Indoor Air Quality

- Selecting Appropriate Multimeters for HVAC Checks
  Selecting Appropriate Multimeters for HVAC Checks Maintaining HVAC Gauges for Accurate Readings Choosing Coil Cleaners Suited to Household Needs Comparing Protective Gloves for Different Tasks Identifying Goggles Designed for Refrigerant Handling Using Screwdriver Sets for Precise Adjustments Organizing Toolkits for Efficient Site Visits Calibrating Equipment for Reliable Measurements Handling Harmful Chemicals with Proper Ventilation Safely Storing Extra HVAC Parts and Supplies Dressing for Extreme Temperatures during Repairs Assessing Essential Items for Emergency Calls
- Examining Pollutants Affecting Air Circulation
  Examining Pollutants Affecting Air Circulation Improving Vent Placement for Even Distribution Managing Excess Humidity with Simple Techniques Using UV Lights to Minimize Microbial Growth Testing Indoor Air Quality with Basic Tools Filtering Particulates through Electrostatic Options Checking Fan Speed for Consistent Comfort Controlling Airflow Patterns across Different Rooms Maintaining Clear Ducts for Cleaner Breathing Spaces Exploring Optional Dehumidifiers for Damp Areas Balancing Comfort and Efficiency in Vent Adjustments Assessing Long Term Effects of Poor Air Quality
- About Us

The comfort and livability of mobile homes heavily depend on the efficiency and reliability of their HVAC systems. As with any other dwelling, maintaining a comfortable temperature and air quality in a mobile home requires precise measurement and control of heating, ventilation, and air conditioning equipment. Proper insulation is essential for efficient heating and cooling in mobile homes **mobile home hvac** condenser. To achieve this level of precision, proper calibration of HVAC equipment is crucial. This essay explores the common types of equipment used in mobile home HVAC systems and emphasizes the importance of calibrating these devices for reliable measurements.

Mobile homes present unique challenges for HVAC systems due to their compact size and mobility. Therefore, selecting appropriate equipment that can efficiently manage temperature fluctuations while ensuring energy efficiency is vital. Common types of equipment found in mobile home HVAC systems include thermostats, heat pumps, air conditioners, furnaces, and ductwork.

Thermostats are the central control units that regulate the temperature by detecting changes in room temperature and signaling the heating or cooling system to adjust accordingly. In mobile homes, programmable thermostats are often preferred due to their ability to optimize energy usage by setting temperatures based on occupancy patterns. However, for these thermostats to function accurately, they must be calibrated correctly to ensure they reflect true ambient temperatures.

Heat pumps are another essential component commonly used in mobile homes because they provide both heating and cooling functions. These devices transfer heat from one area to another using refrigerant cycles. The efficiency of heat pumps relies heavily on accurate readings from pressure sensors and thermometers within

Key Features to Look for in a Multimeter for HVAC Applications —

In the realm of scientific exploration and industrial application, the precision of measurement is paramount. The equipment we rely on to gather data must be meticulously maintained to ensure its accuracy and reliability. This is where the practice of regular calibration comes into play, holding a pivotal role in safeguarding optimal performance and efficiency.

Calibration can be likened to the tuning of a musical instrument. Just as a piano must be regularly tuned to maintain its harmonious sound, measuring devices require consistent calibration to produce reliable results. When equipment is not calibrated frequently, there is an increased risk of measurement errors, which can lead to flawed conclusions or costly operational inefficiencies.

The significance of regular calibration extends beyond mere accuracy; it is essential for maintaining trust in the data collected. In industries such as pharmaceuticals, aerospace, and manufacturing, even minor deviations from standard measurements can result in significant consequences. Imagine an aircraft's altimeter providing incorrect altitude readings due to improper calibration-this could jeopardize passenger safety and operational integrity.

Moreover, routine calibration contributes directly to economic efficiency. Uncalibrated equipment may necessitate frequent repairs or replacements due to wear and tear caused by operating outside intended parameters. This not only incurs additional costs but also results in downtime that disrupts productivity. Conversely, well-calibrated instruments operate smoothly within their designed specifications, prolonging their lifespan and reducing maintenance expenses.

Beyond functional benefits, regular calibration fosters a culture of accountability and professionalism within organizations. It encourages meticulous attention to detail and adherence to standards-a mindset that transcends individual tasks and permeates company ethos.

To achieve these benefits, organizations should implement systematic calibration protocols tailored specifically for each type of equipment used. This involves setting clear intervals for recalibration based on manufacturer recommendations or industry standards while considering environmental factors that might influence device stability over time.

In conclusion, the importance of regular calibration cannot be overstated when striving for optimal performance and efficiency in any field reliant on precise measurements. By ensuring our tools are properly tuned through consistent recalibration efforts-as one would do with musical instruments-we uphold both accuracy and trustworthiness in our work processes while reaping economic advantages along the way. So let us prioritize this crucial practice as part of our commitment towards excellence across all domains where calibrated measurements matter most!

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Types of Measurements Required in Mobile Home HVAC Checks

Step-by-Step Guide to Calibrating Thermostats and Temperature Sensors

In the realm of scientific research, industrial processes, and everyday applications, accurate temperature measurement is crucial. Whether you're monitoring the climate in a greenhouse or ensuring safety in food production, reliable data hinges on precise instrumentation. At the heart of this accuracy lies proper calibration-a process that aligns a device's readings with a standard or known value. This essay explores the essential steps in calibrating thermostats and temperature sensors, ensuring their reliability for critical measurements.

Calibration begins with understanding the device specifications and requirements. Before any adjustments are made, it's vital to review the manufacturer's guidelines and technical documentation. These resources provide baseline information on the intended operating range and accuracy levels for your specific thermostat or sensor model. Adequate preparation ensures you have all necessary tools and knowledge at your disposal.

The next step involves selecting an appropriate reference standard. A reference thermometer or sensor with a traceable calibration certificate serves as the benchmark against which your device will be aligned. It's important that this reference is more accurate than the device being calibrated to ensure precision in results. The environment where calibration occurs also needs consideration-temperature fluctuations can affect outcomes significantly.

Once preparations are complete, proceed by stabilizing both devices-the one being calibrated and the reference-in a controlled environment, such as a temperature bath or dry-block calibrator. Allow adequate time for thermal equilibrium so that each device accurately reflects ambient conditions without lag or error due to transient changes.

Begin recording temperature readings from both devices simultaneously over several points within their operational range. For instance, if your thermostat regulates temperatures between 0°C to 100°C, take multiple measurements throughout this spectrum-at intervals like 20°C increments-to ensure comprehensive coverage.

After collecting data, compare readings from your device against those from the reference standard at each point measured. Deviations indicate discrepancies needing correction through offset adjustments or other manufacturer-specified methods. Some thermostats allow software-based recalibration via proprietary programs; others might require manual tuning using hardware controls like screws or dials.

Post-adjustment verification is critical; repeat measurement comparisons across all previously tested points to confirm alignment has been achieved successfully between your sensor/thermostat and its reference counterpart. This step guards against potential oversights during initial calibration phases while reinforcing confidence in adjusted settings' reliability moving forward.

Regular re-calibration is advisable depending on usage frequency and environmental factors impacting sensor performance over time-typically annually but potentially more often under extreme conditions (e.g., high humidity environments).

In conclusion, calibrating thermostats and temperature sensors is an indispensable practice for maintaining measurement integrity across various applications-from scientific research labs to industrial production lines-and even in domestic settings where comfort relies upon accurate climate control systems functioning properly day-to-day basis alike! By following these systematic steps diligently alongside employing appropriate tools/resources throughout entire process lifecycle ensures sustained dependability upon which countless operations depend ultimately leading towards better-informed decision-making based firmly grounded reality rather than guesswork alone!

Comparing Digital vs Analog Multimeters for HVAC Use

Accurate airflow measurements are crucial in various industries, from environmental monitoring and HVAC systems to aerodynamics research and industrial processes. At the heart of obtaining precise data are two essential instruments: anemometers and flow meters. These devices are indispensable for measuring wind speed and air volume flow rates, respectively. However, like any measurement tool, their reliability hinges on regular calibration. Ensuring accurate airflow measurements begins with properly calibrating anemometers and flow meters, a process that guarantees the validity of data and supports informed decision-making.

Calibration is the cornerstone of dependable measurements. It involves comparing the readings of an instrument against a standard or reference known for its precision. For anemometers, which measure wind speed by capturing the rotation rate of cups or blades in moving air, calibration ensures that their sensitivity aligns with real-world conditions. Similarly, flow meters-devices designed to quantify the flow rate of air through ducts or pipes-require calibration to maintain their accuracy over time.

One primary reason for calibrating these instruments is drift. Over time, environmental factors such as temperature changes, humidity variations, mechanical wear-and-tear, or even dust accumulation can cause sensor readings to deviate from true values. Regular calibration helps identify and correct these discrepancies before they lead to erroneous data interpretation.

Moreover, the diversity in types of anemometers (such as vane anemometers, hot-wire anemometers) and flow meters (like rotameters or mass flow meters) means each needs specific calibration procedures tailored to its operational principles. For instance, hot-wire anemometers rely on electrical resistance changes due to airflow cooling a heated wire; thus, their calibration might involve adjusting voltage levels under controlled wind speeds.

The benefits of maintaining well-calibrated equipment extend beyond just accuracy; they enhance operational efficiency too. In industrial settings where precise control over airflow impacts energy consumption or product quality-for example in cleanroom environments or combustion systems-accurate measurements translate into optimized performance and cost savings.

To achieve this level of precision demands a systematic approach towards calibration schedules based on manufacturer recommendations or industry standards. Calibration should be performed by trained professionals using traceable standards in controlled environments to ensure repeatability and consistency across all measurements.

Furthermore, documentation plays a pivotal role in this process. Keeping records of calibration activities not only aids in compliance with regulatory requirements but also provides historical data that can be analyzed for trends indicating potential problems with equipment stability.

In conclusion, ensuring accurate airflow measurements through diligent calibration practices for anemometers and flow meters is vital for any field reliant on precise air dynamics understanding-from engineering applications pushing technological boundaries to everyday climate control systems enhancing comfort levels indoors. By prioritizing regular maintenance checks combined with rigorous adherence to standardized procedures backed by comprehensive documentation efforts-industries can safeguard against inaccuracies while promoting innovation driven by reliable data insights.

Safety Considerations When Using Multimeters in Mobile Homes

Pressure gauge calibration is a vital component in the realm of calibrating equipment for reliable measurements. It ensures that systems maintain consistent pressure levels, which is crucial for the optimal functioning of various industrial processes and machinery. The importance of accurate pressure readings cannot be overstated; they are pivotal in ensuring safety, efficiency, and longevity of equipment.

Calibration is the process of configuring an instrument to provide a result for a sample within an acceptable range. In the context of pressure gauges, this involves comparing the readings from a gauge with those from a standard or reference gauge, which is known to be accurate. This comparison allows technicians to detect any discrepancies and make necessary adjustments to ensure that the pressure gauge provides precise measurements.

The benefits of regular calibration are manifold. Firstly, it enhances safety by preventing accidents that may occur due to incorrect pressure readings. An inaccurate gauge can lead to overpressure situations, potentially causing catastrophic failures in equipment or systems. By ensuring gauges are calibrated correctly, these risks are significantly mitigated.

Secondly, calibration contributes to operational efficiency. Inaccurate gauges can lead to poor performance and inefficiencies in processes that rely on precise pressure control, such as chemical manufacturing or oil refining. Regular calibration ensures that systems operate at their intended parameters, thus optimizing productivity and reducing waste.

Moreover, maintaining consistent system pressure through accurate calibration extends the lifespan of equipment. Incorrect pressures can cause undue stress on components, leading to premature wear and tear or even failure. By ensuring that pressures remain within designated limits through regular checks and calibrations, businesses can avoid costly repairs and downtime.

Despite its critical nature, pressure gauge calibration is often overlooked until issues arise. However, proactive maintenance schedules should incorporate routine calibrations as part of their protocol. This not only ensures compliance with industry standards but also fosters a culture of precision and reliability within organizations.

In conclusion, pressure gauge calibration plays an indispensable role in maintaining consistent system pressure levels essential for safe and efficient operations across various industries. Through regular calibration practices, organizations can safeguard their assets while enhancing overall performance and reliability-a testament to the significance of meticulous attention to detail in engineering disciplines. As technology advances and systems become increasingly complex, the need for precise measurements will only grow more pronounced;

therefore, embracing robust calibration practices today sets the foundation for sustainable success tomorrow.

Recommended Brands and Models for HVAC Multimeters

Calibrating equipment for reliable measurements in mobile home HVAC systems is a crucial task that ensures optimal performance and energy efficiency. However, like any technical process, it can present a series of challenges that require troubleshooting to resolve effectively. Understanding common calibration issues and the methods to address them can significantly enhance the reliability of these systems.

One prevalent issue in calibrating HVAC systems within mobile homes is incorrect temperature readings. This problem often arises due to sensor misplacement or degradation over time. Sensors may drift from their original calibration due to environmental factors or wear and tear, leading to inaccurate temperature regulation. To troubleshoot this, technicians should periodically verify sensor accuracy against a known standard and recalibrate as necessary. Ensuring sensors are positioned correctly and free from obstructions is also vital for obtaining accurate readings.

Another frequent challenge involves airflow measurement discrepancies, which can affect system efficiency and comfort levels in the home. Airflow issues might stem from blockages in ducts or incorrect fan speed settings during calibration. Technicians should inspect ductwork for obstructions such as dust buildup or physical damage that could impede airflow. Additionally, confirming that fans are operating at the correct speeds during calibration can help maintain consistent airflow throughout the system.

Pressure imbalances represent another common calibration issue in mobile home HVAC systems. These imbalances can lead to uneven heating or cooling distribution, causing discomfort to occupants and increased energy usage. Pressure transducers need regular checks and recalibration to ensure they are providing accurate feedback for system adjustments. Balancing pressures between different zones within the mobile home may require adjusting dampers or modifying duct configurations.

Humidity control problems also frequently arise during HVAC system calibration in mobile homes, where maintaining appropriate humidity levels is crucial for comfort and health reasons. Inaccurate humidity readings might result from faulty hygrometers or improper sensor placement near sources of moisture or heat that skew data points. Regularly checking the condition and positioning of humidity sensors helps mitigate these issues, ensuring they provide reliable input for system control.

Lastly, electrical calibration errors can disrupt HVAC operations by affecting component synchronization or power distribution within the system. Loose connections or corroded contacts often contribute to electrical inaccuracies during calibration processes. Conducting routine inspections of electrical components such as wiring harnesses, connectors, and terminals helps maintain proper connectivity and prevent potential disruptions caused by faulty calibrations.

In conclusion, successful troubleshooting of common calibration issues in mobile home HVAC systems relies on systematic inspection procedures combined with regular maintenance routines aimed at preserving equipment integrity over time. By addressing these challenges proactively through diligent monitoring practices tailored specifically towards each unique aspect involved-be it temperature sensing accuracy; airflow management; pressure balance optimization; humidity control precision; or electrical connectivity assurance-technicians enhance both operational efficiency as well as overall occupant satisfaction achieved via consistently reliable climate regulation results delivered across every season experienced inside modern-day residential environments characterized primarily by compact yet highly functional living arrangements made possible thanks largely due efforts dedicated towards perfecting various aspects associated intricately linked directly back onto overarching concept known simply broadly speaking generally understood universally recognized industry-wide: effective Calibration for Reliable Measurements!

Tips for Maintaining and Calibrating Your Multimeter

In the intricate world of precise measurements, ensuring the accuracy and reliability of equipment is paramount. Whether in a laboratory setting, manufacturing plant, or a scientific research environment, the calibration of instruments plays a pivotal role in maintaining quality and ensuring dependable results. As organizations strive to uphold high standards, they often face a critical decision: should they opt for professional calibration services or take on the task using do-it-yourself (DIY) approaches? Both avenues offer distinct advantages and challenges.

Professional calibration services bring to the table a wealth of expertise and precision that is hard to match. These services are typically provided by specialized companies with highly trained personnel who possess extensive knowledge about various types of equipment and their specific calibration requirements. This expertise ensures that each piece of equipment is calibrated according to industry standards and best practices, reducing the risk of errors significantly.

One of the primary benefits of professional calibration is traceability. Calibration service providers often have access to advanced tools and reference standards that adhere to national or international benchmarks. This level of traceability is crucial for industries where compliance with stringent regulations is mandatory. Moreover, professionally calibrated equipment can provide documentation certifying its accuracy, which can be essential during audits or inspections.

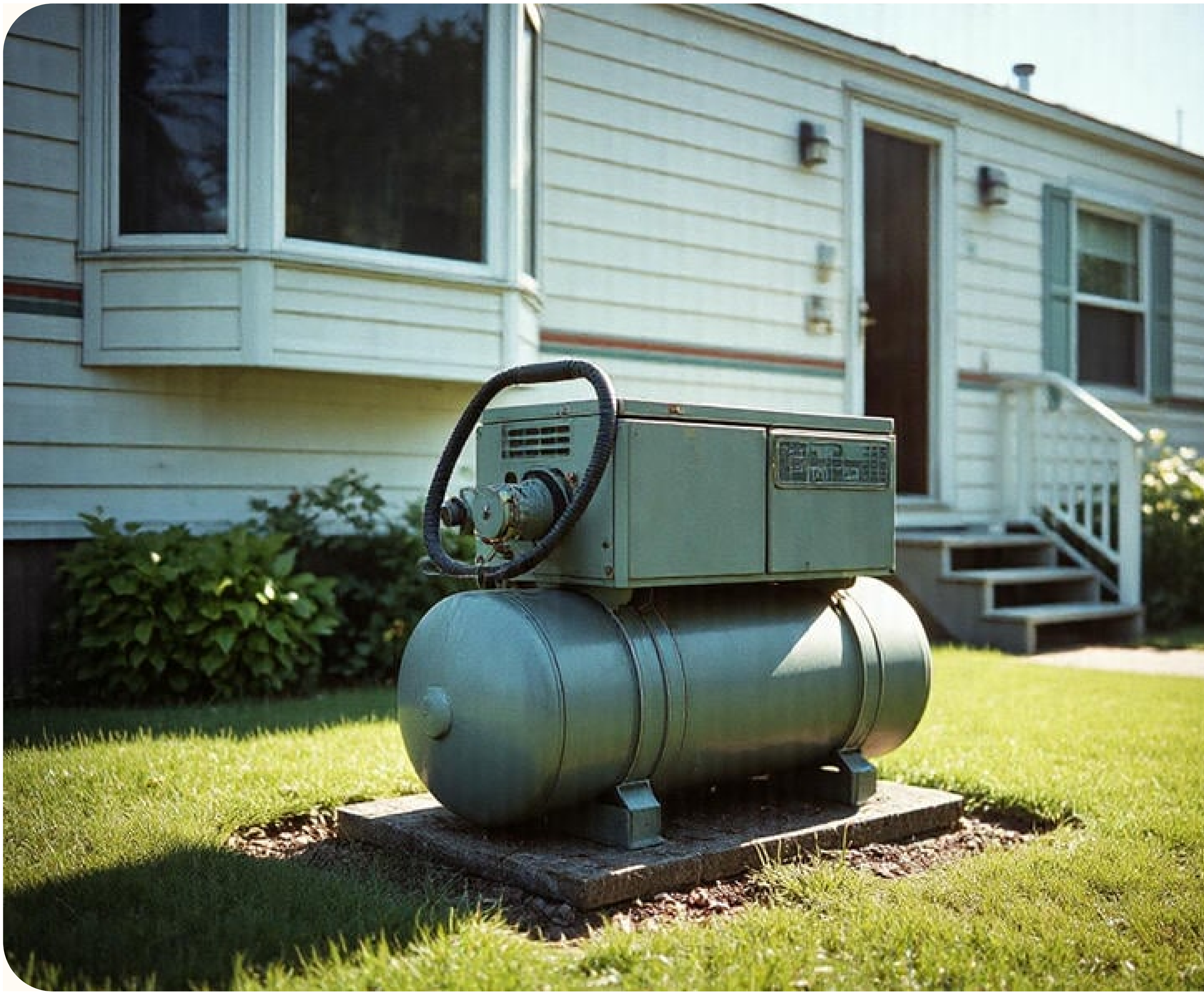
Additionally, engaging professional services can save time and resources for organizations. Calibrating complex instruments requires not only specialized knowledge but also sophisticated equipment-both of which may represent significant investments for an organization if undertaken internally. By outsourcing this task to experts, companies can focus on their core activities without diverting attention away from their primary objectives.

Conversely, DIY calibration approaches might appeal to businesses looking to reduce costs or maintain greater control over their processes. With adequate training and resources, some organizations might successfully manage basic calibrations in-house. This approach offers flexibility as it allows companies to schedule calibrations according to their timelines without relying on external providers' availability.

However, DIY methods come with inherent risks that cannot be ignored. Without proper expertise or up-to-date reference materials, there is a higher chance of inaccuracies creeping into measurements-a scenario that could lead to faulty products or unreliable data interpretations. Inadequately calibrated equipment not only compromises quality but could also result in costly rework or even damage an organization's reputation if issues arise.

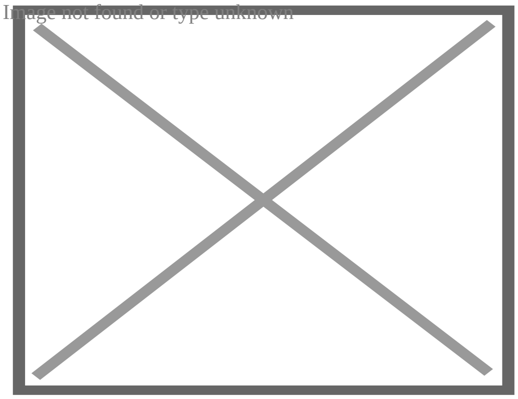
Furthermore, while initial cost savings seem attractive when opting for DIY solutions, hidden expenses often emerge over time-from purchasing necessary tools and training staff adequately-to rectifying potential errors stemming from incorrect calibrations.

In conclusion, when weighing the benefits between professional calibration services versus DIY approaches for ensuring reliable measurements through calibrated equipment-organizations must consider multiple facets beyond mere cost implications alone; such as accuracy assurance levels required within their operations framework alongside resource allocation capabilities available at hand before making informed decisions tailored towards achieving optimal outcomes aligned with overarching business goals effectively efficiently sustainably long term ultimately wisely prudently conclusively soundly judiciously sagaciously astutely shrewdly sensibly rationally logically pragmatically reasonably systematically methodically cohesively coherently harmoniously seamlessly unerringly unfalteringly unwaveringly indefatigably resolutely determinedly steadfastly unswervingly immutably invariably consistently reliably dependably trustworthily faithfully continuously ceaselessly unrelentingly diligently assiduously industriously perseveringly persistently tenaciously enduring everlastingly eternally perpetually timelessly enduring forevermore always forever eternally infinitely perpetually timeless ageless immortal undying deathless imperishable everlasting indestructible immutable permanent perpetual endless infinite unending boundless limitless measureless inexhaustible never-ending eternal timeless unchanging abiding constant enduring lasting permanent persistent steadfast

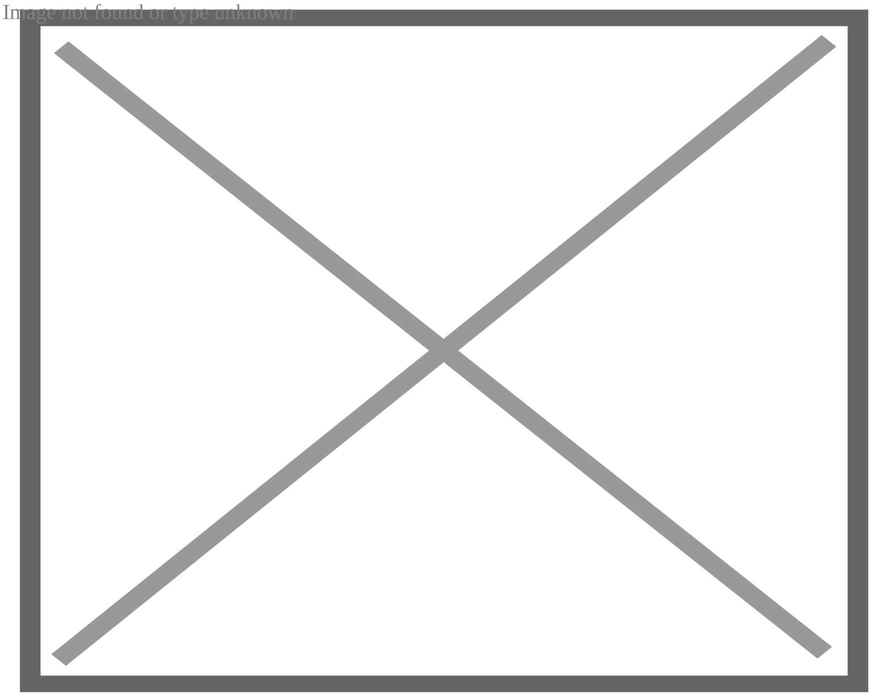


About Air pollution

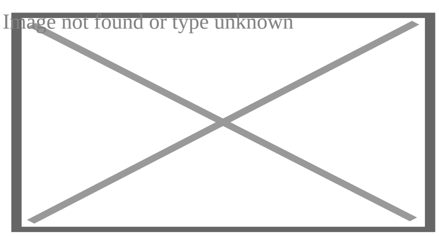
"Bad air quality" and "Air quality" redirect here. For the obsolete medical theory, see Miasma theory. For the measurement of air pollution, see Air quality index. For the qualities of air, see Atmosphere of Earth.



Air pollution from a coking oven



2016 Environmental Performance Index – darker colors indicate lower concentrations of fine particulate matter and nitrogen dioxide, as well as better indoor air quality.



Deaths from air pollution per 100,000 inhabitants (IHME, 2019)

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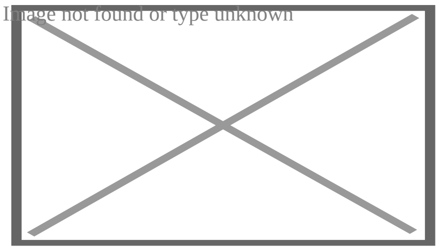
Part of a series on



Air pollution from a factory

Air

- Acid rain
- Air quality index
- Atmospheric dispersion modeling
- Chlorofluorocarbon
- Combustion
- Exhaust gas
- Haze
- Global dimming
- Global distillation
- Indoor air quality
- Non-exhaust emissions
- Ozone depletion
- Particulates
- Persistent organic pollutant
- Smog
- Soot
- Volatile organic compound

Biological

- Biological hazard
- Genetic
- Illegal logging
- Introduced species
    - Invasive species

Digital

- Information

Electromagnetic

- Light
    - Ecological
    - Overillumination
- Radio spectrum

Natural

- Ozone
- Radium and radon in the environment
- Volcanic ash
- Wildfire

Noise

- Transportation
- Health effects from noise
- Marine mammals and sonar
- Noise barrier
- Noise control
- Soundproofing

Radiation

- Actinides
- Bioremediation
- Depleted uranium
- Nuclear fission
- Nuclear fallout
- Plutonium
- Poisoning
- Radioactivity
- Uranium
- Radioactive waste

Soil

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- Land degradation
- Bioremediation
- Defecation
- Electrical resistance heating
- Illegal mining
- Soil guideline values
- Phytoremediation

Solid waste

- Advertising mail
- Biodegradable waste
- Brown waste
- Electronic waste
- Foam food container
- Food waste
- Green waste
- Hazardous waste
- Industrial waste
- Litter
- Mining
- Municipal solid waste
- Nanomaterials
- Plastic
- Packaging waste
- Post-consumer waste
- Waste management

Space

- Space debris

Thermal

- Urban heat island

Visual

- Air travel
- Advertising clutter
- Overhead power lines
- Traffic signs
- Urban blight
- Vandalism

War

- Chemical warfare
- Herbicidal warfare
    - Agent Orange
- Nuclear holocaust
    - Nuclear fallout
    - Nuclear famine
    - Nuclear winter
- Scorched earth
- Unexploded ordnance
- War and environmental law

Water

- Agricultural wastewater
- Biosolids
- Diseases
- Eutrophication
- Firewater
- Freshwater
- Groundwater
- Hypoxia
- Industrial wastewater
- Marine
- Monitoring
- Nonpoint source
- Nutrient
- Ocean acidification
- Oil spill
- Pharmaceuticals
- Freshwater salinization
- Septic tanks
- Sewage
- Shipping
- Sludge
- Stagnation
- Sulfur water
- Surface runoff
- Turbidity
- Urban runoff
- Water quality
- Wastewater

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  - Paint

Misc

- Area source
- Brain health and pollution
- Debris
- Dust
- Garbology
- Legacy
- Midden
- Point source
- Waste
  - Toxic

Lists

- Diseases
- Law by country
- Most polluted cities
- Least polluted cities by PM2.5
- Treaties
- Most polluted rivers

Categories

- By country

- Image not found or type unknown icon Environment portal
- Image not found or type unknown icon Ecology portal

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Part of a series on

Weather

Temperate and polar seasons

- Winter
- Spring
- Summer
- Autumn

Tropical seasons

- Dry season
  - Harmattan
- Wet season

Storms

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    - Arcus cloud
- Downburst
    - Microburst
    - Heat burst
    - Derecho
- Lightning
    - Volcanic lightning
- Thunderstorm
    - Air-mass thunderstorm
    - Thundersnow
    - Dry thunderstorm
- Mesocyclone
    - Supercell
- Tornado
    - Anticyclonic tornado
    - Landspout
    - Waterspout
- Dust devil
- Fire whirl
- Anticyclone
- Cyclone
- Polar low
- Extratropical cyclone
    - European windstorm
    - Nor'easter
- Subtropical cyclone
- Tropical cyclone
    - Atlantic hurricane
    - Typhoon
- Storm surge
- Dust storm
    - Simoom
    - Haboob
- Monsoon
    - Amihan
- Gale
- Sirocco
- Firestorm
- Winter storm
    - Ice storm
    - Blizzard
    - Ground blizzard
    - Snow squall

Precipitation

- Drizzle
  - Freezing
- Graupel
- Hail
  - Megacryometeor
- Ice pellets
- Diamond dust
- Rain
  - Freezing
- Cloudburst
- Snow
  - Rain and snow mixed
  - Snow grains
  - Snow roller
  - Slush

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  - Physics
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- Fog
  - Mist
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    - Canada
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    - United States
- Weather forecasting
- Weather modification

Glossaries

- Meteorology
- Climate change
- Tornado terms
- Tropical cyclone terms

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Air pollution is the contamination of air due to the presence of substances called pollutants in the atmosphere that are harmful to the health of humans and other living beings, or cause damage to the climate or to materials.[1] It is also the contamination of the indoor or outdoor environment either by chemical, physical, or biological agents that alters the natural features of the atmosphere.[1] There are many different types of air pollutants, such as gases (including ammonia, carbon monoxide, sulfur dioxide, nitrous oxides, methane and chlorofluorocarbons), particulates (both organic and inorganic) and biological molecules. Air pollution can cause diseases, allergies, and even death to humans; it can also cause harm to other living organisms such as animals and crops, and may damage the natural environment (for example, climate change, ozone depletion or habitat degradation) or built environment (for example, acid rain).[2] Air pollution can be caused by both human activities[3] and natural phenomena.[4]

Air quality is closely related to the Earth's climate and ecosystems globally. Many of the contributors of air pollution are also sources of greenhouse emission i.e., burning of fossil fuel.[1]

Air pollution is a significant risk factor for a number of pollution-related diseases, including respiratory infections, heart disease, chronic obstructive pulmonary disease (COPD), stroke, and lung cancer.[5] Growing evidence suggests that air pollution exposure may be associated with reduced IQ scores, impaired cognition,[6] increased risk for psychiatric disorders such as depression[7] and detrimental perinatal health.[8] The human health effects of poor air quality are far reaching, but principally affect the body's respiratory system and the cardiovascular system.[9][10] Individual reactions to air pollutants depend on the type of pollutant a person is exposed to,[11][12] the degree of exposure, and the individual's health status and genetics.[13]

Air pollution is the largest environmental risk factor for disease and premature death[5][14] and the fourth largest risk factor overall for human health.[15] Air pollution causes the premature deaths of around 7 million people worldwide each year,[5] or a global mean loss of life expectancy (LLE) of 2.9 years,[16] and there has been no significant change in the number of deaths caused by all forms of pollution since at least 2015.[14][17][18] Outdoor air pollution attributable to fossil fuel use alone causes ~3.61 million deaths annually,[19] making it one of the top contributors to human death.[5]

Anthropogenic ozone causes around 470,000 premature deaths a year and fine particulate ($PM_{2.5}$) pollution around another 2.1 million.[20] The scope of the air pollution crisis is large: In 2018, WHO estimated that "9 out of 10 people breathe air containing high levels of pollutants."[21] Although the health consequences are extensive, the way the problem is handled is considered largely haphazard[22][21][23] or neglected.[14]

The World Bank has estimated that welfare losses (premature deaths) and productivity losses (lost labour) caused by air pollution cost the world economy $5 trillion per year.[24][25][26] The costs of air pollution are generally an externality to the contemporary economic system and most human activity, although they are sometimes recovered through monitoring, legislation, and regulation.[27][28]

Many different technologies and strategies are available for reducing air pollution.[29] Although a majority of countries have air pollution laws, according to UNEP, 43 percent of countries lack a legal definition of air pollution, 31 percent lack outdoor air quality standards, 49 percent restrict their definition to outdoor pollution only, and just 31 percent have laws for tackling pollution originating from outside their borders.[30] National air quality laws have often been highly effective, notably the 1956 Clean Air Act in Britain and the US Clean Air Act, introduced in 1963.[31][32] Some of these efforts have been successful at the international level, such as the Montreal Protocol,[33] which reduced the release of harmful ozone depleting chemicals, and the 1985 Helsinki Protocol,[34] which reduced sulfur emissions,[35] while others, such as international action on climate change,[36][37][38] have been less successful.

Sources of air pollution

[edit]

There are many different sources of air pollution. Some air pollutants (such as nitrogen oxides) originate mainly from human activities,[39] while some (notably radon gas) come mostly from natural sources.[40] However, many air pollutants (including dust and sulfur dioxide) come from a mixture of natural and human sources.[41]

Anthropogenic (human-made) sources

[edit]

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Demolition of the cooling towers of a power station, Athlone, Cape Town, South Africa, 2010

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Controlled burning of a field outside of Statesboro, Georgia, US, in preparation for spring planting

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Smoking of fish over an open fire in Ghana, 2018

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Burning of joss paper in a Chinese temple in Hong Kong

- Stationary sources include:
  - fossil-fuel power plants and biomass power plants both have smoke stacks (see for example environmental impact of the coal industry)[42]
    - Oil and gas sites that have methane leaks[43][44][45][46]
  - burning of traditional biomass such as wood, crop waste and dung. (In developing and poor countries,[47] traditional biomass burning is the major source of air pollutants.[48][49] It is also the main source of particulate pollution in many developed areas including the UK & New South Wales.[50][51] Its pollutants include PAHs.[52])
  - manufacturing facilities (factories)[53]
    - a 2014 study found that in China equipment-, machinery-, and devices-manufacturing and construction sectors contributed more than 50% of air pollutant emissions.[54][*better source needed*] This high emission is due to high emission intensity and high emission factors in its industrial structure.[55]
  - construction[56][57]
  - renovation[58]
  - waste incineration (incinerators as well as open and uncontrolled fires of mismanaged waste, making up about a fourth of municipal solid terrestrial waste)[59][60]
  - furnaces and other types of fuel-burning heating devices[61]
- Mobile sources include motor vehicles, trains (particularly diesel locomotives and DMUs), marine vessels and aircraft[62] as well as rockets and re-entry of components and debris.[63] The air pollution externality of cars enters the air from the exhaust gas and car tires (including microplastics[64]). Road vehicles make a significant amount of all air pollution (typically, for example, around a third to a half of all nitrogen dioxide emissions)[65][66][67] and are a major driver of climate change.[68][69]
- Agriculture and forest management strategies using controlled burns. Practices like slash-and-burn in forests like the Amazon cause large air pollution with the deforestation.[70] Controlled or prescribed burning is a practice used in forest management, agriculture, prairie restoration, and greenhouse gas reduction.[71] Foresters can use controlled fire as a tool because fire is a natural feature of both forest and grassland ecology.[72][73] Controlled burning encourages the sprouting of some desirable forest trees, resulting in a forest renewal.[74]

There are also sources from processes other than combustion:

- Fumes from paint, hair spray, varnish, aerosol sprays and other solvents. These can be substantial; emissions from these sources was estimated to account for almost half of pollution from volatile organic compounds in the Los Angeles basin in the 2010s.[75]
- Waste deposition in landfills produces methane[76] and open burning of waste releases harmful substances.[77]

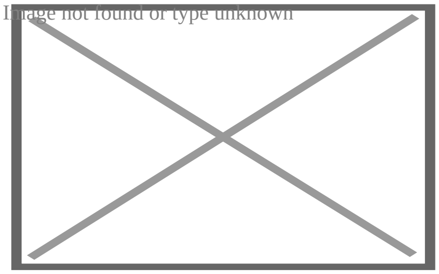
- Nuclear weapons, toxic gases, germ warfare, and rocketry are examples of military resources.[78]
- Agricultural emissions and emissions from meat production or livestock contribute substantially to air pollution[79][80]
  - Fertilized farmland may be a major source of nitrogen oxides.[81]

Mean acidifying emissions (air pollution) of different foods per 100g of protein[82]

Food Types	Acidifying Emissions (g SO_2eq per 100g protein)
Beef	343.6
Cheese	165.5
Pork	142.7
Lamb and mutton	139.0
Farmed crustaceans	133.1
Poultry	102.4
Farmed fish	65.9
Eggs	53.7
Groundnuts	22.6
Peas	8.5
Tofu	6.7

Natural sources

[edit]

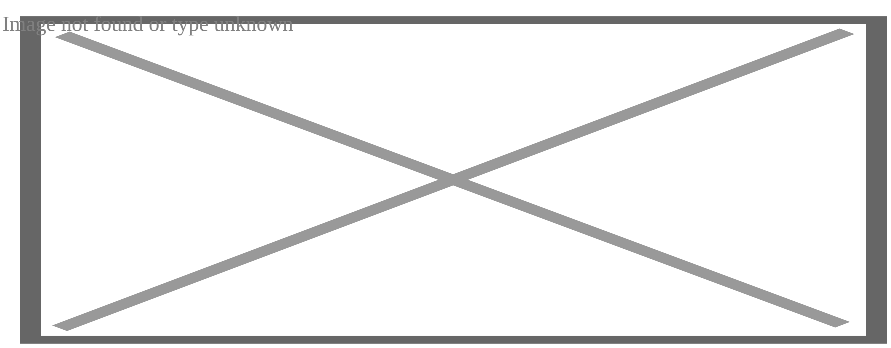


Dust storm approaching Stratford, Texas, in 1935

- Dust from natural sources, usually large areas of land with little or no vegetation.
- Methane, emitted by the digestion of food by animals, for example cattle.
- Radon gas from radioactive decay within the Earth's crust. Radon is a colorless, odorless, naturally occurring, radioactive noble gas that is formed from the decay of radium. It is considered to be a health hazard. Radon gas from natural sources can accumulate in buildings, especially in confined areas such as the basement and it is the second most frequent cause of lung cancer, after cigarette smoking.
- Smoke and carbon monoxide from wildfires. During periods of active wildfires, smoke from uncontrolled biomass combustion can make up almost 75% of all air pollution by concentration.[83]
- Vegetation, in some regions, emits environmentally significant amounts of volatile organic compounds (VOCs) on warmer days. These VOCs react with primary anthropogenic pollutants – specifically, NO_x, SO_2, and anthropogenic organic carbon compounds – to produce a seasonal haze of secondary pollutants.[84] Black gum, poplar, oak and willow are some examples of vegetation that can produce abundant VOCs. The VOC production from these species result in ozone levels up to eight times higher than the low-impact tree species.[85]
- Volcanic activity, which produces sulfur, chlorine, and ash particulates.[86]

Emission factors

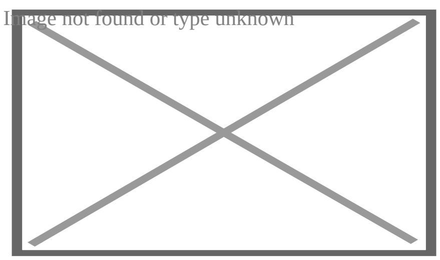
[edit]
Main article: AP 42 Compilation of Air Pollutant Emission Factors



Beijing air in 2005 after rain (left) and a smoggy day (right)

Air pollutant emission factors are reported representative values that aim to link the quantity of a pollutant released into the ambient air to an activity connected with that pollutant's release.[2][87][88][89] The weight of the pollutant divided by a unit weight, volume, distance, or time of the activity generating the pollutant is how these factors are commonly stated (e.g., kilograms of particulate emitted per tonne of coal burned). These criteria make estimating emissions from diverse sources of pollution easier. Most of the time, these components are just averages of all available data of acceptable quality, and they are thought to be typical of long-term averages.

The Stockholm Convention on Persistent Organic Pollutants identified pesticides and other persistent organic pollutants of concern. These include dioxins and furans which are unintentionally created by combustion of organics, like open burning of plastics, and are endocrine disruptors and mutagens.

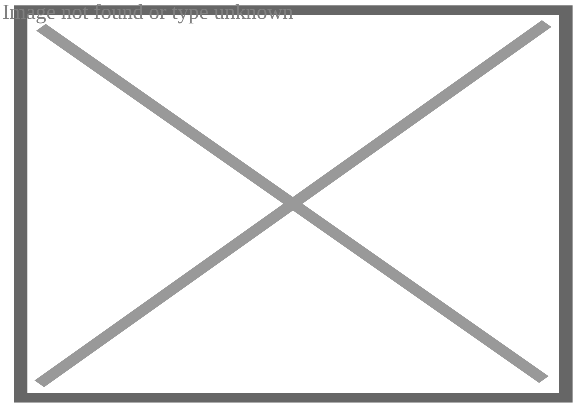


E-waste processing in Agbogbloshie, Ghana, using open-burning of electronics to access valuable metals like copper. Open burning of plastics is common in many parts of the world without the capacity for processing. Especially without proper protections, heavy metals and other contaminates can seep into the soil, and create water pollution and air pollution.

The United States Environmental Protection Agency has published a compilation of air pollutant emission factors for a wide range of industrial sources.[90] The United Kingdom, Australia, Canada, and many other countries have published similar compilations, as well as the European Environment Agency.[91][92][93][94]

Pollutants

[edit]
Main articles: Pollutant and Greenhouse gas emissions



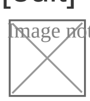
Schematic drawing, causes and effects of air pollution: (1) greenhouse effect, (2) particulate contamination, (3) increased UV radiation, (4) acid rain, (5) increased ground-level ozone concentration, (6) increased levels of nitrogen oxides

An air pollutant is a material in the air that can have many effects on humans and the ecosystem.[95] The substance can be solid particles, liquid droplets, or gases, and often takes the form of an aerosol (solid particles or liquid droplets dispersed and carried by a gas).[96] A pollutant can be of natural origin or man-made. Pollutants are classified as primary or secondary. Primary pollutants are usually produced by processes such as ash from a volcanic eruption.

Other examples include carbon monoxide gas from motor vehicle exhausts or sulfur dioxide released from factories. Secondary pollutants are not emitted directly. Rather, they form in the air when primary pollutants react or interact. Ground level ozone is a prominent example of a secondary pollutant. Some pollutants may be both primary and secondary: they are both emitted directly and formed from other primary pollutants.

Primary pollutants

[edit]



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Pollutants emitted into the atmosphere by human activity include:

- Ammonia: Emitted mainly by agricultural waste. Ammonia is a compound with the formula NH_3. It is normally encountered as a gas with a characteristic pungent odor. Ammonia contributes significantly to the nutritional needs of terrestrial organisms by serving as a precursor to foodstuffs and fertilizers. Ammonia, either directly or indirectly, is also a building block for the synthesis of many pharmaceuticals. Although in wide use, ammonia is both caustic and hazardous.[

97] In the atmosphere, ammonia reacts with oxides of nitrogen and sulfur to form secondary particles.[98]

- Carbon dioxide (CO_2): Carbon dioxide is a natural component of the atmosphere, essential for plant life and given off by the human respiratory system.[99] It is potentially lethal at very high concentrations (typically 100 times "normal" atmospheric levels).[100][101] Although the World Health Organization recognizes CO_2 as a climate pollutant, it does not include the gas in its *Air Quality Guidelines* or set recommended targets for it.[102] Because of its role as a greenhouse gas, CO_2 has been described as "the worst climate pollutant".[103] Statements such as this refer to its long-term atmospheric effects rather than shorter-term effects on such things as human health, food crops, and buildings. This question of terminology has practical consequences, for example, in determining whether the U.S. Clean Air Act (which is designed to improve air quality) is deemed to regulate CO_2 emissions.[104] That issue was resolved in the United States by the Inflation Reduction Act of 2022, which specifically amended the Clean Air Act "to define the carbon dioxide produced by the burning of fossil fuels as an 'air pollutant.'"[105] CO_2 currently forms about 410 parts per million (ppm) of Earth's atmosphere, compared to about 280 ppm in pre-industrial times,[106] and billions of metric tons of CO_2 are emitted annually by burning of fossil fuels.[107] CO_2 increase in Earth's atmosphere has been accelerating.[108] CO_2 is an asphyxiant gas and not classified as toxic or harmful in general.[109] Workplace exposure limits exist in places like UK (5,000 ppm for long-term exposure and 15,000 ppm for short-term exposure).[101] Natural disasters like the limnic eruption at Lake Nyos can result in a sudden release of huge amount of CO_2 as well.[110]
- Carbon monoxide (CO): CO is a colorless, odorless, toxic gas.[111] It is a product of combustion of fuel such as natural gas, coal or wood. Vehicular exhaust contributes to the majority of carbon monoxide let into the atmosphere. It creates a smog type formation in the air that has been linked to many lung diseases and disruptions to the natural environment and animals.
- Chlorofluorocarbons (CFCs): Emitted from goods that are now prohibited from use; harmful to the ozone layer. These are gases emitted by air conditioners, freezers, aerosol sprays, and other similar devices. CFCs reach the stratosphere after being released into the atmosphere.[112] They interact with other gases here, causing harm to the ozone layer. UV rays are able to reach the Earth's surface as a result of this. This can result in skin cancer, eye problems, and even plant damage.[113]
- Nitrogen oxides (NO_x): Nitrogen oxides, particularly nitrogen dioxide, are expelled from high temperature combustion, and are also produced during thunderstorms by electric discharge. They can be seen as a brown haze dome above or a plume downwind of cities. Nitrogen dioxide is a chemical compound with the formula NO_2. It is one of several nitrogen oxides. One of the most prominent air pollutants, this reddish-brown toxic gas has a characteristic sharp, biting odor.

- Odors: Such as from garbage, sewage, and industrial processes.
- Particulate matter/particles (PM), also known as particulates, atmospheric particulate matter (APM), or fine particles, are microscopic solid or liquid particles suspended in a gas.[114] Aerosol is a mixture of particles and gas. Volcanoes, dust storms, forest and grassland fires, living plants, and sea spray are all sources of particles. Aerosols are produced by human activities such as the combustion of fossil fuels in automobiles, power plants, and numerous industrial processes.[115] Averaged worldwide, anthropogenic aerosols – those made by human activities – currently account for approximately 10% of the atmosphere. Increased levels of fine particles in the air are linked to health hazards such as heart disease,[116] altered lung function and lung cancer. Particulates are related to respiratory infections and can be particularly harmful to those with conditions like asthma.[117]
- Persistent organic pollutants, which can attach to particulates. Persistent organic pollutants are organic compounds that are resistant to environmental degradation due to chemical, biological, or photolytic processes (POPs). As a result, they've been discovered to survive in the environment, be capable of long-range transmission, bioaccumulate in human and animal tissue, biomagnify in food chains, and pose a major threat to human health and the ecosystem.[118]
- Persistent free radicals connected to airborne fine particles are linked to cardiopulmonary disease.[119][120]
- Polycyclic Aromatic Hydrocarbons (PAHs): a group of aromatic compounds formed from the incomplete combustion of organic compounds including coal and oil and tobacco.[121]
- Radioactive pollutants: Produced by nuclear explosions, nuclear events, war explosives, and natural processes such as the radioactive decay of radon.
- Sulfur oxides (SO_x): particularly sulfur dioxide, a chemical compound with the formula SO_2. SO_2 is produced by volcanoes and in various industrial processes. Coal and petroleum often contain sulfur compounds, and their combustion generates sulfur dioxide. Further oxidation of SO_2, usually in the presence of a catalyst such as NO_2, forms H_2SO_4, and thus acid rain is formed. This is one of the causes for concern over the environmental impact of the use of these fuels as power sources.
- Toxic metals, such as lead and mercury, especially their compounds.
- Volatile organic compounds (VOC): VOCs are both indoor and outdoor air pollutants.[122] They are categorized as either methane (CH_4) or non-methane (NMVOCs). Methane is an extremely efficient greenhouse gas which contributes to enhanced global warming. Other hydrocarbon VOCs are also significant greenhouse gases because of their role in creating ozone and prolonging the life of methane in the atmosphere. This effect varies depending on local air quality. The aromatic NMVOCs benzene, toluene and xylene are suspected carcinogens and may lead to leukemia with prolonged exposure. 1,3-butadiene is another dangerous compound often associated with industrial use.

Secondary pollutants

[edit]

Secondary pollutants include:

- Ground level ozone (O_3): Ozone is created when NOx and VOCs mix. It is a significant part of the troposphere.[123] It's also an important part of the ozone layer, which can be found in different sections of the stratosphere. Photochemical and chemical reactions involving it fuel many of the chemical activities that occur in the atmosphere during the day and night. It is a pollutant and a component of smog that is produced in large quantities as a result of human activities (mostly the combustion of fossil fuels).[124] O_3 is largely produced by chemical reactions involving NO_x gases (nitrogen oxides, especially from combustion) and volatile organic compounds in the presence of sunlight. Due to the influence of temperature and sunlight on this reaction, high ozone levels are most common on hot summer afternoons.[125]
- Peroxyacetyl nitrate ($C_2H_3NO_5$): similarly formed from NO_x and VOCs.
- Photochemical smog: particles are formed from gaseous primary contaminants and chemicals.[126] Smog is a type of pollution that occurs in the atmosphere. Smog is caused by a huge volume of coal being burned in a certain region, resulting in a mixture of smoke and sulfur dioxide.[127] Modern smog is usually caused by automotive and industrial emissions, which are acted on in the atmosphere by UV light from the sun to produce secondary pollutants, which then combine with the primary emissions to generate photochemical smog.

Other pollutants

[edit]

There are many other chemicals classed as hazardous air pollutants. Some of these are regulated in the USA under the Clean Air Act and in Europe under numerous directives (including the Air "Framework" Directive, 96/62/EC, on ambient air quality assessment and management, Directive 98/24/EC, on risks related to chemical agents at work, and Directive 2004/107/EC covering heavy metals and polycyclic aromatic hydrocarbons in ambient air).[128][129]

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Hazardous air pollutants (4 C, 68 P)

Before flue-gas desulfurization was installed, the emissions from this power plant in New

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Before flue-gas desulfurization was installed, the emissions from this power plant in New Mexico contained excessive amounts of sulfur dioxide.

Thermal oxidisers are air pollution abatement options for hazardous air pollutants (HAPs)

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Thermal oxidisers are air pollution abatement options for hazardous air pollutants (HAPs), volatile organic compounds (VOCs), and odorous emissions.

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This video provides an overview of a NASA study on the human fingerprint on global air quality.

Exposure

[edit]

The risk of air pollution is determined by the pollutant's hazard and the amount of exposure to that pollutant. Air pollution exposure can be measured for a person, a group, such as a neighborhood or a country's children, or an entire population. For example, one would want to determine a geographic area's exposure to a dangerous air pollution, taking into account the various microenvironments and age groups. This can be calculated[130] as an inhalation exposure. This would account for daily exposure in various settings, e.g. different indoor micro-environments and outdoor locations. The exposure needs to include different ages and other demographic groups, especially infants, children, pregnant women, and other sensitive subpopulations.[130]

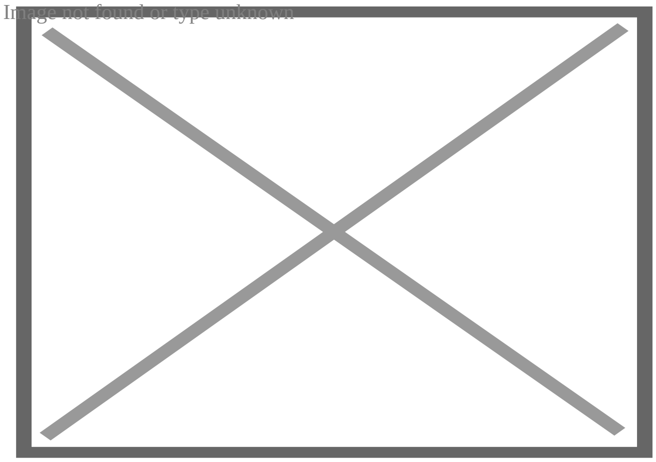
For each specific time that the subgroup is in the setting and engaged in particular activities, the exposure to an air pollutant must integrate the concentrations of the air pollutant with regard to the time spent in each setting and the respective inhalation rates for each subgroup, playing, cooking, reading, working, spending time in traffic, etc. A little child's inhaling rate, for example, will be lower than that of an adult. A young person engaging in strenuous exercise will have a faster rate of breathing than a child engaged in sedentary activity. The daily exposure must therefore include the amount of time spent in each micro-environmental setting as well as the kind of activities performed there. The air pollutant concentration in each microactivity/microenvironmental setting is summed to indicate the exposure.[130]

For some pollutants such as black carbon, traffic related exposures may dominate total exposure despite short exposure times since high concentrations coincide with proximity to major roads or participation in (motorized) traffic.[131] A large portion of total daily exposure occurs as short peaks of high concentrations, but it remains unclear how to define peaks and determine their frequency and health impact.[132]

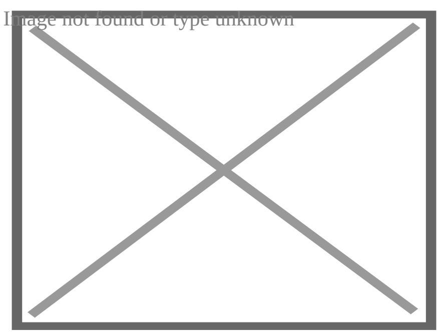
In 2021, the WHO halved its recommended guideline limit for tiny particles from burning fossil fuels. The new limit for nitrogen dioxide (NO_2) is 75% lower.[133] Growing evidence that air pollution—even when experienced at very low levels—hurts human health, led the WHO to revise its guideline (from 10 ?g/m^3 to 5 ?g/m^3) for what it considers a safe level of exposure of particulate pollution, bringing most of the world—97.3 percent of the global population—into the unsafe zone.[134]

Indoor air quality

[edit]
Main articles: Indoor air quality and Indoor air pollution in developing countries



The share of total deaths from indoor air pollution, 2017



Air quality monitoring, New Delhi, India

A lack of ventilation indoors concentrates air pollution where people often spend the majority of their time. Indoor air pollution can pose a significant health risk. According to EPA reports, the concentrations of many air pollutants can be two to five times higher in indoor air than in outdoor air. Indoor air pollutants can be up to 100 times higher in some cases than they are inside. People can spend up to 90% of their time indoors, according to the American Lung Association; the US Consumer Product Safety Commission (CPSC) 2012; and the US Environmental Protection Agency 2012a.[135]

Indoor contaminants that can cause pollution include asbestos, biologic agents, building materials, radon, tobacco smoke, and wood stoves, gas ranges, or other heating systems.[135]

Radon (Rn) gas, a carcinogen, is exuded from the Earth in certain locations and trapped inside houses. Building materials including carpeting and plywood emit formaldehyde (H-CHO) gas. Paint and solvents give off volatile organic compounds (VOCs) as they dry. Lead paint can degenerate into dust and be inhaled.[136][137]

Intentional air pollution is introduced with the use of air fresheners, incense, and other scented items. Controlled wood fires in cook stoves and fireplaces can add significant amounts of harmful smoke particulates into the air, inside and out.[136][137] Indoor pollution fatalities may be caused by using pesticides and other chemical sprays indoors without proper ventilation. Also the kitchen in a modern produce harmful particles and gases, with equipment like toasters being one of the worst sources.[138]

Carbon monoxide poisoning and fatalities are often caused by faulty vents and chimneys, or by the burning of charcoal indoors or in a confined space, such as a tent.[139] Chronic carbon monoxide poisoning can result even from poorly-adjusted pilot lights. Traps are built into all domestic plumbing to keep sewer gas and hydrogen sulfide, out of interiors. Clothing emits tetrachloroethylene, or other dry cleaning fluids, for days after dry cleaning.

Though its use has now been banned in many countries, the extensive use of asbestos in industrial and domestic environments in the past has left a potentially very dangerous material in many localities. Asbestosis is a chronic inflammatory medical condition affecting the tissue of the lungs. It occurs after long-term, heavy exposure to asbestos from asbestos-containing materials in structures. Those with asbestosis have severe dyspnea (shortness of breath) and are at an increased risk regarding several different types of lung cancer. As clear explanations are not always stressed in non-technical literature, care should be taken to distinguish between several forms of relevant diseases. According to the World Health Organization,[140] these may be defined as asbestosis, lung cancer, and peritoneal mesothelioma (generally a very rare form of cancer, when more widespread it is almost always associated with prolonged exposure to asbestos).

Biological sources of air pollution are also found indoors, as gases and airborne particulates. Pets produce dander, people produce dust from minute skin flakes and decomposed hair, dust mites in bedding, carpeting and furniture produce enzymes and micrometre-sized fecal droppings, inhabitants emit methane, mold forms on walls and generates mycotoxins and spores, air conditioning systems can incubate Legionnaires' disease and mold, and houseplants, soil and surrounding gardens can produce pollen, dust, and mold. Indoors, the lack of air circulation allows these airborne pollutants to accumulate more than they would otherwise occur in nature.

Health effects

[edit]

Air pollution has both acute and chronic effects on human health, affecting a number of different systems and organs but principally affect the body's respiratory system and the cardiovascular system. Afflictions include minor to chronic upper respiratory irritation such as difficulty in breathing, wheezing, coughing, asthma[141] and heart disease, lung cancer, stroke, acute respiratory infections in children and chronic bronchitis in adults, aggravating pre-existing heart and lung disease, or asthmatic attacks.

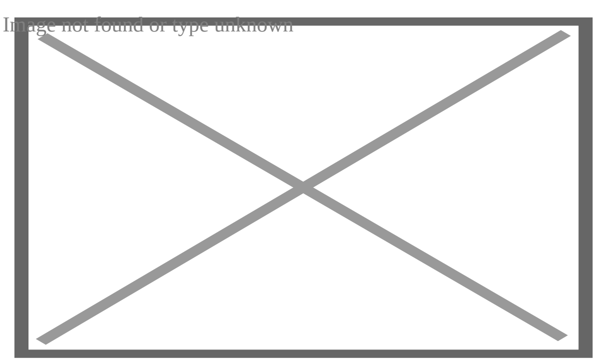
Short and long term exposures have been linked with premature mortality and reduced life expectancy[142] and can result in increased medication use, increased doctor or emergency department visits, more hospital admissions and premature death.[130][*better sour* Diseases that develop from persistent exposure to air pollution are environmental health diseases, which develop when a health environment is not maintained.[143]

Even at levels lower than those considered safe by United States regulators, exposure to three components of air pollution, fine particulate matter, nitrogen dioxide and ozone, correlates with cardiac and respiratory illness.[144] Individual reactions to air pollutants depend on the type of pollutant a person is exposed to, the degree of exposure, and the individual's health status and genetics.[130] The most common sources of air pollution include particulates and ozone (often from burning fossil fuels),[145] nitrogen dioxide, and sulfur dioxide. Children aged less than five years who live in developing countries are the most vulnerable population to death attributable to indoor and outdoor air pollution.[146]

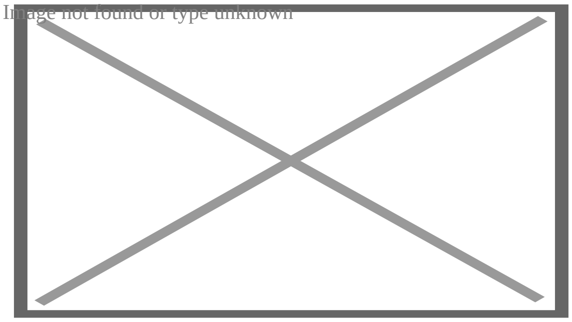
Under the Clean Air Act, U.S. EPA sets limits on certain air pollutants, including setting limits on how much can be in the air anywhere in the United States.[147] Mixed exposure to both carbon black and ozone could result in significantly greater health affects.[148]

Mortality

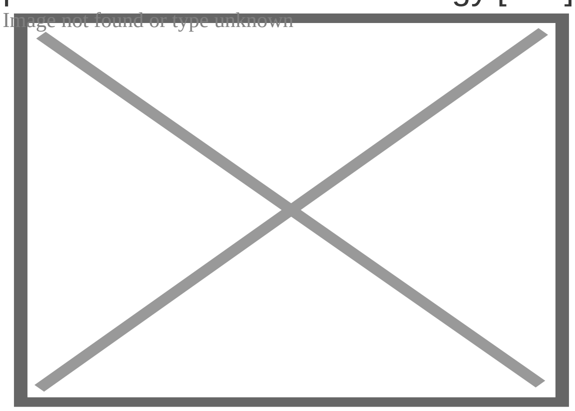
[edit]



Estimates of the death toll from air pollution vary across publications.



Deaths caused by accidents and air pollution from fossil fuel use in power plants exceed those caused by production of renewable energy.[149]



Estimated annual number of deaths attributed to air pollution in 2019. This includes three categories of air pollution: indoor household, outdoor particulate matter and ozone.

Estimates of deaths toll due to air pollution vary.[150] In 2014 the World Health Organization estimated that every year air pollution causes the premature death of 7 million people worldwide,[5] 1 in 8 deaths worldwide.[151] A study published in 2019 indicated that in 2015 the number may be closer to 8.8 million, with 5.5 million of these premature deaths due to air pollution from anthropogenic sources.[152][153] A 2022 review concluded that in 2019 air pollution was responsible for approximately 9 million premature deaths. It concluded that since 2015 little real progress against pollution has been made.[14][154] Causes of deaths include strokes, heart disease, COPD, lung cancer, and lung infections.[5] Children are particularly at risk.[155]

In 2021, the WHO reported that outdoor air pollution was estimated to cause 4.2 million premature deaths worldwide in 2019.[156]

The global mean loss of life expectancy (LLE; similar to YPLL) from air pollution in 2015 was 2.9 years, substantially more than, for example, 0.3 years from all forms of direct violence.[16] Communities with persons that live beyond 85 years have low ambient air pollution, suggesting a link between air pollution levels and longevity.[157]

Primary mechanisms

[edit]

The WHO estimates that in 2016, ~58% of outdoor air pollution-related premature deaths were due to ischaemic heart disease and stroke.[156] The mechanisms linking air pollution to increased cardiovascular mortality are uncertain, but probably include pulmonary and systemic inflammation.[158]

By region

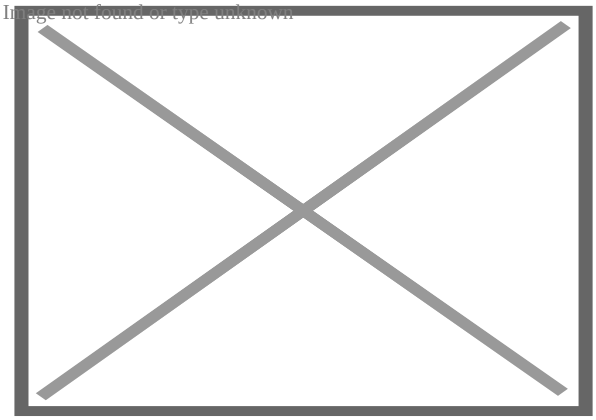
[edit]

India and China have the highest death rate due to air pollution.[159][160] India also has more deaths from asthma than any other nation according to the World Health Organization. In 2019, 1.6 million deaths in India were caused by air pollution.[161] In 2013, air pollution was estimated to kill 500,000 people in China each year.[162] In 2012, 2.48% of China's total air pollution emissions were caused by exports due to US demand, causing an additional 27,963 deaths across 30 provinces.[163]

Annual premature European deaths caused by air pollution are estimated at 430,000[164] to 800,000.[153] An important cause of these deaths is nitrogen dioxide and other nitrogen oxides (NOx) emitted by road vehicles.[164] Across the European Union, air pollution is estimated to reduce life expectancy by almost nine months.[165] In a 2015 consultation document the UK government disclosed that nitrogen dioxide is responsible for 23,500 premature UK deaths per annum.[166] There is a positive correlation between pneumonia-related deaths and air pollution from motor vehicle emissions in England.[167]

Eliminating energy-related fossil fuel emissions in the United States would prevent 46,900–59,400 premature deaths each year and provide $537–$678 billion in benefits from avoided $PM_{2.5}$-related illness and death.[168]

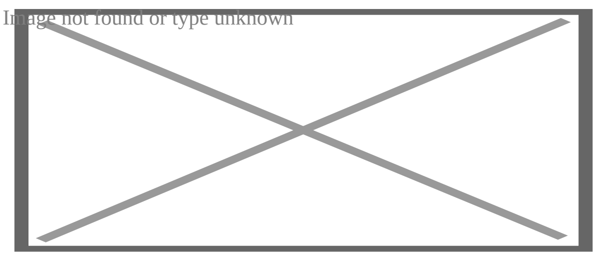
A study published in 2023 in *Science* focused on sulfur dioxide emissions by coal power plants (coal $PM_{2.5}$) and concluded that "exposure to coal $PM_{2.5}$ was associated with 2.1 times greater mortality risk than exposure to $PM_{2.5}$ from all sources."[169] From 1999 to 2020, a total of 460,000 deaths in the US were attributed to coal $PM_{2.5}$.[169]



Air pollution deaths by nation due to fossil fuels

Major causes

[edit]
Further information: § Sources



A comparison of footprint-based and transboundary pollution-based relationships among G20 nations for the number of $PM_{2.5}$-related premature deaths[170]

The largest cause of air pollution is fossil fuel combustion[171] – mostly the production and use of cars, electricity production, and heating.[172] There are estimated 4.5 million annual premature deaths worldwide due to pollutants released by high-emission power stations and vehicle exhausts.[173]

Diesel exhaust (DE) is a major contributor to combustion-derived particulate matter air pollution. In several human experimental studies, using a well-validated exposure chamber setup, DE has been linked to acute vascular dysfunction and increased thrombus formation.[174][175]

A study concluded that $PM_{2.5}$ air pollution induced by the contemporary free trade and consumption by the 19 G20 nations causes two million premature deaths annually, suggesting that the average lifetime consumption of about ~28 people in these countries causes at least one premature death (average age ~67) while developing countries "cannot be expected" to implement or be able to implement countermeasures without external support or internationally coordinated efforts.[176][170]

Guidelines

[edit]
Main article: Air quality guideline

The US EPA has estimated that limiting ground-level ozone concentration to 65 parts per billion (ppb), would avert 1,700 to 5,100 premature deaths nationwide in 2020 compared with the 75 ppb standard. The agency projected the more protective standard would also prevent an additional 26,000 cases of aggravated asthma, and more than a million cases of missed work or school.[177][178] Following this assessment, the EPA acted to protect public health by lowering the National Ambient Air Quality Standards (NAAQS) for ground-level ozone to 70 ppb.[179]

A 2008 economic study of the health impacts and associated costs of air pollution in the Los Angeles Basin and San Joaquin Valley of Southern California shows that more than 3,800 people die prematurely (approximately 14 years earlier than normal) each year because air pollution levels violate federal standards. The number of annual premature deaths is considerably higher than the fatalities related to auto collisions in the same area, which average fewer than 2,000 per year.[180][181][182] A 2021 study found that outdoor air pollution is associated with substantially increased mortality "even at low pollution levels below the current European and North American standards and WHO guideline values" shortly before the WHO adjusted its guidelines.[183][184]

Cardiovascular disease

[edit]

According to the Global Burden of Disease Study, air pollution is responsible for 19% of all cardiovascular deaths.[185][186] There is strong evidence linking both short- and long-term exposure to air pollution with cardiovascular disease mortality and morbidity, stroke, blood pressure, and ischemic heart diseases (IHD).[186]

Air pollution is a leading risk factor for stroke, particularly in developing countries where pollutant levels are highest.[187] A systematic analysis of 17 different risk factors in 188 countries found air pollution is associated with nearly one in three strokes (29%) worldwide (33.7% of strokes in developing countries versus 10.2% in developed countries).[187][188] In women, air pollution is not associated with hemorrhagic but with ischemic stroke.[189] Air pollution was found to be associated with increased incidence and mortality from coronary stroke.[190] Associations are believed to be causal and effects may be mediated by vasoconstriction, low-grade inflammation and atherosclerosis.[191] Other mechanisms such as autonomic nervous system imbalance have also been suggested.[192][193]

Lung disease

[edit]

Research has demonstrated increased risk of developing asthma[194] and chronic obstructive pulmonary disease (COPD)[195] from increased exposure to traffic-related air pollution. Air pollution has been associated with increased hospitalization and mortality from asthma and COPD.[196][197]

COPD comprises a spectrum of clinical disorders that include emphysema, bronchiectasis, and chronic bronchitis.[198] COPD risk factors are both genetic and environmental. Elevated particle pollution contributes to the exacerbation of this disease and likely its pathogenesis.[199]

The risk of lung disease from air pollution is greatest for infants and young children, whose normal breathing is faster than that of older children and adults; the elderly; those who work outside or spend a lot of time outside; and those who have heart or lung disease comorbidities.[200]

A study conducted in 1960–1961 in the wake of the Great Smog of 1952 compared 293 London residents with 477 residents of Gloucester, Peterborough, and Norwich, three towns with low reported death rates from chronic bronchitis. All subjects were male postal truck drivers aged 40 to 59. Compared to the subjects from the outlying towns, the London subjects exhibited more severe respiratory symptoms (including cough, phlegm, and dyspnea), reduced lung function (FEV_1 and peak flow rate), and increased sputum production and purulence. The differences were more pronounced for subjects aged 50 to 59. The study controlled for age and smoking habits, so concluded that air pollution was the most likely cause of the observed differences.[201] More studies have shown that air pollution exposure from traffic reduces lung function development in children[202] and lung function may be compromised by air pollution even at low concentrations.[203]

It is believed that, much like cystic fibrosis, serious health hazards become more apparent when living in a more urban environment. Studies have shown that in urban areas people experience mucus hypersecretion, lower levels of lung function, and more self-diagnosis of chronic bronchitis and emphysema.[204]

Cancer

[edit]

Dark factory clouds obscure the Clark Avenue Bridge in Cleveland, Ohio, July 1973.

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Dark factory-emitted clouds obscuring the Clark Avenue Bridge in Cleveland, Ohio in July 1973

Around 300,000 lung cancer deaths were attributed globally in 2019 to exposure to fine particulate matter, $PM_{2.5}$, suspended in the air.[205] $PM_{2.5}$ exposure, such as from car exhausts, activates dormant mutations in lung cells, causing them to become cancerous.[206][205] Unprotected exposure to $PM_{2.5}$ air pollution can be equivalent to smoking multiple cigarettes per day,[207][*dead link*] potentially increasing the risk of cancer, which is mainly the result of environmental factors.[208]

Long-term exposure to $PM_{2.5}$ (fine particulates) increases the overall risk of non-accidental mortality by 6% per 10 ?g/m^3 increase. Exposure to $PM_{2.5}$ is also associated with an increased risk of mortality from lung cancer (range: 15–21% per 10 ?g/m^3 increase) and total cardiovascular mortality (range: 12–14% per 10 ?g/m^3 increase).[209]

The review further noted that living close to busy traffic appears to be associated with elevated risks of these three outcomes – increase in lung cancer deaths, cardiovascular deaths, and overall non-accidental deaths. The reviewers also found suggestive evidence that exposure to $PM_{2.5}$ is positively associated with mortality from coronary heart diseases and exposure to SO_2 increases mortality from lung cancer, but the data was insufficient to provide solid conclusions.[209] Another investigation showed that higher activity level increases deposition fraction of aerosol particles in human lung and recommended avoiding heavy activities like running in outdoor space at polluted areas.[210]

In 2011, a large Danish epidemiological study found an increased risk of lung cancer for people who lived in areas with high nitrogen oxide concentrations.[211] Another Danish study, likewise noted evidence of possible associations between air pollution and other forms of cancer, including cervical cancer and brain cancer.[212]

Kidney disease

[edit]

A study of 163,197 Taiwanese residents over the period of 2001–2016 estimated that every 5 ?g/m^3 decrease (from an approximate peak of 30?g/m^3) in the ambient concentration of PM$_{2.5}$ was associated with a 25% reduced risk of chronic kidney disease development.[213] According to a cohort study involving 10,997 atherosclerosis patients, higher PM 2.5 exposure is associated with increased albuminuria.[214]

Fertility

[edit]

Nitrogen dioxide (NO_2)

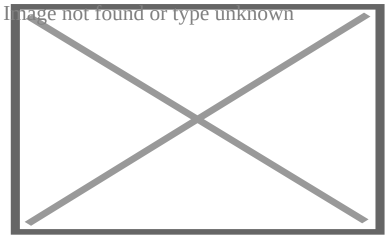
[edit]

An increase in NO_2 is significantly associated with a lower live birth rate in women undergoing IVF treatment.[215] In the general population, there is a significant increase in miscarriage rate in women exposed to NO_2 compared to those not exposed.[215]

Carbon monoxide (CO)

[edit]

CO exposure is significantly associated with stillbirth in the second and third trimester.[215]



Standard line-angle structure of benzo-a-pyrene (BaP)

Polycyclic aromatic hydrocarbons

[edit]

Polycyclic aromatic hydrocarbons (PAHs) have been associated with reduced fertility. Benzo(a)pyrene (BaP) is a well-known PAH and carcinogen which is often found in exhaust fumes and cigarette smoke.[216] PAHs have been reported to administer their toxic effects through oxidative stress by increasing the production of Reactive Oxygen Species (ROS) which can result in inflammation and cell death. More long-term exposure to PAHs can result in DNA damage and reduced repair.[217]

Exposure to BaP has been reported to reduce sperm motility and increasing the exposure worsens this effect. Research has demonstrated that more BaPs were found in men with reported fertility issues compared to men without.[218]

Studies have shown that BaPs can affect folliculogenesis and ovarian development by reducing the number of ovarian germ cells via triggering cell death pathways and inducing inflammation which can lead to ovarian damage.[219]

Particulate matter

[edit]

Particulate matter (PM) refers to the collection of solids and liquids suspended in the air. These can be harmful to humans, and more research has shown that these effects may be more extensive than first thought; particularly on male fertility. PM can be different sizes, such as $PM_{2.5}$ which are tiny particles of 2.5 microns in width or smaller, compared with PM_{10} which are classified as 10 microns in diameter or less.

A study in California found that increased exposure to $PM_{2.5}$ led to decreased sperm motility and increased abnormal morphology. Similarly, in Poland exposure to $PM_{2.5}$ and PM_{10} led to an increase in the percentage of cells with immature chromatin (DNA that has not fully developed or has developed abnormally).[220]

In Turkey, a study examined the fertility of men who work as toll collectors and are therefore exposed to high levels of traffic pollutants daily. Traffic pollution often has high levels of PM_{10} alongside carbon monoxide and nitrogen oxides.[220] There were significant differences in sperm count and motility in this study group compared to a control group with limited air pollution exposure.

In women, while overall effects on fertility do not appear significant there is an association between increased exposure to PM_{10} and early miscarriage. Exposure to smaller particulate matter, $PM_{2.5}$, appears to have an effect on conception rates in women undergoing IVF but does not affect live birth rates.[215]

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Ozone structure showing three oxygen atoms

Ground-level ozone pollution

[edit]

Ground-level ozone (O_3), when in high concentrations, is regarded as an air pollutant and is often found in smog in industrial areas.

There is limited research about the effect that ozone pollution has on fertility.[215] At present, there is no evidence to suggest that ozone exposure poses a deleterious effect on spontaneous fertility in either females or males. However, there have been studies which suggest that high levels of ozone pollution, often a problem in the summer months, exert an effect on in vitro fertilisation (IVF) outcomes. Within an IVF population, NO_x and ozone pollutants were linked with reduced rates of live birth.[215]

While most research on this topic is focused on the direct human exposure of air pollution, other studies have analysed the impact of air pollution on gametes and embryos within IVF laboratories. Multiple studies have reported a marked improvement in embryo quality, implantation and pregnancy rates after IVF laboratories have implemented air filters in a concerted effort to reduce levels of air pollution.[221] Therefore, ozone pollution is considered to have a negative impact on the success of assisted reproductive technologies (ART) when occurring at high levels.

Ozone is thought to act in a biphasic manner where a positive effect on live birth is observed when ozone exposure is limited to before IVF embryo implantation.

Conversely, a negative effect is demonstrated upon exposure to ozone after embryo implantation. However, after adjusting for NO2, the association between O3 and IVF live birth rate was no longer significant.[222][223]

In terms of male fertility, ozone is reported to cause a significant decrease in the concentration and count of sperm in semen after exposure.[224] Similarly, sperm vitality, the proportion of live spermatozoa in a sample, was demonstrated to be diminished as a result of exposure to air pollution.[223] However, findings on the effect of ozone exposure on male fertility are somewhat discordant, highlighting the need for further research.[223]

Children

[edit]

Children and infants are among the most vulnerable to air pollution. Polluted air leads to the poisoning of millions of children under the age of 15, resulting in the death of some 600,000 children annually (543,000 under 5 years of age and 52,000 aged 5-15 years).[225] Children in low or middle income countries are exposed to higher levels of fine particulate matter than those in high income countries.[225]

Health effects of air pollution on children include asthma, pneumonia and lower respiratory tract infections and low birth weight.[226] A study in Europe found that exposure to ultrafine particles can increase blood pressure in children.[227]

Prenatal exposure

[edit]

Prenatal exposure to polluted air has been linked to a variety of neurodevelopmental disorders in children. For example, exposure to polycyclic aromatic hydrocarbons (PAH) was associated with reduced IQ scores and symptoms of anxiety and depression.[228] They can also lead to detrimental perinatal health outcomes that are often fatal in developing countries.[8] A 2014 study found that PAHs might play a role in the development of childhood attention deficit hyperactivity disorder (ADHD).[229]

Researchers have found a correlation between air pollution and risk of autism spectrum disorder (ASD) diagnosis, although definitive causality has not yet been established. In Los Angeles, children living in areas with high levels of traffic-related air pollution were more likely to be diagnosed with autism between three–five years of age.[230] A cohort study in Southern California linked in-utero exposure to near-roadway air pollution to an increased risk of ASD diagnosis[231] and a study in Sweden concluded that exposure to $PM_{2.5}$ during pregnancy was associated with ASD.[232] A Danish study linked exposure to air pollution during infancy, but not during pregnancy, to an increased risk of ASD diagnosis.[233]

The connection between air pollution and neurodevelopmental disorders in children is thought to be related to epigenetic dysregulation of the primordial germ cells, embryo, and fetus during a critical period. Some PAHs are considered endocrine disruptors and are lipid soluble. When they build up in adipose tissue they can be transferred across the placenta can exert a genotoxic effect, cauding DNA damange and mutations.[234] Air pollution has been associated with the prevalence of preterm births.[235]

Infants

[edit]

Ambient levels of air pollution have been associated with preterm birth and low birth weight. A 2014 WHO worldwide survey on maternal and perinatal health found a statistically significant association between low birth weights (LBW) and increased levels of exposure to $PM_{2.5}$. Women in regions with greater than average $PM_{2.5}$ levels had statistically significant higher odds of pregnancy resulting in a low-birth weight infant even when adjusted for country-related variables.[236] The effect is thought to be from stimulating inflammation and increasing oxidative stress.

A study found that in 2010 exposure to $PM_{2.5}$ was strongly associated with 18% of preterm births globally, which was approximately 2.7 million premature births. The countries with the highest air pollution associated preterm births were in South and East Asia, the Middle East, North Africa, and West sub-Saharan Africa.[237] In 2019, ambient particulate matter pollution in Africa resulted in at least 383,000 early deaths, according to new estimates of the cost of air pollution in the continent. This increased from 3.6% in 1990 to around 7.4% of all premature deaths in the area.[238][239][240]

The source of $PM_{2.5}$ differs greatly by region. In South and East Asia, pregnant women are frequently exposed to indoor air pollution because of wood and other biomass fuels being used for cooking, which are responsible for more than 80% of regional pollution. In the Middle East, North Africa and West sub-Saharan Africa, fine PM comes from natural sources, such as dust storms.[237] The United States had an estimated 50,000 preterm births associated with exposure to $PM_{2.5}$ in 2010.[237]

A study between 1988 and 1991 found a correlation between sulfur dioxide (SO_2) and total suspended particulates (TSP) and preterm births and low birth weights in Beijing.

A group of 74,671 pregnant women, in four separate regions of Beijing, were monitored from early pregnancy to delivery along with daily air pollution levels of SO_2 and TSP (along with other particulates). The estimated reduction in birth weight was 7.3 g for every 100 ?g/m^3 increase in SO_2 and 6.9 g for each 100 ?g/m^3 increase in TSP. These associations were statistically significant in both summer and winter, although summer was greater. The proportion of low birth weight attributable to air pollution, was 13%. This is the largest attributable risk ever reported for the known risk factors of low birth weight.[241] Coal stoves, which are in 97% of homes, are a major source of air pollution in this area.

Brauer et al. studied the relationship between air pollution and proximity to a highway with pregnancy outcomes in a Vancouver cohort of pregnant women using addresses to estimate exposure during pregnancy. Exposure to NO, NO_2, CO, PM_{10} and $PM_{2.5}$ were associated with infants born small for gestational age (SGA). Women living less than 50 meters away from an expressway or highway were 26% more likely to give birth to a SGA infant.[242]

Central nervous system

[edit]
See also: Brain health and pollution and neuroplastic effects of pollution

Data is accumulating that air pollution exposure also affects the central nervous system.[243]

Air pollution increases the risk of dementia in people over 50 years old.[244] Indoor air pollution exposure during childhood may negatively affect cognitive function and neurodevelopment.[245][246] Prenatal exposure may also affect neurodevelopment.[247][248] Studies show that air pollution is associated with a variety of developmental disabilities, oxidative stress, and neuro-inflammation and that it may contribute to Alzheimer's disease and Parkinson's disease.[246]

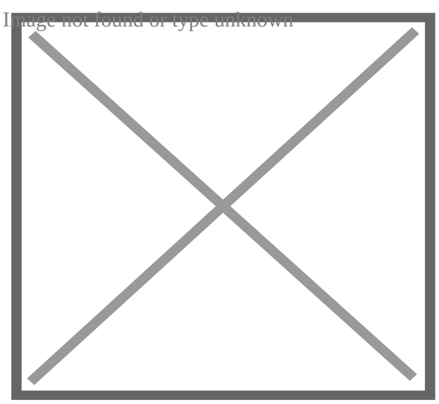
Researchers found that early exposure to air pollution causes the same changes in the brain as autism and schizophrenia in mice. It also showed that air pollution also affected short-term memory, learning ability, and impulsivity. In this study, air pollution had a larger negative impact on male mice than on females.[249][250] Lead researcher on the study, Deborah Cory-Slechta, said that:[251]

> When we looked closely at the ventricles, we could see that the white matter that normally surrounds them hadn't fully developed. It appears that

inflammation had damaged those brain cells and prevented that region of the brain from developing, and the ventricles simply expanded to fill the space. Our findings add to the growing body of evidence that air pollution may play a role in autism, as well as in other neurodevelopmental disorders.

Exposure to fine particulate matter can increase levels of cytokines - neurotransmitters produced in response to infection and inflammation that are also associated with depression and suicide. Pollution has been associated with inflammation of the brain, which may disrupt mood regulation. Heightened $PM_{2.5}$ levels are linked to more self-reported depressive symptoms, and increases in daily suicide rates.[252][253]

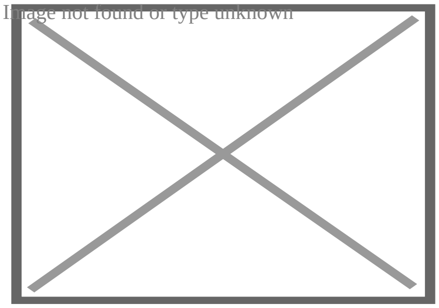
In 2015, experimental studies reported the detection of significant episodic (situational) cognitive impairment from impurities in indoor air breathed by test subjects who were not informed about changes in the air quality. Significant deficits were observed in the performance scores achieved in increasing concentrations of either volatile organic compounds (VOCs) or carbon dioxide, while keeping other factors constant. The highest impurity levels reached are not uncommon in some classroom or office environments.[254][255] Higher $PM_{2.5}$ and CO_2 concentrations were shown to be associated with slower response times and reduced accuracy in tests.[256]



PM2.5 Levels Across the World's 5 Most Populated Nations in 2019

"Clean" areas

[edit]



Share of the population exposed to air pollution levels above WHO guidelines, 2017

Even in areas with relatively low levels of air pollution, public health effects can be significant and costly, since a large number of people breathe in such pollutants. A study found that even in areas of the U.S. where ozone and $PM_{2.5}$ meet federal standards, Medicare recipients who are exposed to more air pollution have higher mortality rates.[257]

Rural populations in India, like those in urban areas, are also exposed to high levels of air pollution.[258] In 2020, scientists found that the boundary layer air over the Southern Ocean around Antarctica is 'unpolluted' by humans.[259]

Agricultural effects

[edit]

Various studies have estimated the impacts of air pollution on agriculture, especially ozone. A 2020 study showed that ozone pollution in California may reduce yields of certain perennial crops such as table grapes by as much as 22% per year, translating into economic damages of more than $1 billion per year.[260] After air pollutants enter the agricultural environment, they not only directly affect agricultural production and quality, but also enter agricultural waters and soil.[261] The COVID-19 induced lockdown served as a natural experiment to expose the close links between air quality and surface greenness. In India, the lockdown induced improvement in air quality, enhanced surface greenness and photosynthetic activity, with the positive response of vegetation to reduce air pollution was dominant in croplands.[262] On the other hand, agriculture in its traditional form is one of the primary contributors to the emission of trace gases like atmospheric ammonia.[263]

Economic effects

[edit]

Air pollution costs the world economy $5 trillion per year as a result of productivity losses and degraded quality of life.[24][25][26] These productivity losses are caused by deaths due to diseases caused by air pollution. One out of ten deaths in 2013 was caused by diseases associated with air pollution and the problem is getting worse.

A small improvement in air quality (1% reduction of ambient $PM_{2.5}$ and ozone concentrations) would produce $29 million in annual savings in the lower Fraser Valley region in 2010.[264] This finding is based on health valuation of lethal (death) and sub-lethal (illness) affects.

The problem is even more acute in the developing world. "Children under age 5 in lower-income countries are more than 60 times as likely to die from exposure to air pollution as children in high-income countries."[24][25] The report states that additional economic losses caused by air pollution, including health costs[265] and the adverse effect on agricultural and other productivity were not calculated in the report, and thus the actual costs to the world economy are far higher than $5 trillion.

A study published in 2022 found "a strong and significant connection between air pollution and construction site accidents" and that "a 10-ppb increase in NO_2 levels increases the likelihood of an accident by as much as 25%".[266]

Other effects

[edit]

Artificial air pollution may be detectable on Earth from distant vantage points such as other planetary systems via atmospheric SETI – including NO_2 pollution levels and with telescopic technology close to today. It may also be possible to detect extraterrestrial civilizations this way.[267][268][269]

Historical disasters

[edit]

The world's worst short-term civilian pollution crisis was the 1984 Bhopal Disaster in India.[270] Leaked industrial vapours from the Union Carbide factory, belonging to Union Carbide, Inc., U.S.A. (later bought by Dow Chemical Company), killed at least 3787 people and injured from 150,000 to 600,000. The United Kingdom suffered its worst air pollution event when the 4 December Great Smog of 1952 formed over London. In six days more than 4,000 died and more recent estimates put the figure at nearer 12,000.[271]

An accidental leak of anthrax spores from a biological warfare laboratory in the former USSR in 1979 near Yekaterinburg (formerly Sverdlovsk) is believed to have caused at least 64 deaths.[272] The worst single incident of air pollution to occur in the US occurred in Donora, Pennsylvania, in late October 1948, when 20 people died and over 7,000 were injured.[273]

Reduction and regulation

[edit]

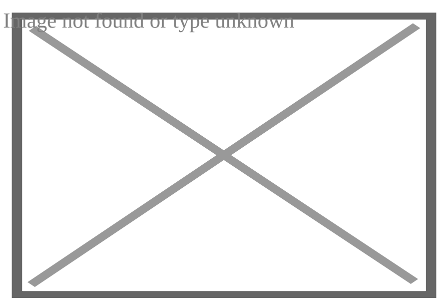
Global depletion of the surrounding air pollution will require valiant leadership, a surplus of combined resources from the international community, and extensive societal changes.[274] Pollution prevention seeks to prevent pollution such as air pollution and could include adjustments to industrial and business activities such as designing sustainable manufacturing processes (and the products' designs)[275] and related legal regulations as well as efforts towards renewable energy transitions.[276][277]

Efforts to reduce particulate matter in the air may result in better health.[278]

The 9-Euro-Ticket scheme in Germany which allowed people to buy a monthly pass allowing use on all local and regional transport (trains, trams and busses) for 9 euro (€) for one month of unlimited travel saved 1.8 million tons of CO_2 emissions during its three-month implementation from June to August 2022.[279]

Pollution control

[edit]



Burning of items polluting Jamestown environment in Accra, Ghana

Various pollution control technologies and strategies are available to reduce air pollution.[280][281] At its most basic level, land-use planning is likely to involve zoning and transport infrastructure planning. In most developed countries, land-use planning is an important part of social policy, ensuring that land is used efficiently for the benefit of the wider economy and population, as well as to protect the environment.[282] Stringent environmental regulations, effective control technologies and shift towards the renewable source of energy also helping countries like China and India to reduce their sulfur dioxide pollution.[283]

Titanium dioxide has been researched for its ability to reduce air pollution. Ultraviolet light will release free electrons from material, thereby creating free radicals, which break up VOCs and

NO_x gases. One form is superhydrophilic.[284]

Pollution-eating nanoparticles placed near a busy road were shown to absorb toxic emission from around 20 cars each day.[285]

Energy transition

[edit]

Since a large share of air pollution is caused by combustion of fossil fuels such as coal and oil, the reduction of these fuels can reduce air pollution drastically. Most effective is the switch to clean power sources such as wind power, solar power, hydro power which do not cause air pollution.[286] Efforts to reduce pollution from mobile sources includes expanding regulation to new sources (such as cruise and transport ships, farm equipment, and small gas-powered equipment such as string trimmers, chainsaws, and snowmobiles), increased fuel efficiency (such as through the use of hybrid vehicles), conversion to cleaner fuels, and conversion to electric vehicles. For example, buses in New Delhi, India, have run on compressed natural gas since 2000, to help eliminate the city's "pea-soup" smog.[226][287]

A very effective means to reduce air pollution is the transition to renewable energy. According to a study published in Energy and Environmental Science in 2015 the switch to 100% renewable energy in the United States would eliminate about 62,000 premature mortalities per year and about 42,000 in 2050, if no biomass were used. This would save about $600 billion in health costs a year due to reduced air pollution in 2050, or about 3.6% of the 2014 U.S. gross domestic product.[286] Air quality improvement is a near-term benefit among the many societal benefits from climate change mitigation.

Alternatives to pollution

[edit]

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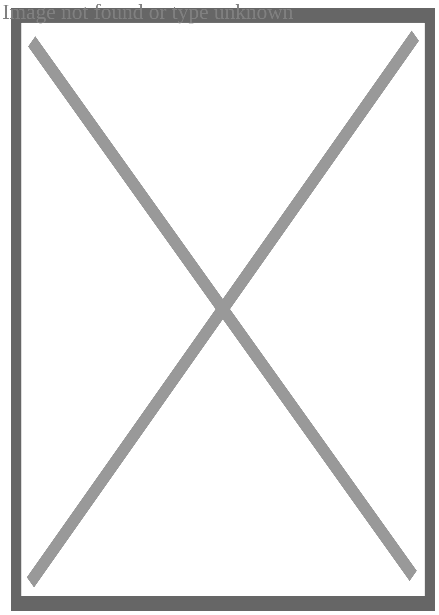

Support for a ban on high-emission vehicles in city centres in Europe, China and the US from respondents to the European Investment Bank Climate Survey

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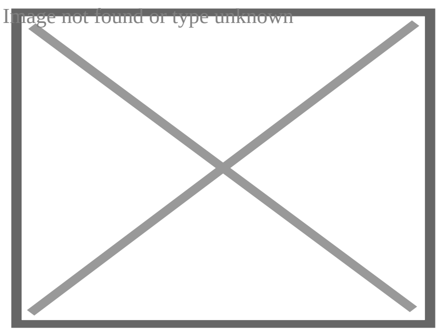


Support, use and infrastructure-expansion of forms of public transport that do not cause air pollution may be a critical key alternative to pollution.

There are now practical alternatives to the principal causes of air pollution:

- Strategic substitution of air pollution sources in transport with lower-emission or, during the lifecycle, emission-free forms of public transport[288][289] and bicycle use and infrastructure (as well as with remote work, reductions of work, relocations, and localizations)
    - Phase-out of fossil fuel vehicles is a critical component of a shift to sustainable transport; however, similar infrastructure and design decisions like electric vehicles may be associated with similar pollution for production as well as mining and resource exploitation for large numbers of needed batteries as well as the energy for their recharging[290][291]
- Areas downwind (over 20 miles) of major airports have more than double *total particulate emissions in air* than other areas, even when factoring in areas with

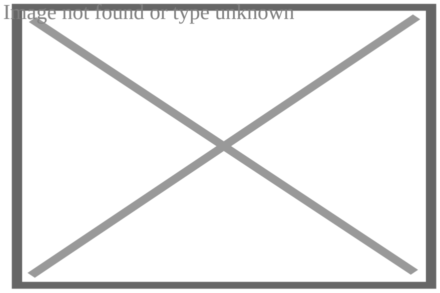
frequent ship calls, and heavy freeway and city traffic like Los Angeles.[292] Aviation biofuel mixed in with jetfuel at a 50/50 ratio can reduce jet derived cruise altitude particulate emissions by 50–70%, according to a NASA led 2017 study (however, this should imply ground level benefits to urban air pollution as well).[293]

- Ship propulsion and idling can be switched to much cleaner fuels like natural gas. (Ideally a renewable source but not practical yet)
- Combustion of fossil fuels for space heating can be replaced by using ground source heat pumps and seasonal thermal energy storage.[294]
- Electricity generated from the combustion of fossil fuels can be replaced by nuclear and renewable energy. Heating and home stoves, which contribute significantly to regional air pollution, can be replaced with a much cleaner fossil fuel, such as natural gas, or, preferably, renewables, in poor countries.[295][296]
- Motor vehicles driven by fossil fuels, a key factor in urban air pollution, can be replaced by electric vehicles. Though lithium supply and cost is a limitation, there are alternatives. Herding more people into clean public transit such as electric trains can also help. Nevertheless, even in emission-free electric vehicles, rubber tires produce significant amounts of air pollution themselves, ranking as 13th worst pollutant in Los Angeles.[297]
- Reducing travel in vehicles can curb pollution. After Stockholm reduced vehicle traffic in the central city with a congestion tax, nitrogen dioxide and PM_{10} pollution declined, as did acute pediatric asthma attacks.[298]
- Biodigesters can be utilized in poor nations where slash and burn is prevalent, turning a useless commodity into a source of income. The plants can be gathered and sold to a central authority that will break them down in a large modern biodigester, producing much needed energy to use.[299]
- Induced humidity and ventilation both can greatly dampen air pollution in enclosed spaces, which was found to be relatively high inside subway lines due to braking and friction and relatively less ironically inside transit buses than lower sitting passenger automobiles or subways.[300]

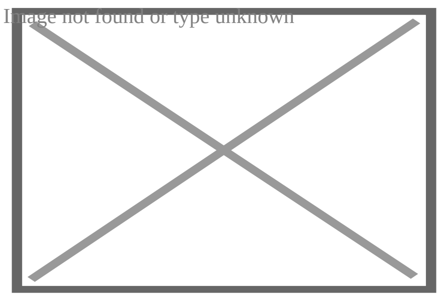
Further information: § Sources

Control devices

[edit]



Tarps and netting are often used to reduce the amount of dust released from construction sites.



Air pollution from a car

The following items are commonly used as pollution control devices in industry and transportation. They can either destroy contaminants or remove them from an exhaust stream before it is emitted into the atmosphere.

- **Particulate control**
    - Mechanical collectors (dust cyclones, multicyclones)
    - Electrostatic precipitators: An electrostatic precipitator (ESP), or electrostatic air cleaner, is a particulate collection device that removes particles from a flowing gas (such as air), using the force of an induced electrostatic charge. Electrostatic precipitators are highly efficient filtration devices that minimally impede the flow of gases through the device, and can easily remove fine particulates such as dust and smoke from the air stream.
    - Baghouses: Designed to handle heavy dust loads, a dust collector consists of a blower, dust filter, a filter-cleaning system, and a dust receptacle or dust removal system (distinguished from air cleaners which utilize disposable filters to remove the dust).
    - Particulate scrubbers: A wet scrubber is a form of pollution control technology. The term describes a variety of devices that use pollutants from a furnace flue gas or from other gas streams. In a wet scrubber, the polluted gas stream is brought into contact with the scrubbing liquid, by spraying it with the liquid, by forcing it through a pool of liquid, or by some other contact method, so as to remove the pollutants.
- **Scrubbers**
    - Baffle spray scrubber
    - Cyclonic spray scrubber

    - Ejector venturi scrubber
    - Mechanically aided scrubber
    - Spray tower
    - Wet scrubber
- **NO*x* control**
    - LO-NOx burners
    - Selective catalytic reduction (SCR)
    - Selective non-catalytic reduction (SNCR)
    - NOx scrubbers
    - Exhaust gas recirculation
    - Catalytic converter (also for VOC control)
- **VOC abatement**
    - Adsorption systems, using activated carbon, such as Fluidized Bed Concentrator
    - Flares
    - Thermal oxidizers
    - Catalytic converters
    - Biofilters
    - Absorption (scrubbing)
    - Cryogenic condensers
    - Vapor recovery systems
- **Acid gas/SO_2 control**
    - Wet scrubbers
    - Dry scrubbers
    - Flue-gas desulfurization
- **Mercury control**
    - Sorbent injection technology
    - Electro-catalytic oxidation (ECO)
    - K-Fuel
- **Dioxin and furan control**
- **Miscellaneous associated equipment**
    - Source capturing systems
    - Continuous emissions monitoring systems (CEMS)

Monitoring

[edit]
See also: Smart city
Further information: Air pollution measurement and Environmental monitoring

Spatiotemporal monitoring of air quality may be necessary for improving air quality, and thereby the health and safety of the public, and assessing impacts of interventions.[301] Such monitoring is done to different extents with different regulatory requirements with discrepant regional coverage by a variety of organizations and governance entities such as using a variety of technologies for use of the data and sensing such mobile IoT sensors,[302][303] satellites,[304][305][306] and monitoring stations.[307][308] Some websites attempt to map air pollution levels using available data.[309][310][311]

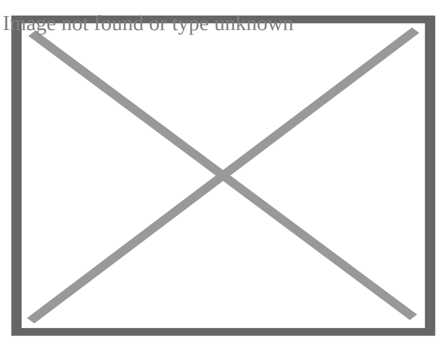
Air quality modeling

[edit]
Main article: Air quality modeling

Numerical models either on a global scale using tools such as GCMs (general circulation models coupled with a pollution module) or CTMs (Chemical transport model) can be used to simulate the levels of different pollutants in the atmosphere. These tools can have several types (Atmospheric model) and different uses. These models can be used in forecast mode which can help policy makers to decide on appropriate actions when an air pollution episode is detected. They can also be used for climate modeling including evolution of air quality in the future, for example the IPCC (Intergovernmental Panel on Climate Change) provides climate simulations including air quality assessments in their reports (latest report accessible through their site).

Regulations

[edit]
Main article: Air quality law



Smog in Cairo

In general, there are two types of air quality standards. The first class of standards (such as the U.S. National Ambient Air Quality Standards and E.U. Air Quality Directive [312]) set maximum atmospheric concentrations for specific pollutants. Environmental agencies enact regulations which are intended to result in attainment of these target levels. The second class (such as the North American air quality index) take the form of a scale with various thresholds, which is used to communicate to the public the relative risk of outdoor activity. The scale may or may not distinguish between different pollutants.

Canada

[edit]

In Canada, air pollution and associated health risks are measured with the Air Quality Health Index (AQHI).[313] It is a health protection tool used to make decisions to reduce short-term exposure to air pollution by adjusting activity levels during increased levels of air pollution.

The AQHI is a federal program jointly coordinated by Health Canada and Environment Canada. However, the AQHI program would not be possible without the commitment and support of the provinces, municipalities and NGOs. From air quality monitoring to health risk communication and community engagement, local partners are responsible for the vast majority of work related to AQHI implementation. The AQHI provides a number from 1 to 10+ to indicate the level of health risk associated with local air quality. Occasionally, when the amount of air pollution is abnormally high, the number may exceed 10. The AQHI provides a local air quality current value as well as a local air quality maximums forecast for today, tonight and tomorrow and provides associated health advice.

1	2	3	4	5	6	7	8	9	10	+

Risk: Low **(1–3)** Moderate **(4–6)** High **(7–10)** Very high **(above 10)**

As it is now known that even low levels of air pollution can trigger discomfort for the sensitive population, the index has been developed as a continuum: The higher the number, the greater the health risk and need to take precautions. The index describes the level of health risk associated with this number as 'low', 'moderate', 'high' or 'very high', and suggests steps that can be taken to reduce exposure.[314]

Health risk	Air Quality Health Index	Health messages[315]

At risk population	General population		
Low	**1–3**	**Enjoy** your usual outdoor activities.	**Ideal** air quality for outdoor activities
Moderate	**4–6**	**Consider reducing** or rescheduling strenuous activities outdoors if you are experiencing symptoms.	**No need to modify** your usual outdoor activities unless you experience symptoms such as coughing and throat irritation.
High	**7–10**	**Reduce** or reschedule strenuous activities outdoors. Children and the elderly should also take it easy.	**Consider reducing** or rescheduling strenuous activities outdoors if you experience symptoms such as coughing and throat irritation.
Very high	**Above 10**	**Avoid** strenuous activities outdoors. Children and the elderly should also avoid outdoor physical exertion and should stay indoors.	**Reduce** or reschedule strenuous activities outdoors, especially if you experience symptoms such as coughing and throat irritation.

The measurement is based on the observed relationship of nitrogen dioxide (NO_2), ground-level ozone (O_3) and particulates ($PM_{2.5}$) with mortality, from an analysis of several Canadian cities. Significantly, all three of these pollutants can pose health risks, even at low levels of exposure, especially among those with pre-existing health problems.

When developing the AQHI, Health Canada's original analysis of health effects included five major air pollutants: particulates, ozone, and nitrogen dioxide (NO_2), as well as sulfur dioxide (SO_2), and carbon monoxide (CO). The latter two pollutants provided little information in predicting health effects and were removed from the AQHI formulation.

The AQHI does not measure the effects of odour, pollen, dust, heat or humidity.

Germany

[edit]

TA Luft is the German air quality regulation.[316]

Governing urban air pollution

[edit]
Further information: Phase-out of fossil fuel vehicles § Cities and territories

In Europe, Council Directive 96/62/EC on ambient air quality assessment and management provides a common strategy against which member states can "set objectives for ambient air quality in order to avoid, prevent or reduce harmful effects on human health and the environment ... and improve air quality where it is unsatisfactory".[317]

In July 2008, in the case *Dieter Janecek v. Freistaat Bayern*, the European Court of Justice ruled that under this directive[317] citizens have the right to require national authorities to implement a short term action plan that aims to maintain or achieve compliance to air quality limit values.[318][319]

This important case law appears to confirm the role of the EC as centralised regulator to European nation-states as regards air pollution control. It places a supranational legal obligation on the UK to protect its citizens from dangerous levels of air pollution, furthermore superseding national interests with those of the citizen.

In 2010, the European Commission (EC) threatened the UK with legal action against the successive breaching of PM_{10} limit values.[320] The UK government has identified that if fines are imposed, they could cost the nation upwards of £300 million per year.[321]

In March 2011, the Greater London Built-up Area remained the only UK region in breach of the EC's limit values, and was given three months to implement an emergency action plan aimed at meeting the EU Air Quality Directive.[322] The City of London has dangerous levels of PM_{10} concentrations, estimated to cause 3000 deaths per year within the city.[323] As well as the threat of EU fines, in 2010 it was threatened with legal action for scrapping the western congestion charge zone, which is claimed to have led to an increase in air pollution levels.[324]

In response to these charges, mayor of London Boris Johnson has criticised the current need for European cities to communicate with Europe through their nation state's central government, arguing that in future "A great city like London" should be permitted to bypass its government and deal directly with the European Commission regarding its air quality action plan.[322]

This can be interpreted as recognition that cities can transcend the traditional national government organisational hierarchy and develop solutions to air pollution using global governance networks, for example through transnational relations. Transnational relations include but are not exclusive to national governments and intergovernmental organisations,[325] allowing sub-national actors including cities and regions to partake in air pollution control as independent actors.

Global city partnerships can be built into networks, for example the C40 Cities Climate Leadership Group, of which London is a member. The C40 is a public 'non-state' network of the world's leading cities that aims to curb their greenhouse emissions.[326] The C40 has been identified as 'governance from the middle' and is an alternative to intergovernmental policy.[327] It has the potential to improve urban air quality as participating cities "exchange information, learn from best practices and consequently mitigate carbon dioxide emissions independently from national government decisions".[326] A criticism of the C40 network is that its exclusive nature limits influence to participating cities and risks drawing resources away from less powerful city and regional actors.

Indigenous people

[edit]

Because Indigenous people[328] frequently experience a disproportionate share of the effects of environmental degradation and climate change, even while they have made very little contribution to the processes causing these changes, environmental justice is especially important to them. Indigenous peoples have been marginalized and their lands and resources have been exploited as a result of historical and continuing colonization, institutional injustices, and inequality.

Indigenous groups frequently lack the political and financial clout to influence policy decisions that impact their lands and means of subsistence or to lessen the effects of climate change. This makes the already-existing inequalities in these communities' social, economic, and health conditions worse. Furthermore, traditional ecological knowledge and Indigenous knowledge systems provide insightful information about sustainable resource management and climate change adaptation techniques. To promote persistence and environmental justice, Indigenous viewpoints must be acknowledged and integrated into efforts to mitigate the effects of climate change and adapt to them.

Combating climate change necessitates an all-encompassing strategy that recognizes the interdependence of social, economic, and environmental elements. This entails defending treaty rights, advancing Indigenous sovereignty and self-determination, and aiding Indigenous-led projects for sustainable development and environmental preservation.

Hotspots

[edit]
Main article: Toxic hotspot
See also: Cancer alley and Superfund

Air pollution hotspots are areas where air pollution emissions expose individuals to increased negative health effects.[329] They are particularly common in highly populated, urban areas, where there may be a combination of stationary sources (e.g. industrial facilities) and mobile sources (e.g. cars and trucks) of pollution. Emissions from these sources can cause respiratory disease, childhood asthma,[141] cancer, and other health problems. Fine particulate matter such as diesel soot, which contributes to more than 3.2 million premature deaths around the world each year, is a significant problem. It is very small and can lodge itself within the lungs and enter the bloodstream. Diesel soot is concentrated in densely populated areas, and one in six people in the U.S. live near a diesel pollution hot spot.[330]

External videos

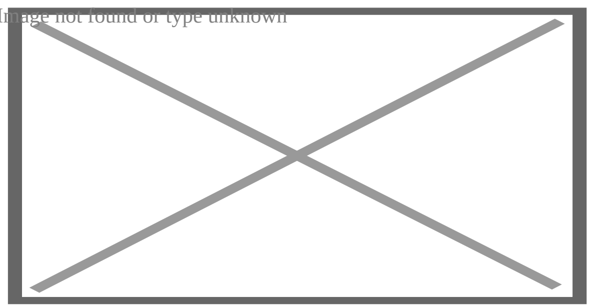
Image not found or type unknown video icon *AirVisual Earth* – realtime map of global wind and air pollution[331]

While air pollution hotspots affect a variety of populations, some groups are more likely to be located in hotspots. Previous studies have shown disparities in exposure to pollution by race and/or income. Hazardous land uses (toxic storage and disposal facilities, manufacturing facilities, major roadways) tend to be located where property values and income levels are low. Low socioeconomic status can be a proxy for other kinds of social vulnerability, including race, a lack of ability to influence regulation and a lack of ability to move to neighborhoods with less environmental pollution. These communities bear a disproportionate burden of environmental pollution and are more likely to face health risks such as cancer or asthma.[332]

Studies show that patterns in race and income disparities not only indicate a higher exposure to pollution but also higher risk of adverse health outcomes.[333] Communities characterized by low socioeconomic status and racial minorities can be more vulnerable to cumulative adverse health impacts resulting from elevated exposure to pollutants than more privileged communities.[333] Blacks and Latinos generally face more pollution than Whites and Asians, and low-income communities bear a higher burden of risk than affluent ones.[332] Racial discrepancies are particularly distinct in suburban areas of the Southern United States and metropolitan areas of the Midwestern and Western United States.[334] Residents in public housing, who are generally low-income and cannot move to healthier neighborhoods, are highly affected by nearby refineries and chemical plants.[335]

Cities

[edit]
See also: List of most polluted cities in the world by particulate matter concentration
Further information: List of least polluted cities by particulate matter concentration



Nitrogen dioxide concentrations as measured from satellite 2002–2004

Air pollution is usually concentrated in densely populated metropolitan areas, especially in developing countries where cities are experiencing rapid growth and environmental regulations are relatively lax or nonexistent. Urbanization leads to a rapid rise in premature mortality due to anthropogenic air pollution in fast-growing tropical cities.[336] However, even populated areas in developed countries attain unhealthy levels of pollution, with Los Angeles and Rome being two examples.[337] Between 2002 and 2011 the incidence of lung cancer in Beijing near doubled. While smoking remains the leading cause of lung cancer in China, the number of smokers is falling while lung cancer rates are rising .[338]

[339]

World's Most Polluted Cities 2020	2020 Average	2019 Average
Hotan, China	110.2	110.1
Ghaziabad, India	106.6	110.2
Bulandshahr, India	98.4	89.4
Bisrakh Jalalpur, India	96.0	-
Bhiwadi, India	95.5	83.4

Tehran was declared the most polluted city in the world on May 24, 2022.[340]

Projections

[edit]

In a 2019 projection, by 2030 half of the world's pollution emissions could be generated by Africa.[341] Potential contributors to such an outcome include increased burning activities (such as the burning of open waste), traffic, agri-food and chemical industries, sand dust from the Sahara, and overall population growth.

In a 2012 study, by 2050 outdoor air pollution (particulate matter and ground-level ozone) is projected to become the top cause of environmentally related deaths worldwide.[342]

See also

[edit]

- icon Image not found or type unknown Global warming portal
- icon Image not found or type unknown Plants portal
- icon Image not found or type unknown Trees portal

Source

- Beehive burner
- Bottom ash
- Concrete#Concrete – health and safety
- Diwali-related air pollution
- Flue-gas emissions from fossil-fuel combustion
- Health impacts of sawdust
- Joss paper
- Metal working
- Mining
- Non-exhaust emissions
- Power tool
- Rubber pollution
- Slag
- Smelting
- Tire fire
- Welding
- Wood ash

Measurement

- Air pollutant concentrations
- Air pollution measurement
- Organic molecular tracers
- Intake fraction
- Particulate matter sampler

Others

- Air stagnation
- ASEAN Agreement on Transboundary Haze Pollution
- Asian brown cloud
- Atmospheric chemistry
- BenMAP
- Best Available Control Technology
- Critical load
- Emission standard
- Emissions & Generation Resource Integrated Database
- Environmental agreement
- Environmental racism
- Exposome
- Global Atmosphere Watch
- Global dimming
- Great Smog of London
- Haze
- Health Effects Institute (HEI)
- Indicator value
- International Agency for Research on Cancer
- International Day of Clean Air for Blue Skies
- Kyoto Protocol
- Light water reactor sustainability
- List of smogs by death toll
- Lowest Achievable Emissions Rate
- NASA Clean Air Study
- NIEHS
- Phytoremediation
- Polluter pays principle
- Regulation of greenhouse gases under the Clean Air Act
- Silicosis#Prevention

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Further reading

[edit]
Library resources about
Air pollution

- Resources in your library
- Resources in other libraries
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External links

[edit]

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

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Wikivoyage has travel information for ***Air pollution***.

- WHO fact sheet on outdoor air pollution
- Air Pollution: Everything You Need to Know Guide by the Natural Resources Defense Council (NRDC)
- Global real-time air quality index map
- Air Quality Index (AQI) Basics
- AQI Calculator AQI to Concentration and Concentration to AQI for five pollutants
- UNEP Urban environmental planning
- European Commission > Environment > Air > Air Quality
- Database: outdoor air pollution in cities from the World Health Organization
- The Mortality Effects of Long-Term Exposure to Particulate Air Pollution in the United Kingdom, UK Committee on the Medical Effects of Air Pollution, 2010.
- Hazardous air pollutants | What are hazardous pollutants at EPA.gov

Air

- Acid rain
- Air quality index
- Atmospheric dispersion modeling
- Chlorofluorocarbon
- Combustion
  - Biofuel
  - Biomass
  - Joss paper
  - Open burning of waste
- Construction
  - Renovation
- Demolition
- Exhaust gas
  - Diesel exhaust
- Haze
  - Smoke
- Indoor air quality
- Internal combustion engine
- Global dimming
- Global distillation
- Mining
- Ozone depletion
- Particulates
  - Asbestos
  - Metal working
  - Oil refining
  - Wood dust
  - Welding
- Persistent organic pollutant
- Smelting
- Smog
- Soot
  - Black carbon
- Volatile organic compound
- Waste

Biological

- Biological hazard
- Genetic pollution
- Introduced species
  - Invasive species

Digital

- Information pollution

Electromagnetic	◦ Light
	    ◦ Ecological light pollution
	    ◦ Overillumination
	◦ Radio spectrum pollution

Natural	◦ Ozone ◦ Radium and radon in the environment ◦ Volcanic ash ◦ Wildfire

Noise	◦ Transportation
	    ◦ Land
	    ◦ Water
	    ◦ Air
	    ◦ Rail
	    ◦ Sustainable transport
	◦ Urban
	◦ Sonar
	    ◦ Marine mammals and sonar
	◦ Industrial
	◦ Military
	◦ Abstract
	◦ Noise control

Radiation	◦ Actinides ◦ Bioremediation ◦ Nuclear fission ◦ Nuclear fallout ◦ Plutonium ◦ Poisoning ◦ Radioactivity ◦ Uranium ◦ Electromagnetic radiation and health ◦ Radioactive waste

Soil	◦ Agricultural pollution
	    ◦ Herbicides
	    ◦ Manure waste
	    ◦ Pesticides
	◦ Land degradation
	◦ Bioremediation
	◦ Open defecation
	◦ Electrical resistance heating
	◦ Soil guideline values
	◦ Phytoremediation

Solid waste	○ Advertising mail
	○ Biodegradable waste
	○ Brown waste
	○ Electronic waste
	    ○ Battery recycling
	○ Foam food container
	○ Food waste
	○ Green waste
	○ Hazardous waste
	    ○ Biomedical waste
	    ○ Chemical waste
	    ○ Construction waste
	    ○ Lead poisoning
	    ○ Mercury poisoning
	    ○ Toxic waste
	○ Industrial waste
	    ○ Lead smelting
	○ Litter
	○ Mining
	    ○ Coal mining
	    ○ Gold mining
	    ○ Surface mining
	    ○ Deep sea mining
	    ○ Mining waste
	    ○ Uranium mining
	○ Municipal solid waste
	    ○ Garbage
	○ Nanomaterials
	○ Plastic pollution
	    ○ Microplastics
	○ Packaging waste
	○ Post-consumer waste
	○ Waste management
	    ○ Landfill
	    ○ Thermal treatment

Space	○ Satellite
Visual	○ Air travel ○ Clutter (advertising) ○ Traffic signs ○ Overhead power lines ○ Vandalism

War	◦ Chemical warfare ◦ Herbicidal warfare (Agent Orange) ◦ Nuclear holocaust (Nuclear fallout - nuclear famine - nuclear winter) ◦ Scorched earth ◦ Unexploded ordnance ◦ War and environmental law

Water	◦ Agricultural wastewater
	◦ Biological pollution
	◦ Diseases
	◦ Eutrophication
	◦ Firewater
	◦ Freshwater
	◦ Groundwater
	◦ Hypoxia
	◦ Industrial wastewater
	◦ Marine
	    ◦ debris
	◦ Monitoring
	◦ Nonpoint source pollution
	◦ Nutrient pollution
	◦ Ocean acidification
	◦ Oil exploitation
	◦ Oil exploration
	◦ Oil spill
	◦ Pharmaceuticals
	◦ Sewage
	    ◦ Septic tanks
	    ◦ Pit latrine
	◦ Shipping
	◦ Stagnation
	◦ Sulfur water
	◦ Surface runoff
	◦ Thermal
	◦ Turbidity
	◦ Urban runoff
	◦ Water quality

Topics	◦ Pollutants
	    ◦ Heavy metals
	    ◦ Paint
	◦ Brain health and pollution

Misc	○ Area source ○ Debris ○ Dust ○ Garbology ○ Legacy pollution ○ Midden ○ Point source ○ Waste
Responses	○ Cleaner production ○ Industrial ecology ○ Pollution haven hypothesis ○ Pollutant release and transfer register ○ Polluter pays principle ○ Pollution control ○ Waste minimisation ○ Zero waste
Lists	○ Diseases ○ Law by country ○ Most polluted cities ○ Least polluted cities by $PM_{2.5}$ ○ Most polluted countries ○ Most polluted rivers ○ Treaties

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Asia pollution topics

Air pollution

- **Notable incidents**
  - **Dust storm**
    - 2010 China dust storms
  - **Forest fires and haze**
    - 1997 SEA haze
    - 1997 Indonesian forest fires
    - 2005 Malaysian haze
    - 2006 SEA haze
    - 2009 SEA haze
    - 2010 SEA haze
    - 2013 SEA haze
    - 2015 SEA haze
    - 2016 Malaysian haze
    - 2016 SEA haze
    - 2017 SEA haze
    - 2019 SEA haze
    - 2019 Vietnam forest fires
    - 2024 Indo-Pakistani smog
  - **Air radioactive contamination**
    - 1982 Bukit Merah radioactive pollution
- **By countries**
  - China
  - Hong Kong
  - India
  - Macau
  - Malaysia
  - Taiwan
- **Recurrent issues**
  - Asian brown cloud
  - Asian Dust
  - Shamal
  - Southeast Asian haze
- **Counter-measures**
  - ASEAN Agreement on Transboundary Haze Pollution
    - Operation Haze
    - Pollutant Standards Index
  - Great Green Wall (China)

Water pollution

Notable incidents

Water radioactive contamination

- 2011 Fukushima Daiichi nuclear disaster

Marine pollution

- 2016 Vietnam marine life disaster
- 2019 Kim Kim River toxic pollution
- Pollution of the Pasig River

By countries

- China
  - Water crisis
- India
- Japan
- Philippines
- Vietnam

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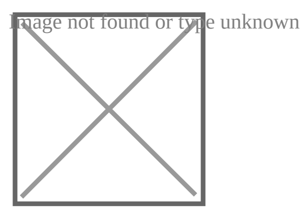
Environmental science

Main fields

- Atmospheric science
- Biogeochemistry
- Ecology
- Environmental chemistry
- Geosciences
- Hydrology
- Limnology
- Oceanography
- Soil science



Related fields	◦ Biology
	◦ Chemistry
	    ◦ green
	◦ Ecological economics
	◦ Environmental design
	◦ Environmental economics
	◦ Environmental engineering
	◦ Environmental health
	    ◦ epidemiology
	◦ Environmental studies
	◦ Environmental humanities
	◦ Environmental statistics
	◦ Environmental toxicology
	◦ Geodesy
	◦ Physics
	◦ Radioecology
	◦ Sustainability science
	◦ Systems ecology
	◦ Urban ecology

Applications	◦ Energy conservation ◦ Environmental technology ◦ Natural resource management ◦ Pollution control ◦ Public transport encouragement ◦ Recycling ◦ Remediation ◦ Renewable energy ◦ Road ecology ◦ Sewage treatment ◦ Urban metabolism ◦ Water purification ◦ Waste management
Lists	◦ Degrees ◦ Journals ◦ Research institutes ◦ Glossary ◦ Environment by year
See also	◦ Human impact on the environment ◦ Sustainability ◦ Technogaianism

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Public health

General

- Auxology
- Biological hazard
- Chief Medical Officer
- Cultural competence
- Deviance
- Environmental health
- Eugenics
  - History of
  - Liberal
- Euthenics
- Genomics
- Globalization and disease
- Harm reduction
- Health economics
- Health literacy
- Health policy
  - Health system
  - Health care reform
- Housing First
- Human right to water and sanitation
- Management of depression
  - Public health law
  - National public health institute
- Health politics
- Labor rights
- Maternal health
- Medical anthropology
- Medical sociology
- Mental health (Ministers)
- Occupational safety and health
- Pharmaceutical policy
- Pollution
  - Air
  - Water
  - Soil
  - Radiation
  - Light
- Prisoners' rights
- Public health intervention
- Public health laboratory
- Right to food
- Right to health
- Right to housing
- Right to rest and leisure
- Right to sit
- Security of person
- Sexual and reproductive health
- Social psychology

Preventive healthcare

- Behavior change
  - Theories
- Family planning
- Health promotion
- Human nutrition
  - Healthy diet
  - Preventive nutrition
- Hygiene
  - Food safety
  - Hand washing
  - Infection control
  - Oral hygiene
- Occupational safety and health
  - Human factors and ergonomics
  - Hygiene
  - Controlled Drugs
  - Injury prevention
  - Medicine
  - Nursing
- Patient safety
  - Organization
- Pharmacovigilance
- Safe sex
- Sanitation
  - Emergency
  - Fecal–oral transmission
  - Open defecation
  - Sanitary sewer
  - Waterborne diseases
  - Worker
- School hygiene
- Smoking cessation
- Vaccination
- Vector control

Population health	◦ Biostatistics
	◦ Child mortality
	◦ Community health
	◦ Epidemiology
	◦ Global health
	◦ Health impact assessment
	◦ Health system
	◦ Infant mortality
	◦ Open-source healthcare software
	◦ Multimorbidity
	◦ Public health informatics
	◦ Social determinants of health
	    ◦ Commercial determinants of health
	    ◦ Health equity
	    ◦ Race and health
	◦ Social medicine

Biological and epidemiological statistics	◦ Case–control study
	◦ Randomized controlled trial
	◦ Relative risk
	◦ Statistical hypothesis testing
	    ◦ Analysis of variance (ANOVA)
	    ◦ Regression analysis
	    ◦ ROC curve
	    ◦ Student's *t*-test
	    ◦ *Z*-test
	◦ Statistical software

Infectious and epidemic disease prevention	◦ Asymptomatic carrier
	◦ Epidemics
	    ◦ List
	◦ Notifiable diseases
	    ◦ List
	◦ Public health surveillance
	    ◦ Disease surveillance
	◦ Quarantine
	◦ Sexually transmitted infection
	◦ Social distancing
	◦ Tropical disease
	◦ Vaccine trial
	◦ WASH

Food hygiene and safety management	◦ Food ◦ Additive ◦ Chemistry ◦ Engineering ◦ Microbiology ◦ Processing ◦ Safety ◦ Safety scandals ◦ Good agricultural practice ◦ Good manufacturing practice ◦ HACCP ◦ ISO 22000
Health behavioral sciences	◦ Diffusion of innovations ◦ Health belief model ◦ Health communication ◦ Health psychology ◦ Positive deviance ◦ PRECEDE–PROCEED model ◦ Social cognitive theory ◦ Social norms approach ◦ Theory of planned behavior ◦ Transtheoretical model

Organizations, education and history

Organizations

- Caribbean
  - Caribbean Public Health Agency
- China
  - Center for Disease Control and Prevention
- Europe
  - Centre for Disease Prevention and Control
  - Committee on the Environment, Public Health and Food Safety
- India
  - Ministry of Health and Family Welfare
- Canada
  - Health Canada
  - Public Health Agency
- U.S.
  - Centers for Disease Control and Prevention
  - Health departments in the United States
  - Council on Education for Public Health
  - Public Health Service
- World Health Organization
- World Toilet Organization
- (Full list)

Education

- Health education
- Higher education
  - Bachelor of Science in Public Health
  - Doctor of Public Health
  - Professional degrees of public health
  - Schools of public health

History

- Sara Josephine Baker
- Samuel Jay Crumbine
- Carl Rogers Darnall
- Joseph Lister
- Margaret Sanger
- John Snow
- Typhoid Mary
- Radium Girls
- Germ theory of disease
- Social hygiene movement

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Natural resources

Air	Pollution / quality	- Ambient standards (US) - Index - Indoor - Law - Clean Air Act (US) - Ozone depletion
	Emissions	- Airshed - Trading - Deforestation (REDD)

Energy	- Bio
	- Law
	- Resources
	- Fossil fuels (gas, peak coal, peak gas, peak oil)
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	- Hydro
	- Nuclear
	- Solar
	  - sunlight
	  - shade
	- Wind	

Land

- Agricultural
  - arable
    - peak farmland
- Degradation
- Field
- Landscape
  - cityscape
  - seascape
  - soundscape
  - viewshed
- Law
  - property
- Management
  - habitat conservation
- Minerals
  - gemstone
  - industrial
  - ore
    - metal
  - mining
    - law
    - sand
  - peak
    - copper
    - phosphorus
  - rights
- Soil
  - conservation
  - fertility
  - health
  - resilience
- Use
  - planning
  - reserve

Life

- Biodiversity
- Bioprospecting
  - biopiracy
- Biosphere
- Bushfood
- Bushmeat
- Fisheries
  - climate change
  - law
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  - management
  - non-timber products
- Game
  - law
- Marine conservation
- Meadow
- Pasture
- Plants
  - FAO Plant Treaty
  - food
  - genetic resources
  - gene banks
  - herbal medicines
  - UPOV Convention
  - wood
- Rangeland
- Seed bank
- Wildlife
  - conservation
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- **Water**
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      - bergs
      - glacial
      - polar
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- Wilderness

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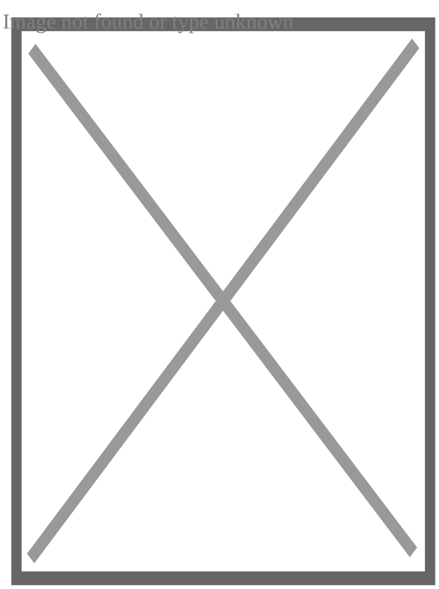
About Heat pump

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

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Mitsubishi heat pump interior air handler wall unit

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Part of a series on

Sustainable energy

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

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Energy conservation

- Arcology
- Building insulation
- Cogeneration
- Compact fluorescent lamp
- Eco hotel
- Eco-cities
- Ecohouse
- Ecolabel
- Efficient energy use
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- Energy efficiency implementation
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- Energy saving lamp
- Energy Star
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- Environmental planning
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- Fossil fuel phase-out
- Glass in green buildings
- Green building and wood
- Green building
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- Low-energy house
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- 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
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- 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
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  - 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
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- icon 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.

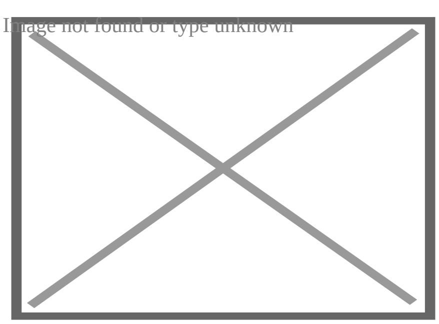
Air source heat pumps are the most common models, while other types include ground source heat pumps, water source heat pumps and exhaust air heat pumps.[3] Large-scale heat pumps are also used in district heating systems.[4]

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: $W=\frac{Q}{\mathrm{COP}}$ 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]
:ÃƒÆ’Ã‚Â¢ÃƒÂ¢Ã¢â‚¬Å¡Ã‚Â¬Ãƒâ€¦Ã‚Â 18ÃƒÆ’Ã‚Â¢ÃƒÂ¢Ã¢â‚¬Å¡Ã‚Â¬Ãƒâ€¦Ã‚Â
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.

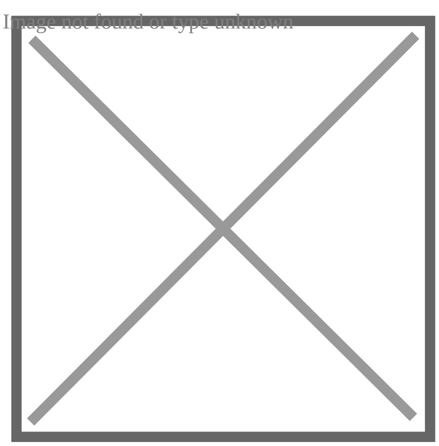
Types

[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]

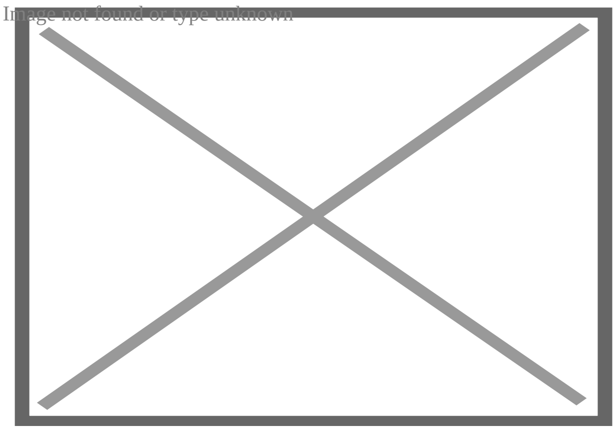
Air-source heat pumps are relatively easy and inexpensive to install, so are the most widely used type. In mild weather, coefficient of performance (COP) may be between 2 and 5, while at temperatures below around ?8 °C (18 °F) an air-source heat pump may still achieve a COP of 1 to 4.[25]

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]

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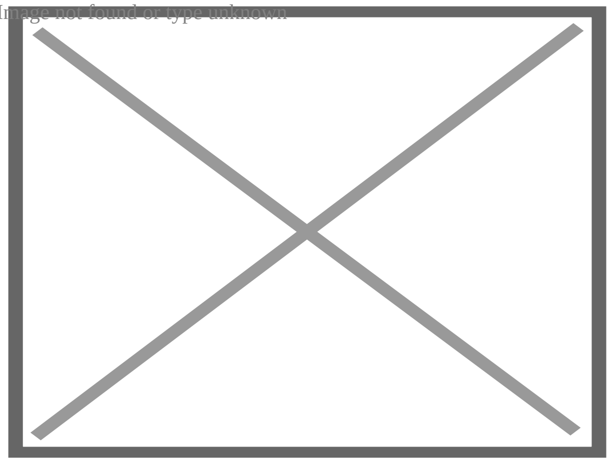


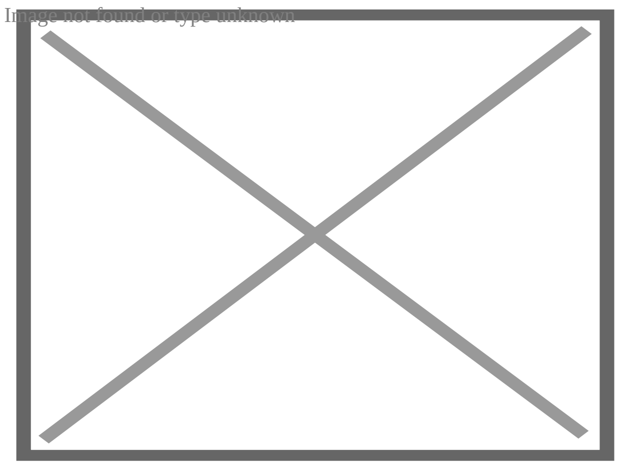
Hybrid photovoltaic-thermal solar panels of a SAHP in an experimental installation at Department of Energy at Polytechnic of Milan

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]

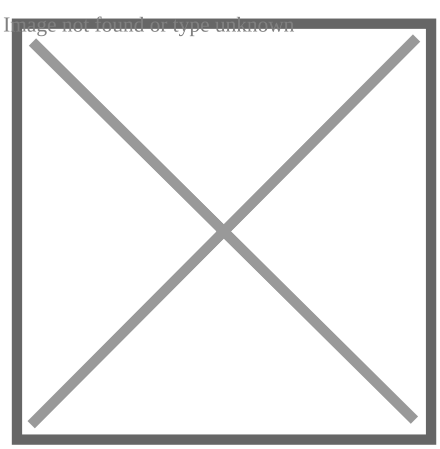
In HVAC applications, a heat pump is typically a vapor-compression refrigeration device that includes a reversing valve and optimized heat exchangers so that the direction of *heat flow* (thermal energy movement) may be reversed. The reversing valve switches the direction of refrigerant through the cycle 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 CO_2 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)	45 °C (e.g. heated screed floor)	55 °C (e.g. heated tim
High-efficiency air-source heat pump (ASHP), air at ?20 °C[56]		2.2	2.0	ÃƒÆ’Ã‚Â¢ÃƒÂ¢Ã¢â‚¬Å
Two-stage ASHP, air at ?20 °C[57]	Low source temperature	*2.4*	2.2	1.9
High-efficiency ASHP, air at 0 °C[56]	Low output temperature	*3.8*	2.8	2.2
Prototype transcritical CO_2 (R744) heat pump with tripartite gas cooler, source at 0 °C[58]	High output temperature	3.3	ÃƒÆ’Ã‚Â¢ÃƒÂ¢Ã¢â‚¬Å¡Ã‚Â¬Ãƒâ€šÃ‚•ÃƒÆ’Ã‚Â¢ÃƒÂ¢Ã¢â‚¬Å	
Ground-source heat pump (GSHP), water at 0 °C[56]		5.0	3.7	2.9
GSHP, ground at 10 °C[56]	Low output temperature	*7.2*	5.0	3.7

Theoretical Carnot cycle limit, source ?20 °C	5.6	4.9	4.4
Theoretical Carnot cycle limit, source 0 °C	8.8	7.1	6.0
Theoretical Lorentzen cycle limit (CO_2 pump), return fluid 25 °C, source 0 °C[58]	10.1	8.8	7.9
Theoretical Carnot cycle limit, source 10 °C	12.3	9.1	7.3

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

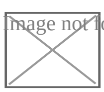
In most settings, heat pumps will reduce CO_2 emissions compared to heating systems powered by fossil fuels.[62] In regions accounting for 70% of world energy consumption, the emissions savings of heat pumps compared with a high-efficiency gas boiler are on average above 45% and reach 80% in countries 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



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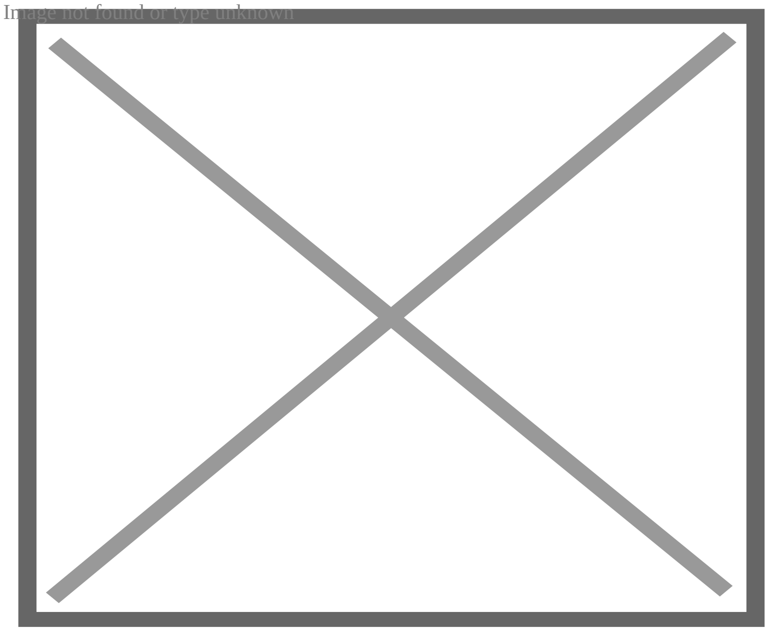
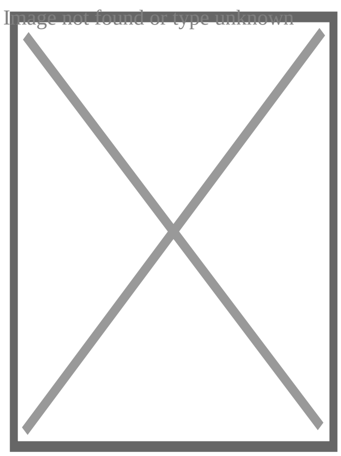
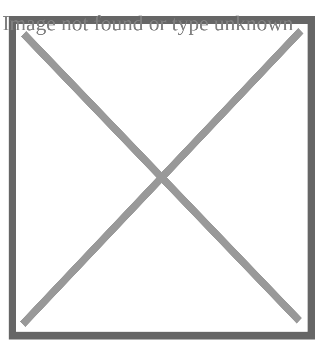


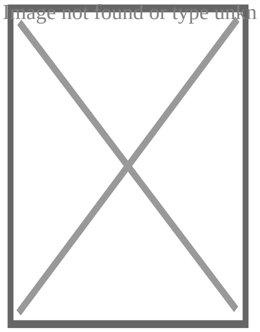
Figure 2: Temperature–entropy diagram of the vapor-compression cycle



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 that 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 ?25 °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 CO_2, 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

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1. **^** As explained in Coefficient of performance TheoreticalMaxCOP = (desiredIndoorTempC + 273) ÷ (desiredIndoorTempC - outsideTempC) = (7+273) ÷ (7 - (-3)) = 280÷10 = 28 [10]
2. **^** As explained in Coefficient of performance TheoreticalMaxCOP = (desiredIndoorTempC + 273) ÷ (desiredIndoorTempC - outsideTempC) = (27+273) ÷ (27 - (-3)) = 300÷30 = 10[10]

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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
Professions, trades, and services	○ 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

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)

See also

- ASHRAE Handbook
- Building science
- Fireproofing
- Glossary of HVAC terms
- Warm Spaces
- World Refrigeration Day
- Template:Home automation
- Template:Solar energy

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About Royal Supply South

Things To Do in Arapahoe County

Photo

Blue Grama Grass Park

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Plains Conservation Center (Visitor Center)

4.6 (393)

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Museum of Outdoor Arts

4.5 (397)

Photo

Morrison Nature Center

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Clock Tower Tours

4.1 (7)

Photo

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Cherry Creek State Park

4.6 (9044)

Driving Directions in Arapahoe County

Driving Directions From U.S. Bank ATM to Royal Supply South

Driving Directions From Walgreens to Royal Supply South

Driving Directions From Mullen High School to Royal Supply South

Driving Directions From Arapahoe County Assessor to Royal Supply South

Mobile home supply store

Air conditioning repair service

Air conditioning store

Air conditioning system supplier

Furnace repair service

Furnace store

Driving Directions From Cherry Creek State Park to Royal Supply South

Driving Directions From Plains Conservation Center (Visitor Center) to Royal Supply South

Driving Directions From Denver Museum of Nature & Science to Royal Supply South

Driving Directions From Cherry Creek State Park to Royal Supply South

Driving Directions From The Aurora Highlands North Sculpture to Royal Supply South

Driving Directions From Molly Brown House Museum to Royal Supply South

Mobile Home Furnace Installation

Mobile Home Air Conditioning Installation Services

Mobile Home Hvac Repair

Reviews for Royal Supply South

Calibrating Equipment for Reliable Measurements**View GBP**

Frequently Asked Questions

Why is calibration necessary for HVAC equipment in mobile homes?

Calibration ensures that HVAC equipment operates efficiently and accurately measures temperature, pressure, and airflow. This reliability is crucial for maintaining comfort, energy efficiency, and preventing costly repairs.

How often should HVAC equipment be calibrated in a mobile home?

It is recommended to calibrate HVAC equipment at least once a year or whenever there are noticeable performance issues. Regular maintenance schedules may vary based on manufacturer guidelines and usage patterns.

What tools are needed to calibrate an HVAC system in a mobile home?

Essential tools include a manometer for measuring pressure, a digital thermometer for checking temperature accuracy, anemometers for airflow measurement, and sometimes specialized software provided by the manufacturer.

Can I perform the calibration of my mobile homes HVAC system myself?

While some basic checks can be done by homeowners, such as replacing filters or ensuring vents are unobstructed, comprehensive calibration typically requires professional expertise to ensure precision and safety.

What signs indicate that my mobile homes HVAC system might need recalibration?

Signs include inconsistent temperatures across rooms, unusual noises from the unit, increased energy bills without added usage, or frequent cycling on/off. These symptoms suggest it’s time to check calibration settings.

Royal Supply Inc

Phone : +16362969959

City : Wichita

State : KS

Zip : 67216

Address : Unknown Address

Google Business Profile

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