

- **Reviewing Key Safety Measures for Mobile Home HVAC Work**
Reviewing Key Safety Measures for Mobile Home HVAC Work Understanding PPE Guidelines for Mobile Home Furnace Repair Following OSHA Standards During Mobile Home AC Installations Noting Electrical Hazard Precautions in Mobile Home HVAC Projects Planning Lockout Procedures for Mobile Home Heating Maintenance Checking for Proper Ventilation in Mobile Home HVAC Crawl Spaces Confirming Compliance with HUD Requirements for Mobile Home Ducts Conducting On Site Safety Assessments Before Mobile Home AC Repairs Checking Gas Line Integrity in Mobile Home Heating Systems Identifying Combustion Clearance Issues in Mobile Home Furnaces Monitoring Air Quality Factors During Mobile Home HVAC Upkeep Coordinating Exit Strategies for Emergencies in Mobile Home HVAC Work
- **Identifying Warning Signs of Outdated Components**
Identifying Warning Signs of Outdated Components Converting Older Units to High Efficiency Models Examining Duct Layout for Better Distribution Adjusting Equipment Size to Fit Modern Needs Evaluating Newer Options to Replace Electric Heaters Implementing Airflow Balancing Techniques Overcoming Physical Constraints in Legacy Structures Transitioning to Improved Refrigerants for Compliance Strengthening Insulation to Enhance Performance Matching Compatibility of Controls and Existing Wiring Coordinating Expert Consultations for Complex Projects Planning Timelines for Effective System Upgrades
- **About Us**



Electric heaters have long been a staple in the heating solutions for mobile homes. However, as we move towards more sustainable and efficient living standards, it's essential to evaluate their limitations and challenges, particularly when considering newer options that may be better suited for modern needs.

One of the primary limitations of using electric heaters in mobile homes is their energy efficiency-or lack thereof. Electric heaters can consume a significant amount of electricity, leading to higher utility bills. This is especially concerning in regions where electricity costs are high or where the grid relies heavily on non-renewable sources, thereby increasing the carbon footprint associated with their use. Space constraints in mobile homes require innovative HVAC installation techniques **Mobile Home Furnace Installation** experience. Furthermore, mobile homes often lack the insulation found in traditional houses, which means more energy is required to maintain comfortable temperatures.

Another challenge is safety. Electric heaters can pose fire risks if not properly maintained or used incorrectly. In compact spaces like mobile homes, where space is at a premium and flammable materials may be nearby, this risk is magnified. The potential for accidents increases during peak usage times in winter months when demand on electrical systems can lead to overheating or circuit overloads.

Additionally, electric heaters often provide uneven heat distribution within a mobile home. They tend to focus warmth around their immediate vicinity while leaving other areas cold. This inconsistency can result in discomfort for occupants and necessitate additional heating devices or methods to achieve desired comfort levels throughout the entire home.

Moreover, electric heaters typically offer limited control over temperature settings compared to more modern heating solutions like programmable thermostats connected with central HVAC systems or smart home technology which allow users to tailor their environment precisely according to personal preferences and schedules.

Given these limitations and challenges, evaluating newer alternatives becomes crucial. Options such as heat pumps or propane-based systems might offer greater efficiency and cost-effectiveness over time while also enhancing safety features through advanced technology integrations.

In conclusion, while electric heaters have served as an accessible heating solution for many years within mobile homes, their drawbacks prompt an exploration of alternative options that align with current demands for sustainability, safety, comfort, and efficiency. As technology advances continue providing innovative solutions tailored specifically for small spaces like those found in mobile homes; it becomes increasingly important not only consider but actively pursue these newer alternatives that promise improved living conditions without compromising on environmental considerations or economic practicality.

As the world continues to grapple with the challenges of climate change and rising energy costs, the demand for efficient and sustainable heating technologies has never been more pressing. Traditional electric heaters, long a staple in many households, are now being scrutinized for their inefficiency and environmental impact. In response, a variety of newer heating technologies and alternatives have emerged, promising not only to reduce energy consumption but also to provide a cleaner, greener way to maintain comfort in our homes.

One of the most promising advancements is the heat pump technology. Unlike conventional electric heaters that convert electricity directly into heat, heat pumps transfer heat from one place to another - much like a refrigerator works but in reverse. Air-source heat pumps extract warmth from the outside air even in cold temperatures and deliver it inside. Ground-source or geothermal heat pumps take advantage of the relatively constant temperature underground. These systems can be incredibly efficient; for every unit of electricity they use, they can produce several units of heat.

Another innovative solution gaining traction is infrared heating panels. These panels emit infrared rays that directly warm objects and people rather than heating the surrounding air. This method mimics how the sun heats surfaces on Earth and can create a comfortable environment while using less energy than traditional convection-based systems.

Biomass heating is also emerging as an attractive alternative for those looking to replace electric heaters with something more sustainable. Biomass boilers burn organic materials such as wood pellets or chips to generate heat. While this does release carbon dioxide, it is considered carbon-neutral because the plants absorbed CO₂ during their growth phase. Moreover, biomass systems can often be integrated into existing radiators or underfloor heating systems with minimal modification.

Hydronic radiant floor systems present another modern option by circulating warm water through pipes beneath floor surfaces. This method provides uniform warmth throughout a space without creating drafts or hot spots common in rooms heated by forced-air systems.

Innovative hybrid systems are also making headway by combining different technologies for optimal efficiency and flexibility. For instance, some setups integrate solar thermal collectors with heat pumps or biomass boilers to leverage renewable resources whenever possible while having reliable backup options when needed.

The adoption of smart thermostats and home automation technologies further complements these innovations by providing precise control over heating schedules and allowing homeowners to optimize energy usage based on real-time data about occupancy patterns or weather forecasts.

While these newer options offer compelling benefits over traditional electric heaters - including lower operational costs, reduced environmental impact, improved indoor air quality - they may come with higher upfront installation expenses depending on specific circumstances like home insulation levels or local climate conditions.

In conclusion, as we evaluate new options to replace electric heaters in our quest for sustainability and efficiency, it's clear that there are numerous viable alternatives available today ranging from cutting-edge technological solutions like heat pumps and infrared panels to more established methods like biomass boilers. Each offers its own set of advantages tailored toward different needs and preferences; thus careful consideration should be given when selecting which approach best fits individual requirements while contributing positively towards broader ecological goals.

Posted by on

Posted by on

Posted by on

Essential Safety Gear and Equipment for Technicians

In recent years, the quest for more energy-efficient heating options has become increasingly critical as we strive to reduce our carbon footprint and minimize energy costs. The traditional electric heater, while convenient and widely used, is often criticized for its inefficiency in terms of energy consumption compared to newer and more sustainable heating systems. This essay aims to provide a comparative analysis of various modern heating options that could potentially replace electric heaters, focusing on their energy efficiency.

To begin with, heat pumps have emerged as a leading alternative due to their impressive energy efficiency. Unlike electric heaters that convert electricity directly into heat, heat pumps transfer heat from outside sources like air or ground into indoor spaces. This method can be up to three times more efficient than conventional electric heating because it merely moves heat rather than generating it from scratch. Air-source and ground-source (geothermal) heat pumps are the most common types, each offering different advantages based on climatic conditions and installation feasibility.

Another promising option is the use of solar thermal systems. These systems harness solar energy through collectors usually installed on rooftops, converting sunlight into usable thermal energy for space heating or water heating purposes. While the initial setup cost can be high, the operational costs are minimal since sunlight is free and abundant in many regions. However, their efficiency can vary significantly depending on geographic location and weather conditions; hence, they are best suited for areas with substantial sunshine throughout the year.

Biomass boilers represent another viable alternative by utilizing organic materials such as wood pellets or chips as fuel. These boilers have gained popularity due to their ability to utilize renewable resources while also providing a sustainable solution for waste management. With advancements in technology, biomass boilers have become more efficient and user-friendly. However, they require regular maintenance and a steady supply of biomass fuel which might not be feasible for all users.

Additionally, infrared heaters offer an innovative approach by directly warming objects and people rather than air in a room. This technology reduces unnecessary heating of empty spaces-a common issue with traditional electric heaters-thus enhancing overall energy efficiency. Infrared heaters can be particularly effective in well-insulated environments where radiant heat absorption is maximized.

Finally, district heating systems present an interesting community-based solution where centralized plants produce heat distributed via insulated pipes to multiple buildings within an area. By utilizing combined heat and power (CHP) plants or waste-to-energy facilities as sources of thermal energy production, district heating achieves higher efficiencies compared to individual building systems.

In conclusion, when evaluating newer options to replace electric heaters from an energy efficiency perspective, it's evident that several alternatives offer significant benefits over traditional methods. Heat pumps stand out due to their superior efficiency ratings; however other solutions like solar thermal systems, biomass boilers, infrared heaters-and even district heating networks-provide compelling choices depending on specific needs and circumstances such as geographical location or infrastructure availability. As we continue exploring these alternatives amidst growing environmental concerns and economic considerations alike; choosing wisely will ensure both sustainable practices today-and better prospects tomorrow-for future generations seeking warmth without compromise upon our planet's wellbeing overall!





Proper Procedures for Handling Refrigerants and Chemicals

When evaluating newer options to replace electric heaters, it is crucial to delve into the cost considerations associated with installation, operation, and maintenance. These three facets not only determine the immediate financial outlay but also influence long-term economic sustainability and environmental impacts.

Installation costs often serve as the initial barrier or gateway in adopting a new heating solution. Emerging technologies such as heat pumps, radiant floor heating, or solar thermal systems might require more sophisticated installation procedures compared to traditional electric heaters. This could involve specialized labor, specific infrastructural adjustments, or even significant architectural modifications. For instance, installing a geothermal heat pump may necessitate drilling which can drive up costs significantly more than simply replacing an electric wall heater. Hence, it is important for consumers and businesses alike to assess whether the upfront installation investment aligns with their budgetary constraints and long-term savings expectations.

Once installed, operational costs become a primary concern. Electric heaters are notorious for their high energy consumption which translates directly into elevated utility bills. Newer alternatives often boast better energy efficiency and lower operating expenses. Heat pumps, for example, utilize ambient air or ground temperatures to provide heating at a fraction of the electric cost required by resistance-based heaters. However, these savings can be influenced by factors such as climate conditions and electricity prices in different regions. Therefore, when considering replacements like high-efficiency gas furnaces or biomass boilers, one must evaluate not just their advertised efficiency but also how these systems perform under specific environmental circumstances.

Maintenance costs represent another critical aspect of evaluating replacement options for electric heaters. Traditional electric units generally have fewer mechanical parts leading to lower maintenance demands; however, they may still require regular checks for safety and performance optimization. Conversely, while more complex systems like solar thermal panels or hydronic heating might offer substantial energy efficiencies and operational savings over time, they could incur higher maintenance fees due to their complexity or reliance on external factors like weather conditions.

In conclusion, when contemplating newer options for replacing electric heaters-whether driven by environmental concerns or economic incentives-a comprehensive assessment of installation costs against potential operational savings and future maintenance expenses is essential. By carefully weighing these factors within the context of individual needs and regional characteristics, consumers can make informed decisions that balance initial investments with sustainable benefits over time.

Electrical Safety Protocols for Mobile Home HVAC Work

As concerns about climate change and environmental sustainability continue to rise, the quest for reducing carbon footprints has become a global imperative. One area ripe for innovation is home heating—specifically, the evaluation of newer options to replace electric heaters with more environmentally friendly solutions.

Electric heaters, while commonly used due to their convenience and availability, are not necessarily the most sustainable choice. They often rely on electricity generated from fossil fuels, which contributes significantly to carbon emissions. As such, there is an urgent need to explore alternative technologies that can provide efficient heating while minimizing environmental impact.

One promising solution is heat pump technology. Heat pumps operate by transferring heat from one place to another rather than generating it directly through electricity. This method is significantly more energy-efficient compared to traditional electric heaters. By utilizing ambient heat from the ground or air, heat pumps can reduce electricity consumption substantially. Moreover, when powered by renewable energy sources like solar or wind power, they offer an almost entirely carbon-neutral solution.

Another innovative option gaining traction is infrared heating panels. Unlike conventional heaters that warm up the air in a room, infrared panels directly heat objects and individuals within a space through radiation. This direct form of heating means less energy loss and quicker warmth delivery. Additionally, these panels can be integrated into smart home systems, allowing users to optimize their energy use further by programming and automating heating schedules according to occupancy patterns.

Biomass boilers present yet another alternative worth considering. These systems burn organic materials such as wood pellets or chips instead of relying on electricity or fossil fuels. Properly managed biomass resources are considered renewable because they can be replenished over time without depleting natural ecosystems drastically. While initial setup costs may be higher, biomass boilers can offer long-term savings and substantial reductions in carbon emissions compared to electric heaters.

However, transitioning from electric heaters to these newer options requires careful consideration of various factors such as installation costs, local climate conditions, availability of resources (like biomass), and infrastructure capabilities (such as access to renewable energy). Policymakers play a crucial role in facilitating this transition by providing incentives for adopting greener technologies and investing in research that further enhances their efficiency and affordability.

In conclusion, evaluating newer options for replacing electric heaters offers a tangible opportunity to reduce our carbon footprint significantly. While no single solution may fit all scenarios perfectly due to varying regional needs and constraints, embracing a mix of innovative technologies like heat pumps, infrared panels, and biomass boilers can pave the way towards more sustainable home heating practices. As we move forward into an era where environmental responsibility takes center stage globally-the choices we make today will indeed shape the world we leave for future generations tomorrow.

Best Practices for Ensuring Structural Integrity During Installation and Maintenance

In recent years, the quest to replace traditional electric heaters with more advanced heating systems has gained significant momentum. As the world becomes increasingly conscious of energy efficiency and sustainability, consumers are exploring modern alternatives that not only

provide warmth but also enhance user experience through comfort, safety, and ease of use.

Comfort is a critical factor that users consider when evaluating modern heating systems. Unlike conventional electric heaters that often produce uneven heat distribution and dry air, newer options such as hydronic heating and radiant floor systems offer a more consistent and natural warmth. These systems work by circulating warm water or utilizing infrared technology to heat spaces evenly, creating an environment where every corner of a room feels just right. Furthermore, many advanced systems come equipped with smart thermostats that allow users to customize temperature settings based on their preferences or even schedule heating cycles to align with their daily routines. This level of personalization ensures optimal comfort tailored to individual needs.

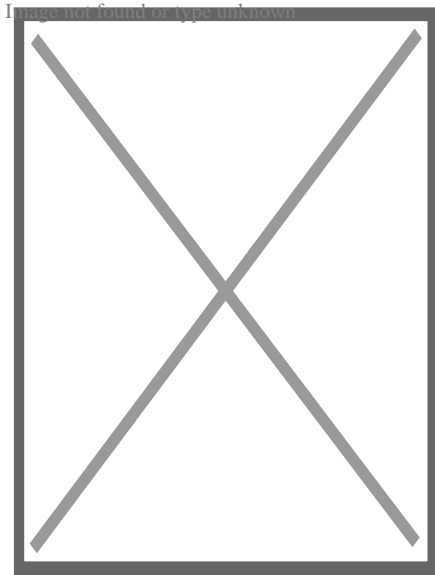
Safety is another paramount concern when choosing a replacement for electric heaters. Traditional electric heaters can pose various risks, including overheating, electrical faults, and fire hazards if not used properly. In contrast, modern heating solutions have been designed with enhanced safety features to mitigate such dangers. For instance, hydronic systems reduce the risk of burns since they do not rely on exposed elements or high surface temperatures. Additionally, many contemporary models incorporate automatic shut-off mechanisms and child-lock functions to prevent accidents and ensure peace of mind for families.

Ease of use is equally essential in evaluating new heating options. As technology evolves, so does the expectation for intuitive interfaces and seamless integration into everyday life. Modern heating systems often feature user-friendly controls that can be managed through smartphone apps or voice-activated devices like smart home assistants. This connectivity allows users to adjust settings remotely—turning on the heat before arriving home from work or lowering it while away on vacation—all with a few taps on their phone or simple voice commands. Such convenience not only improves user experience but also promotes energy saving by enabling precise control over energy consumption.

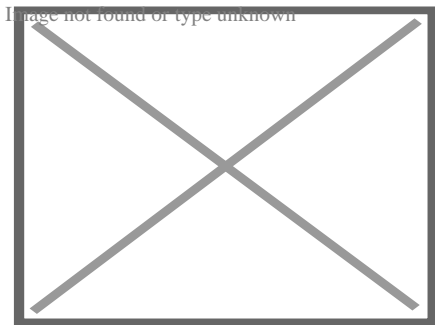
In conclusion, as homeowners consider replacing outdated electric heaters with newer options, focusing on user experience aspects like comfort, safety, and ease of use becomes crucial. Modern heating systems offer significant advantages in these areas by providing consistent warmth without compromising on safety or convenience. By embracing these innovative solutions, consumers can enjoy enhanced living environments that cater to their specific needs while also contributing to broader goals of sustainability and energy efficiency.

About Heat pump

This article is about devices used to heat and potentially also cool a building (or water) using the refrigeration cycle. For more about the theory, see Heat pump and refrigeration cycle. For details of the most common type, see air source heat pump. For a similar device for cooling only, see air conditioner. For heat pumps used to keep food cool, see refrigerator. For other uses, see Heat pump (disambiguation).



External heat exchanger of an air-source heat pump for both heating and cooling



Mitsubishi heat pump interior air handler wall unit

- v
- t
- e

Part of a series on

Sustainable energy

A car drives past 4 wind turbines in a field, with more on the horizon

Image not found or type unknown



Energy conservation

- Arcology
- Building insulation
- Cogeneration
- Compact fluorescent lamp
- Eco hotel
- Eco-cities
- Ecohouse
- Ecolabel
- Efficient energy use
- Energy audit
- Energy efficiency implementation
- Energy recovery
- Energy recycling
- Energy saving lamp
- Energy Star
- Energy storage
- Environmental planning
- Environmental technology
- Fossil fuel phase-out
- Glass in green buildings
- Green building and wood
- Green building
- Heat pump
- List of low-energy building techniques
- Low-energy house
- Microgeneration
- Passive house
- Passive solar building design
- Sustainable architecture
- Sustainable city
- Sustainable habitat
- Sustainable refurbishment
- Thermal energy storage
- Tropical green building
- Waste-to-energy
- Zero heating building
- Zero-energy building

Renewable energy

- Biofuel
 - Sustainable
- Biogas
- Biomass
- Carbon-neutral fuel
- Geothermal energy
- Geothermal power
- Geothermal heating
- Hydropower
 - Hydroelectricity
 - Micro hydro
 - Pico hydro
 - Run-of-the-river
 - Small hydro
- Marine current power
- Marine energy
- Tidal power
 - Tidal barrage
 - Tidal farm
 - Tidal stream generator
- Ocean thermal energy conversion
- Renewable energy transition
- Renewable heat
- Solar
- Wave
- Wind
 - Community
 - Farm
 - Floating wind turbine
 - Forecasting
 - Industry
 - Lens
 - Outline
 - Rights
 - Turbine
 - Windbelt
 - Windpump

Sustainable transport

- Green vehicle
 - Electric vehicle
 - Bicycle
 - Solar vehicle
 - Wind-powered vehicle
- Hybrid vehicle
 - Human-electric
 - Twike
 - Plug-in
- Human-powered transport
 - Helicopter
 - Hydrofoil
 - Land vehicle
 - Bicycle
 - Cycle rickshaw
 - Kick scooter
 - Quadracycle
 - Tricycle
 - Velomobile
 - Roller skating
 - Skateboarding
 - Walking
 - Watercraft
- Personal transporter
- Rail transport
 - Tram
- Rapid transit
 - Personal rapid transit
-  Category image not found or type unknown
-  Renewable energy portal

A **heat pump** is a device that consumes energy (usually electricity) to transfer heat from a cold heat sink to a hot heat sink. Specifically, the heat pump transfers thermal energy using a refrigeration cycle, cooling the cool space and warming the warm space.^[1] In cold weather, a heat pump can move heat from the cool outdoors to warm a house (e.g. winter); the pump may also be designed to move heat from the house to the warmer outdoors in warm weather (e.g. summer). As they transfer heat rather than generating heat, they are more energy-efficient than other ways of heating or cooling a home.^[2]

A gaseous refrigerant is compressed so its pressure and temperature rise. When operating as a heater in cold weather, the warmed gas flows to a heat exchanger in the indoor space where some of its thermal energy is transferred to that indoor space, causing the gas to condense to its liquid state. The liquified refrigerant flows to a heat exchanger in the outdoor space where the pressure falls, the liquid evaporates and the temperature of the gas falls. It is now colder than the temperature of the outdoor space being used as a heat source. It can again take up energy from the heat source, be compressed and repeat the cycle.

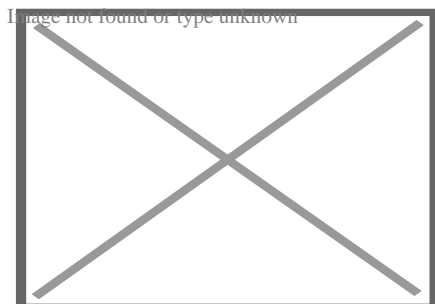
Air source heat pumps are the most common models, while other types include ground source heat pumps, water source heat pumps and exhaust air heat pumps.^[3] Large-scale heat pumps are also used in district heating systems.^[4]

The efficiency of a heat pump is expressed as a coefficient of performance (COP), or seasonal coefficient of performance (SCOP). The higher the number, the more efficient a heat pump is. For example, an air-to-water heat pump that produces 6kW at a SCOP of 4.62 will give over 4kW of energy into a heating system for every kilowatt of energy that the heat pump uses itself to operate. When used for space heating, heat pumps are typically more energy-efficient than electric resistance and other heaters.

Because of their high efficiency and the increasing share of fossil-free sources in electrical grids, heat pumps are playing a role in climate change mitigation.^{[5][6]} Consuming 1 kWh of electricity, they can transfer 1^[7] to 4.5 kWh of thermal energy into a building. The carbon footprint of heat pumps depends on how electricity is generated, but they usually reduce emissions.^[8] Heat pumps could satisfy over 80% of global space and water heating needs with a lower carbon footprint than gas-fired condensing boilers: however, in 2021 they only met 10%.^[4]

Principle of operation

[edit]



A: indoor compartment, B: outdoor compartment, I: insulation, 1: condenser, 2: expansion valve, 3: evaporator, 4: compressor

Main articles: Heat pump and refrigeration cycle and Vapor-compression refrigeration

Heat flows spontaneously from a region of higher temperature to a region of lower temperature. Heat does not flow spontaneously from lower temperature to higher, but it can be made to flow in this direction if work is performed. The work required to transfer a given amount of heat is usually much less than the amount of heat; this is the motivation for using heat pumps in applications such as the heating of water and the interior of buildings.^[9]

The amount of work required to drive an amount of heat Q from a lower-temperature reservoir such as ambient air to a higher-temperature reservoir such as the interior of a

building is: Image not found or type unknown where

- W is the work performed on the working fluid by the heat pump's compressor.
- Q is the heat transferred from the lower-temperature reservoir to the higher-temperature reservoir.
- COP is the instantaneous coefficient of performance for the heat pump at the temperatures prevailing in the reservoirs at one instant.

The coefficient of performance of a heat pump is greater than one so the work required is less than the heat transferred, making a heat pump a more efficient form of heating than electrical resistance heating. As the temperature of the higher-temperature reservoir increases in response to the heat flowing into it, the coefficient of performance decreases, causing an increasing amount of work to be required for each unit of heat being transferred.^[9]

The coefficient of performance, and the work required by a heat pump can be calculated easily by considering an ideal heat pump operating on the reversed Carnot cycle:

- If the low-temperature reservoir is at a temperature of 270 K (−3 °C) and the interior of the building is at 280 K (7 °C) the relevant coefficient of performance is 27. This means only 1 joule of work is required to transfer 27 joules of heat from a reservoir at 270 K to another at 280 K. The one joule of work ultimately ends up as thermal energy in the interior of the building so for each 27 joules of heat that are removed from the low-temperature reservoir, 28 joules of heat are added to the building interior, making the heat pump even more attractive from an efficiency perspective.^[note 1]
- As the temperature of the interior of the building rises progressively to 300 K (27 °C) the coefficient of performance falls progressively to 9. This means each joule of work is responsible for transferring 9 joules of heat out of the low-temperature reservoir and into the building. Again, the 1 joule of work ultimately ends up as thermal energy in the interior of the building so 10 joules of heat are added to the building interior.^[note 2]

This is the theoretical amount of heat pumped but in practice it will be less for various reasons, for example if the outside unit has been installed where there is not enough airflow. More data sharing with owners and academics—perhaps from heat meters—could improve efficiency in the long run.^[11]

History

[edit]

Milestones:

1748

William Cullen demonstrates artificial refrigeration.^[12]

1834

Jacob Perkins patents a design for a practical refrigerator using dimethyl ether.^[13]

1852

Lord Kelvin describes the theory underlying heat pumps.^[14]

1855–1857

Peter von Rittinger develops and builds the first heat pump.^[15]

1877

In the period before 1875, heat pumps were for the time being pursued for vapour compression evaporation (open heat pump process) in salt works with their obvious advantages for saving wood and coal. In 1857, Peter von Rittinger was the first to try to implement the idea of vapor compression in a small pilot plant. Presumably inspired by Rittinger's experiments in Ebensee, Antoine-Paul Piccard from the University of Lausanne and the engineer J. H. Weibel from the Weibel–Briquet company in Geneva built the world's first really functioning vapor compression system with a two-stage piston compressor. In 1877 this first heat pump in Switzerland was installed in the Bex salt works.^{[14][16]}

1928

Aurel Stodola constructs a closed-loop heat pump (water source from Lake Geneva) which provides heating for the Geneva city hall to this day.^[17]

1937–1945

During the First World War, fuel prices were very high in Switzerland but it had plenty of hydropower.^[14]

ˆfÆ'†â€™fâ€ ˆcâ,-â,,cƒÆ'ˆcâ,-ˆ ˆfˆcˆcâ€šˆ-ˆcâ€žˆcˆfÆ'†â€™fˆcˆc

In the period before and especially during the Second World War, when neutral Switzerland was completely surrounded by fascist-ruled countries, the coal shortage became alarming again. Thanks to their leading position in energy technology, the Swiss companies Sulzer, Escher Wyss and Brown Boveri built and put in operation around 35 heat pumps between 1937 and 1945. The main heat sources were lake water, river water, groundwater, and waste heat.

Particularly noteworthy are the six historic heat pumps from the city of Zurich with heat outputs from 100 kW to 6 MW. An international milestone is the heat pump built by Escher Wyss in 1937/38 to replace the wood stoves in the City Hall of Zurich. To avoid noise and vibrations, a recently developed rotary piston compressor was used. This historic heat pump heated the town hall for 63 years until 2001. Only then was it replaced by a new, more efficient heat pump.^[14]

1945

John Sumner, City Electrical Engineer for Norwich, installs an experimental water-source heat pump fed central heating system, using a nearby river to heat new Council administrative buildings. It had a seasonal efficiency ratio of 3.42, average thermal delivery of 147 kW, and peak output of 234 kW.^[18]

1948

Robert C. Webber is credited as developing and building the first ground-source heat pump.^[19]

1951

First large scale installation—the Royal Festival Hall in London is opened with a town gas-powered reversible water-source heat pump, fed by the Thames, for both winter heating and summer cooling needs.^[18]

2019

The Kigali Amendment to phase out harmful refrigerants takes effect.

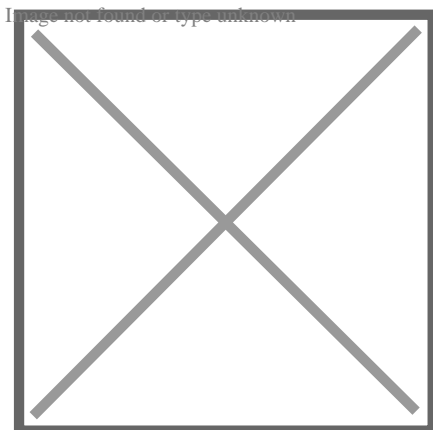
Types

[edit]

Air-source

[edit]

This section is an excerpt from Air source heat pump. [edit]



Heat pump on balcony of apartment

An air source heat pump (ASHP) is a heat pump that can absorb heat from air outside a building and release it inside; it uses the same vapor-compression refrigeration process and much the same equipment as an air conditioner, but in the opposite direction. ASHPs are the most common type of heat pump and, usually being smaller, tend to be used to heat individual houses or flats rather than blocks, districts or industrial processes.^{[20][21]}

Air-to-air heat pumps provide hot or cold air directly to rooms, but do not usually provide hot water. *Air-to-water* heat pumps use radiators or underfloor heating to heat a whole house and are often also used to provide domestic hot water.

An ASHP can typically gain 4 kWh thermal energy from 1 kWh electric energy. They are optimized for flow temperatures between 30 and 40 °C (86 and 104 °F), suitable for buildings with heat emitters sized for low flow temperatures. With losses in efficiency, an ASHP can even provide full central heating with a flow temperature up to 80 °C (176 °F).^[22]

As of 2023 about 10% of building heating worldwide is from ASHPs. They are the main way to phase out gas boilers (also known as "furnaces") from houses, to avoid their greenhouse gas emissions.^[23]

Air-source heat pumps are used to move heat between two heat exchangers, one outside the building which is fitted with fins through which air is forced using a fan and the other which either directly heats the air inside the building or heats water which is then circulated around the building through radiators or underfloor heating which releases the heat to the building. These devices can also operate in a cooling mode where they extract heat via the internal heat exchanger and eject it into the ambient air using the external heat exchanger. Some can be used to heat water for washing which is stored in a domestic hot water tank.^[24]

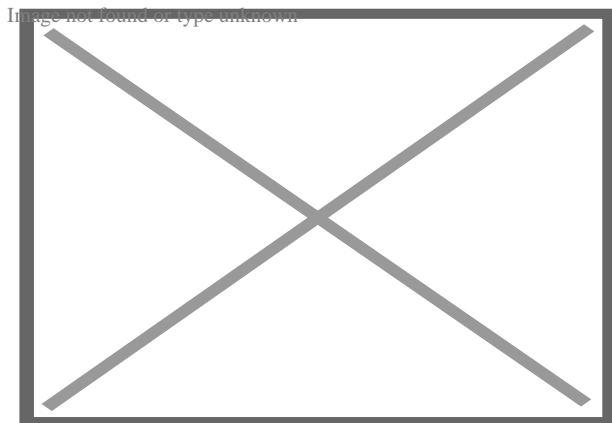
Air-source heat pumps are relatively easy and inexpensive to install, so are the most widely used type. In mild weather, coefficient of performance (COP) may be between 2 and 5, while at temperatures below around 8 °C (18 °F) an air-source heat pump may still achieve a COP of 1 to 4.^[25]

While older air-source heat pumps performed relatively poorly at low temperatures and were better suited for warm climates, newer models with variable-speed compressors remain highly efficient in freezing conditions allowing for wide adoption and cost savings in places like Minnesota and Maine in the United States.^[26]

Ground source

[edit]

This section is an excerpt from Ground source heat pump. [edit]



A heat pump in combination with heat and cold storage

A ground source heat pump (also geothermal heat pump) is a heating/cooling system for buildings that use a type of heat pump to transfer heat to or from the ground, taking advantage of the relative constancy of temperatures of the earth through the seasons. Ground-source heat pumps (GSHPs) – or geothermal heat pumps (GHP), as they are commonly termed in North America – are among the most energy-efficient technologies for providing HVAC and water heating, using far less energy than can be achieved by burning a fuel in a boiler/furnace or by use of resistive electric heaters.

Efficiency is given as a coefficient of performance (CoP) which is typically in the range 3 – 6, meaning that the devices provide 3 – 6 units of heat for each unit of electricity used. Setup costs are higher than for other heating systems, due to the requirement to install ground loops over large areas or to drill bore holes, and for this reason, ground source is often suitable when new blocks of flats are built.^[27] Otherwise air-source heat pumps are often used instead.

Heat recovery ventilation

[edit]

Main article: Heat recovery ventilation

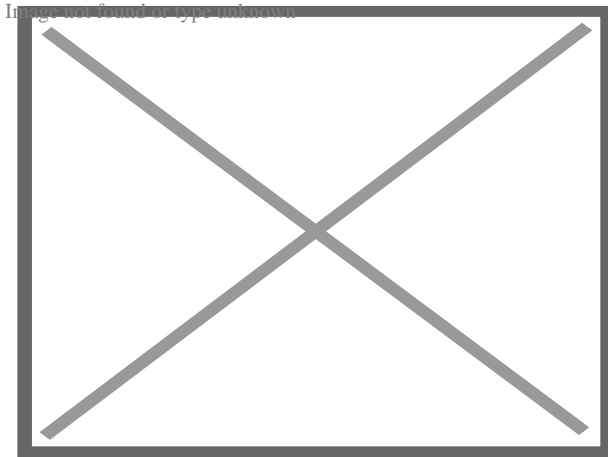
Exhaust air heat pumps extract heat from the exhaust air of a building and require mechanical ventilation. Two classes exist:

- Exhaust air-air heat pumps transfer heat to intake air.
- Exhaust air-water heat pumps transfer heat to a heating circuit that includes a tank of domestic hot water.

Solar-assisted

[edit]

This section is an excerpt from Solar-assisted heat pump. [edit]



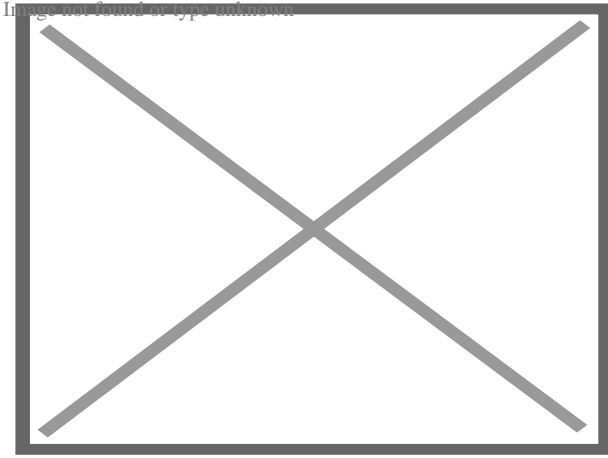
Hybrid photovoltaic-thermal solar panels of a SAHP in an experimental installation at Department of Energy at Polytechnic of Milan

A solar-assisted heat pump (SAHP) is a machine that combines a heat pump and thermal solar panels and/or PV solar panels in a single integrated system.^[28] Typically these two technologies are used separately (or only placing them in parallel) to produce hot water.^[29] In this system the solar thermal panel performs the function of the low temperature heat source and the heat produced is used to feed the heat pump's evaporator.^[30] The goal of this system is to get high coefficient of performance (COP) and then produce energy in a more efficient and less expensive way.

It is possible to use any type of solar thermal panel (sheet and tubes, roll-bond, heat pipe, thermal plates) or hybrid (mono/polycrystalline, thin film) in combination with the heat pump. The use of a hybrid panel is preferable because it allows covering a part of the electricity demand of the heat pump and reduce the power consumption and consequently the variable costs of the system.

Water-source

[edit]



Water-source heat exchanger being installed

A water-source heat pump works in a similar manner to a ground-source heat pump, except that it takes heat from a body of water rather than the ground. The body of water does, however, need to be large enough to be able to withstand the cooling effect of the unit without freezing or creating an adverse effect for wildlife.^[31] The largest water-source heat pump was installed in the Danish town of Esbjerg in 2023.^{[32][33]}

Others

[edit]

A thermoacoustic heat pump operates as a thermoacoustic heat engine without refrigerant but instead uses a standing wave in a sealed chamber driven by a loudspeaker to achieve a temperature difference across the chamber.^[34]

Electrocaloric heat pumps are solid state.^[35]

Applications

[edit]

The International Energy Agency estimated that, as of 2021, heat pumps installed in buildings have a combined capacity of more than 1000 GW.^[4] They are used for heating, ventilation, and air conditioning (HVAC) and may also provide domestic hot water and tumble clothes drying.^[36] The purchase costs are supported in various countries by consumer rebates.^[37]

Space heating and sometimes also cooling

[edit]

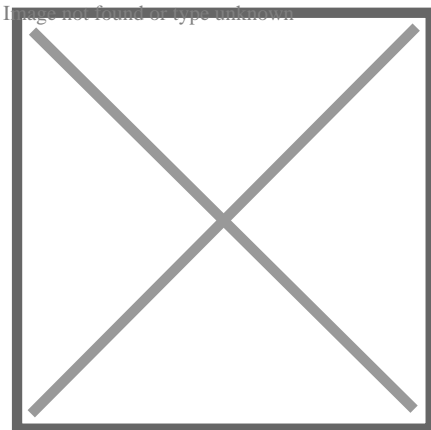
In HVAC applications, a heat pump is typically a vapor-compression refrigeration device that includes a reversing valve and optimized heat exchangers so that the direction of *heat flow* (thermal energy movement) may be reversed. The reversing valve switches the direction of refrigerant through the cycle and therefore the heat pump may deliver either heating or cooling to a building.

Because the two heat exchangers, the condenser and evaporator, must swap functions, they are optimized to perform adequately in both modes. Therefore, the Seasonal Energy Efficiency Rating (SEER in the US) or European seasonal energy efficiency ratio of a reversible heat pump is typically slightly less than those of two separately optimized machines. For equipment to receive the US Energy Star rating, it must have a rating of at least 14 SEER. Pumps with ratings of 18 SEER or above are considered highly efficient. The highest efficiency heat pumps manufactured are up to 24 SEER.[³⁸]

Heating seasonal performance factor (in the US) or Seasonal Performance Factor (in Europe) are ratings of heating performance. The SPF is Total heat output per annum / Total electricity consumed per annum in other words the average heating COP over the year.[³⁹]

Window mounted heat pump

[edit]



Saddle-style window mounted heat pump 3D sketch

Window mounted heat pumps run on standard 120v AC outlets and provide heating, cooling, and humidity control. They are more efficient with lower noise levels, condensation management, and a smaller footprint than window mounted air conditioners that just do cooling.^[40]

Water heating

[edit]

In water heating applications, heat pumps may be used to heat or preheat water for swimming pools, homes or industry. Usually heat is extracted from outdoor air and transferred to an indoor water tank.^[41]^[42]

District heating

[edit]

Large (megawatt-scale) heat pumps are used for district heating.^[43] However as of 2022 about 90% of district heat is from fossil fuels.^[44] In Europe, heat pumps account for a mere 1% of heat supply in district heating networks but several countries have targets to decarbonise their networks between 2030 and 2040.^[4] Possible sources of heat for such applications are sewage water, ambient water (e.g. sea, lake and river water), industrial waste heat, geothermal energy, flue gas, waste heat from district cooling and heat from solar seasonal thermal energy storage.^[45] Large-scale heat pumps for district heating combined with thermal energy storage offer high flexibility for the integration of variable renewable energy. Therefore, they are regarded as a key technology for limiting climate change by phasing out fossil fuels.^[45]^[46] They are also a crucial element of systems which can both heat and cool districts.^[47]

Industrial heating

[edit]

There is great potential to reduce the energy consumption and related greenhouse gas emissions in industry by application of industrial heat pumps, for example for process heat.^[48]^[49] Short payback periods of less than 2 years are possible, while achieving

a high reduction of CO₂ emissions (in some cases more than 50%).^{[50][51]} Industrial heat pumps can heat up to 200 °C, and can meet the heating demands of many light industries.^{[52][53]} In Europe alone, 15 GW of heat pumps could be installed in 3,000 facilities in the paper, food and chemicals industries.^[4]

Performance

[edit]

Main article: Coefficient of performance

The performance of a heat pump is determined by the ability of the pump to extract heat from a low temperature environment (the *source*) and deliver it to a higher temperature environment (the *sink*).^[54] Performance varies, depending on installation details, temperature differences, site elevation, location on site, pipe runs, flow rates, and maintenance.

In general, heat pumps work most efficiently (that is, the heat output produced for a given energy input) when the difference between the heat source and the heat sink is small. When using a heat pump for space or water heating, therefore, the heat pump will be most efficient in mild conditions, and decline in efficiency on very cold days. Performance metrics supplied to consumers attempt to take this variation into account.

Common performance metrics are the SEER (in cooling mode) and seasonal coefficient of performance (SCOP) (commonly used just for heating), although SCOP can be used for both modes of operation.^[54] Larger values of either metric indicate better performance.^[54] When comparing the performance of heat pumps, the term *performance* is preferred to *efficiency*, with coefficient of performance (COP) being used to describe the ratio of useful heat movement per work input.^[54] An electrical resistance heater has a COP of 1.0, which is considerably lower than a well-designed heat pump which will typically have a COP of 3 to 5 with an external temperature of 10 °C and an internal temperature of 20 °C. Because the ground is a constant temperature source, a ground-source heat pump is not subjected to large temperature fluctuations, and therefore is the most energy-efficient type of heat pump.^[54]

The "seasonal coefficient of performance" (SCOP) is a measure of the aggregate energy efficiency measure over a period of one year which is dependent on regional climate.^[54] One framework for this calculation is given by the Commission Regulation (EU) No. 813/2013.^[55]

A heat pump's operating performance in cooling mode is characterized in the US by either its energy efficiency ratio (EER) or seasonal energy efficiency ratio (SEER), both of which have units of BTU/(h·W) (note that 1 BTU/(h·W) = 0.293 W/W) and larger values indicate better performance.

COP variation with output temperature

Pump type and source	Typical use	35 °C (e.g. heated screed floor)
High-efficiency air-source heat pump (ASHP), air at 20 °C [56]		2.2
Two-stage ASHP, air at 20 °C [57]	Low source temperature	2.4
High-efficiency ASHP, air at 0 °C [56]	Low output temperature	3.8
Prototype transcritical CO ₂ (R744) heat pump with tripartite gas cooler, source at 0 °C [58]	High output temperature	3.3
Ground-source heat pump (GSHP), water at 0 °C [56]		5.0
GSHP, ground at 10 °C [56]	Low output temperature	7.2

Theoretical Carnot cycle limit, source ?20 °C	5.6
Theoretical Carnot cycle limit, source 0 °C	8.8
Theoretical Lorentzen cycle limit (CO ₂ pump), return fluid 25 °C, source 0 °C ^[58]	10.1
Theoretical Carnot cycle limit, source 10 °C	12.3

Carbon footprint

[edit]

The carbon footprint of heat pumps depends on their individual efficiency and how electricity is produced. An increasing share of low-carbon energy sources such as wind and solar will lower the impact on the climate.

heating system	emissions of energy source	efficiency	resulting emissions for thermal energy
heat pump with onshore wind power	11 gCO ₂ /kWh ^[59]	400% (COP=4)	3 gCO ₂ /kWh
heat pump with global electricity mix	436 gCO ₂ /kWh ^[60] (2022)	400% (COP=4)	109 gCO ₂ /kWh

natural-gas thermal (high efficiency)	201 gCO ₂ /kWh ^[61]	90% ^[citation needed]	223 gCO ₂ /kWh
heat pump electricity by lignite (old power plant) and low performance	1221 gCO ₂ /kWh ^[61]	300% (COP=3)	407 gCO ₂ /kWh

In most settings, heat pumps will reduce CO₂ emissions compared to heating systems powered by fossil fuels.^[62] In regions accounting for 70% of world energy consumption, the emissions savings of heat pumps compared with a high-efficiency gas boiler are on average above 45% and reach 80% in countries with cleaner electricity mixes.^[4] These values can be improved by 10 percentage points, respectively, with alternative refrigerants. In the United States, 70% of houses could reduce emissions by installing a heat pump.^[63]^[4] The rising share of renewable electricity generation in many countries is set to increase the emissions savings from heat pumps over time.^[4]

Heating systems powered by green hydrogen are also low-carbon and may become competitors, but are much less efficient due to the energy loss associated with hydrogen conversion, transport and use. In addition, not enough green hydrogen is expected to be available before the 2030s or 2040s.^[64]^[65]

Operation

[edit]

See also: Vapor-compression refrigeration



This section **needs additional citations for verification**. Please help improve this article by adding citations to reliable sources in this section. Unsourced material may be challenged and removed. *(May 2021)* *(Learn how and when to remove this message)*

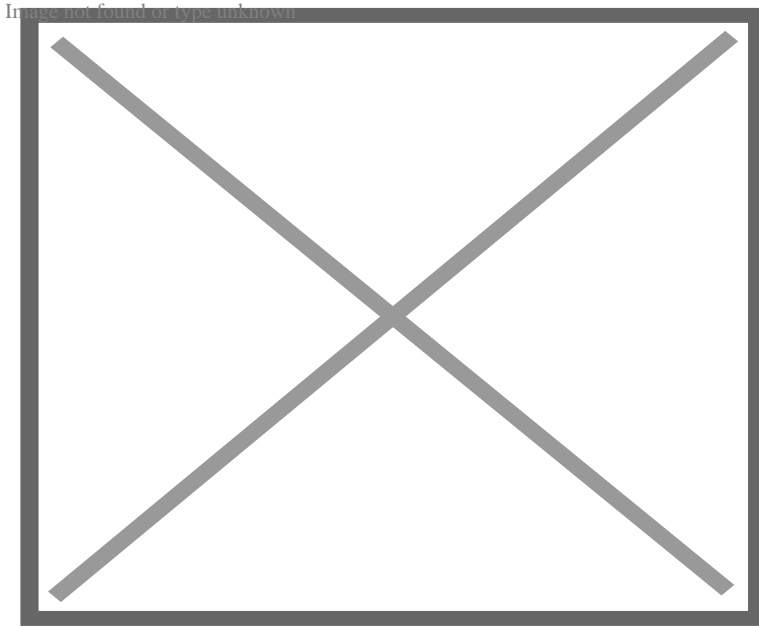
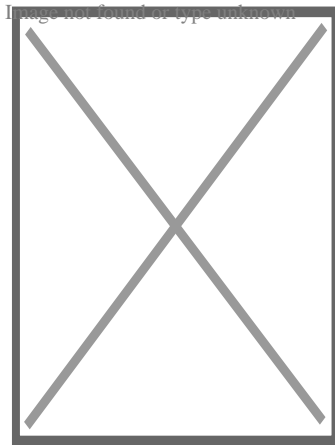
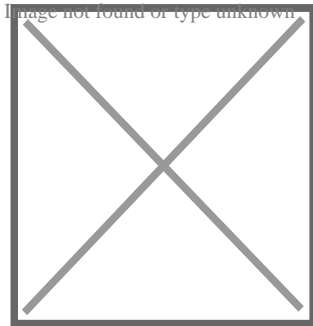


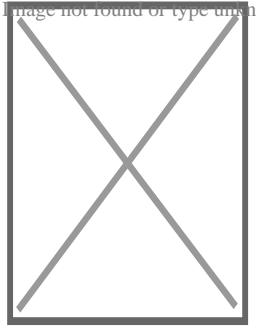
Figure 2: Temperature–entropy diagram of the vapor-compression cycle



An internal view of the outdoor unit of an Ecodan air source heat pump



Large heat pump setup for a commercial building



Wiring and connections to a central air unit inside

Vapor-compression uses a circulating refrigerant as the medium which absorbs heat from one space, compresses it thereby increasing its temperature before releasing it in another space. The system normally has eight main components: a compressor, a reservoir, a reversing valve which selects between heating and cooling mode, two thermal expansion valves (one used when in heating mode and the other when used in cooling mode) and two heat exchangers, one associated with the external heat source/sink and the other with the interior. In heating mode the external heat exchanger is the evaporator and the internal one being the condenser; in cooling mode the roles are reversed.

Circulating refrigerant enters the compressor in the thermodynamic state known as a saturated vapor^[66] and is compressed to a higher pressure, resulting in a higher temperature as well. The hot, compressed vapor is then in the thermodynamic state known as a superheated vapor and it is at a temperature and pressure at which it can be condensed with either cooling water or cooling air flowing across the coil or tubes. In heating mode this heat is used to heat the building using the internal heat exchanger, and in cooling mode this heat is rejected via the external heat exchanger.

The condensed, liquid refrigerant, in the thermodynamic state known as a saturated liquid, is next routed through an expansion valve where it undergoes an abrupt reduction in pressure. That pressure reduction results in the adiabatic flash evaporation of a part of the liquid refrigerant. The auto-refrigeration effect of the adiabatic flash evaporation lowers the temperature of the liquid and-vapor refrigerant mixture to where it is colder than the temperature of the enclosed space to be refrigerated.

The cold mixture is then routed through the coil or tubes in the evaporator. A fan circulates the warm air in the enclosed space across the coil or tubes carrying the cold refrigerant liquid and vapor mixture. That warm air evaporates the liquid part of the cold refrigerant mixture. At the same time, the circulating air is cooled and thus lowers

the temperature of the enclosed space to the desired temperature. The evaporator is where the circulating refrigerant absorbs and removes heat which is subsequently rejected in the condenser and transferred elsewhere by the water or air used in the condenser.

To complete the refrigeration cycle, the refrigerant vapor from the evaporator is again a saturated vapor and is routed back into the compressor.

Over time, the evaporator may collect ice or water from ambient humidity. The ice is melted through defrosting cycle. An internal heat exchanger is either used to heat/cool the interior air directly or to heat water that is then circulated through radiators or underfloor heating circuit to either heat or cool the buildings.

Improvement of coefficient of performance by subcooling

[edit]

Main article: Subcooling

Heat input can be improved if the refrigerant enters the evaporator with a lower vapor content. This can be achieved by cooling the liquid refrigerant after condensation. The gaseous refrigerant condenses on the heat exchange surface of the condenser. To achieve a heat flow from the gaseous flow center to the wall of the condenser, the temperature of the liquid refrigerant must be lower than the condensation temperature.

Additional subcooling can be achieved by heat exchange between relatively warm liquid refrigerant leaving the condenser and the cooler refrigerant vapor emerging from the evaporator. The enthalpy difference required for the subcooling leads to the superheating of the vapor drawn into the compressor. When the increase in cooling achieved by subcooling is greater than the compressor drive input required to overcome the additional pressure losses, such a heat exchange improves the coefficient of performance.^[67]

One disadvantage of the subcooling of liquids is that the difference between the condensing temperature and the heat-sink temperature must be larger. This leads to a moderately high pressure difference between condensing and evaporating pressure, whereby the compressor energy increases.

Refrigerant choice

[edit]

Main article: Refrigerant

Pure refrigerants can be divided into organic substances (hydrocarbons (HCs), chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), hydrofluoroolefins (HFOs), and HCFOs), and inorganic substances (ammonia (NH

₃), carbon dioxide (CO

₂), and water (H

₂O)^[68].^[69] Their boiling points are usually below $\approx 25\text{ °C}$.^[70]

In the past 200 years, the standards and requirements for new refrigerants have changed. Nowadays low global warming potential (GWP) is required, in addition to all the previous requirements for safety, practicality, material compatibility, appropriate atmospheric life,^[clarification needed] and compatibility with high-efficiency products. By 2022, devices using refrigerants with a very low GWP still have a small market share but are expected to play an increasing role due to enforced regulations,^[71] as most countries have now ratified the Kigali Amendment to ban HFCs.^[72] Isobutane (R600A) and propane (R290) are far less harmful to the environment than conventional hydrofluorocarbons (HFC) and are already being used in air-source heat pumps.^[73] Propane may be the most suitable for high temperature heat pumps.^[74] Ammonia (R717) and carbon dioxide (R-744) also have a low GWP. As of 2023 smaller CO

₂ heat pumps are not widely available and research and development of them continues.^[75] A 2024 report said that refrigerants with GWP are vulnerable to further international restrictions.^[76]

Until the 1990s, heat pumps, along with fridges and other related products used chlorofluorocarbons (CFCs) as refrigerants, which caused major damage to the ozone layer when released into the atmosphere. Use of these chemicals was banned or severely restricted by the Montreal Protocol of August 1987.^[77]

Replacements, including R-134a and R-410A, are hydrofluorocarbons (HFC) with similar thermodynamic properties with insignificant ozone depletion potential (ODP) but had problematic GWP.^[78] HFCs are powerful greenhouse gases which contribute to climate change.^[79]^[80] Dimethyl ether (DME) also gained in popularity as a refrigerant in combination with R404a.^[81] More recent refrigerants include difluoromethane (R32) with a lower GWP, but still over 600.

refrigerant	20-year GWP	100-year GWP
R-290 propane ^[82]	0.072	0.02
R-600a isobutane		3 ^[83]
R-32 ^[82]	491	136
R-410a ^[84]	4705	2285
R-134a ^[84]	4060	1470
R-404a ^[84]	7258	4808

Devices with R-290 refrigerant (propane) are expected to play a key role in the future. ^{[74][85]} The 100-year GWP of propane, at 0.02, is extremely low and is approximately 7000 times less than R-32. However, the flammability of propane requires additional safety measures: the maximum safe charges have been set significantly lower than for lower flammability refrigerants (only allowing approximately 13.5 times less refrigerant in the system than R-32).^{[86][87][88]} This means that R-290 is not suitable for all situations or locations. Nonetheless, by 2022, an increasing number of devices with R-290 were offered for domestic use, especially in Europe. ^[citation needed]

At the same time, ^[when?] HFC refrigerants still dominate the market. Recent government mandates have seen the phase-out of R-22 refrigerant. Replacements such as R-32 and R-410A are being promoted as environmentally friendly but still have a high GWP.^[89] A heat pump typically uses 3 kg of refrigerant. With R-32 this amount still has a 20-year impact equivalent to 7 tons of CO₂, which corresponds to two years of natural gas heating in an average household. Refrigerants with a high ODP have already been phased out. ^[citation needed]

Government incentives

[edit]

Financial incentives aim to protect consumers from high fossil gas costs and to reduce greenhouse gas emissions,^[90] and are currently available in more than 30 countries around the world, covering more than 70% of global heating demand in 2021. ^[4]

Australia

[edit]

Food processors, brewers, petfood producers and other industrial energy users are exploring whether it is feasible to use renewable energy to produce industrial-grade

heat. Process heating accounts for the largest share of onsite energy use in Australian manufacturing, with lower-temperature operations like food production particularly well-suited to transition to renewables.

To help producers understand how they could benefit from making the switch, the Australian Renewable Energy Agency (ARENA) provided funding to the Australian Alliance for Energy Productivity (A2EP) to undertake pre-feasibility studies at a range of sites around Australia, with the most promising locations advancing to full feasibility studies.^[91]

In an effort to incentivize energy efficiency and reduce environmental impact, the Australian states of Victoria, New South Wales, and Queensland have implemented rebate programs targeting the upgrade of existing hot water systems. These programs specifically encourage the transition from traditional gas or electric systems to heat pump based systems.^{[92][93][94][95][96]}

Canada

[edit]

In 2022, the Canada Greener Homes Grant^[97] provides up to \$5000 for upgrades (including certain heat pumps), and \$600 for energy efficiency evaluations.

China

[edit]

Purchase subsidies in rural areas in the 2010s reduced burning coal for heating, which had been causing ill health.^[98]

In the 2024 report by the International Energy Agency (IEA) titled "The Future of Heat Pumps in China," it is highlighted that China, as the world's largest market for heat pumps in buildings, plays a critical role in the global industry. The country accounts for over one-quarter of global sales, with a 12% increase in 2023 alone, despite a global sales dip of 3% the same year.^[99]

Heat pumps are now used in approximately 8% of all heating equipment sales for buildings in China as of 2022, and they are increasingly becoming the norm in central and southern regions for both heating and cooling. Despite their higher upfront costs

and relatively low awareness, heat pumps are favored for their energy efficiency, consuming three to five times less energy than electric heaters or fossil fuel-based solutions. Currently, decentralized heat pumps installed in Chinese buildings represent a quarter of the global installed capacity, with a total capacity exceeding 250 GW, which covers around 4% of the heating needs in buildings.^[99]

Under the Announced Pledges Scenario (APS), which aligns with China's carbon neutrality goals, the capacity is expected to reach 1,400 GW by 2050, meeting 25% of heating needs. This scenario would require an installation of about 100 GW of heat pumps annually until 2050. Furthermore, the heat pump sector in China employs over 300,000 people, with employment numbers expected to double by 2050, underscoring the importance of vocational training for industry growth. This robust development in the heat pump market is set to play a significant role in reducing direct emissions in buildings by 30% and cutting PM2.5 emissions from residential heating by nearly 80% by 2030.^{[99][100]}

European Union

[edit]

To speed up the deployment rate of heat pumps, the European Commission launched the Heat Pump Accelerator Platform in November 2024.^[101] It will encourage industry experts, policymakers, and stakeholders to collaborate, share best practices and ideas, and jointly discuss measures that promote sustainable heating solutions.^[102]

United Kingdom

[edit]

As of 2022: heat pumps have no Value Added Tax (VAT) although in Northern Ireland they are taxed at the reduced rate of 5% instead of the usual level of VAT of 20% for most other products.^[103] As of 2022 the installation cost of a heat pump is more than a gas boiler, but with the "Boiler Upgrade Scheme"^[104] government grant and assuming electricity/gas costs remain similar their lifetime costs would be similar on average.^[105] However lifetime cost relative to a gas boiler varies considerably depending on several factors, such as the quality of the heat pump installation and the tariff used.^[106] In 2024 England was criticised for still allowing new homes to be built with gas boilers, unlike some other counties where this is banned.^[107]

United States

[edit]

Further information: Environmental policy of the Joe Biden administration and Climate change in the United States

The High-efficiency Electric Home Rebate Program was created in 2022 to award grants to State energy offices and Indian Tribes in order to establish state-wide high-efficiency electric-home rebates. Effective immediately, American households are eligible for a tax credit to cover the costs of buying and installing a heat pump, up to \$2,000. Starting in 2023, low- and moderate-level income households will be eligible for a heat-pump rebate of up to \$8,000.^[108]

In 2022, more heat pumps were sold in the United States than natural gas furnaces.^[109]

In November 2023 Biden's administration allocated 169 million dollars from the Inflation Reduction Act to speed up production of heat pumps. It used the Defense Production Act to do so, because according to the administration, energy that is better for the climate is also better for national security.^[110]

Notes

[edit]

- [^] As explained in Coefficient of performance TheoreticalMaxCOP = $(\text{desiredIndoorTempC} + 273) \div (\text{desiredIndoorTempC} - \text{outsideTempC}) = (7+273) \div (7 - (-3)) = 280 \div 10 = 28$ ^[10]
- [^] As explained in Coefficient of performance TheoreticalMaxCOP = $(\text{desiredIndoorTempC} + 273) \div (\text{desiredIndoorTempC} - \text{outsideTempC}) = (27+273) \div (27 - (-3)) = 300 \div 30 = 10$ ^[10]

References

[edit]

- [^] "Heat Pump Systems". *Energy.gov*. Retrieved 26 March 2024.
- [^] "Heat Pump Systems". *US Department of Energy*. Archived from the original on 27 April 2023. Retrieved 27 April 2023.
- [^] "Exhaust air heat pumps". *Energy Saving Trust*. Retrieved 22 February 2024.
- [^] **a b c d e f g h i** *Technology Report: The Future of Heat Pumps*. *International Energy Agency (Report)*. November 2022. Archived from the original on 6 January 2023. Retrieved 6 January 2023. License: CC BY 4.0.
- [^] IPCC AR6 WG3 Ch11 2022, Sec. 11.3.4.1.

6. ^ IPCC SR15 Ch2 2018, p. 142.
7. ^ Everitt, Neil (11 September 2023). "Study proves heat pump efficiency at low temperatures". *Cooling Post*. Retrieved 22 January 2024.
8. ^ Deetjen, Thomas A.; Walsh, Liam; Vaishnav, Parth (28 July 2021). "US residential heat pumps: the private economic potential and its emissions, health, and grid impacts". *Environmental Research Letters*. **16** (8): 084024. Bibcode:2021ERL....16h4024D. doi:10.1088/1748-9326/ac10dc. ISSN 1748-9326. S2CID 236486619.
9. ^ **a b** G. F. C. Rogers and Y. R. Mayhew (1957), *Engineering Thermodynamics, Work and Heat Transfer*, Section 13.1, Longmans, Green & Company Limited.
10. ^ **a b** "Is there some theoretical maximum coefficient of performance (COP) for heat pumps and chillers?". *Physics Stack Exchange*. Retrieved 22 February 2024.
11. ^ Williamson, Chris (13 October 2022). "Heat pumps are great. Let's make them even better". *All you can heat*. Retrieved 22 February 2024.
12. ^ "The often forgotten Scottish inventor whose innovation changed the world". *The National*. 10 April 2022. Retrieved 21 February 2024.
13. ^ Bathe, Greville; Bathe, Dorothy (1943). *Jacob Perkins, his inventions, his times, & his contemporaries*. *The Historical Society of Pennsylvania*. p. 149.
14. ^ **a b c d** "History of Heat Pumping Technologies in Switzerland – Texts". *www.aramis.admin.ch*. Archived from the original on 23 November 2021. Retrieved 14 September 2023.
15. ^ Banks, David L. (6 May 2008). *An Introduction to Thermogeology: Ground Source Heating and Cooling* (PDF). Wiley-Blackwell. ISBN 978-1-4051-7061-1. Archived (PDF) from the original on 20 December 2016. Retrieved 5 March 2014.
16. ^ Wirth, E. (1955), *Aus der Entwicklungsgeschichte der Wärmepumpe*, *Schweizerische Bauzeitung* (in German), vol. 73, pp. 647–650, archived from the original on 20 November 2021, retrieved 20 November 2021
17. ^ Randall, Ian (31 July 2022). "Heat pumps: The centuries-old system now at the heart of the Government's energy strategy". *Daily Express*. Retrieved 16 March 2024.
18. ^ **a b** *Electricity supply in the United Kingdom : a chronology – from the beginnings of the industry to 31 December 1985*. The Electricity Council. 1987. ISBN 978-0851881058. OCLC 17343802.
19. ^ Banks, David (August 2012). *An Introduction to Thermogeology: Ground Source Heating and Cooling*. John Wiley & Sons. p. 123.
20. ^ "Why Britain's homes will need different types of heat pump". *The Economist*. ISSN 0013-0613. Retrieved 19 February 2024.
21. ^ "What is an Air-Source Heat Pump? A Complete Guide In 2024". *NEWNTIDE*. 24 October 2024. Retrieved 30 September 2024.
22. ^ Le, Khoa; Huang, M.J.; Hewitt, Neil (2018). "Domestic High Temperature Air Source Heat Pump: Performance Analysis Using TRNSYS Simulations". *International High Performance Buildings Conference*. West Lafayette, IN, USA:

- 5th International High Performance Buildings Conference at Purdue University: 1. Retrieved 20 February 2022.*
23. ^ *"Heat pumps show how hard decarbonisation will be". The Economist. ISSN 0013-0613. Retrieved 14 September 2023.*
 24. ^ *Lawrence, Karen. "Air source heat pumps explained". Which?. Archived from the original on 4 October 2022. Retrieved 4 October 2022.*
 25. ^ *Canada, Natural Resources (22 April 2009). "Heating and Cooling With a Heat Pump". natural-resources.canada.ca. Retrieved 22 February 2024.*
 26. ^ *"Heat pumps do work in the cold – Americans just don't know it yet". Grist. 9 May 2022. Archived from the original on 9 May 2022. Retrieved 9 May 2022.*
 27. ^ *"Heat pumps are hot items. But for people living in condos, getting one presents some challenges".*
 28. ^ *Sezen, Kutbay; Gungor, Afsin (1 January 2023). "Comparison of solar assisted heat pump systems for heating residences: A review". Solar Energy. **249**: 424–445. doi:10.1016/j.solener.2022.11.051. ISSN 0038-092X. "Photovoltaic-thermal direct expansion solar assisted heat pump (PV/T-DX-SAHP) system enables to benefit the waste heat for evaporation of refrigerant in PV/T collector-evaporator, while providing better cooling for PV cells (Yao et al., 2020)."*
 29. ^ *"Solar-assisted heat pumps". Archived from the original on 28 February 2020. Retrieved 21 June 2016.*
 30. ^ *"Pompe di calore elio-assistite" (in Italian). Archived from the original on 7 January 2012. Retrieved 21 June 2016.*
 31. ^ *Energy Saving Trust (13 February 2019). "Could a water source heat pump work for you?". Energy Saving Trust. Archived from the original on 4 October 2022. Retrieved 4 October 2022.*
 32. ^ *Baraniuk, Chris (29 May 2023). "The 'exploding' demand for giant heat pumps". BBC News. Archived from the original on 7 September 2023. Retrieved 19 September 2023.*
 33. ^ *Ristau, Oliver (24 July 2022). "Energy transition, the Danish way". DW. Archived from the original on 9 August 2023. Retrieved 19 September 2023.*
 34. ^ *Padavic-Callaghan, Karmela (6 December 2022). "Heat pump uses a loudspeaker and wet strips of paper to cool air". New Scientist. Archived from the original on 4 January 2023. Retrieved 4 January 2023.*
 35. ^ *Everitt, Neil (14 August 2023). "Scientists claim solid-state heat pump breakthrough". Cooling Post. Archived from the original on 24 September 2023. Retrieved 17 September 2023.*
 36. ^ *"Heat Pump Systems". U.S. Department of Energy. Archived from the original on 4 July 2017. Retrieved 5 February 2016.*
 37. ^ *"Renewable Heat Incentive – Domestic RHI – paid over 7 years". Ground Source Heat Pump Association. Archived from the original on 8 March 2018. Retrieved 12 March 2017.*
 38. ^ *"Heat Pump Efficiency | Heat Pump SEER Ratings". Carrier. Archived from the original on 14 January 2023. Retrieved 14 January 2023.*

39. ^ "COP and SPF for Heat Pumps Explained". Green Business Watch UK. 7 November 2019. Retrieved 22 February 2024.
40. ^ "Why This Window Heat Pump is Genius – Undecided with Matt Ferrell". 11 June 2024.
41. ^ "How it Works — Heat Pump Water Heaters (HPWHs)". www.energystar.gov. Retrieved 22 January 2024.
42. ^ "Heat-pump hot water systems". Sustainability Victoria. Retrieved 22 January 2024.
43. ^ Baraniuk, Chris (29 May 2023). "The 'exploding' demand for giant heat pumps". BBC News. Archived from the original on 7 September 2023. Retrieved 17 September 2023.
44. ^ "District Heating – Energy System". IEA. Retrieved 22 January 2024.
45. ^ **a b** David, Andrei; et al. (2017). "Heat Roadmap Europe: Large-Scale Electric Heat Pumps in District Heating Systems". *Energies*. **10** (4): 578. doi: 10.3390/en10040578.
46. ^ Sayegh, M. A.; et al. (2018). "Heat pump placement, connection and operational modes in European district heating". *Energy and Buildings*. **166**: 122–144. Bibcode:2018EneBu.166..122S. doi:10.1016/j.enbuild.2018.02.006. Archived from the original on 14 December 2019. Retrieved 10 July 2019.
47. ^ Buffa, Simone; et al. (2019), "5th generation district heating and cooling systems: A review of existing cases in Europe", *Renewable and Sustainable Energy Reviews (in German)*, vol. 104, pp. 504–522, doi: 10.1016/j.rser.2018.12.059
48. ^ "Home". Annex 35. Retrieved 22 February 2024.
49. ^ "Industrial Heat Pumps: it's time to go electric". World Business Council for Sustainable Development (WBCSD). Retrieved 22 February 2024.
50. ^ IEA HPT TCP Annex 35 Publications Archived 2018-09-21 at the Wayback Machine
51. ^ "Application of Industrial Heat Pumps. Annex 35 two-page summary". HPT – Heat Pumping Technologies. Retrieved 28 December 2023.
52. ^ "Norwegian Researchers Develop World's Hottest Heat Pump". *Ammonia21*. 5 August 2021. Archived from the original on 23 May 2022. Retrieved 7 June 2022.
53. ^ "Heat pumps are key to helping industry turn electric". World Business Council for Sustainable Development (WBCSD). Archived from the original on 24 September 2023. Retrieved 4 October 2022.
54. ^ **a b c d e f** "Heating and cooling with a heat pump: Efficiency terminology". Natural Resources Canada. 8 September 2022. Archived from the original on 3 April 2023. Retrieved 3 April 2023.
55. ^ Commission Regulation (EU) No 813/2013 of 2 August 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for space heaters and combination heaters
56. ^ **a b c d** The Canadian Renewable Energy Network 'Commercial Earth Energy Systems', Figure 29 Archived 2011-05-11 at the Wayback Machine. . Retrieved

- December 8, 2009.
57. ^ Technical Institute of Physics and Chemistry, Chinese Academy of Sciences 'State of the Art of Air-source Heat Pump for Cold Region', Figure 5 Archived 2016-04-14 at the Wayback Machine. . Retrieved April 19, 2008.
 58. ^ **a b** SINTEF Energy Research 'Integrated CO₂ Heat Pump Systems for Space Heating and DHW in low-energy and passive houses', J. Steen, Table 3.1, Table 3.3 Archived 2009-03-18 at the Wayback Machine. . Retrieved April 19, 2008.
 59. ^ *"How Wind Can Help Us Breathe Easier"*. *Energy.gov*. Archived from the original on 28 August 2023. Retrieved 13 September 2023.
 60. ^ *"Global Electricity Review 2023"*. *Ember*. 11 April 2023. Archived from the original on 11 April 2023. Retrieved 13 September 2023.
 61. ^ **a b** Quaschnig 2022
 62. ^ *"The UK is sabotaging its own plan to decarbonize heating"*. *Engadget*. 27 May 2021. Archived from the original on 6 June 2021. Retrieved 6 June 2021.
 63. ^ Deetjen, Thomas A; Walsh, Liam; Vaishnav, Parth (28 July 2021). "US residential heat pumps: the private economic potential and its emissions, health, and grid impacts". *Environmental Research Letters*. **16** (8): 084024. Bibcode:2021ERL....16h4024D. doi:10.1088/1748-9326/ac10dc. S2CID 236486619.
 64. ^ *"Can the UK rely on hydrogen to save its gas boilers?"*. *inews.co.uk*. 21 May 2021. Archived from the original on 6 June 2021. Retrieved 6 June 2021.
 65. ^ IEA (2022), Global Hydrogen Review 2022, IEA, Paris <https://www.iea.org/reports/global-hydrogen-review-2022> Archived 2023-01-10 at the Wayback Machine , License: CC BY 4.0
 66. ^ Saturated vapors and saturated liquids are vapors and liquids at their saturation temperature and saturation pressure. A superheated vapor is at a temperature higher than the saturation temperature corresponding to its pressure.
 67. ^ Ludwig von Cube, Hans (1981). *Heat Pump Technology*. Butterworths. pp. 22–23. ISBN 0-408-00497-5. Archived from the original on 3 April 2023. Retrieved 2 January 2023.
 68. ^ Chamoun, Marwan; Rulliere, Romuald; Haberschill, Philippe; Berail, Jean Francois (1 June 2012). "Dynamic model of an industrial heat pump using water as refrigerant". *International Journal of Refrigeration*. **35** (4): 1080–1091. doi:10.1016/j.ijrefrig.2011.12.007. ISSN 0140-7007.
 69. ^ Wu, Di (2021). "Vapor compression heat pumps with pure Low-GWP refrigerants". *Renewable and Sustainable Energy Reviews*. **138**: 110571. doi:10.1016/j.rser.2020.110571. ISSN 1364-0321. S2CID 229455137. Archived from the original on 24 September 2023. Retrieved 17 November 2022.
 70. ^ *"Everything you need to know about the wild world of heat pumps"*. *MIT Technology Review*. Archived from the original on 1 August 2023. Retrieved 19 September 2023.
 71. ^ Miara, Marek (22 October 2019). "Heat Pumps with Climate-Friendly Refrigerant Developed for Indoor Installation". *Fraunhofer ISE*. Archived from the

- original on 20 February 2022. Retrieved 21 February 2022.
72. ^ Rabe, Barry G. (23 September 2022). "Pivoting from global climate laggard to leader: Kigali and American HFC policy". Brookings. Archived from the original on 4 October 2022. Retrieved 4 October 2022.
 73. ^ Itteilag, Richard L. (9 August 2012). *Green Electricity and Global Warming*. AuthorHouse. p. 77. ISBN 9781477217405. Archived from the original on 23 November 2021. Retrieved 1 November 2020.
 74. ^ **a b** "Propane-powered heat pumps are greener". *The Economist*. 6 September 2023. ISSN 0013-0613. Archived from the original on 17 September 2023. Retrieved 17 September 2023.
 75. ^ "Smart CO2 Heat Pump". *www.dti.dk*. Archived from the original on 30 January 2023. Retrieved 17 September 2023.
 76. ^ "Annex 53 Advanced Cooling/Refrigeration Technologies 2 page summary". *HPT – Heat Pumping Technologies*. Retrieved 19 February 2024.
 77. ^ "Handbook for the Montreal Protocol on Substances that Deplete the Ozone Layer – 7th Edition". United Nations Environment Programme – Ozone Secretariat. 2007. Archived from the original on 30 May 2016. Retrieved 18 December 2016.
 78. ^ "Refrigerants – Environmental Properties". *The Engineering ToolBox*. Archived from the original on 14 March 2013. Retrieved 12 September 2016.
 79. ^ R-410A#Environmental effects.
 80. ^ *Ecometrica.com* (27 June 2012). "Calculation of green house gas potential of R-410A". Archived from the original on 13 July 2015. Retrieved 13 July 2015.
 81. ^ "R404 and DME Refrigerant blend as a new solution to limit global warming potential" (PDF). 14 March 2012. Archived from the original (PDF) on 14 March 2012.
 82. ^ **a b** IPCC_AR6_WG1_Ch7 2021, 7SM-26
 83. ^ *LearnMetrics* (12 May 2023). "List of Low GWP Refrigerants: 69 Refrigerants Below 500 GWP". *LearnMetrics*. Archived from the original on 10 June 2023. Retrieved 13 September 2023.
 84. ^ **a b c** "Global warming potential (GWP) of HFC refrigerants". *iifiir.org*. Archived from the original on 24 September 2023. Retrieved 13 September 2023.
 85. ^ Everitt, Neil (15 September 2023). "Quantum plant has 1 million heat pump capacity". *Cooling Post*. Archived from the original on 24 September 2023. Retrieved 17 September 2023.
 86. ^ Miara, Marek (22 October 2019). "Heat Pumps with Climate-Friendly Refrigerant Developed for Indoor Installation". *Fraunhofer ISE*. Archived from the original on 20 February 2022. Retrieved 21 February 2022.
 87. ^ "Refrigerant Safety – About Refrigerant Safety, Toxicity and Flammability". *Checkmark*. Retrieved 17 April 2024.
 88. ^ "A2L – Mildly Flammable Refrigerants". *ACR Journal*. 1 September 2015. Retrieved 17 April 2024.

89. ^ US Environmental Protection Agency, OAR (14 November 2014). "Phaseout of Ozone-Depleting Substances (ODS)". US EPA. Archived from the original on 24 September 2015. Retrieved 16 February 2020.
90. ^ "Heat Pumps". IEA. Archived from the original on 17 September 2023. Retrieved 17 September 2023.
91. ^ "Electrifying industrial processes with heat pumps". 22 March 2022. Archived from the original on 8 August 2022. Retrieved 9 August 2022.
92. ^ Department of Energy, Environment and Climate Action, Victoria Government (Australia) (11 October 2023). "Hot water systems for businesses". Victoria Government.
93. ^ Department of Energy, Environment and Climate Action (Australia), Victoria Government (23 September 2023). "Hot water systems for households". Victoria Government.
94. ^ New South Wales Climate and Energy Action, New South Wales Government (Australia) (8 December 2023). "Upgrade your hot water system". NSW Government.
95. ^ Australian Government, Queensland (5 October 2023). "Queensland Business Energy Saving and Transformation Rebates". Queensland Government.
96. ^ Time To Save (21 November 2023). "Hot Water Rebates in Australia: A Detailed Guide For Businesses". Timetosave.
97. ^ "Canada Greener Homes Grant". 17 March 2021. Archived from the original on 17 January 2022. Retrieved 17 January 2022.
98. ^ "Coal fired boiler replacement in Beijing rural area". Archived from the original on 24 March 2023. Retrieved 14 September 2023.
99. ^ **a b c** "Executive summary – The Future of Heat Pumps in China – Analysis". IEA. Retrieved 12 April 2024.
100. ^ IEA (2024), The Future of Heat Pumps in China, IEA, Paris <https://www.iea.org/reports/the-future-of-heat-pumps-in-china>, Licence: CC BY 4.0
101. ^ "The Heat Pump Accelerator Platform". European Commission. 2024. Retrieved 27 November 2024.
102. ^ "Heat pumps". European Commission. 2024. Retrieved 27 November 2024.
103. ^ "HMCR rates for goods and services". 11 July 2022. Archived from the original on 22 July 2022. Retrieved 24 August 2022.
104. ^ "Apply for the Boiler Upgrade Scheme". Archived from the original on 19 September 2023. Retrieved 14 September 2023.
105. ^ "BBC Radio 4 – Sliced Bread, Air Source Heat Pumps". BBC. Archived from the original on 30 April 2022. Retrieved 30 April 2022.
106. ^ Lawrence, Karen (3 May 2024). "Air source heat pump costs and savings". Which?. Retrieved 7 June 2024.
107. ^ "Clean Heat without the Hot Air: British and Dutch lessons and challenges". UKERC. Retrieved 7 June 2024.

108. ^ Shao, Elena. "H. R. 5376 – Inflation Reduction Act of 2022". *Congress.gov*. U.S. Congress. Archived from the original on 17 November 2022. Retrieved 17 November 2022.
109. ^ "As Heat Pumps Go Mainstream, a Big Question: Can They Handle Real Cold?". *The New York Times*. 22 February 2023. Archived from the original on 11 April 2023. Retrieved 11 April 2023.
110. ^ Frazin, Rachel (17 November 2023). "Biden administration uses wartime authority to bolster energy efficient manufacturing". *The Hill*. Retrieved 29 November 2023.

Sources

[edit]

IPCC reports

[edit]

- IPCC (2021). Masson-Delmotte, V.; Zhai, P.; Pirani, A.; Connors, S. L.; et al. (eds.). *Climate Change 2021: The Physical Science Basis (PDF)*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press (In Press).
 - Forster, P.; Storelvmo, T.; Armour, K.; Collins, W. (2021). "Chapter 7: The Earth's energy budget, climate feedbacks, and climate sensitivity Supplementary Material" (PDF). IPCC AR6 WG1 2021.
- IPCC (2018). Masson-Delmotte, V.; Zhai, P.; Pörtner, H.-O.; Roberts, D.; et al. (eds.). *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (PDF)*. Intergovernmental Panel on Climate Change. <https://www.ipcc.ch/sr15/>.
 - Rogelj, J.; Shindell, D.; Jiang, K.; Fifita, S.; et al. (2018). "Chapter 2: Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development" (PDF). IPCC SR15 2018. pp. 93–174.
- IPCC (2022). Shula, P. R.; Skea, J.; Slade, R.; Al Khourdajie, A.; et al. (eds.). *Climate Change 2022: Mitigation of Climate Change (PDF)*. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK and New York, New York, USA: Cambridge University Press (In Press). Archived from the original (PDF) on 4 April 2022. Retrieved 10 May 2022.
 - IPCC (2022). "Industry" (PDF). IPCC AR6 WG3 2022.

Other

[edit]

- *Quaschnig, Volker. "Specific Carbon Dioxide Emissions of Various Fuels". Retrieved 22 February 2022.*

External links

[edit]

-  [Media related to Heat pumps at Wikimedia Commons](#)

- v
- t
- e

Heating, ventilation, and air conditioning

- Air changes per hour
- Bake-out
- Building envelope
- Convection
- Dilution
- Domestic energy consumption
- Enthalpy
- Fluid dynamics
- Gas compressor
- Heat pump and refrigeration cycle
- Heat transfer
- Humidity
- Infiltration
- Latent heat
- Noise control
- Outgassing
- Particulates
- Psychrometrics
- Sensible heat
- Stack effect
- Thermal comfort
- Thermal destratification
- Thermal mass
- Thermodynamics
- Vapour pressure of water

Fundamental concepts

Technology

- Absorption-compression heat pump
- Absorption refrigerator
- Air barrier
- Air conditioning
- Antifreeze
- Automobile air conditioning
- Autonomous building
- Building insulation materials
- Central heating
- Central solar heating
- Chilled beam
- Chilled water
- Constant air volume (CAV)
- Coolant
- Cross ventilation
- Dedicated outdoor air system (DOAS)
- Deep water source cooling
- Demand controlled ventilation (DCV)
- Displacement ventilation
- District cooling
- District heating
- Electric heating
- Energy recovery ventilation (ERV)
- Firestop
- Forced-air
- Forced-air gas
- Free cooling
- Heat recovery ventilation (HRV)
- Hybrid heat
- Hydronics
- Ice storage air conditioning
- Kitchen ventilation
- Mixed-mode ventilation
- Microgeneration
- Passive cooling
- Passive daytime radiative cooling
- Passive house
- Passive ventilation
- Radiant heating and cooling
- Radiant cooling
- Radiant heating
- Radon mitigation
- Refrigeration
- Renewable heat
- Room air distribution
- Solar air heat
- Solar combisystem
- Solar cooling

- Air conditioner inverter
- Air door
- Air filter
- Air handler
- Air ionizer
- Air-mixing plenum
- Air purifier
- Air source heat pump
- Attic fan
- Automatic balancing valve
- Back boiler
- Barrier pipe
- Blast damper
- Boiler
- Centrifugal fan
- Ceramic heater
- Chiller
- Condensate pump
- Condenser
- Condensing boiler
- Convection heater
- Compressor
- Cooling tower
- Damper
- Dehumidifier
- Duct
- Economizer
- Electrostatic precipitator
- Evaporative cooler
- Evaporator
- Exhaust hood
- Expansion tank
- Fan
- Fan coil unit
- Fan filter unit
- Fan heater
- Fire damper
- Fireplace
- Fireplace insert
- Freeze stat
- Flue
- Freon
- Fume hood
- Furnace
- Gas compressor
- Gas heater
- Gasoline heater
- Grease duct

**Measurement
and control**

- Air flow meter
- Aquastat
- BACnet
- Blower door
- Building automation
- Carbon dioxide sensor
- Clean air delivery rate (CADR)
- Control valve
- Gas detector
- Home energy monitor
- Humidistat
- HVAC control system
- Infrared thermometer
- Intelligent buildings
- LonWorks
- Minimum efficiency reporting value (MERV)
- Normal temperature and pressure (NTP)
- OpenTherm
- Programmable communicating thermostat
- Programmable thermostat
- Psychrometrics
- Room temperature
- Smart thermostat
- Standard temperature and pressure (STP)
- Thermographic camera
- Thermostat
- Thermostatic radiator valve
- Architectural acoustics
- Architectural engineering
- Architectural technologist
- Building services engineering
- Building information modeling (BIM)
- Deep energy retrofit
- Duct cleaning
- Duct leakage testing
- Environmental engineering
- Hydronic balancing
- Kitchen exhaust cleaning
- Mechanical engineering
- Mechanical, electrical, and plumbing
- Mold growth, assessment, and remediation
- Refrigerant reclamation
- Testing, adjusting, balancing

**Professions,
trades,
and services**

Industry organizations

- AHRI
- AMCA
- ASHRAE
- ASTM International
- BRE
- BSRIA
- CIBSE
- Institute of Refrigeration
- IIR
- LEED
- SMACNA
- UMC

Health and safety

- Indoor air quality (IAQ)
- Passive smoking
- Sick building syndrome (SBS)
- Volatile organic compound (VOC)
- ASHRAE Handbook
- Building science
- Fireproofing

See also

- Glossary of HVAC terms
- Warm Spaces
- World Refrigeration Day
- Template:Home automation
- Template:Solar energy

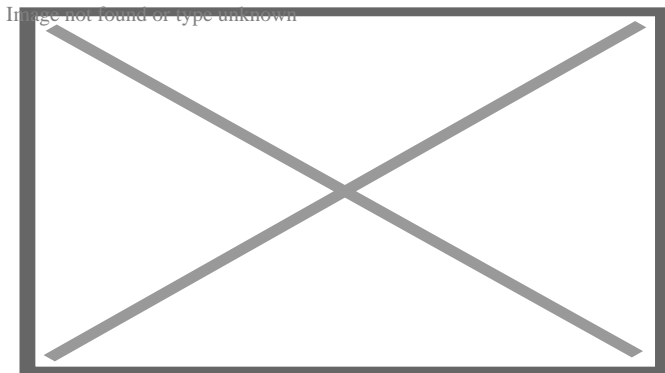
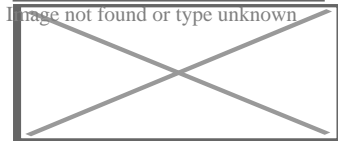
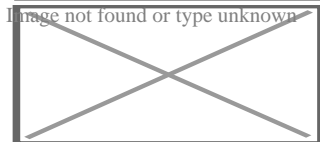
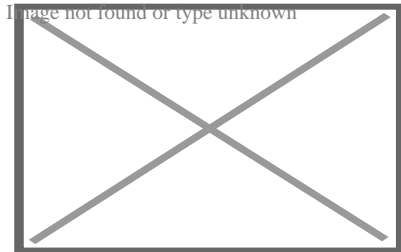
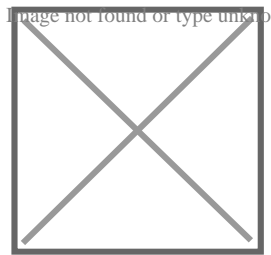
Authority control databases: National            

[Edit this at Wikidata](#)

- Germany
- United States
- France
- Japan
- Czech Republic
- Israel

About Air conditioning

This article is about cooling of air. For the Curved Air album, see Air Conditioning (album). For a similar device capable of both cooling and heating, see heat pump. "a/c" redirects here. For the abbreviation used in banking and book-keeping, see Account (disambiguation). For other uses, see AC.



There are various types of air conditioners. Popular examples include: Window-mounted air conditioner (Suriname, 1955); Ceiling-mounted cassette air conditioner (China, 2023); Wall-mounted air conditioner (Japan, 2020); Ceiling-mounted console (Also called ceiling suspended) air conditioner (China, 2023); and portable air conditioner (Vatican City, 2018).

Air conditioning, often abbreviated as **A/C** (US) or **air con** (UK),^[1] is the process of removing heat from an enclosed space to achieve a more comfortable interior temperature (sometimes referred to as 'comfort cooling') and in some cases also strictly controlling the humidity of internal air. Air conditioning can be achieved using a mechanical 'air conditioner' or by other methods, including passive cooling and ventilative cooling.^{[2][3]} Air conditioning is a member of a family of systems and techniques that provide heating, ventilation, and air conditioning (HVAC).^[4] Heat pumps are similar in many ways to air conditioners, but use a reversing valve to allow them both to heat and to cool an enclosed space.^[5]

Air conditioners, which typically use vapor-compression refrigeration, range in size from small units used in vehicles or single rooms to massive units that can cool large buildings.^[6] Air source heat pumps, which can be used for heating as well as cooling, are becoming increasingly common in cooler climates.

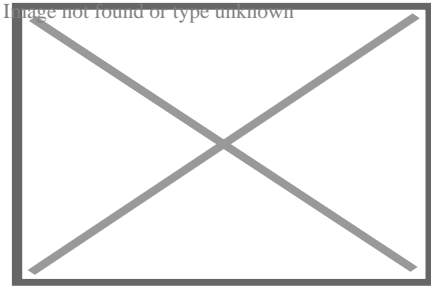
Air conditioners can reduce mortality rates due to higher temperature.^[7] According to the International Energy Agency (IEA) 1.6 billion air conditioning units were used globally in 2016.^[8] The United Nations called for the technology to be made more sustainable to mitigate climate change and for the use of alternatives, like passive cooling, evaporative cooling, selective shading, windcatchers, and better thermal insulation.

History

[edit]

Air conditioning dates back to prehistory.^[9] Double-walled living quarters, with a gap between the two walls to encourage air flow, were found in the ancient city of Hamoukar, in modern Syria.^[10] Ancient Egyptian buildings also used a wide variety of passive air-conditioning techniques.^[11] These became widespread from the Iberian Peninsula through North Africa, the Middle East, and Northern India.^[12]

Passive techniques remained widespread until the 20th century when they fell out of fashion and were replaced by powered air conditioning. Using information from engineering studies of traditional buildings, passive techniques are being revived and modified for 21st-century architectural designs.^{[13][12]}



An array of air conditioner condenser units outside a commercial office building

Air conditioners allow the building's indoor environment to remain relatively constant, largely independent of changes in external weather conditions and internal heat loads. They also enable deep plan buildings to be created and have allowed people to live comfortably in hotter parts of the world.^[14]

Development

[edit]

Preceding discoveries

[edit]

In 1558, Giambattista della Porta described a method of chilling ice to temperatures far below its freezing point by mixing it with potassium nitrate (then called "nitre") in his popular science book *Natural Magic*.^[15]^[16]^[17] In 1620, Cornelis Drebbel demonstrated "Turning Summer into Winter" for James I of England, chilling part of the Great Hall of Westminster Abbey with an apparatus of troughs and vats.^[18] Drebbel's contemporary Francis Bacon, like della Porta a believer in science communication, may not have been present at the demonstration, but in a book published later the same year, he described it as "experiment of artificial freezing" and said that "Nitre (or rather its spirit) is very cold, and hence nitre or salt when added to snow or ice intensifies the cold of the latter, the nitre by adding to its cold, but the salt by supplying activity to the cold of the snow."^[15]

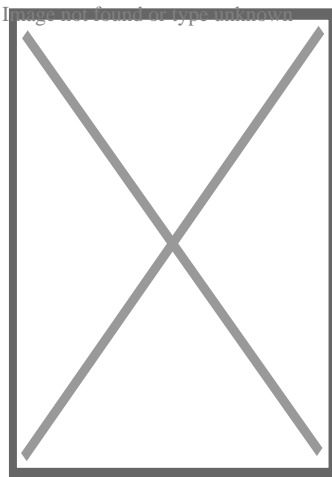
In 1758, Benjamin Franklin and John Hadley, a chemistry professor at the University of Cambridge, conducted experiments applying the principle of evaporation as a means to cool an object rapidly. Franklin and Hadley confirmed that the evaporation of highly volatile liquids (such as alcohol and ether) could be used to drive down the temperature of an object past the freezing point of water. They experimented with the

bulb of a mercury-in-glass thermometer as their object. They used a bellows to speed up the evaporation. They lowered the temperature of the thermometer bulb down to $-14\text{ }^{\circ}\text{C}$ ($7\text{ }^{\circ}\text{F}$) while the ambient temperature was $18\text{ }^{\circ}\text{C}$ ($64\text{ }^{\circ}\text{F}$). Franklin noted that soon after they passed the freezing point of water $0\text{ }^{\circ}\text{C}$ ($32\text{ }^{\circ}\text{F}$), a thin film of ice formed on the surface of the thermometer's bulb and that the ice mass was about 6 mm ($1/4\text{ in}$) thick when they stopped the experiment upon reaching $-14\text{ }^{\circ}\text{C}$ ($7\text{ }^{\circ}\text{F}$). Franklin concluded: "From this experiment, one may see the possibility of freezing a man to death on a warm summer's day."^[19]

The 19th century included many developments in compression technology. In 1820, English scientist and inventor Michael Faraday discovered that compressing and liquefying ammonia could chill air when the liquefied ammonia was allowed to evaporate.^[20] In 1842, Florida physician John Gorrie used compressor technology to create ice, which he used to cool air for his patients in his hospital in Apalachicola, Florida. He hoped to eventually use his ice-making machine to regulate the temperature of buildings.^{[20][21]} He envisioned centralized air conditioning that could cool entire cities. Gorrie was granted a patent in 1851,^[22] but following the death of his main backer, he was not able to realize his invention.^[23] In 1851, James Harrison created the first mechanical ice-making machine in Geelong, Australia, and was granted a patent for an ether vapor-compression refrigeration system in 1855 that produced three tons of ice per day.^[24] In 1860, Harrison established a second ice company. He later entered the debate over competing against the American advantage of ice-refrigerated beef sales to the United Kingdom.^[24]

First devices

[edit]



Willis Carrier, who is credited with building the first modern electrical air conditioning unit

Electricity made the development of effective units possible. In 1901, American inventor Willis H. Carrier built what is considered the first modern electrical air conditioning unit.^{[25][26][27][28]} In 1902, he installed his first air-conditioning system, in the Sackett-Wilhelms Lithographing & Publishing Company in Brooklyn, New York.^[29] His invention controlled both the temperature and humidity, which helped maintain consistent paper dimensions and ink alignment at the printing plant. Later, together with six other employees, Carrier formed The Carrier Air Conditioning Company of America, a business that in 2020 employed 53,000 people and was valued at \$18.6 billion.^{[30][31]}

In 1906, Stuart W. Cramer of Charlotte, North Carolina, was exploring ways to add moisture to the air in his textile mill. Cramer coined the term "air conditioning" in a patent claim which he filed that year, where he suggested that air conditioning was analogous to "water conditioning", then a well-known process for making textiles easier to process.^[32] He combined moisture with ventilation to "condition" and change the air in the factories; thus, controlling the humidity that is necessary in textile plants. Willis Carrier adopted the term and incorporated it into the name of his company.^[33]

Domestic air conditioning soon took off. In 1914, the first domestic air conditioning was installed in Minneapolis in the home of Charles Gilbert Gates. It is, however, possible that the considerable device (c. 2.1 m × 1.8 m × 6.1 m; 7 ft × 6 ft × 20 ft) was never used, as the house remained uninhabited^[20] (Gates had already died in October 1913.)

In 1931, H.H. Schultz and J.Q. Sherman developed what would become the most common type of individual room air conditioner: one designed to sit on a window ledge. The units went on sale in 1932 at US\$10,000 to \$50,000 (the equivalent of \$200,000 to \$1,100,000 in 2023.)^[20] A year later, the first air conditioning systems for cars were offered for sale.^[34] Chrysler Motors introduced the first practical semi-portable air conditioning unit in 1935,^[35] and Packard became the first automobile manufacturer to offer an air conditioning unit in its cars in 1939.^[36]

Further development

[edit]

Innovations in the latter half of the 20th century allowed more ubiquitous air conditioner use. In 1945, Robert Sherman of Lynn, Massachusetts, invented a portable, in-window air conditioner that cooled, heated, humidified, dehumidified, and filtered the air.^[37] The first inverter air conditioners were released in 1980–1981.^{[38][39]}

In 1954, Ned Cole, a 1939 architecture graduate from the University of Texas at Austin, developed the first experimental "suburb" with inbuilt air conditioning in each house. 22 homes were developed on a flat, treeless track in northwest Austin, Texas, and the community was christened the 'Austin Air-Conditioned Village.' The residents were subjected to a year-long study of the effects of air conditioning led by the nation's premier air conditioning companies, builders, and social scientists. In addition, researchers from UT's Health Service and Psychology Department studied the effects on the "artificially cooled humans." One of the more amusing discoveries was that each family reported being troubled with scorpions, the leading theory being that scorpions sought cool, shady places. Other reported changes in lifestyle were that mothers baked more, families ate heavier foods, and they were more apt to choose hot drinks.^[40]^[41]

Air conditioner adoption tends to increase above around \$10,000 annual household income in warmer areas.^[42] Global GDP growth explains around 85% of increased air condition adoption by 2050, while the remaining 15% can be explained by climate change.^[42]

As of 2016 an estimated 1.6 billion air conditioning units were used worldwide, with over half of them in China and USA, and a total cooling capacity of 11,675 gigawatts.^[8]^[43] The International Energy Agency predicted in 2018 that the number of air conditioning units would grow to around 4 billion units by 2050 and that the total cooling capacity would grow to around 23,000 GW, with the biggest increases in India and China.^[8] Between 1995 and 2004, the proportion of urban households in China with air conditioners increased from 8% to 70%.^[44] As of 2015, nearly 100 million homes, or about 87% of US households, had air conditioning systems.^[45] In 2019, it was estimated that 90% of new single-family homes constructed in the US included air conditioning (ranging from 99% in the South to 62% in the West).^[46]^[47]

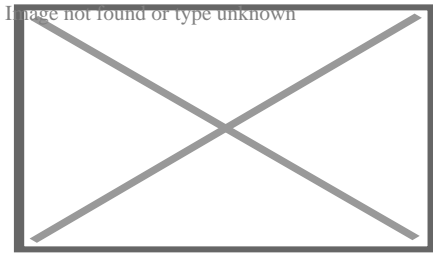
Operation

[edit]

Operating principles

[edit]

Main article: Vapor-compression refrigeration



A simple stylized diagram of the refrigeration cycle: 1) condensing coil, 2) expansion valve, 3) evaporator coil, 4) compressor

Cooling in traditional air conditioner systems is accomplished using the vapor-compression cycle, which uses a refrigerant's forced circulation and phase change between gas and liquid to transfer heat.^{[48][49]} The vapor-compression cycle can occur within a unitary, or packaged piece of equipment; or within a chiller that is connected to terminal cooling equipment (such as a fan coil unit in an air handler) on its evaporator side and heat rejection equipment such as a cooling tower on its condenser side. An air source heat pump shares many components with an air conditioning system, but includes a reversing valve, which allows the unit to be used to heat as well as cool a space.^[50]

Air conditioning equipment will reduce the absolute humidity of the air processed by the system if the surface of the evaporator coil is significantly cooler than the dew point of the surrounding air. An air conditioner designed for an occupied space will typically achieve a 30% to 60% relative humidity in the occupied space.^[51]

Most modern air-conditioning systems feature a dehumidification cycle during which the compressor runs. At the same time, the fan is slowed to reduce the evaporator temperature and condense more water. A dehumidifier uses the same refrigeration cycle but incorporates both the evaporator and the condenser into the same air path; the air first passes over the evaporator coil, where it is cooled^[52] and dehumidified before passing over the condenser coil, where it is warmed again before it is released back into the room.^[citation needed]

Free cooling can sometimes be selected when the external air is cooler than the internal air. Therefore, the compressor does not need to be used, resulting in high cooling efficiencies for these times. This may also be combined with seasonal thermal energy storage.^[53]

Heating

[edit]

Main article: Heat pump

Some air conditioning systems can reverse the refrigeration cycle and act as an air source heat pump, thus heating instead of cooling the indoor environment. They are also commonly referred to as "reverse cycle air conditioners". The heat pump is significantly more energy-efficient than electric resistance heating, because it moves energy from air or groundwater to the heated space and the heat from purchased electrical energy. When the heat pump is in heating mode, the indoor evaporator coil switches roles and becomes the condenser coil, producing heat. The outdoor condenser unit also switches roles to serve as the evaporator and discharges cold air (colder than the ambient outdoor air).

Most air source heat pumps become less efficient in outdoor temperatures lower than 4 °C or 40 °F.^[54] This is partly because ice forms on the outdoor unit's heat exchanger coil, which blocks air flow over the coil. To compensate for this, the heat pump system must temporarily switch back into the regular air conditioning mode to switch the outdoor evaporator coil *back* to the condenser coil, to heat up and defrost. Therefore, some heat pump systems will have electric resistance heating in the indoor air path that is activated only in this mode to compensate for the temporary indoor air cooling, which would otherwise be uncomfortable in the winter.

Newer models have improved cold-weather performance, with efficient heating capacity down to 14 °F (−26 °C).^{[55][54][56]} However, there is always a chance that the humidity that condenses on the heat exchanger of the outdoor unit could freeze, even in models that have improved cold-weather performance, requiring a defrosting cycle to be performed.

The icing problem becomes much more severe with lower outdoor temperatures, so heat pumps are sometimes installed in tandem with a more conventional form of heating, such as an electrical heater, a natural gas, heating oil, or wood-burning fireplace or central heating, which is used instead of or in addition to the heat pump during harsher winter temperatures. In this case, the heat pump is used efficiently during milder temperatures, and the system is switched to the conventional heat source when the outdoor temperature is lower.

Performance

[edit]

Main articles: coefficient of performance, Seasonal energy efficiency ratio, and European seasonal energy efficiency ratio

The coefficient of performance (COP) of an air conditioning system is a ratio of useful heating or cooling provided to the work required.^{[57][58]} Higher COPs equate to lower

operating costs. The COP usually exceeds 1; however, the exact value is highly dependent on operating conditions, especially absolute temperature and relative temperature between sink and system, and is often graphed or averaged against expected conditions.^[59] Air conditioner equipment power in the U.S. is often described in terms of "tons of refrigeration", with each approximately equal to the cooling power of one short ton (2,000 pounds (910 kg) of ice melting in a 24-hour period. The value is equal to 12,000 BTU_{IT} per hour, or 3,517 watts.^[60] Residential central air systems are usually from 1 to 5 tons (3.5 to 18 kW) in capacity.^[citation needed]

The efficiency of air conditioners is often rated by the seasonal energy efficiency ratio (SEER), which is defined by the Air Conditioning, Heating and Refrigeration Institute in its 2008 standard AHRI 210/240, *Performance Rating of Unitary Air-Conditioning and Air-Source Heat Pump Equipment*.^[61] A similar standard is the European seasonal energy efficiency ratio (ESEER).^[citation needed]

Efficiency is strongly affected by the humidity of the air to be cooled. Dehumidifying the air before attempting to cool it can reduce subsequent cooling costs by as much as 90 percent. Thus, reducing dehumidifying costs can materially affect overall air conditioning costs.^[62]

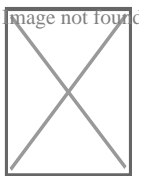
Control system

[edit]

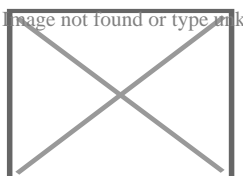
Wireless remote control

[edit]

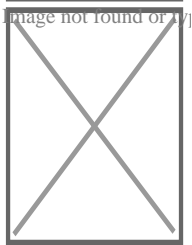
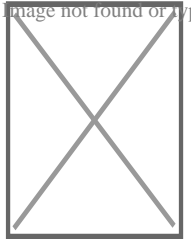
Main articles: Remote control and Infrared blaster



A
wireless
remote
controller



The infrared transmitting LED on the remote



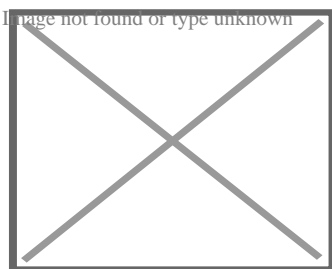
The infrared receiver on the air conditioner

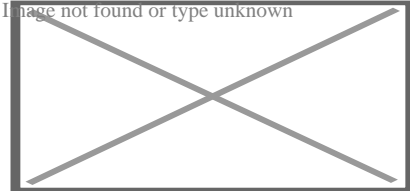
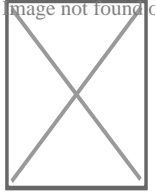
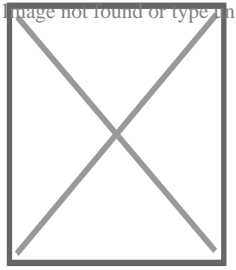
This type of controller uses an infrared LED to relay commands from a remote control to the air conditioner. The output of the infrared LED (like that of any infrared remote) is invisible to the human eye because its wavelength is beyond the range of visible light (940 nm). This system is commonly used on mini-split air conditioners because it is simple and portable. Some window and ducted central air conditioners uses it as well.

Wired controller

[edit]

Main article: Thermostat





Several wired controllers (Indonesia, 2024)

A wired controller, also called a "wired thermostat," is a device that controls an air conditioner by switching heating or cooling on or off. It uses different sensors to measure temperatures and actuate control operations. Mechanical thermostats commonly use bimetallic strips, converting a temperature change into mechanical displacement, to actuate control of the air conditioner. Electronic thermostats, instead, use a thermistor or other semiconductor sensor, processing temperature change as electronic signals to control the air conditioner.

These controllers are usually used in hotel rooms because they are permanently installed into a wall and hard-wired directly into the air conditioner unit, eliminating the need for batteries.

Types

[edit]

Types	Typical Capacity*	Air supply	Mounting	Typical application
Mini-split	small – large	Direct	Wall	Residential
Window	very small – small	Direct	Window	Residential
Portable	very small – small	Direct / Ducted	Floor	Residential, remote areas

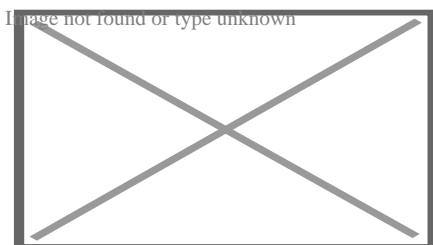
Ducted (individual)	small – very large	Ducted	Ceiling	Residential, commercial
Ducted (central)	medium – very large	Ducted	Ceiling	Residential, commercial
Ceiling suspended	medium – large	Direct	Ceiling	Commercial
Cassette	medium – large	Direct / Ducted	Ceiling	Commercial
Floor standing	medium – large	Direct / Ducted	Floor	Commercial
Packaged	very large	Direct / Ducted	Floor	Commercial
Packaged RTU (Rooftop Unit)	very large	Ducted	Rooftop	Commercial

* where the typical capacity is in kilowatt as follows:

- very small: <1.5 kW
- small: 1.5–3.5 kW
- medium: 4.2–7.1 kW
- large: 7.2–14 kW
- very large: >14 kW

Mini-split and multi-split systems

[edit]



Evaporator, indoor unit, or terminal, side of a ductless split-type air conditioner

Ductless systems (often mini-split, though there are now ducted mini-split) typically supply conditioned and heated air to a single or a few rooms of a building, without ducts and in a decentralized manner.^[63] Multi-zone or multi-split systems are a common application of ductless systems and allow up to eight rooms (zones or locations) to be conditioned independently from each other, each with its indoor unit

and simultaneously from a single outdoor unit.

The first mini-split system was sold in 1961 by Toshiba in Japan, and the first wall-mounted mini-split air conditioner was sold in 1968 in Japan by Mitsubishi Electric, where small home sizes motivated their development. The Mitsubishi model was the first air conditioner with a cross-flow fan.^{[64][65][66]} In 1969, the first mini-split air conditioner was sold in the US.^[67] Multi-zone ductless systems were invented by Daikin in 1973, and variable refrigerant flow systems (which can be thought of as larger multi-split systems) were also invented by Daikin in 1982. Both were first sold in Japan.^[68] Variable refrigerant flow systems when compared with central plant cooling from an air handler, eliminate the need for large cool air ducts, air handlers, and chillers; instead cool refrigerant is transported through much smaller pipes to the indoor units in the spaces to be conditioned, thus allowing for less space above dropped ceilings and a lower structural impact, while also allowing for more individual and independent temperature control of spaces. The outdoor and indoor units can be spread across the building.^[69] Variable refrigerant flow indoor units can also be turned off individually in unused spaces.^[citation needed] The lower start-up power of VRF's DC inverter compressors and their inherent DC power requirements also allow VRF solar-powered heat pumps to be run using DC-providing solar panels.

Ducted central systems

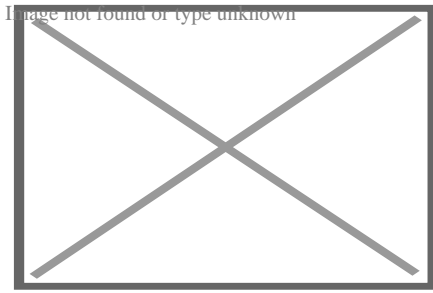
[edit]

Split-system central air conditioners consist of two heat exchangers, an outside unit (the condenser) from which heat is rejected to the environment and an internal heat exchanger (the evaporator, or Fan Coil Unit, FCU) with the piped refrigerant being circulated between the two. The FCU is then connected to the spaces to be cooled by ventilation ducts.^[70] Floor standing air conditioners are similar to this type of air conditioner but sit within spaces that need cooling.

Central plant cooling

[edit]

See also: Chiller



Industrial air conditioners on top of the shopping mall *Passage* in Linz, Austria

Large central cooling plants may use intermediate coolant such as chilled water pumped into air handlers or fan coil units near or in the spaces to be cooled which then duct or deliver cold air into the spaces to be conditioned, rather than ducting cold air directly to these spaces from the plant, which is not done due to the low density and heat capacity of air, which would require impractically large ducts. The chilled water is cooled by chillers in the plant, which uses a refrigeration cycle to cool water, often transferring its heat to the atmosphere even in liquid-cooled chillers through the use of cooling towers. Chillers may be air- or liquid-cooled. [⁷¹][⁷²]

Portable units

[edit]

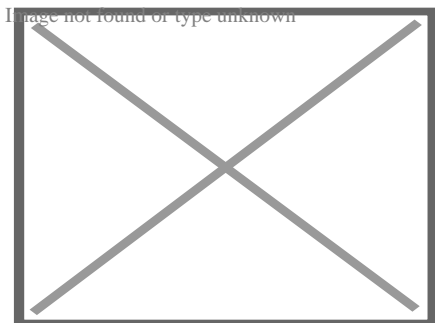
A portable system has an indoor unit on wheels connected to an outdoor unit via flexible pipes, similar to a permanently fixed installed unit (such as a ductless split air conditioner).

Hose systems, which can be *monoblock* or *air-to-air*, are vented to the outside via air ducts. The *monoblock* type collects the water in a bucket or tray and stops when full. The *air-to-air* type re-evaporates the water, discharges it through the ducted hose, and can run continuously. Many but not all portable units draw indoor air and expel it outdoors through a single duct, negatively impacting their overall cooling efficiency.

Many portable air conditioners come with heat as well as a dehumidification function. [⁷³]

Window unit and packaged terminal

[edit]



Through-the-wall PTAC units, University Motor Inn, Philadelphia

Main article: Packaged terminal air conditioner

The packaged terminal air conditioner (PTAC), through-the-wall, and window air conditioners are similar. These units are installed on a window frame or on a wall opening. The unit usually has an internal partition separating its indoor and outdoor sides, which contain the unit's condenser and evaporator, respectively. PTAC systems may be adapted to provide heating in cold weather, either directly by using an electric strip, gas, or other heaters, or by reversing the refrigerant flow to heat the interior and draw heat from the exterior air, converting the air conditioner into a heat pump. They may be installed in a wall opening with the help of a special sleeve on the wall and a custom grill that is flush with the wall and window air conditioners can also be installed in a window, but without a custom grill.^[74]

Packaged air conditioner

[edit]

Packaged air conditioners (also known as self-contained units)^{[75][76]} are central systems that integrate into a single housing all the components of a split central system, and deliver air, possibly through ducts, to the spaces to be cooled. Depending on their construction they may be outdoors or indoors, on roofs (rooftop units),^{[77][78]} draw the air to be conditioned from inside or outside a building and be water or air-cooled. Often, outdoor units are air-cooled while indoor units are liquid-cooled using a cooling tower.^{[70][79][80][81][82][83]}

Types of compressors

[edit]

Compressor types	Common applications	Typical capacity	Efficiency	Durability	Repairability
Reciprocating	Refrigerator, Walk-in freezer, portable air conditioners	small – large	very low (small capacity) medium (large capacity)	very low	medium
Rotary vane	Residential mini splits	small	low	low	easy
Scroll	Commercial and central systems, VRF	medium	medium	medium	easy
Rotary screw	Commercial chiller	medium – large	medium	medium	hard
Centrifugal	Commercial chiller	very large	medium	high	hard
Maglev Centrifugal	Commercial chiller	very large	high	very high	very hard

Reciprocating

[edit]

Main article: Reciprocating compressor

This compressor consists of a crankcase, crankshaft, piston rod, piston, piston ring, cylinder head and valves. ^[*citation needed*]

Scroll

[edit]

Main article: Scroll compressor

This compressor uses two interleaving scrolls to compress the refrigerant.^[84] it consists of one fixed and one orbiting scrolls. This type of compressor is more efficient because it has 70 percent less moving parts than a reciprocating compressor. ^[*citation needed*]

Screw

[edit]

Main article: Rotary-screw compressor

This compressor use two very closely meshing spiral rotors to compress the gas. The gas enters at the suction side and moves through the threads as the screws rotate. The meshing rotors force the gas through the compressor, and the gas exits at the end of the screws. The working area is the inter-lobe volume between the male and female rotors. It is larger at the intake end, and decreases along the length of the rotors until the exhaust port. This change in volume is the compression. ^[*citation needed*]

Capacity modulation technologies

[edit]

There are several ways to modulate the cooling capacity in refrigeration or air conditioning and heating systems. The most common in air conditioning are: on-off cycling, hot gas bypass, use or not of liquid injection, manifold configurations of multiple compressors, mechanical modulation (also called digital), and inverter technology. ^[*citation needed*]

Hot gas bypass

[edit]

Hot gas bypass involves injecting a quantity of gas from discharge to the suction side. The compressor will keep operating at the same speed, but due to the bypass, the refrigerant mass flow circulating with the system is reduced, and thus the cooling capacity. This naturally causes the compressor to run uselessly during the periods when the bypass is operating. The turn down capacity varies between 0 and 100%.^[85]

Manifold configurations

[edit]

Several compressors can be installed in the system to provide the peak cooling capacity. Each compressor can run or not in order to stage the cooling capacity of the unit. The turn down capacity is either 0/33/66 or 100% for a trio configuration and either 0/50 or 100% for a tandem.^[*citation needed*]

Mechanically modulated compressor

[edit]

This internal mechanical capacity modulation is based on periodic compression process with a control valve, the two scroll set move apart stopping the compression for a given time period. This method varies refrigerant flow by changing the average time of compression, but not the actual speed of the motor. Despite an excellent turndown ratio – from 10 to 100% of the cooling capacity, mechanically modulated scrolls have high energy consumption as the motor continuously runs.^[*citation needed*]

Variable-speed compressor

[edit]

Main article: Inverter compressor

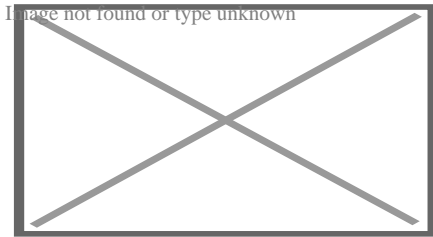
This system uses a variable-frequency drive (also called an Inverter) to control the speed of the compressor. The refrigerant flow rate is changed by the change in the speed of the compressor. The turn down ratio depends on the system configuration and manufacturer. It modulates from 15 or 25% up to 100% at full capacity with a single inverter from 12 to 100% with a hybrid tandem. This method is the most efficient way to modulate an air conditioner's capacity. It is up to 58% more efficient than a fixed speed system.^[*citation needed*]

Impact

[edit]

Health effects

[edit]



Rooftop condenser unit fitted on top of an Osaka Municipal Subway 10 series subway carriage. Air conditioning has become increasingly prevalent on public transport vehicles as a form of climate control, and to ensure passenger comfort and drivers' occupational safety and health.

In hot weather, air conditioning can prevent heat stroke, dehydration due to excessive sweating, electrolyte imbalance, kidney failure, and other issues due to hyperthermia. [8][86] Heat waves are the most lethal type of weather phenomenon in the United States. [87][88] A 2020 study found that areas with lower use of air conditioning correlated with higher rates of heat-related mortality and hospitalizations. [89] The August 2003 France heatwave resulted in approximately 15,000 deaths, where 80% of the victims were over 75 years old. In response, the French government required all retirement homes to have at least one air-conditioned room at 25 °C (77 °F) per floor during heatwaves. [8]

Air conditioning (including filtration, humidification, cooling and disinfection) can be used to provide a clean, safe, hypoallergenic atmosphere in hospital operating rooms and other environments where proper atmosphere is critical to patient safety and well-being. It is sometimes recommended for home use by people with allergies, especially mold. [90][91] However, poorly maintained water cooling towers can promote the growth and spread of microorganisms such as *Legionella pneumophila*, the infectious agent responsible for Legionnaires' disease. As long as the cooling tower is kept clean (usually by means of a chlorine treatment), these health hazards can be avoided or reduced. The state of New York has codified requirements for registration, maintenance, and testing of cooling towers to protect against Legionella. [92]

Economic effects

[edit]

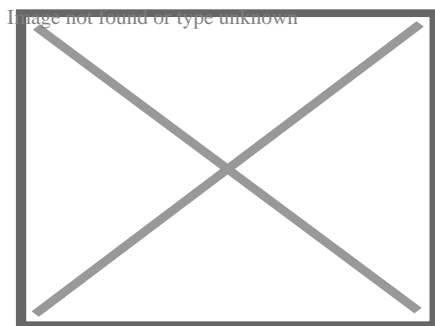
First designed to benefit targeted industries such as the press as well as large factories, the invention quickly spread to public agencies and administrations with studies with claims of increased productivity close to 24% in places equipped with air conditioning. [93]

Air conditioning caused various shifts in demography, notably that of the United States starting from the 1970s. In the US, the birth rate was lower in the spring than during other seasons until the 1970s but this difference then declined since then.^[94] As of 2007, the Sun Belt contained 30% of the total US population while it was inhabited by 24% of Americans at the beginning of the 20th century.^[95] Moreover, the summer mortality rate in the US, which had been higher in regions subject to a heat wave during the summer, also evened out.^[7]

The spread of the use of air conditioning acts as a main driver for the growth of global demand of electricity.^[96] According to a 2018 report from the International Energy Agency (IEA), it was revealed that the energy consumption for cooling in the United States, involving 328 million Americans, surpasses the combined energy consumption of 4.4 billion people in Africa, Latin America, the Middle East, and Asia (excluding China).^[8] A 2020 survey found that an estimated 88% of all US households use AC, increasing to 93% when solely looking at homes built between 2010 and 2020.^[97]

Environmental effects

[edit]



Air conditioner farm in the facade of a building in Singapore

Space cooling including air conditioning accounted globally for 2021 terawatt-hours of energy usage in 2016 with around 99% in the form of electricity, according to a 2018 report on air-conditioning efficiency by the International Energy Agency.^[8] The report predicts an increase of electricity usage due to space cooling to around 6200 TWh by 2050,^{[8][98]} and that with the progress currently seen, greenhouse gas emissions attributable to space cooling will double: 1,135 million tons (2016) to 2,070 million tons.^[8] There is some push to increase the energy efficiency of air conditioners. United Nations Environment Programme (UNEP) and the IEA found that if air conditioners could be twice as effective as now, 460 billion tons of GHG could be cut over 40 years.^[99] The UNEP and IEA also recommended legislation to decrease the use of hydrofluorocarbons, better building insulation, and more sustainable temperature-

controlled food supply chains going forward.[⁹⁹]

Refrigerants have also caused and continue to cause serious environmental issues, including ozone depletion and climate change, as several countries have not yet ratified the Kigali Amendment to reduce the consumption and production of hydrofluorocarbons.[¹⁰⁰] CFCs and HCFCs refrigerants such as R-12 and R-22, respectively, used within air conditioners have caused damage to the ozone layer,[¹⁰¹] and hydrofluorocarbon refrigerants such as R-410A and R-404A, which were designed to replace CFCs and HCFCs, are instead exacerbating climate change.[¹⁰²] Both issues happen due to the venting of refrigerant to the atmosphere, such as during repairs. HFO refrigerants, used in some if not most new equipment, solve both issues with an ozone damage potential (ODP) of zero and a much lower global warming potential (GWP) in the single or double digits vs. the three or four digits of hydrofluorocarbons.[¹⁰³]

Hydrofluorocarbons would have raised global temperatures by around 0.3–0.5 °C (0.5–0.9 °F) by 2100 without the Kigali Amendment. With the Kigali Amendment, the increase of global temperatures by 2100 due to hydrofluorocarbons is predicted to be around 0.06 °C (0.1 °F).[¹⁰⁴]

Alternatives to continual air conditioning include passive cooling, passive solar cooling, natural ventilation, operating shades to reduce solar gain, using trees, architectural shades, windows (and using window coatings) to reduce solar gain. [*citation needed*]

Social effects

[edit]

Socioeconomic groups with a household income below around \$10,000 tend to have a low air conditioning adoption,[⁴²] which worsens heat-related mortality.[⁷] The lack of cooling can be hazardous, as areas with lower use of air conditioning correlate with higher rates of heat-related mortality and hospitalizations.[⁸⁹] Premature mortality in NYC is projected to grow between 47% and 95% in 30 years, with lower-income and vulnerable populations most at risk.[⁸⁹] Studies on the correlation between heat-related mortality and hospitalizations and living in low socioeconomic locations can be traced in Phoenix, Arizona,[¹⁰⁵] Hong Kong,[¹⁰⁶] China,[¹⁰⁶] Japan,[¹⁰⁷] and Italy.[¹⁰⁸][¹⁰⁹] Additionally, costs concerning health care can act as another barrier, as the lack of private health insurance during a 2009 heat wave in Australia, was associated with heat-related hospitalization.[¹⁰⁹]

Disparities in socioeconomic status and access to air conditioning are connected by some to institutionalized racism, which leads to the association of specific marginalized communities with lower economic status, poorer health, residing in hotter neighborhoods, engaging in physically demanding labor, and experiencing limited access to cooling technologies such as air conditioning.^[109] A study overlooking Chicago, Illinois, Detroit, and Michigan found that black households were half as likely to have central air conditioning units when compared to their white counterparts.^[110] Especially in cities, Redlining creates heat islands, increasing temperatures in certain parts of the city.^[109] This is due to materials heat-absorbing building materials and pavements and lack of vegetation and shade coverage.^[111] There have been initiatives that provide cooling solutions to low-income communities, such as public cooling spaces.^{[8][111]}

Other techniques

[edit]

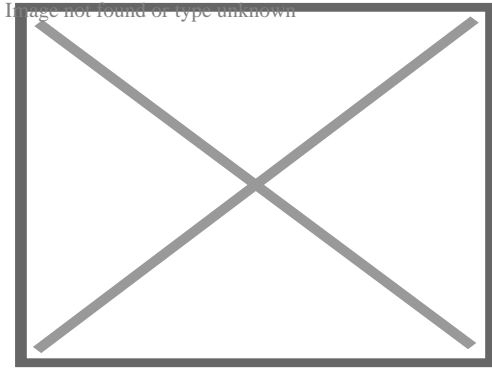
Buildings designed with passive air conditioning are generally less expensive to construct and maintain than buildings with conventional HVAC systems with lower energy demands.^[112] While tens of air changes per hour, and cooling of tens of degrees, can be achieved with passive methods, site-specific microclimate must be taken into account, complicating building design.^[12]

Many techniques can be used to increase comfort and reduce the temperature in buildings. These include evaporative cooling, selective shading, wind, thermal convection, and heat storage.^[113]

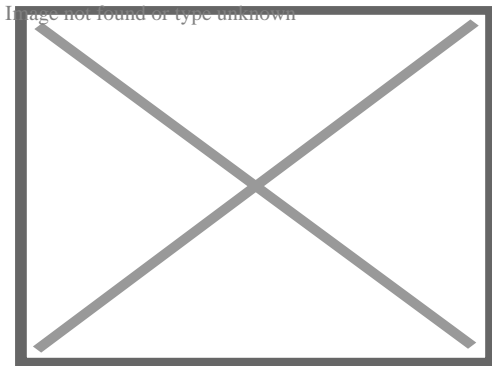
Passive ventilation

[edit]

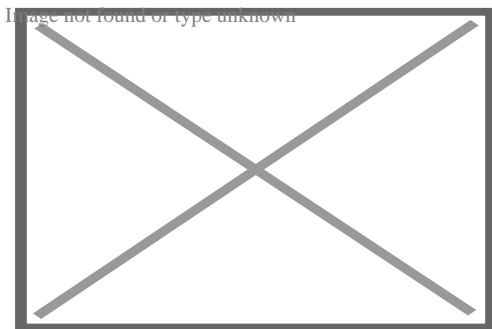
This section is an excerpt from Passive ventilation. [edit]



The ventilation system of a regular earthship



Dogtrot houses are designed to maximise natural ventilation.



A roof turbine ventilator, colloquially known as a 'Whirly Bird' is an application of wind driven ventilation.

Passive ventilation is the process of supplying air to and removing air from an indoor space without using mechanical systems. It refers to the flow of external air to an indoor space as a result of pressure differences arising from natural forces.

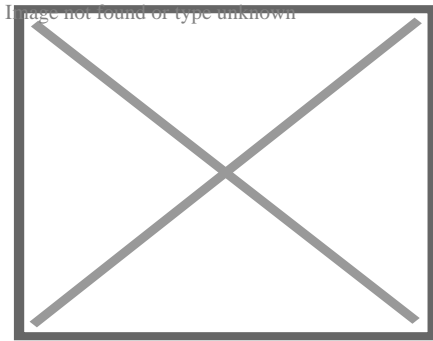
There are two types of natural ventilation occurring in buildings: *wind driven ventilation* and *buoyancy-driven ventilation*. Wind driven ventilation arises from the different pressures created by wind around a building or structure, and openings being formed on the perimeter which then permit flow through the building. Buoyancy-driven ventilation occurs as a result of the directional buoyancy force that results from temperature differences between the interior and exterior.^[114]

Since the internal heat gains which create temperature differences between the interior and exterior are created by natural processes, including the heat from people, and wind effects are variable, naturally ventilated buildings are sometimes called "breathing buildings".

Passive cooling

[edit]

This section is an excerpt from Passive cooling.[edit]



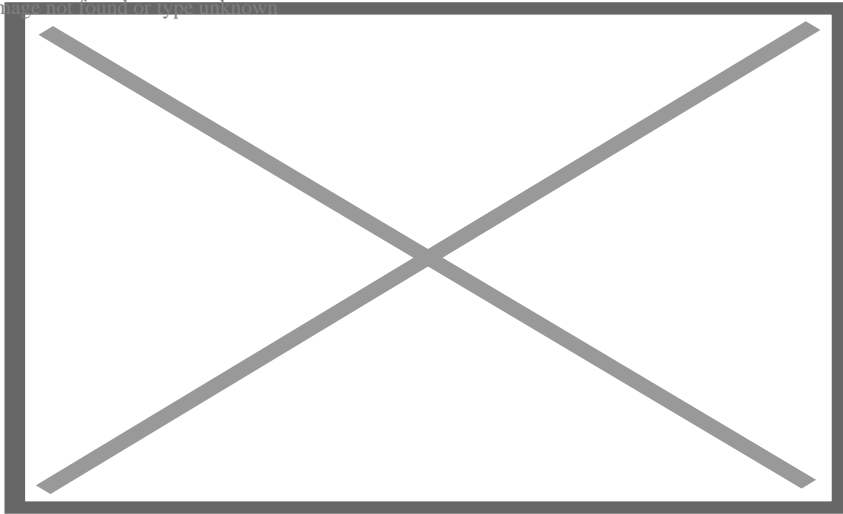
A traditional Iranian solar cooling design using a wind tower

Passive cooling is a building design approach that focuses on heat gain control and heat dissipation in a building in order to improve the indoor thermal comfort with low or no energy consumption.^{[115][116]} This approach works either by preventing heat from entering the interior (heat gain prevention) or by removing heat from the building (natural cooling).^[117]

Natural cooling utilizes on-site energy, available from the natural environment, combined with the architectural design of building components (e.g. building envelope), rather than mechanical systems to dissipate heat.^[118] Therefore, natural cooling depends not only on the architectural design of the building but on how the site's natural resources are used as heat sinks (i.e. everything that absorbs or dissipates heat). Examples of on-site heat sinks are the upper atmosphere (night sky), the outdoor air (wind), and the earth/soil.

Passive cooling is an important tool for design of buildings for climate change adaptation – reducing dependency on energy-intensive air conditioning in warming environments.^{[119][120]}

Image not found or type unknown

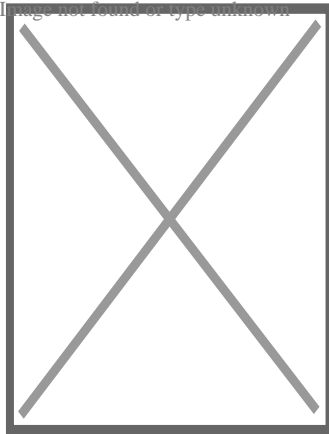


A pair of short windcatchers (*malqaf*) used in traditional architecture; wind is forced down on the windward side and leaves on the leeward side (*cross-ventilation*). In the absence of wind, the circulation can be driven with evaporative cooling in the inlet (which is also designed to catch dust). In the center, a *shuksheika* (roof lantern vent), used to shade the qa'a below while allowing hot air rise out of it (*stack effect*).^[11]

Daytime radiative cooling

[edit]

Image not found or type unknown



Passive daytime radiative cooling (PDRC) surfaces are high in solar reflectance and heat emittance, cooling with zero energy use or pollution.^[121]

Passive daytime radiative cooling (PDRC) surfaces reflect incoming solar radiation and heat back into outer space through the infrared window for cooling during the daytime.

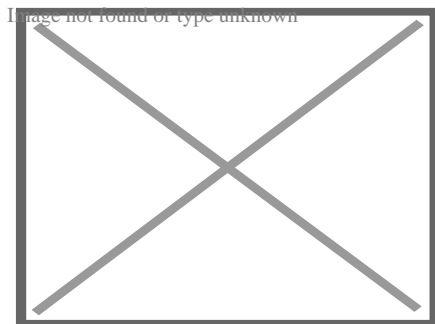
In areas that are cold at night or in winter, heat storage is used. Heat may be stored in earth or masonry; air is drawn past the masonry to heat or cool it.^[13]

In areas that are below freezing at night in winter, snow and ice can be collected and stored in ice houses for later use in cooling.^[13] This technique is over 3,700 years old in the Middle East.^[128] Harvesting outdoor ice during winter and transporting and storing for use in summer was practiced by wealthy Europeans in the early 1600s,^[15] and became popular in Europe and the Americas towards the end of the 1600s.^[129] This practice was replaced by mechanical compression-cycle icemakers.

Evaporative cooling

[edit]

Main article: Evaporative cooler



An evaporative cooler

In dry, hot climates, the evaporative cooling effect may be used by placing water at the air intake, such that the draft draws air over water and then into the house. For this reason, it is sometimes said that the fountain, in the architecture of hot, arid climates, is like the fireplace in the architecture of cold climates.^[11] Evaporative cooling also makes the air more humid, which can be beneficial in a dry desert climate.^[130]

Evaporative coolers tend to feel as if they are not working during times of high humidity, when there is not much dry air with which the coolers can work to make the air as cool as possible for dwelling occupants. Unlike other types of air conditioners, evaporative coolers rely on the outside air to be channeled through cooler pads that cool the air before it reaches the inside of a house through its air duct system; this cooled outside air must be allowed to push the warmer air within the house out through an exhaust opening such as an open door or window.^[131]

See also

[edit]

- Air filter
- Air purifier
- Cleanroom
- Crankcase heater
- Energy recovery ventilation
- Indoor air quality
- Particulates

References

[edit]

- [^] "Air Con". *Cambridge Dictionary*. Archived from the original on May 3, 2022. Retrieved January 6, 2023.
- [^] *Dissertation Abstracts International: The humanities and social sciences*. A. University Microfilms. 2005. p. 3600.
- [^] *1993 ASHRAE Handbook: Fundamentals*. ASHRAE. 1993. ISBN 978-0-910110-97-6.
- [^] *Enteria, Napoleon; Sawachi, Takao; Saito, Kiyoshi (January 31, 2023). Variable Refrigerant Flow Systems: Advances and Applications of VRF*. Springer Nature. p. 46. ISBN 978-981-19-6833-4.
- [^] *Agencies, United States Congress House Committee on Appropriations Subcommittee on Dept of the Interior and Related (1988). Department of the Interior and Related Agencies Appropriations for 1989: Testimony of public witnesses, energy programs, Institute of Museum Services, National Endowment for the Arts, National Endowment for the Humanities*. U.S. Government Printing Office. p. 629.
- [^] "Earth Tubes: Providing the freshest possible air to your building". *Earth Rangers Centre for Sustainable Technology Showcase*. Archived from the original on January 28, 2021. Retrieved May 12, 2021.
- [^] **a b c** Barreca, Alan; Clay, Karen; Deschenes, Olivier; Greenstone, Michael; Shapiro, Joseph S. (February 2016). "Adapting to Climate Change: The Remarkable Decline in the US Temperature-Mortality Relationship over the Twentieth Century". *Journal of Political Economy*. **124** (1): 105–159. doi:10.1086/684582.
- [^] **a b c d e f g h i j** International Energy Agency (May 15, 2018). *The Future of Cooling - Opportunities for energy-efficient air conditioning (PDF) (Report)*. Archived (PDF) from the original on June 26, 2024. Retrieved July 1, 2024.
- [^] Laub, Julian M. (1963). *Air Conditioning & Heating Practice*. Holt, Rinehart and Winston. p. 367. ISBN 978-0-03-011225-6.
- [^] "Air-conditioning found at 'oldest city in the world". *The Independent*. June 24, 2000. Archived from the original on December 8, 2023. Retrieved December 9, 2023.

11. ^ **a b c** Mohamed, Mady A.A. (January 2010). Lehmann, S.; Waer, H.A.; Al-Qawasmi, J. (eds.). *Traditional Ways of Dealing with Climate in Egypt. The Seventh International Conference of Sustainable Architecture and Urban Development (SAUD 2010)*. Amman, Jordan: The Center for the Study of Architecture in Arab Region (CSAAR Press). pp. 247–266. Archived from the original on May 13, 2021. Retrieved May 12, 2021.
12. ^ **a b c** Ford, Brian (September 2001). "Passive downdraught evaporative cooling: principles and practice". *Architectural Research Quarterly*. **5** (3): 271–280. doi:10.1017/S1359135501001312.
13. ^ **a b c** Attia, Shady; Herde, André de (June 22–24, 2009). *Designing the Malqaf for Summer Cooling in Low-Rise Housing, an Experimental Study*. 26th Conference on Passive and Low Energy Architecture (PLEA2009). Quebec City. Archived from the original on May 13, 2021. Retrieved May 12, 2021.
14. ^ US EPA, OAR (October 17, 2014). "Heating, Ventilation and Air-Conditioning Systems, Part of Indoor Air Quality Design Tools for Schools". epa.gov. Archived from the original on July 5, 2022. Retrieved July 5, 2022.
15. ^ **a b c** Shachtman, Tom (1999). "Winter in Summer". *Absolute zero and the conquest of cold*. Boston: Houghton Mifflin Harcourt. ISBN 978-0395938881. OCLC 421754998. Archived from the original on May 13, 2021. Retrieved May 12, 2021.
16. ^ Porta, Giambattista Della (1584). *Magiae naturalis* (PDF). London. LCCN 09023451. Archived (PDF) from the original on May 13, 2021. Retrieved May 12, 2021. "In our method I shall observe what our ancestors have said; then I shall show by my own experience, whether they be true or false "
17. ^ Beck, Leonard D. (October 1974). "Things Magical in the collections of the Rare Book and Special Collections Division" (PDF). *Library of Congress Quarterly Journal*. **31**: 208–234. Archived (PDF) from the original on March 24, 2021. Retrieved May 12, 2021.
18. ^ Laszlo, Pierre (2001). *Salt: Grain of Life*. Columbia University Press. p. 117. ISBN 978-0231121989. OCLC 785781471. "Cornelius Drebbel air conditioning."
19. ^ Franklin, Benjamin (June 17, 1758). "Archived copy". Letter to John Lining. Archived from the original on February 25, 2021. Retrieved May 12, 2021.cite press release: CS1 maint: archived copy as title (link)
20. ^ **a b c d** Green, Amanda (January 1, 2015). "The Cool History of the Air Conditioner". *Popular Mechanics*. Archived from the original on April 10, 2021. Retrieved May 12, 2021.
21. ^ "John Gorrie". *Encyclopædia Britannica*. September 29, 2020. Archived from the original on March 13, 2021. Retrieved May 12, 2021.
22. ^ Gorrie, John "Improved process for the artificial production of ice" U.S. Patent no. 8080 (Issued: May 6, 1851).
23. ^ Wright, E. Lynne (2009). *It Happened in Florida: Remarkable Events That Shaped History*. Rowman & Littlefield. pp. 13–. ISBN 978-0762761692.

24. [^] **a b** Bruce-Wallace, L. G. (1966). "Harrison, James (1816–1893)". *Australian Dictionary of Biography*. Vol. 1. Canberra: National Centre of Biography, Australian National University. ISBN 978-0-522-84459-7. ISSN 1833-7538. OCLC 70677943. Retrieved May 12, 2021.
25. [^] Palermo, Elizabeth (May 1, 2014). "Who Invented Air Conditioning?". *livescience.com*. Archived from the original on January 16, 2021. Retrieved May 12, 2021.
26. [^] Varrasi, John (June 6, 2011). "Global Cooling: The History of Air Conditioning". *American Society of Mechanical Engineers*. Archived from the original on March 8, 2021. Retrieved May 12, 2021.
27. [^] Simha, R. V. (February 2012). "Willis H Carrier". *Resonance*. **17** (2): 117–138. doi:10.1007/s12045-012-0014-y. ISSN 0971-8044. S2CID 116582893.
28. [^] Gulledge III, Charles; Knight, Dennis (February 11, 2016). "Heating, Ventilating, Air-Conditioning, And Refrigerating Engineering". *National Institute of Building Sciences*. Archived from the original on April 20, 2021. Retrieved May 12, 2021. " Though he did not actually invent air-conditioning nor did he take the first documented scientific approach to applying it, Willis Carrier is credited with integrating the scientific method, engineering, and business of this developing technology and creating the industry we know today as air-conditioning."
29. [^] "Willis Carrier – 1876–1902". *Carrier Global*. Archived from the original on February 27, 2021. Retrieved May 12, 2021.
30. [^] "Carrier Reports First Quarter 2020 Earnings". *Carrier Global (Press release)*. May 8, 2020. Archived from the original on January 24, 2021. Retrieved May 12, 2021.
31. [^] "Carrier Becomes Independent, Publicly Traded Company, Begins Trading on New York Stock Exchange". *Carrier Global (Press release)*. April 3, 2020. Archived from the original on February 25, 2021. Retrieved May 12, 2021.
32. [^] Cramer, Stuart W. "Humidifying and air conditioning apparatus" U.S. Patent no. 852,823 (filed: April 18, 1906; issued: May 7, 1907).
 - See also: Cramer, Stuart W. (1906) "Recent development in air conditioning" in: *Proceedings of the Tenth Annual Convention of the American Cotton Manufacturers Association Held at Asheville, North Carolina May 16–17, 1906*. Charlotte, North Carolina, USA: Queen City Publishing Co. pp. 182-211.
33. [^] US patent US808897A, Carrier, Willis H., "Apparatus for treating air", published January 2, 1906, issued January 2, 1906 and Buffalo Forge Company "Archived copy" (PDF). Archived from the original on December 5, 2019. Retrieved May 12, 2021.cite web: CS1 maint: archived copy as title (link) CS1 maint: bot: original URL status unknown (link)
34. [^] "First Air-Conditioned Auto". *Popular Science*. Vol. 123, no. 5. November 1933. p. 30. ISSN 0161-7370. Archived from the original on April 26, 2021. Retrieved May 12, 2021.

35. ^ "Room-size air conditioner fits under window sill". *Popular Mechanics*. Vol. 63, no. 6. June 1935. p. 885. ISSN 0032-4558. Archived from the original on November 22, 2016. Retrieved May 12, 2021.
36. ^ "Michigan Fast Facts and Trivia". *50states.com*. Archived from the original on June 18, 2017. Retrieved May 12, 2021.
37. ^ US patent US2433960A, Sherman, Robert S., "Air conditioning apparatus", published January 6, 1948, issued January 6, 1948
38. ^ "IEEE milestones (39) Inverter Air Conditioners, 1980–1981" (PDF). March 2021. Archived (PDF) from the original on January 21, 2024. Retrieved February 9, 2024.
39. ^ "Inverter Air Conditioners, 1980–1981 IEEE Milestone Celebration Ceremony" (PDF). March 16, 2021. Archived (PDF) from the original on January 21, 2024. Retrieved February 9, 2024.
40. ^ Seale, Avrel (August 7, 2023). "Texas alumnus and his alma mater central to air-conditioned homes". *UT News*. Retrieved November 13, 2024.
41. ^ "Air Conditioned Village". *Atlas Obscura*. Retrieved November 13, 2024.
42. ^ **a b c** Davis, Lucas; Gertler, Paul; Jarvis, Stephen; Wolfram, Catherine (July 2021). "Air conditioning and global inequality". *Global Environmental Change*. **69**: 102299. Bibcode:2021GEC....6902299D. doi:10.1016/j.gloenvcha.2021.102299.
43. ^ Pierre-Louis, Kendra (May 15, 2018). "The World Wants Air-Conditioning. That Could Warm the World". *The New York Times*. Archived from the original on February 16, 2021. Retrieved May 12, 2021.
44. ^ Carroll, Rory (October 26, 2015). "How America became addicted to air conditioning". *The Guardian*. Los Angeles. Archived from the original on March 13, 2021. Retrieved May 12, 2021.
45. ^ Lester, Paul (July 20, 2015). "History of Air Conditioning". *United States Department of Energy*. Archived from the original on June 5, 2020. Retrieved May 12, 2021.
46. ^ Cornish, Cheryl; Cooper, Stephen; Jenkins, Salima. *Characteristics of New Housing (Report)*. United States Census Bureau. Archived from the original on April 11, 2021. Retrieved May 12, 2021.
47. ^ "Central Air Conditioning Buying Guide". *Consumer Reports*. March 3, 2021. Archived from the original on May 9, 2021. Retrieved May 12, 2021.
48. ^ Petchers, Neil (2003). *Combined Heating, Cooling & Power Handbook: Technologies & Applications : an Integrated Approach to Energy Resource Optimization*. The Fairmont Press. p. 737. ISBN 978-0-88173-433-1.
49. ^ Krarti, Moncef (December 1, 2020). *Energy Audit of Building Systems: An Engineering Approach, Third Edition*. CRC Press. p. 370. ISBN 978-1-000-25967-4.
50. ^ "What is a Reversing Valve". *Samsung India*. Archived from the original on February 22, 2019. Retrieved May 12, 2021.
51. ^ "Humidity and Comfort" (PDF). *DriSteem*. Archived from the original (PDF) on May 16, 2018. Retrieved May 12, 2021.

52. ^ Perryman, Oliver (April 19, 2021). "Dehumidifier vs Air Conditioning". *Dehumidifier Critic*. Archived from the original on May 13, 2021. Retrieved May 12, 2021.
53. ^ Snijders, Aart L. (July 30, 2008). "Aquifer Thermal Energy Storage (ATES) Technology Development and Major Applications in Europe" (PDF). Toronto and Region Conservation Authority. Arnhem: IFTech International. Archived (PDF) from the original on March 8, 2021. Retrieved May 12, 2021.
54. ^ **a b** "Cold Climate Air Source Heat Pump" (PDF). Minnesota Department of Commerce, Division of Energy Resources. Archived (PDF) from the original on January 2, 2022. Retrieved March 29, 2022.
55. ^ "Even in Frigid Temperatures, Air-Source Heat Pumps Keep Homes Warm From Alaska Coast to U.S. Mass Market". nrel.gov. Archived from the original on April 10, 2022. Retrieved March 29, 2022.
56. ^ "Heat Pumps: A Practical Solution for Cold Climates". RMI. December 10, 2020. Archived from the original on March 31, 2022. Retrieved March 28, 2022.
57. ^ "TEM Instruction Sheet" (PDF). TE Technology. March 14, 2012. Archived from the original (PDF) on January 24, 2013. Retrieved May 12, 2021.
58. ^ "Coefficient of Performance (COP) heat pumps". Grundfos. November 18, 2020. Archived from the original on May 3, 2021. Retrieved May 12, 2021.
59. ^ "Unpotted HP-199-1.4-0.8 at a hot-side temperature of 25 °C" (PDF). TE Technology. Archived from the original (PDF) on January 7, 2009. Retrieved February 9, 2024.
60. ^ Newell, David B.; Tiesinga, Eite, eds. (August 2019). *The International System of Units (SI)* (PDF). National Institute of Standards and Technology. doi:10.6028/NIST.SP.330-2019. Archived (PDF) from the original on April 22, 2021. Retrieved May 13, 2021.
61. ^ ANSI/AHRI 210/240-2008: 2008 Standard for Performance Rating of Unitary Air-Conditioning & Air-Source Heat Pump Equipment (PDF). Air Conditioning, Heating and Refrigeration Institute. 2012. Archived from the original on March 29, 2018. Retrieved May 13, 2021.
62. ^ Baraniuk, Chris. "Cutting-Edge Technology Could Massively Reduce the Amount of Energy Used for Air Conditioning". *Wired*. ISSN 1059-1028. Retrieved July 18, 2024.
63. ^ "M-Series Contractor Guide" (PDF). Mitsubishi.com. p. 19. Archived (PDF) from the original on March 18, 2021. Retrieved May 12, 2021.
64. ^
"ÃfÆ'Ã†â€™Ãfâ€ Åçâ,-â,,çÃfÆ'Ãçâ,-Ã ÃfÂçÃçâ€ šÂ-Ãçâ€žÂçÃfÆ'Ã†â€™ÃfÂçÃçâ€
ÃfÆ'Ã†â€™Ãfâ€ Åçâ,-â,,çÃfÆ'Ãçâ,-Ã ÃfÂçÃçâ€ šÂ-Ãçâ€žÂçÃfÆ'Ã†â€™ÃfÂçÃçâ€
|
ÃfÆ'Ã†â€™Ãfâ€ Åçâ,-â,,çÃfÆ'Ãçâ,-Ã ÃfÂçÃçâ€ šÂ-Ãçâ€žÂçÃfÆ'Ã†â€™ÃfÂçÃçâ€
|
ÃfÆ'Ã†â€™Ãfâ€ Åçâ,-â,,çÃfÆ'Ãçâ,-Ã ÃfÂçÃçâ€ šÂ-Ãçâ€žÂçÃfÆ'Ã†â€™ÃfÂçÃçâ€
ÃfÆ'Ã†â€™Ãfâ€ Åçâ,-â,,çÃfÆ'Ãçâ,-Ã ÃfÂçÃçâ€ šÂ-Ãçâ€žÂçÃfÆ'Ã†â€™ÃfÂçÃçâ€

de
shouene-kaden.net. Archived from the original on September 7, 2022. Retrieved January 21, 2024.

65. ^ "Air conditioner | History". Toshiba Carrier. April 2016. Archived from the original on March 9, 2021. Retrieved May 12, 2021.
66. ^ "1920s–1970s | History". Mitsubishi Electric. Archived from the original on March 8, 2021. Retrieved May 12, 2021.
67. ^ Wagner, Gerry (November 30, 2021). "The Duct Free Zone: History of the Mini Split". HPAC Magazine. Retrieved February 9, 2024.
68. ^ "History of Daikin Innovation". Daikin. Archived from the original on June 5, 2020. Retrieved May 12, 2021.
69. ^ Feit, Justin (December 20, 2017). "The Emergence of VRF as a Viable HVAC Option". buildings.com. Archived from the original on December 3, 2020. Retrieved May 12, 2021.
70. ^ **a b** "Central Air Conditioning". United States Department of Energy. Archived from the original on January 30, 2021. Retrieved May 12, 2021.
71. ^ Kreith, Frank; Wang, Shan K.; Norton, Paul (April 20, 2018). *Air Conditioning and Refrigeration Engineering*. CRC Press. ISBN 978-1-351-46783-4.
72. ^ Wang, Shan K. (November 7, 2000). *Handbook of Air Conditioning and Refrigeration*. McGraw-Hill Education. ISBN 978-0-07-068167-5.
73. ^ Hleborodova, Veronika (August 14, 2018). "Portable Vs Split System Air Conditioning | Pros & Cons". Canstar Blue. Archived from the original on March 9, 2021. Retrieved May 12, 2021.
74. ^ Kamins, Toni L. (July 15, 2013). "Through-the-Wall Versus PTAC Air Conditioners: A Guide for New Yorkers". Brick Underground. Archived from the original on January 15, 2021. Retrieved May 12, 2021.
75. ^ "Self-Contained Air Conditioning Systems". Daikin Applied Americas. 2015. Archived from the original on October 30, 2020. Retrieved May 12, 2021.
76. ^ "LSWU/LSWD Vertical Water-Cooled Self-Contained Unit Engineering Guide" (PDF). Johnson Controls. April 6, 2018. Archived (PDF) from the original on May 13, 2021. Retrieved May 12, 2021.
77. ^ "Packaged Rooftop Unit" (PDF). Carrier Global. 2016. Archived (PDF) from the original on May 13, 2021. Retrieved May 12, 2021.
78. ^ "Packaged Rooftop Air Conditioners" (PDF). Trane Technologies. November 2006. Archived (PDF) from the original on May 13, 2021. Retrieved May 12, 2021.
79. ^ "What is Packaged Air Conditioner? Types of Packged Air Condtioners". Bright Hub Engineering. January 13, 2010. Archived from the original on February 22,

2018. Retrieved May 12, 2021.
80. ^ Evans, Paul (November 11, 2018). "RTU Rooftop Units explained". *The Engineering Mindset*. Archived from the original on January 15, 2021. Retrieved May 12, 2021.
 81. ^ "water-cooled – Johnson Supply". *studylib.net*. 2000. Archived from the original on May 13, 2021. Retrieved May 12, 2021.
 82. ^ "Water Cooled Packaged Air Conditioners" (PDF). Japan: Daikin. May 2, 2003. Archived (PDF) from the original on June 19, 2018. Retrieved May 12, 2021.
 83. ^ "Water Cooled Packaged Unit" (PDF). Daikin. Archived (PDF) from the original on May 13, 2021. Retrieved May 12, 2021.
 84. ^ Lun, Y. H. Venus; Tung, S. L. Dennis (November 13, 2019). *Heat Pumps for Sustainable Heating and Cooling*. Springer Nature. p. 25. ISBN 978-3-030-31387-6.
 85. ^ Ghanbariannaeni, Ali; Ghazanfarihashemi, Ghazalehsadat (June 2012). "Bypass Method For Recip Compressor Capacity Control". *Pipeline and Gas Journal*. **239** (6). Archived from the original on August 12, 2014. Retrieved February 9, 2024.
 86. ^ "Heat Stroke (Hyperthermia)". *Harvard Health*. January 2, 2019. Archived from the original on January 29, 2021. Retrieved May 13, 2021.
 87. ^ "Weather Related Fatality and Injury Statistics". *National Weather Service*. 2021. Archived from the original on August 24, 2022. Retrieved August 24, 2022.
 88. ^ "Extreme Weather: A Guide to Surviving Flash Floods, Tornadoes, Hurricanes, Heat Waves, Snowstorms Tsunamis and Other Natural Disasters". *Reference Reviews*. **26** (8): 41. October 19, 2012. doi:10.1108/09504121211278322. ISSN 0950-4125. Archived from the original on January 21, 2024. Retrieved December 9, 2023.
 89. ^ **a b c** Gamarro, Harold; Ortiz, Luis; González, Jorge E. (August 1, 2020). "Adapting to Extreme Heat: Social, Atmospheric, and Infrastructure Impacts of Air-Conditioning in Megacities—The Case of New York City". *ASME Journal of Engineering for Sustainable Buildings and Cities*. **1** (3). doi:10.1115/1.4048175. ISSN 2642-6641. S2CID 222121944.
 90. ^ Spiegelman, Jay; Friedman, Herman; Blumstein, George I. (September 1, 1963). "The effects of central air conditioning on pollen, mold, and bacterial concentrations". *Journal of Allergy*. **34** (5): 426–431. doi:10.1016/0021-8707(63)90007-8. ISSN 0021-8707. PMID 14066385.
 91. ^ Portnoy, Jay M.; Jara, David (February 1, 2015). "Mold allergy revisited". *Annals of Allergy, Asthma & Immunology*. **114** (2): 83–89. doi:10.1016/j.anai.2014.10.004. ISSN 1081-1206. PMID 25624128.
 92. ^ "Subpart 4-1 – Cooling Towers". *New York Codes, Rules and Regulations*. June 7, 2016. Archived from the original on May 13, 2021. Retrieved May 13, 2021.
 93. ^ Nordhaus, William D. (February 10, 2010). "Geography and macroeconomics: New data and new findings". *Proceedings of the National Academy of Sciences*.

- 103** (10): 3510–3517. doi:10.1073/pnas.0509842103. ISSN 0027-8424. PMC 1363683. PMID 16473945.
94. ^ Barreca, Alan; Deschenes, Olivier; Guldi, Melanie (2018). "Maybe next month? Temperature shocks and dynamic adjustments in birth rates". *Demography*. **55** (4): 1269–1293. doi:10.1007/s13524-018-0690-7. PMC 7457515. PMID 29968058.
 95. ^ Glaeser, Edward L.; Tobio, Kristina (January 2008). "The Rise of the Sunbelt". *Southern Economic Journal*. **74** (3): 609–643. doi:10.1002/j.2325-8012.2008.tb00856.x.
 96. ^ Sherman, Peter; Lin, Haiyang; McElroy, Michael (2018). "Projected global demand for air conditioning associated with extreme heat and implications for electricity grids in poorer countries". *Energy and Buildings*. **268**: 112198. doi:10.1016/j.enbuild.2022.112198. ISSN 0378-7788. S2CID 248979815.
 97. ^ *Air Filters Used in Air Conditioning and General Ventilation Part 1: Methods of Test for Atmospheric Dust Spot Efficiency and Synthetic Dust Weight Arrestance (Withdrawn Standard)*. British Standards Institution. March 29, 1985. BS 6540-1:1985.
 98. ^ Mutschler, Robin; Rüdüsüli, Martin; Heer, Philipp; Eggimann, Sven (April 15, 2021). "Benchmarking cooling and heating energy demands considering climate change, population growth and cooling device uptake". *Applied Energy*. **288**: 116636. Bibcode:2021ApEn..28816636M. doi:10.1016/j.apenergy.2021.116636. ISSN 0306-2619.
 99. ^ **a b** "Climate-friendly cooling could cut years of Greenhouse Gas Emissions and save US\$ trillions: UN". doi:10.1163/9789004322714_cclc_2020-0252-0973. cite journal: Cite journal requires |journal= (help)
 100. ^ Gerretsen, Isabelle (December 8, 2020). "How your fridge is heating up the planet". *BBC Future*. Archived from the original on May 10, 2021. Retrieved May 13, 2021.
 101. ^ *Encyclopedia of Energy: Ph-S*. Elsevier. 2004. ISBN 978-0121764821.
 102. ^ Corberan, J.M. (2016). "New trends and developments in ground-source heat pumps". *Advances in Ground-Source Heat Pump Systems*. pp. 359–385. doi:10.1016/B978-0-08-100311-4.00013-3. ISBN 978-0-08-100311-4.
 103. ^ Roselli, Carlo; Sasso, Maurizio (2021). *Geothermal Energy Utilization and Technologies 2020*. MDPI. ISBN 978-3036507040.
 104. ^ "Cooling Emissions and Policy Synthesis Report: Benefits of cooling efficiency and the Kigali Amendment, United Nations Environment Programme - International Energy Agency, 2020" (PDF).
 105. ^ Harlan, Sharon L.; Declet-Barreto, Juan H.; Stefanov, William L.; Petitti, Diana B. (February 2013). "Neighborhood Effects on Heat Deaths: Social and Environmental Predictors of Vulnerability in Maricopa County, Arizona". *Environmental Health Perspectives*. **121** (2): 197–204. Bibcode:2013EnvHP.121..197H. doi:10.1289/ehp.1104625. ISSN 0091-6765. PMC 3569676. PMID 23164621.

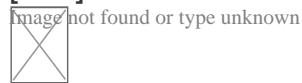
106. ^ **a b** Chan, Emily Ying Yang; Goggins, William B; Kim, Jacqueline Jakyoun; Griffiths, Sian M (April 2012). "A study of intracity variation of temperature-related mortality and socioeconomic status among the Chinese population in Hong Kong". *Journal of Epidemiology and Community Health*. **66** (4): 322–327. doi:10.1136/jech.2008.085167. ISSN 0143-005X. PMC 3292716. PMID 20974839.
107. ^ Ng, Chris Fook Sheng; Ueda, Kayo; Takeuchi, Ayano; Nitta, Hiroshi; Konishi, Shoko; Bagrowicz, Rinako; Watanabe, Chiho; Takami, Akinori (2014). "Sociogeographic Variation in the Effects of Heat and Cold on Daily Mortality in Japan". *Journal of Epidemiology*. **24** (1): 15–24. doi:10.2188/jea.JE20130051. PMC 3872520. PMID 24317342.
108. ^ Stafoggia, Massimo; Forastiere, Francesco; Agostini, Daniele; Biggeri, Annibale; Bisanti, Luigi; Cadum, Ennio; Caranci, Nicola; de'Donato, Francesca; De Lisio, Sara; De Maria, Moreno; Michelozzi, Paola; Miglio, Rossella; Pandolfi, Paolo; Picciotto, Sally; Rognoni, Magda (2006). "Vulnerability to Heat-Related Mortality: A Multicity, Population-Based, Case-Crossover Analysis". *Epidemiology* . **17** (3): 315–323. doi:10.1097/01.ede.0000208477.36665.34. ISSN 1044-3983. JSTOR 20486220. PMID 16570026. S2CID 20283342.
109. ^ **a b c d** Gronlund, Carina J. (September 2014). "Racial and Socioeconomic Disparities in Heat-Related Health Effects and Their Mechanisms: a Review". *Current Epidemiology Reports*. **1** (3): 165–173. doi:10.1007/s40471-014-0014-4. PMC 4264980. PMID 25512891.
110. ^ O'Neill, M. S. (May 11, 2005). "Disparities by Race in Heat-Related Mortality in Four US Cities: The Role of Air Conditioning Prevalence". *Journal of Urban Health: Bulletin of the New York Academy of Medicine*. **82** (2): 191–197. doi:10.1093/jurban/jti043. PMC 3456567. PMID 15888640.
111. ^ **a b** Sampson, Natalie R.; Gronlund, Carina J.; Buxton, Miatta A.; Catalano, Linda; White-Newsome, Jalonne L.; Conlon, Kathryn C.; O'Neill, Marie S.; McCormick, Sabrina; Parker, Edith A. (April 1, 2013). "Staying cool in a changing climate: Reaching vulnerable populations during heat events". *Global Environmental Change*. **23** (2): 475–484. Bibcode:2013GEC....23..475S. doi:10.1016/j.gloenvcha.2012.12.011. ISSN 0959-3780. PMC 5784212. PMID 29375195.
112. ^ Niktash, Amirreza; Huynh, B. Phuoc (July 2–4, 2014). *Simulation and Analysis of Ventilation Flow Through a Room Caused by a Two-sided Windcatcher Using a LES Method (PDF)*. World Congress on Engineering. Lecture Notes in Engineering and Computer Science. Vol. 2. London. eISSN 2078-0966. ISBN 978-9881925350. ISSN 2078-0958. Archived (PDF) from the original on April 26, 2018. Retrieved May 13, 2021.
113. ^ Zhang, Chen; Kazanci, Ongun Berk; Levinson, Ronnen; Heiselberg, Per; Olesen, Bjarne W.; Chiesa, Giacomo; Sodagar, Behzad; Ai, Zhengtao; Selkowitz, Stephen; Zinzi, Michele; Mahdavi, Ardeshir (November 15, 2021). "Resilient cooling strategies – A critical review and qualitative assessment". *Energy and*

- Buildings*. **251**: 111312. Bibcode:2021EneBu.25111312Z. doi: 10.1016/j.enbuild.2021.111312. hdl:2117/363031. ISSN 0378-7788.
114. ^ Linden, P. F. (1999). "The Fluid Mechanics of Natural Ventilation". *Annual Review of Fluid Mechanics*. **31**: 201–238. Bibcode:1999AnRFM..31..201L. doi:10.1146/annurev.fluid.31.1.201.
 115. ^ Santamouris, M.; Asimakoupolos, D. (1996). *Passive cooling of buildings* (1st ed.). London: James & James (Science Publishers) Ltd. ISBN 978-1-873936-47-4.
 116. ^ Leo Samuel, D.G.; Shiva Nagendra, S.M.; Maiya, M.P. (August 2013). "Passive alternatives to mechanical air conditioning of building: A review". *Building and Environment*. **66**: 54–64. Bibcode:2013BuEnv..66...54S. doi:10.1016/j.buildenv.2013.04.016.
 117. ^ M.j, Limb (January 1, 1998). "BIB 08: An Annotated Bibliography: Passive Cooling Technology for Office Buildings in Hot Dry and Temperate Climates".
 118. ^ Niles, Philip; Kenneth, Haggard (1980). *Passive Solar Handbook*. California Energy Resources Conservation. ASIN B001UYRTMM.
 119. ^ "Cooling: The hidden threat for climate change and sustainable goals". *phys.org*. Retrieved September 18, 2021.
 120. ^ Ford, Brian (September 2001). "Passive downdraught evaporative cooling: principles and practice". *Arq: Architectural Research Quarterly*. **5** (3): 271–280. doi:10.1017/S1359135501001312. ISSN 1474-0516. S2CID 110209529.
 121. ^ **a b** Chen, Meijie; Pang, Dan; Chen, Xingyu; Yan, Hongjie; Yang, Yuan (2022). "Passive daytime radiative cooling: Fundamentals, material designs, and applications". *EcoMat*. **4**. doi:10.1002/eom2.12153. S2CID 240331557. "Passive daytime radiative cooling (PDRC) dissipates terrestrial heat to the extremely cold outer space without using any energy input or producing pollution. It has the potential to simultaneously alleviate the two major problems of energy crisis and global warming."
 122. ^ Raman, Aaswath P.; Anoma, Marc Abou; Zhu, Linxiao; Rephaeli, Eden; Fan, Shanhui (November 2014). "Passive radiative cooling below ambient air temperature under direct sunlight". *Nature*. **515** (7528): 540–544. Bibcode:2014Natur.515..540R. doi:10.1038/nature13883. PMID 25428501.
 123. ^ **a b** Bijarniya, Jay Prakash; Sarkar, Jahar; Maiti, Pralay (November 2020). "Review on passive daytime radiative cooling: Fundamentals, recent researches, challenges and opportunities". *Renewable and Sustainable Energy Reviews*. **133**: 110263. Bibcode:2020RSErv.13310263B. doi:10.1016/j.rser.2020.110263. S2CID 224874019.
 124. ^ Mokhtari, Reza; Ulpiani, Giulia; Ghasempour, Roghayeh (July 2022). "The Cooling Station: Combining hydronic radiant cooling and daytime radiative cooling for urban shelters". *Applied Thermal Engineering*. **211**: 118493. Bibcode:2022AppTE.21118493M. doi:10.1016/j.applthermaleng.2022.118493.
 125. ^ Yang, Yuan; Zhang, Yifan (July 2020). "Passive daytime radiative cooling: Principle, application, and economic analysis". *MRS Energy & Sustainability*. **7**

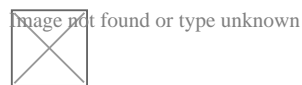
- (1). doi:10.1557/mre.2020.18.
126. ^ Miranda, Nicole D.; Renaldi, Renaldi; Khosla, Radhika; McCulloch, Malcolm D. (October 2021). "Bibliometric analysis and landscape of actors in passive cooling research". *Renewable and Sustainable Energy Reviews*. **149**: 111406. Bibcode:2021RSErv.14911406M. doi:10.1016/j.rser.2021.111406.
127. ^ **a b** Needham, Joseph; Wang, Ling (1991). *Science and Civilisation in China, Volume 4: Physics and Physical Technology, Part 2, Mechanical Engineering*. Cambridge University Press. ISBN 978-0521058032. OCLC 468144152.
128. ^ Dalley, Stephanie (2002). *Mari and Karana: Two Old Babylonian Cities (2nd ed.)*. Piscataway, New Jersey: Gorgias Press. p. 91. ISBN 978-1931956024. OCLC 961899663. Archived from the original on January 29, 2021. Retrieved May 13, 2021.
129. ^ Nagengast, Bernard (February 1999). "Comfort from a Block of Ice: A History of Comfort Cooling Using Ice" (PDF). *ASHRAE Journal*. **41** (2): 49. ISSN 0001-2491. Archived (PDF) from the original on May 13, 2021. Retrieved May 13, 2021.
130. ^ Bahadori, Mehdi N. (February 1978). "Passive Cooling Systems in Iranian Architecture". *Scientific American*. **238** (2): 144–154. Bibcode:1978SciAm.238b.144B. doi:10.1038/SCIENTIFICAMERICAN0278-144.
131. ^ Smith, Shane (2000). *Greenhouse Gardener's Companion: Growing Food and Flowers in Your Greenhouse Or Sunspace*. Illustrated by Marjorie C. Leggitt (illustrated, revised ed.). Golden, Colorado: Fulcrum Publishing. p. 62. ISBN 978-1555914509. OCLC 905564174. Archived from the original on May 13, 2021. Retrieved August 25, 2020.

External links

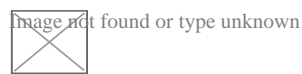
[edit]



Wikimedia Commons has media related to ***Air conditioners***.



Look up ***Cassette air conditioner*** in Wiktionary, the free dictionary.



Wikiversity has learning resources about ***Refrigeration and air conditioning***

- U.S. patent 808,897 Carrier's original patent
- U.S. patent 1,172,429
- U.S. patent 2,363,294
- *Scientific American*, "Artificial Cold", 28 August 1880, p. 138
- *Scientific American*, "The Presidential Cold Air Machine", 6 August 1881, p. 84

- v
- t
- e

Heating, ventilation, and air conditioning

Fundamental concepts

- Air changes per hour
- Bake-out
- Building envelope
- Convection
- Dilution
- Domestic energy consumption
- Enthalpy
- Fluid dynamics
- Gas compressor
- Heat pump and refrigeration cycle
- Heat transfer
- Humidity
- Infiltration
- Latent heat
- Noise control
- Outgassing
- Particulates
- Psychrometrics
- Sensible heat
- Stack effect
- Thermal comfort
- Thermal destratification
- Thermal mass
- Thermodynamics
- Vapour pressure of water

Technology

- Absorption-compression heat pump
- Absorption refrigerator
- Air barrier
- Air conditioning
- Antifreeze
- Automobile air conditioning
- Autonomous building
- Building insulation materials
- Central heating
- Central solar heating
- Chilled beam
- Chilled water
- Constant air volume (CAV)
- Coolant
- Cross ventilation
- Dedicated outdoor air system (DOAS)
- Deep water source cooling
- Demand controlled ventilation (DCV)
- Displacement ventilation
- District cooling
- District heating
- Electric heating
- Energy recovery ventilation (ERV)
- Firestop
- Forced-air
- Forced-air gas
- Free cooling
- Heat recovery ventilation (HRV)
- Hybrid heat
- Hydronics
- Ice storage air conditioning
- Kitchen ventilation
- Mixed-mode ventilation
- Microgeneration
- Passive cooling
- Passive daytime radiative cooling
- Passive house
- Passive ventilation
- Radiant heating and cooling
- Radiant cooling
- Radiant heating
- Radon mitigation
- Refrigeration
- Renewable heat
- Room air distribution
- Solar air heat
- Solar combisystem
- Solar cooling

- Air conditioner inverter
- Air door
- Air filter
- Air handler
- Air ionizer
- Air-mixing plenum
- Air purifier
- Air source heat pump
- Attic fan
- Automatic balancing valve
- Back boiler
- Barrier pipe
- Blast damper
- Boiler
- Centrifugal fan
- Ceramic heater
- Chiller
- Condensate pump
- Condenser
- Condensing boiler
- Convection heater
- Compressor
- Cooling tower
- Damper
- Dehumidifier
- Duct
- Economizer
- Electrostatic precipitator
- Evaporative cooler
- Evaporator
- Exhaust hood
- Expansion tank
- Fan
- Fan coil unit
- Fan filter unit
- Fan heater
- Fire damper
- Fireplace
- Fireplace insert
- Freeze stat
- Flue
- Freon
- Fume hood
- Furnace
- Gas compressor
- Gas heater
- Gasoline heater
- Grease duct

**Measurement
and control**

- Air flow meter
- Aquastat
- BACnet
- Blower door
- Building automation
- Carbon dioxide sensor
- Clean air delivery rate (CADR)
- Control valve
- Gas detector
- Home energy monitor
- Humidistat
- HVAC control system
- Infrared thermometer
- Intelligent buildings
- LonWorks
- Minimum efficiency reporting value (MERV)
- Normal temperature and pressure (NTP)
- OpenTherm
- Programmable communicating thermostat
- Programmable thermostat
- Psychrometrics
- Room temperature
- Smart thermostat
- Standard temperature and pressure (STP)
- Thermographic camera
- Thermostat
- Thermostatic radiator valve
- Architectural acoustics
- Architectural engineering
- Architectural technologist
- Building services engineering
- Building information modeling (BIM)
- Deep energy retrofit
- Duct cleaning
- Duct leakage testing
- Environmental engineering
- Hydronic balancing
- Kitchen exhaust cleaning
- Mechanical engineering
- Mechanical, electrical, and plumbing
- Mold growth, assessment, and remediation
- Refrigerant reclamation
- Testing, adjusting, balancing

**Professions,
trades,
and services**

Industry organizations

- AHRI
- AMCA
- ASHRAE
- ASTM International
- BRE
- BSRIA
- CIBSE
- Institute of Refrigeration
- IIR
- LEED
- SMACNA
- UMC

Health and safety

- Indoor air quality (IAQ)
- Passive smoking
- Sick building syndrome (SBS)
- Volatile organic compound (VOC)
- ASHRAE Handbook
- Building science
- Fireproofing

See also

- Glossary of HVAC terms
- Warm Spaces
- World Refrigeration Day
- Template:Home automation
- Template:Solar energy

- v
- t
- e

Home appliances

- Air conditioner
- Air fryer
- Air ioniser
- Air purifier
- Barbecue grill
- Blender
 - Immersion blender
- Bread machine
- Bug zapper
- Coffee percolator
- Clothes dryer
 - combo
- Clothes iron
- Coffeemaker
- Dehumidifier
- Dishwasher
 - drying cabinet
- Domestic robot
 - comparison
- Deep fryer
- Electric blanket
- Electric drill
- Electric kettle
- Electric knife
- Electric water boiler
- Electric heater
- Electric shaver
- Electric toothbrush
- Epilator
- Espresso machine
- Evaporative cooler
- Food processor
- Fan
 - attic
 - bladeless
 - ceiling
 - Fan heater
 - window

Types

- Freezer
- Garbage disposer
- Hair dryer
- Hair iron
- Humidifier
- Icemaker
- Ice cream maker
- Induction cooker
- Instant hot water dispenser
- Juicer

- See also**
- Appliance plug
 - Appliance recycling

- v
- t
- e

Roofs

Roof shapes

- Arched roof
- Barrel roof
- Board roof
- Bochka roof
- Bow roof
- Butterfly roof
- Clerestory
- Conical roof
- Dome
- Flat roof
- Gable roof
- Gablet roof
- Gambrel roof
- Half-hipped roof
- Hip roof
- Onion dome
- Mansard roof
- Pavilion roof
- Rhombic roof
- Ridged roof
- Saddle roof
- Sawtooth roof
- Shed roof
- Tented roof

Cross-gabled roof

Image not found or type unknown

Roof elements

- Air conditioning unit
- Attic
- Catslide
- Chimney
- Collar beam
- Dormer
- Eaves
- Flashing
- Gable
- Green roof
- Gutter
- Hanging beam
- Joist
- Lightning rod
- Loft
- Purlin
- Rafter
- Ridge vent
- Roof batten
- Roof garden
- Roofline
- Roof ridge
- Roof sheeting
- Roof tiles
- Roof truss
- Roof window
- Skylight
- Soffit
- Solar panels
- Spire
- Weathervane
- Wind brace

- v
- t
- e

Electronics

Branches

- Analogue electronics
- Digital electronics
- Electronic engineering
- Instrumentation
- Microelectronics
- Optoelectronics
- Power electronics
- Printed electronics
- Semiconductor
- Schematic capture
- Thermal management
- 2020s in computing
- Atomtronics
- Bioelectronics
- List of emerging electronics
- Failure of electronic components

Advanced topics

- Flexible electronics
- Low-power electronics
- Molecular electronics
- Nanoelectronics
- Organic electronics
- Photonics
- Piezotronics
- Quantum electronics
- Spintronics

**Electronic
equipment**

- Air conditioner
- Central heating
- Clothes dryer
- Computer/Notebook
- Camera
- Dishwasher
- Freezer
- Home robot
- Home cinema
- Home theater PC
- Information technology
- Cooker
- Microwave oven
- Mobile phone
- Networking hardware
- Portable media player
- Radio
- Refrigerator
- Robotic vacuum cleaner
- Tablet
- Telephone
- Television
- Water heater
- Video game console
- Washing machine

- Audio equipment
- Automotive electronics
- Avionics
- Control system
- Data acquisition
- e-book
- e-health
- Electromagnetic warfare
- Electronics industry
- Embedded system
- Home appliance
- Home automation
- Integrated circuit
- Home appliance
 - Consumer electronics
 - Major appliance
 - Small appliance
- Marine electronics
- Microwave technology
- Military electronics
- Multimedia
- Nuclear electronics
- Open-source hardware
- Radar and Radio navigation
- Radio electronics
- Terahertz technology
- Wired and Wireless Communications

Applications

Authority control databases: National   

About Durham Supply Inc

Photo

Image not found or type unknown

Photo

Image not found or type unknown

Photo

Image not found or type unknown

Photo

Image not found or type unknown

Photo

Image not found or type unknown

Things To Do in Tulsa County

Photo

Image not found or type unknown

Blue Whale of Catoosa

4.5 (3899)

Photo

Image not found or type unknown

The Tulsa Arts District

4.7 (22)

Photo

Image not found or type unknown

The Cave House

4.6 (249)

Photo

Image not found or type unknown

Route 66 Historical Village

4.4 (718)

Photo

Tulsa Botanic Garden

4.7 (1397)

Photo

Image not found or type unknown

Oxley Nature Center

4.8 (563)

Driving Directions in Tulsa County

Driving Directions From Harmon Security Group LLC. to Durham Supply Inc

Driving Directions From Tulsa to Durham Supply Inc

Driving Directions From Best Western Airport to Durham Supply Inc

Driving Directions From East Central High School to Durham Supply Inc

Driving Directions From Waffle House to Durham Supply Inc

https://www.google.com/maps/dir/Brookhaven+Hospitales/Durham+Supply+Inc/@36.1595.8495188,14z/data=!3m1!4b1!4m14!4m13!1m5!1m1!1sChIJ05Q-HwTztocR0q6HuDgEScA!2m2!1d-95.8495188!2d36.1581877!1m5!1m1!1sChIJDzPLSlrytocRY_EaORpHGro!2m2!1d-95.8384781!2d36.1563128!3e0

https://www.google.com/maps/dir/Tulsa+VA+Behavioral+Medicine+Clinic/Durham+Supply+Inc/@36.1595.8620661,14z/data=!3m1!4b1!4m14!4m13!1m5!1m1!1sChIJP1coZeTytocRFxBglazhJ4U!2m2!1d-95.8620661!2d36.1490383!1m5!1m1!1sChIJDzPLSlrytocRY_EaORpHGro!2m2!1d-95.8384781!2d36.1563128!3e2

https://www.google.com/maps/dir/Oakwood+Homes/Durham+Supply+Inc/@36.157059,-95.836308,14z/data=!3m1!4b1!4m14!4m13!1m5!1m1!1sChIJbexf2QzztocRV_e5kJ6IxHo!2m2!1d-95.836308!2d36.157059!1m5!1m1!1sChIJDzPLSlrytocRY_EaORpHGro!2m2!1d-95.8384781!2d36.1563128!3e1

https://www.google.com/maps/dir/Country+Inn+%26+Suites+by+Radisson%2C+Tulsa%2C+OK/@36.1595.8518718,14z/data=!3m1!4b1!4m14!4m13!1m5!1m1!1sChIJs1WK-qvztocRWQSiVmJF8_4!2m2!1d-95.8518718!2d36.1686628!1m5!1m1!1sChIJDzPLSlrytocRY_EaORpHGro!2m2!1d-95.8384781!2d36.1563128!3e3

https://www.google.com/maps/dir/Subway/Durham+Supply+Inc/@36.146335,-95.8525478,14z/data=!3m1!4b1!4m14!4m13!1m5!1m1!1sChIJM9DFTBnztocR4Q462chGc!2m2!1d-95.8525478!2d36.146335!1m5!1m1!1sChIJDzPLSlrytocRY_EaORpHGro!2m2!1d-95.8384781!2d36.1563128!3e0

Driving Directions From The Tulsa Arts District to Durham Supply Inc

Driving Directions From Gathering Place to Durham Supply Inc

Driving Directions From Philbrook Museum of Art to Durham Supply Inc

Driving Directions From Gathering Place to Durham Supply Inc

Driving Directions From Route 66 Historical Village to Durham Supply Inc

Driving Directions From Route 66 Historical Village to Durham Supply Inc

https://www.google.com/maps/dir/Streetwalker+Tours/Durham+Supply+Inc/@36.152246,95.9886238,14z/data=!3m1!4b1!4m14!4m13!1m5!1m1!1sunknown!2m2!1d-95.9886238!2d36.1522464!1m5!1m1!1sChIJDzPLSlrytocRY_EaORpHGro!2m2!1d-95.8384781!2d36.1563128!3e0

https://www.google.com/maps/dir/Blue+Whale+of+Catoosa/Durham+Supply+Inc/@36.195.7329257,14z/data=!3m1!4b1!4m14!4m13!1m5!1m1!1sunknown!2m2!1d-95.7329257!2d36.1937732!1m5!1m1!1sChIJDzPLSlrytocRY_EaORpHGro!2m2!1d-95.8384781!2d36.1563128!3e2

https://www.google.com/maps/dir/Tulsa+Zoo/Durham+Supply+Inc/@36.2130533,-95.9065019,14z/data=!3m1!4b1!4m14!4m13!1m5!1m1!1sunknown!2m2!1d-95.9065019!2d36.2130533!1m5!1m1!1sChIJDzPLSlrytocRY_EaORpHGro!2m2!1d-95.8384781!2d36.1563128!3e1

Reviews for Durham Supply Inc

Durham Supply Inc

Image not found or type unknown

B Mann

(5)

I was in need of some items for a double wide that I am remodeling and this place is the only place in town that had what I needed (I didn't even try the other rude place)while I was there I learned the other place that was in Tulsa that also sold mobile home supplies went out of business (no wonder the last time I was in there they were VERY RUDE and high priced) I like the way Dunham does business they answered all my questions and got me the supplies I needed, very friendly, I will be back to purchase the rest of my items when the time comes.

Durham Supply Inc

Image not found or type unknown

Ethel Schiller

(5)

This place is really neat, if they don't have it they can order it from another of their stores and have it there overnight in most cases. Even hard to find items for a trailer! I definitely recommend this place to everyone! O and the prices is awesome too!

Durham Supply Inc

Image not found or type unknown

Gerald Clifford Brewster

(5)

We will see, the storm door I bought says on the tag it's 36x80, but it's 34x80. If they return it.....they had no problems returning it. And it was no fault of there's, you measure a mobile home door different than a standard door!

Durham Supply Inc

Image not found or type unknown

Dennis Champion

(5)

Durham supply and Royal supply seems to find the most helpful and friendly people to work in their stores, we are based out of Kansas City out here for a few remodels and these guys treated us like we've gone there for years.

Evaluating Newer Options to Replace Electric Heaters [View GBP](#)

Royal Supply Inc

Phone : +16362969959

City : Oklahoma City

State : OK

Zip : 73149

Address : Unknown Address

Google Business Profile

Company Website : <https://royal-durhamsupply.com/locations/oklahoma-city-oklahoma/>

Sitemap

[Privacy Policy](#)

[About Us](#)

Follow us