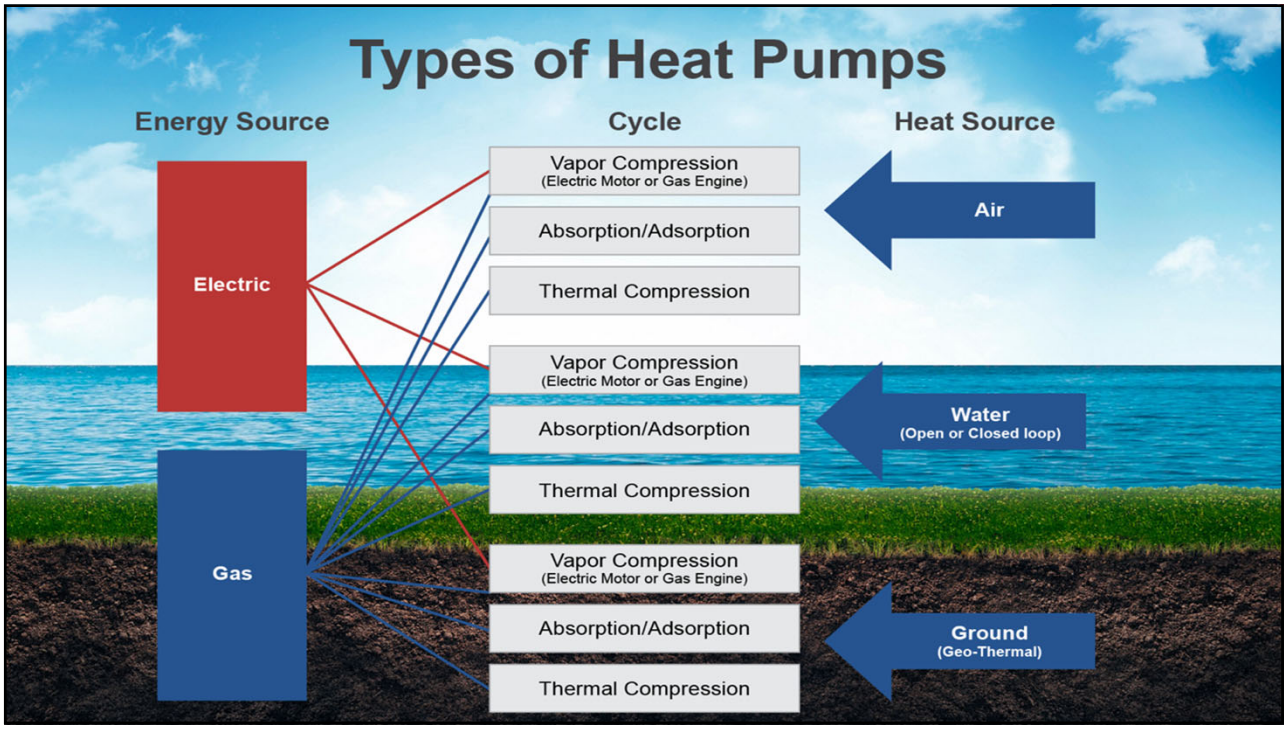


Air Source System in Cooling Mode
(Typical Electric or Engine Driven Air Conditioning)



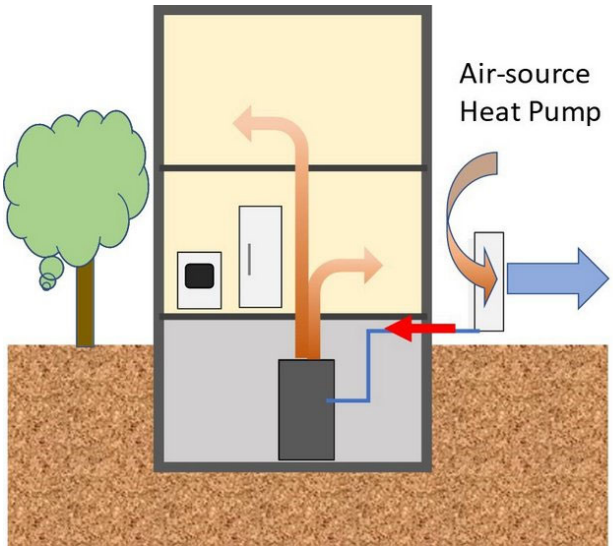
Air Source Heating Mode





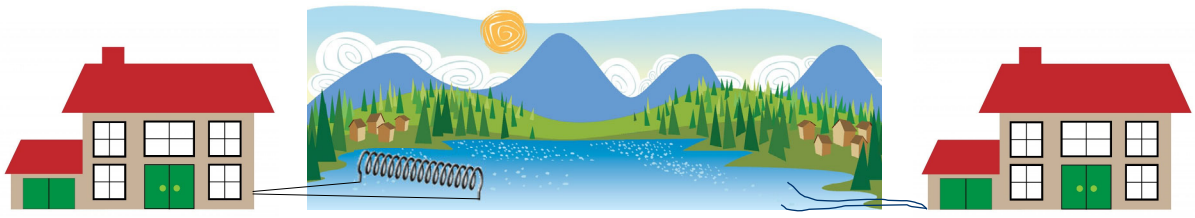
Air Source

- Takes heat from air in the winter and uses it to heat the space
- Takes heat away from the space in the summer to cool the indoor air
- Outside unit could be electric, gas engine or absorber



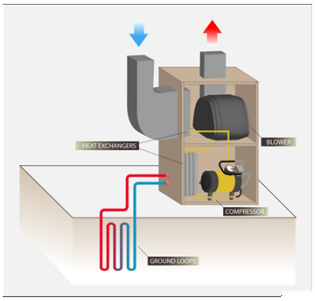
Water Source Heat Pumps

- Closed Loop
  - Just like ground source, antifreeze solution is in a closed circuit and completely isolated from the water source
  - Water from a close by lake or pond is used as the heat source/sink
- Open Loop
  - Lake or pond water is circulated directly through the loop



Ground Source Heat Pumps

- Soil temperature is almost constant year round
  - Warmer than air in the winter
  - Cooler than air in the summer
- Types of Ground Source Heat Pumps
  - Electric heat pumps
  - Gas engine heat pumps
  - Absorption heat pumps



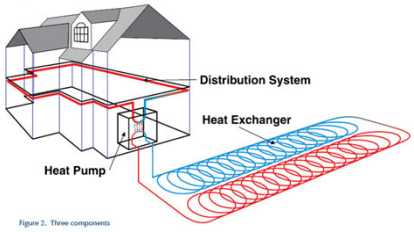


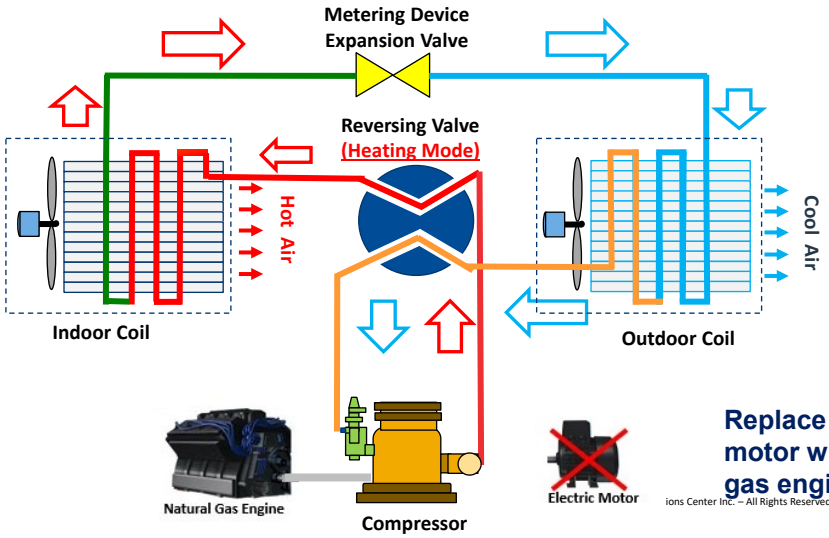
Figure 2. Three components

Natural Gas Heat Pump Options

Absorption system

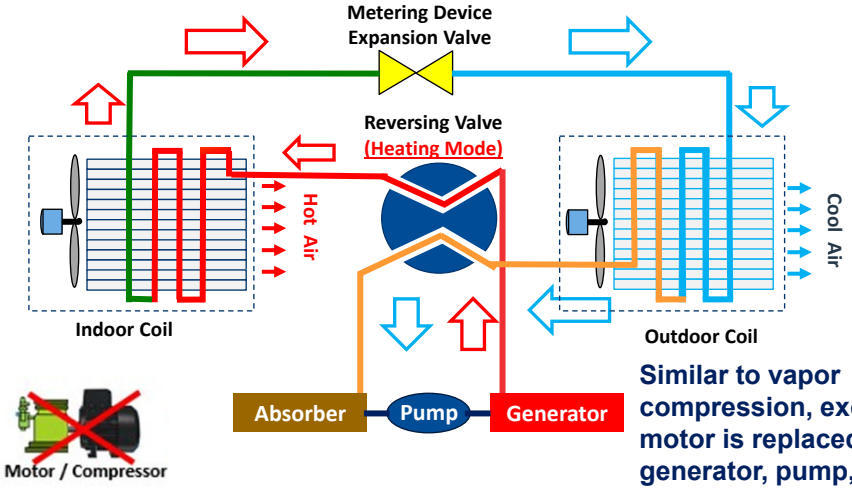
Engine-driven system

GHP: Engine Driven (Heating mode)



Replace electric motor with natural gas engine

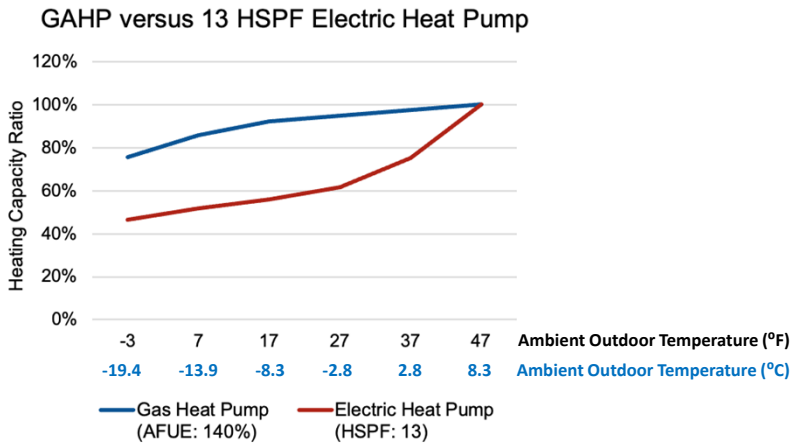
GHP: Absorption(Heating mode)



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

GHP vs EHP Heating Capacity at Various Outdoor Temperatures

Gas heat pumps do a much better job heating at lower temperatures than electric heat pumps.



* Courtesy of Stone Mountain Technologies

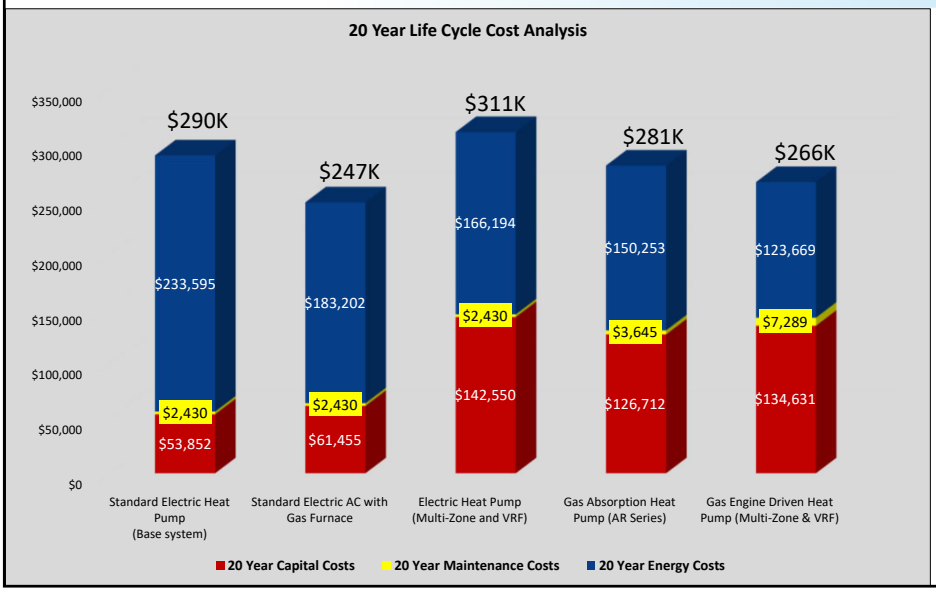
GHP Products

Company	Type	Technology	Best Applications	Status	Heat Sizes	Cooling Sizes
Anesi	Heating, Water Heating	Absorption	Residential, Commercial	Commercially available	10,000 to 140,000 BTU/h	Future cooling 1-4 tons
Blue Mountain Energy	Heating, Cooling, Water Heating	IC Engine	Residential, Commercial, Industrial	Commercially available, 5 & 11 Ton, field testing others	91,000 to 410,000 BTU/h	5, 8, 11, 15, and 30 Tons
Broad USA	Heating, Cooling, Water Heating	Absorption	Commercial, Industrial	Commercially available	962,000 BTU to 57,800,000 BTU/h	30 to 3,968 Tons
Energy Concepts	Heating, Cooling, Water Heating	Absorption	Commercial, Industrial	Commercially available	396,000 to 40,000,000 BTU/h	20 Tons to 2,000 Tons, down to -50ºF
HeatAmp	Heating, Water Heating	Adsorption (Chemisorption)	Residential	Field test 2023	Up to 50,000 BTU/h	n/a
Robur	Heating, Cooling, Water Heating	Absorption	Residential, Commercial	Commercially available	120,000 BTU/h	5 Tons
ThermoLift	Heating, Cooling, Water Heating	Thermal Compressor	Residential	Field demos	55,000 to 75,000 BTU/h	3 Tons
Thermax	Heating, Water Heating	Absorption (Waste heat fired)	Commercial, Industrial	Commercially available	835,035 to 136,484,680 BTU/h	n/a
Yanmar	Heating, Cooling, Water Heating	IC Engine	Residential, Commercial, Industrial	Commercially available	108,000 to 198,000 BTU/h	8, 10, 12, and 14 tons
York	Heating, Water Heating	Absorption (Waste heat fired)	Commercial, Industrial	Commercially available	10,000,000 to 24,000,000 BTU/h	n/a
Vicot	Heating, Water Heating	Absorption	Residential, Commercial	Commercially available. Resid. units: Field Trial	68,000 BTU to 290,000 BTU/h	n/a

Key: Residential, Commercial, Industrial, Heating, Cooling, Water Heating

https:///consortia.myescenter.com/GHP/ESC-GHP_Avialability_Chart.pdf

Life Cycle Costs of GHPs



Note: GHPs can cost 3X that of conventional HVAC systems, but generally have overall lower life cycle costs than conventional systems.

Assumptions: 20-ton system amortized over 20 years at 5% interest with $.13/kWh, $10/kW, and $.93/Therm energy rates, with 2% energy & maintenance inflation rates.

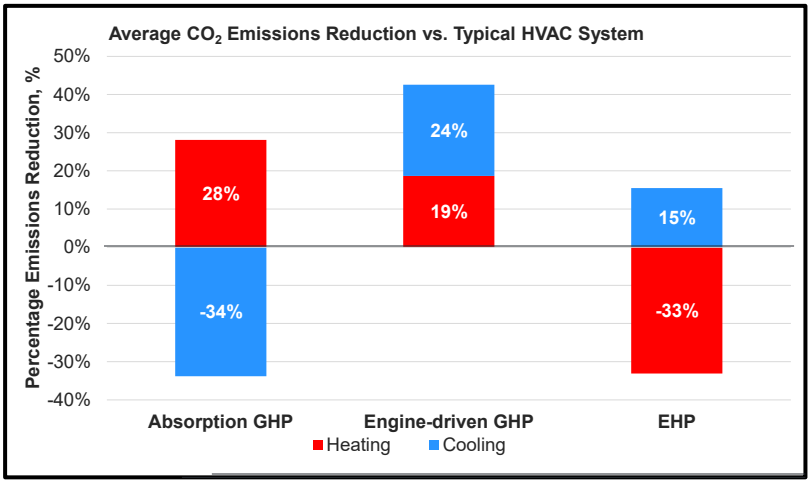
Note that life cycle costs will vary based on regional energy rates.

https://gasairconditioning.com/general-resources/tools/

Lifetime Emissions for Gas and Electric Heat Pumps at Commercial Buildings

Baseline is RTU with gas heat & electric cooling.

See study for detailed analysis.



Source: https://consortia.myescenter.com/GHP/ESC_GHP_Operating_Costs-Emissions-Study-ICF-August2021-Full.pdf

Boilers for Building Heat

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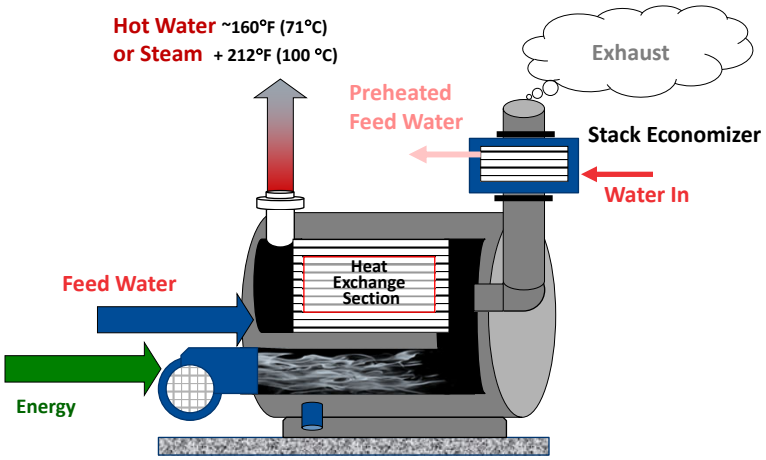
Typical Boiler Schematic



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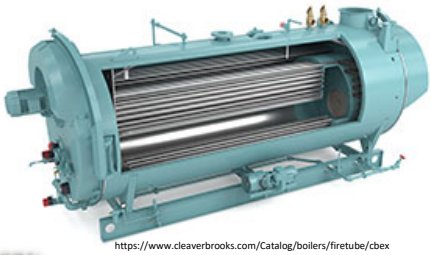
Types of Boilers (see boiler details in Unit 2)

Sectional

Fire Tube



https://www.cleaverbrooks.com/Catalog/boilers/firetube/cbex

Fin Tube

https://www.lochinvar.com

Coiled Tube

Water Tube

https://www.cleaverbrooks.com/Catalog/boilers/packaged-watertube-boilers/flx

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Hydronic Floor Heating

- Boilers can provide hot water for Radiant Floor Heating
  - "In floor" radiant heating uses a hot fluid that runs through tubing (often PEX plastic)
  - Hot water from boiler circulates through system
  - Heat radiates to space
  - No air movement
  - Quiet system

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Steam & Hot Water Heating Systems

- Boilers provide heat to heat exchangers that transfer heat to space
  - Radiator – Radiates heat to space through natural convection
  - Fan Coil System – Steam or hot water passes through coil – with fan blowing air across the coils

In Ceiling Fan Coil System

Baseboard Style

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Hydronic Heating System Components

- In Ceiling Fan Coil Systems
- Baseboard Styles
- Radiators

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Boiler Systems

- Pro's
  - Soft Heat – no drafts from radiator systems
  - Long life expectancy
- Con's
  - Water treatment
  - System maintenance
  - Floor space requirements
  - Operational vulnerability – one boiler

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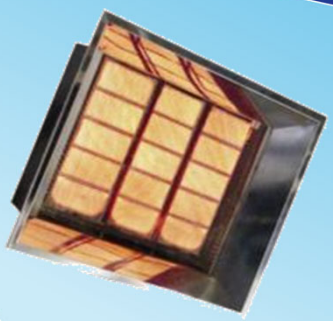
Gas Infrared Systems



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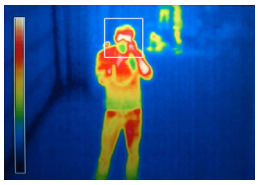
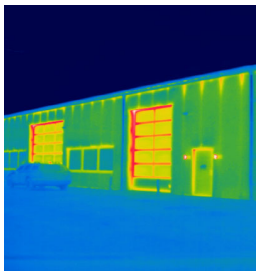
What is Infrared Heat?

- **Infrared (Radiant) Heat** is an energy wave generated by a hot source through the vibration of molecules
- Energy is absorbed directly by people and objects
- Does not depend on heating of the air to heat those people and objects
- The Sun – energy is projected over 90 million miles through space to earth at the speed of light





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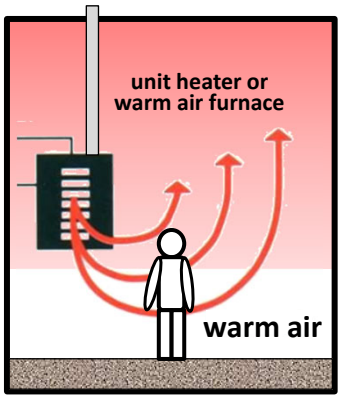
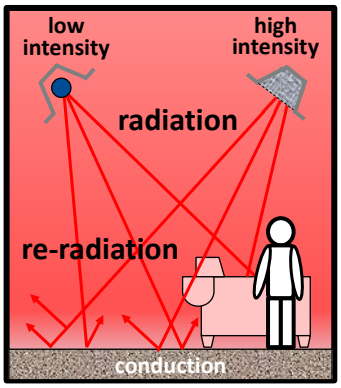
Warm Air vs. Infrared Heating Systems



Forced Warm Air



Infrared Heating

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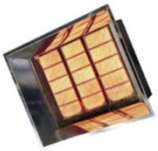
Infrared Natural Gas Heat Systems

- Types of systems
  - High intensity units
  - Low intensity tubular units
- 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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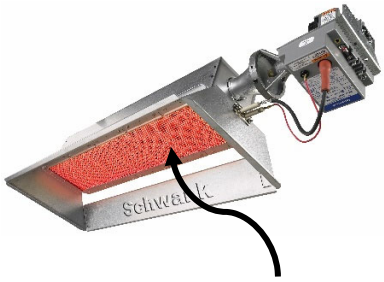
High Intensity Infrared Heaters

- Shorter wavelength – visible energy
- Higher temperature range
- Spot heat potential
- Indoor & outdoor applications
- Transmits heat over greater distances – 12-40 feet (3.6-12.2 meters)



~ 1600 – 1800°F
(~ 871.1 – 982.2°)

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Low Intensity (Tube) Heaters

- Tube heaters with closed combustion burners – nonvisible (longer wavelength)
- Vented or non-vented versions
- Vacuum or pressure tube styles
- Install 10-20 feet (3-6 meters)from objects to be heated

~ 600 – 800°F
(~315.5 – 426.6°C)

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Typical "IR" Applications

- Loading Docks
- Machine Shops
- Aircraft Hangars
- Repair Garages
- Implement Dealers
- Car / Truck Dealers
- Maintenance Areas
- Indoor Sports Arenas
  - Hockey, Tennis, etc.
- Truck Terminals
- Warehouses
- Factories
- Stadiums
- Steel Mills
- Gymnasiums
- Foundries
- Firehouses
- Grandstands

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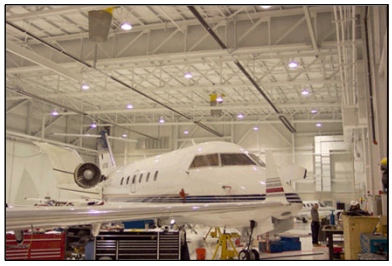
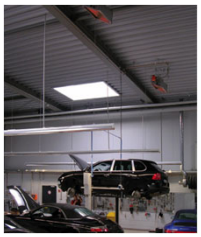
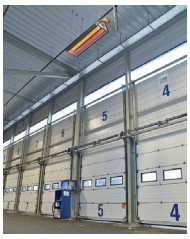
IR Installations

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Combo Heating Systems

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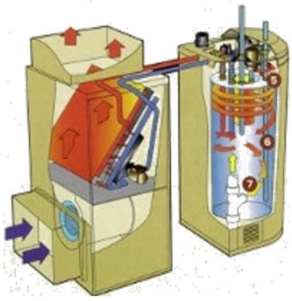
Types of Combo Systems

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

"A highly efficient combination system can reduce water heating and space heating energy use by 15 percent or more compared to a standard water heater and space heating installation"

http://www.builditgreen.org/attachments/wysiwyg/22/Combo-Systems.pdf



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Water Heater Combo Systems

- Typically used in smaller spaces such as apartments
- System design and component selection is critical
- High efficiency models are available that allow venting of the water heaters through a wall instead of a chimney
- Competitive with other conventional options such as heat pumps and electric water heaters
- Can use tank or tankless water heater units

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Boiler Combo Systems

- Boiler has a small water coil typically above the combustion chamber. As the boiler runs hot water is produced.
  - Hot water from the boiler used to provide space heat through hydronic / radiator system.
  - Hot water also sent to indirect storage tank, with internal coils to transfer heat from the boiler water to the domestic hot water.

Source: GAMA

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Thermostats and Reset Controls

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Programmable Thermostats

- Choice of battery-powered or hardwired with battery back-up
- Meets ENERGY STAR® specifications
- For small commercial installations – thermostats look and operate much like residential thermostats
- Universal – choice of 7 day, 5/1/1 or 5/2 day programmable or non-programmable versions
- Programmable fan
- Optional remote sensing of indoor/outdoor temps and humidity
- Automatic daylight savings option

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Medium to Large Commercial Controls

- Computerized Control Systems
  - Programmable Controllers
  - Sensors
  - Wired & Wireless Options
  - Monitoring, Reporting and Analysis Programs
  - Temperature, Humidity and CO2 monitoring & control

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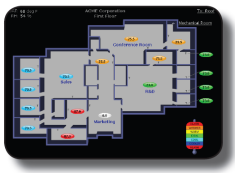
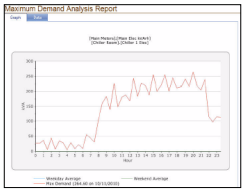
Commercial Controls Can Offer

Floorplan Views





Operations Analysis

System Monitoring Capability

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Reset Controllers

- Have two temperature sensors – one outside the building & one in the boiler water
- As outdoor temperature fluctuates, the controller adjusts the water temperature setting to the lowest setting needed to meet the heating demand based on programming
- Limits exist in the controls to keep the boiler from operating outside of its safe performance range
- Save 1% of energy consumption for every 4°F (-15.5°C) of reduction in boiler water temperature

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Associations and Resources

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

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Associations & Resources

- ESC – Commercial Buildings Consortium
  - Located in Washington, DC
  - Consortium of utility companies interested in the promotion of products & technologies for the commercial building marketplace
  - www.ESCenter.org

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Associations & Resources

- DOE – U.S. Department of Energy
  - Located in Washington, DC
  - Federal Energy Management Program
  - www1.eere.energy.gov/femp

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Associations & Resources

- ASHRAE - American Society of Heating, Refrigerating and Air-Conditioning Engineers – Atlanta, GA
  - Advances heating, ventilation, air conditioning and refrigeration through research, standards writing, publishing and continuing education
  - www.ashrae.org

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