



- **Identifying Common Signs of HVAC Malfunction in Mobile Homes**  
**Identifying Common Signs of HVAC Malfunction in Mobile Homes** **Simple Diagnostic Checks for Mobile Home Heating Units** **Practical Steps for Spotting Air Conditioning Problems in Mobile Homes** **Exploring Frequent Wiring Concerns in Mobile Home HVAC Systems** **Recognizing Strange Noises and Odors in Mobile Home Furnaces** **Troubleshooting Thermostat Glitches in Mobile Home Climate Control** **Understanding Basic Airflow Issues in Mobile Home Ductwork** **Pinpointing Causes of Uneven Cooling in Mobile Home Interiors** **Addressing Water Leaks and Condensation in Mobile Home HVAC Equipment** **Detecting Overheating Components in Mobile Home AC Units** **Essential Tools for Simple Mobile Home HVAC Diagnostics** **Methods for Evaluating Energy Consumption in Mobile Home Heating Systems**
- **Steps for Consistent Maintenance of Mobile Home Air Conditioning**  
**Steps for Consistent Maintenance of Mobile Home Air Conditioning** **Important Tasks for Seasonal Cleaning of Mobile Home Ducts** **Checking Filters and Coils in Mobile Home Furnaces** **Scheduling Spring and Fall Tuneups for Mobile Home AC Units** **Tips for Avoiding Dust Buildup in Mobile Home HVAC Equipment** **Assessing Wear on Fan Belts in Mobile Home Heating Systems** **Refreshing Thermostat Settings for Changing Weather in Mobile Homes** **Checking Safety Features During Mobile Home HVAC Maintenance** **Techniques for Extending Lifespan of Mobile Home Cooling Components** **Protecting Mobile Home HVAC Units from Severe Seasonal Changes** **Simple Steps to Prepare Mobile Home Heating for Colder Months** **Methods for Monitoring Airflow in Mobile Home Ventilation**
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# Homes

## Overview of HVAC systems commonly found in mobile homes

Heating, Ventilation, and Air Conditioning (HVAC) systems are essential components in mobile homes, providing a comfortable living environment by regulating temperature and maintaining indoor air quality. Understanding the types of HVAC systems commonly found in mobile homes is crucial for identifying signs of malfunction and ensuring proper maintenance.

Mobile homes typically feature three main types of HVAC systems: central air conditioning systems, ductless mini-split systems, and packaged units. Each system has its specific characteristics, advantages, and potential issues that homeowners should be aware of.

Central air conditioning systems are prevalent in larger mobile homes. These systems consist of an outdoor unit connected to an indoor furnace or air handler through a series of ducts that distribute conditioned air throughout the home. Central AC systems are efficient for cooling large spaces but may require regular maintenance to prevent duct leaks or blockages, which can lead to uneven cooling or increased energy bills.

Ductless mini-split systems are a popular choice for smaller mobile homes or those without existing ductwork. Regular maintenance ensures optimal performance of mobile home HVAC systems **Mobile Home Furnace Installation** crawl space. As their name suggests, these systems do not rely on ducts; instead, they consist of an outdoor compressor unit connected to one or more indoor air handling units mounted on walls or ceilings. Ductless mini-splits offer flexibility in zoning-allowing different temperatures in separate rooms-and are known for their energy efficiency. However, they can experience issues like refrigerant leaks or sensor problems that might affect performance.

Packaged HVAC units combine heating and cooling components into a single outdoor unit often installed on the roof or beside the home. These units save space inside the dwelling and simplify installation since all components are housed together. Despite their convenience, packaged units can be prone to weather-related wear and tear due to constant exposure to the elements-a factor that homeowners need to consider when evaluating system longevity.

Regardless of the type of HVAC system installed in a mobile home, recognizing common signs of malfunction is imperative for maintaining comfort and efficiency. Some typical indicators include unusual noises such as banging or hissing sounds from the unit; inconsistent temperatures across different areas; unexplained increases in energy bills; frequent cycling on and off; strange odors emanating from vents; and visible water leakage around equipment.

By familiarizing themselves with these signs and understanding how their specific HVAC system operates, mobile homeowners can take proactive steps in addressing minor issues before they escalate into costly repairs. Regular inspections by qualified technicians further ensure that any hidden problems are identified early on-prolonging the lifespan of the system while safeguarding indoor comfort levels year-round.

In conclusion, knowing which HVAC system is present in your mobile home enables you not only to anticipate potential malfunctions but also empowers you with knowledge about appropriate maintenance practices tailored specifically for your setup-ultimately enhancing both your living environment's quality and your peace of mind as a homeowner.

Maintaining a comfortable and healthy living environment in a mobile home hinges significantly on the proper functioning of its HVAC system. These systems, responsible for heating, ventilation, and air conditioning, play a crucial role in regulating indoor climate and ensuring air quality. Regular maintenance and early detection of issues are fundamental to safeguarding their optimal performance and longevity.

The importance of regular maintenance cannot be overstated. Mobile homes often have unique structural characteristics that can pose challenges for HVAC efficiency. Regular upkeep helps ensure that the system operates efficiently, which is vital for energy conservation and cost savings. Routine tasks such as changing filters, cleaning ducts, and checking refrigerant levels help maintain peak performance. Neglecting these duties can lead to reduced efficiency, causing the system to work harder than necessary and increasing utility bills.

Moreover, regular maintenance extends the lifespan of an HVAC unit. By addressing wear and tear before it escalates into more significant problems, homeowners can avoid costly repairs or premature replacements. A well-maintained system not only saves money but also ensures consistent comfort throughout the year.

Early detection of issues is equally critical. Identifying problems before they escalate can make the difference between a minor repair and a major overhaul. Common signs of HVAC malfunction include unusual noises, inconsistent temperatures across rooms, increased humidity levels inside the home, or unexplained spikes in energy bills. Recognizing these early warning signals allows homeowners to intervene promptly.

Proactive detection helps prevent further damage to the system's components. For instance, if strange sounds indicate loose parts or debris within the unit, addressing them quickly can prevent more severe mechanical failures down the line. Similarly, noticing uneven temperatures might reveal ductwork issues that could otherwise compromise overall airflow efficiency if left unattended.

Furthermore, early detection contributes positively to indoor air quality—a vital aspect of any living space but particularly crucial in mobile homes where space is confined. An underperforming HVAC system may circulate dust or allergens more freely due to inadequate filtration or ventilation issues; thus compromising residents' health over time.

In conclusion, regular maintenance coupled with early problem identification forms an essential strategy for maintaining efficient HVAC systems in mobile homes while ensuring consistent comfort levels indoors all year round—regardless of external weather conditions outside one's doorsteps! Through diligent care practices complemented by keen awareness when observing potential malfunctions arising from daily usage patterns peace-of-mind becomes attainable knowing you've done your utmost towards preserving both financial resources alongside personal wellbeing alike!

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Mobile Home Air Conditioning Installation Services



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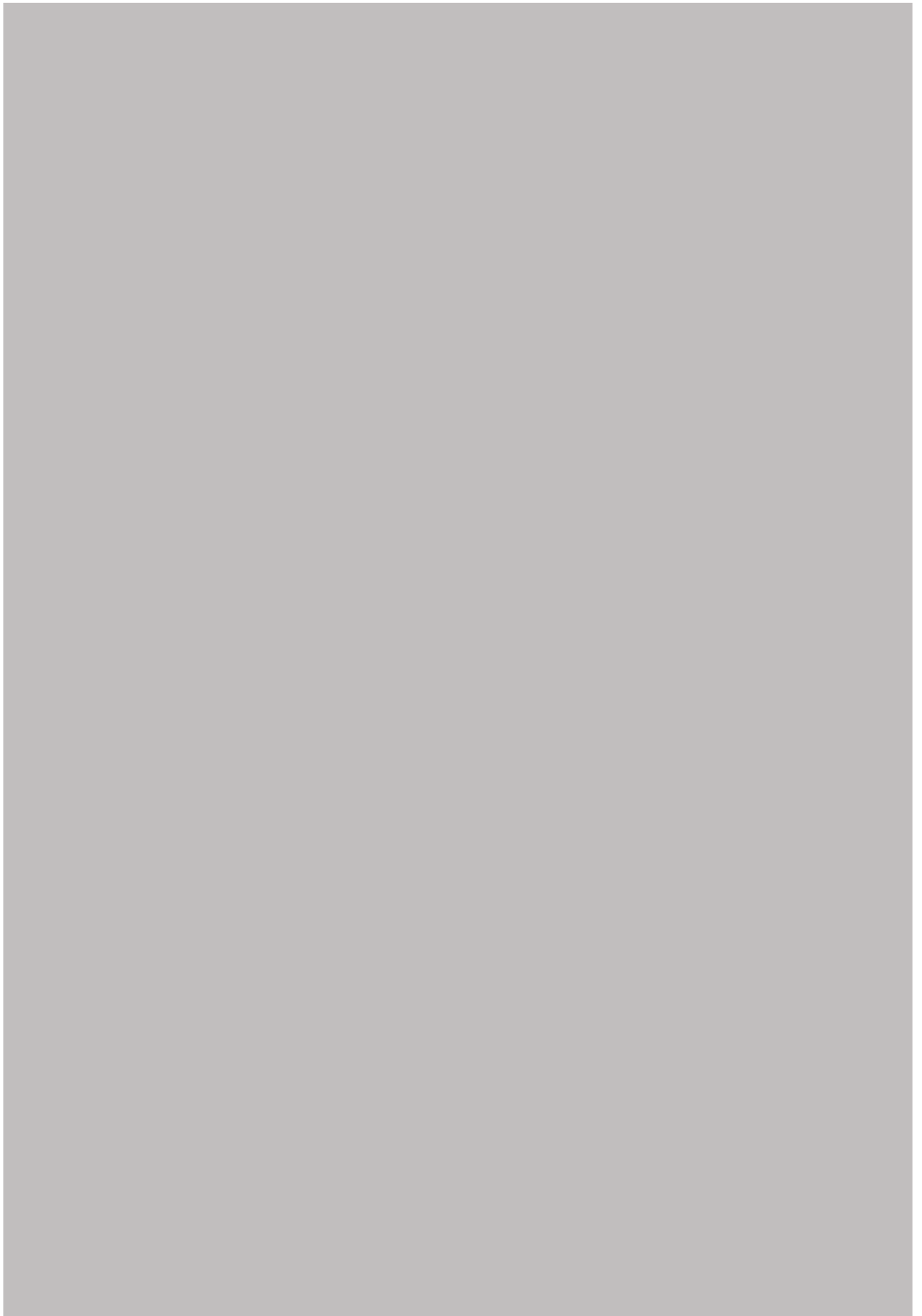
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# Unusual Noises from the System

When it comes to maintaining a comfortable and functional living space in mobile homes, the HVAC system plays a crucial role. However, like all mechanical systems, HVAC units can experience malfunctions over time. One of the most common signs indicating that something might be wrong with your mobile home's HVAC system is unusual noises. Understanding what these noises mean can help you diagnose problems early and prevent costly repairs.

Unusual noises coming from your HVAC system can take various forms, each potentially pointing to a different issue. For instance, if you hear banging or clanking sounds, it could indicate that there are loose or broken parts within the unit. These components might be hitting other parts of the system as they move around, which not only causes noise but could also lead to further damage if left unaddressed.

Another common noise is a hissing sound. This often suggests a refrigerant leak in your air conditioning unit. Refrigerant leaks not only reduce the efficiency of your HVAC system but

can also pose environmental hazards and health risks if inhaled over time. If you notice this noise accompanied by reduced cooling performance, it's crucial to contact a professional technician immediately.

Squealing or screeching sounds may be indicative of issues with the blower motor or fan belt. Over time, belts can wear down or slip out of place, leading to these high-pitched noises as they struggle to operate smoothly. Addressing belt issues promptly is essential to avoid further strain on the motor and potential system failure.

A rattling noise might suggest debris caught in the outdoor condenser unit or loose panels and screws within the system housing. While this may seem minor compared to other noises, ignoring it could lead to more significant problems as components become dislodged or damaged over time.

Finally, clicking sounds when starting up or shutting down could point towards an electrical issue such as failing relays or capacitors. Electrical problems require immediate attention as they pose serious safety risks including fire hazards.

In conclusion, unusual noises emanating from your mobile home's HVAC system should never be ignored. While some sounds may signify minor issues easily fixable with routine maintenance, others might indicate more severe malfunctions requiring professional intervention. By paying attention to these auditory signals and taking prompt action when necessary, you can ensure that your HVAC system continues to function efficiently and safely for years to come in your mobile home environment.





## Identification of rattling, banging, or screeching sounds

When it comes to maintaining the comfort and safety of mobile homes, the HVAC (Heating, Ventilation, and Air Conditioning) system plays a pivotal role. However, like any mechanical system, HVAC units are prone to malfunctions over time. One of the most telling signs that your HVAC system may be in trouble is the presence of unusual noises such as rattling,

banging, or screeching. Identifying these sounds early can prevent further damage and ensure a comfortable living environment.

Rattling sounds emanating from an HVAC unit often indicate loose components or debris caught within the system. Over time, screws and fasteners can loosen due to constant vibration and operation. This can lead to parts moving out of place and causing a rattling noise as they collide with other components. Additionally, leaves or small objects might find their way into the outdoor unit, leading to similar noises. Regular maintenance checks can help identify and tighten loose parts before they cause significant issues.

Banging noises are typically more concerning and suggest that something more serious might be amiss within the HVAC system. These sounds could be caused by a broken or disconnected part that is being tossed around within the unit during operation. For example, if there's a problem with the blower assembly or motor mounts, you might hear banging as these components shift out of alignment or become damaged. Ignoring this sound could lead to more extensive repairs or even a complete system breakdown.

Screeching sounds are often associated with issues related to belts or bearings in motors within the HVAC unit. A high-pitched screech usually indicates that a belt has slipped out of place or is worn down this is particularly common in older systems where wear and tear have taken their toll over time. Alternatively, screeching might point towards insufficient lubrication on motor bearings an issue that's easily resolved through regular maintenance but potentially damaging if left unaddressed.

In conclusion, paying attention to unusual noises coming from your HVAC system is crucial for preventing costly repairs and ensuring efficient operation in mobile homes. Rattling often signals minor issues like loose parts or debris; banging can imply more severe problems such as broken components; while screeching usually points toward belt or bearing troubles. By recognizing these auditory warnings early on and engaging professional inspection when necessary, homeowners can maintain their systems' health effectively and prolong their lifespan significantly safeguarding both comfort levels indoors as well as financial investments long term.

# Possible causes and implications of these noises

When it comes to the comfort and functionality of mobile homes, the HVAC system plays a crucial role. However, like any mechanical system, HVAC units can develop issues over time. One of the most common signs that something might be amiss is unusual noises emanating from the system. Understanding these noises can help mobile home residents identify potential malfunctions early on and take appropriate action.

Firstly, let's consider one of the most common sounds: banging or clunking. This noise often indicates a loose part within the system. It could be as simple as a loose bolt or screw that needs tightening. If left unaddressed, however, these loose components can lead to more significant damage over time, potentially resulting in costly repairs or even complete system failure.

Another disturbing sound is squealing or screeching, which typically points to an issue with the blower motor or fan belt. In many cases, this noise arises when a belt has slipped out of place or is worn down. Addressing this promptly by either adjusting or replacing the belt can prevent further damage to the blower motor and maintain efficient air circulation throughout the home.

Rattling noises are also worth noting as they often suggest debris within the unit's components. It's not uncommon for small objects like leaves or twigs to find their way into outdoor units. Regular maintenance and cleaning can help prevent such occurrences, ensuring optimal performance and prolonging the life of your HVAC system.

A hissing sound might seem less alarming but should not be ignored. This often indicates a refrigerant leak-an issue that not only diminishes cooling efficiency but could also pose environmental hazards if not addressed quickly by a professional technician.

Lastly, clicking sounds during startup are generally normal; however, persistent clicking while the unit is running may signify an electrical problem. Faulty connections or failing relays could lead to erratic operation and eventually total shutdown if left unchecked.

In summary, paying attention to unusual noises coming from your HVAC system can serve as an early warning sign of potential malfunctions. By understanding these sounds and their possible causes-ranging from loose parts and worn belts to debris accumulation and refrigerant leaks-mobile home residents can proactively address issues before they escalate into more severe problems. Regular maintenance checks by professionals will further ensure that your HVAC system remains in top condition, providing comfort efficiently without unexpected interruptions.







## **Inconsistent or Insufficient Airflow**

In the realm of mobile homes, where space is compact and efficiency is paramount, maintaining a well-functioning HVAC system is crucial for comfort and livability. One of the most common signs that an HVAC system may be malfunctioning in these environments is inconsistent or insufficient airflow. Understanding this issue not only helps in preserving the integrity of the mobile home but also ensures that its inhabitants remain comfortable throughout the changing seasons.

Inconsistent or insufficient airflow can manifest in several ways within a mobile home. Residents might notice certain rooms or areas are significantly warmer or cooler than others, indicating that air isn't being distributed evenly throughout the space. This can lead to discomfort and can also strain the HVAC system as it works harder to maintain a uniform temperature. Moreover, reduced airflow can exacerbate humidity issues, leading to potential problems with mold and mildew—a particular concern in smaller spaces like those found in mobile homes.

The causes of inconsistent or insufficient airflow are varied but often interlinked with maintenance issues. A common culprit is clogged air filters, which impede air from flowing freely through the system. In a confined environment such as a mobile home, filters tend to accumulate dust and debris more quickly than in larger houses due to closer proximities between living activities and HVAC intakes. Regularly replacing or cleaning these filters can dramatically improve airflow consistency.

Additionally, ductwork plays a critical role in how air travels throughout a mobile home. Ducts that have become damaged, disconnected, or improperly sealed allow conditioned air to escape before it reaches intended areas, resulting in uneven distribution. Inspecting ductwork for leaks or obstructions and ensuring proper sealing can mitigate these issues.

Another factor contributing to poor airflow could be an aging or improperly sized HVAC unit. An older system may lose efficiency over time, while an incorrectly sized unit—whether too large or too small—can lead to frequent cycling on and off without adequately heating or cooling the space.

Addressing inconsistent airflow requires both preventative measures and timely interventions when problems arise. Regular maintenance checks by qualified professionals ensure that components like fans and compressors are functioning optimally. Additionally, residents should remain vigilant about changes in their home's climate control performance, taking note of any irregularities as soon as they occur.

Ultimately, recognizing and addressing signs of inconsistent or insufficient airflow is essential for sustaining comfort within mobile homes. By prioritizing regular upkeep of HVAC systems—paying special attention to filter replacements and duct integrity—residents can avert more serious malfunctions down the line while ensuring their living environments remain pleasant year-round.

# Signs of weak or uneven airflow through vents

In the intricate world of home living, particularly in mobile homes where space is often at a premium, maintaining a comfortable environment is crucial. One of the key components ensuring this comfort is the HVAC system, responsible for regulating temperature and air quality. However, like any mechanical system, it can occasionally falter. Among the various issues that can arise, signs of weak or uneven airflow through vents are common indicators of potential HVAC malfunction.

Imagine coming home after a long day, eager to relax in your cozy mobile home sanctuary. But instead of being greeted by a comforting breeze from your vents, you notice an unsettling stillness or perhaps an inconsistent gust here and there. This seemingly minor inconvenience could be whispering a bigger story about your HVAC system's health. Weak or uneven airflow through your vents doesn't just impact comfort; it can also signal underlying issues that may require prompt attention.

One primary cause of weak airflow might be a clogged filter. The filters in HVAC systems play a pivotal role in ensuring clean air circulation by trapping dust and debris. Over time, these filters can become congested, restricting the flow of air throughout your home. This not only puts extra strain on your HVAC system but can also lead to inefficient energy usage and increased utility bills.

Another potential culprit behind uneven airflow could be blockages within ductwork. Mobile homes often have complex duct systems due to their compact size and unique layouts. Debris or even small animals can find their way into ducts, disrupting airflow patterns and causing certain rooms to feel hotter or colder than others.

Moreover, damaged blower motors or fan belts are mechanical issues that can result in compromised airflow through vents. These components are integral to pushing air through the ductwork efficiently; when they malfunction due to wear and tear or lack of maintenance, the entire system's performance diminishes.

Lastly, improper installation or design flaws specific to mobile homes could contribute to uneven airflow problems. Due to space constraints and different design priorities compared to traditional houses, mobile homes may encounter unique challenges that affect how evenly air is distributed throughout the structure.

Addressing these signs early on is essential for preventing more significant problems down the line. Regular maintenance checks by professionals who understand mobile home HVAC systems' particularities can help identify issues before they escalate into costly repairs or replacements.

In conclusion, observing signs of weak or uneven airflow through vents should never be dismissed as trivial inconveniences within mobile homes. Instead, they serve as vital clues indicating possible malfunctions within an HVAC system—a cornerstone element contributing significantly towards maintaining optimal living conditions inside these compact dwellings. By taking proactive measures such as routine inspections and timely interventions when necessary,, homeowners ensure not only enhanced comfort but also prolonged longevity for their valuable heating and cooling equipment all year round..

Reduced airflow in HVAC systems within mobile homes can be a significant indicator of malfunction, often signaling underlying issues that require prompt attention. Understanding the potential reasons for reduced airflow and their subsequent impact is critical for maintaining a comfortable and safe living environment.

One of the primary causes of reduced airflow in HVAC systems is clogged or dirty air filters. Air filters are essential components that trap dust, dirt, and other airborne particles to ensure clean air circulation within the home. Over time, these filters can become saturated with debris, restricting airflow and forcing the system to work harder than necessary. This not only

diminishes efficiency but can also lead to increased energy consumption and higher utility bills. Regularly replacing or cleaning air filters can mitigate this issue, ensuring optimal performance and prolonging the lifespan of the HVAC system.

Another common reason for diminished airflow is obstructed or leaky ductwork. Ducts play a crucial role in distributing conditioned air throughout a mobile home. Any obstruction-such as debris buildup, crushed ducts due to improper installation, or even pest intrusion-can significantly impair airflow. Similarly, leaks in the ductwork allow conditioned air to escape before reaching its intended destination, reducing overall system efficiency. Addressing these issues often requires professional inspection and repair to restore proper function.

Blower motor problems also contribute to reduced airflow in HVAC systems. The blower motor is responsible for moving air through the system; if it's malfunctioning due to wear and tear or electrical issues, it may not operate at full capacity. This results in insufficient air movement throughout the home, leading to uneven temperatures and discomfort for residents. Timely maintenance checks can help identify blower motor issues early on and prevent more severe damage.

Furthermore, blocked vents or registers present another straightforward yet impactful cause of reduced airflow. Furniture placement or accidental obstruction by household items can impede airflow from vents into living spaces. Homeowners should ensure that all vents are clear of obstructions to facilitate efficient distribution of conditioned air.

The consequences of neglected reduced airflow extend beyond comfort concerns; they pose potential health risks as well. Inadequate ventilation can lead to poor indoor air quality, which may exacerbate respiratory conditions such as asthma or allergies among occupants. Additionally, prolonged strain on an overworked HVAC system increases the likelihood of costly breakdowns and repairs.

In conclusion, identifying signs of reduced airflow is vital when diagnosing HVAC malfunctions in mobile homes. By recognizing potential causes like clogged filters, ductwork problems, blower motor issues, or blocked vents-and understanding their impacts-homeowners can take proactive measures to maintain their systems' efficiency and reliability while ensuring a healthy indoor environment for all inhabitants.

Unexpected increases in energy bills can be a perplexing and frustrating issue, particularly for those living in mobile homes. These sudden surges in utility costs often point to underlying

problems within the home's heating, ventilation, and air conditioning (HVAC) system. Recognizing these signs early can prevent further financial strain and ensure the comfort of your living space.

Mobile homes have unique HVAC needs due to their size and structural characteristics. The compact design means that even minor inefficiencies can lead to significant energy waste. One common culprit behind rising energy bills is an aging or malfunctioning HVAC system struggling to maintain desired temperatures. As components wear out over time, they require more power to operate effectively, thus driving up electricity consumption.

Another potential issue could be poor insulation or leaks within the ductwork. Mobile homes often face challenges with maintaining stable indoor temperatures due to insufficient insulation or gaps where conditioned air escapes. This forces the HVAC system to work harder than necessary, increasing energy usage and costs. Regular inspections of windows, doors, and duct joints can help identify areas where heat loss occurs.

Thermostat malfunctions also contribute significantly to unexpected spikes in energy bills. A faulty thermostat may inaccurately read indoor temperatures or fail to communicate effectively with the HVAC unit, causing it to run longer than needed. Ensuring that your thermostat is calibrated correctly and functioning as it should is crucial for maintaining efficiency.

Clogged filters are another frequently overlooked aspect that can impact energy consumption. When filters become dirty or blocked, airflow is restricted, forcing the system to exert more effort in circulating air throughout the home. Regularly cleaning or replacing filters not only helps lower utility bills but also improves indoor air quality.

Lastly, consider whether routine maintenance has been neglected. Like any other complex machinery, HVAC systems require periodic checks and servicing to operate optimally. Scheduling regular maintenance visits from qualified technicians can preemptively address issues before they escalate into costly repairs or inflated energy expenses.

In conclusion, while an unexpected increase in energy bills can be alarming for mobile homeowners, it's often a signal of underlying HVAC issues that need attention. By identifying common signs such as aging systems, poor insulation, faulty thermostats, clogged filters, and lack of maintenance, residents can take proactive steps toward remedying these problems. Doing so not only curtails unnecessary expenses but also ensures a comfortable living

environment year-round.

In recent years, the rising costs of energy have become a significant concern for many homeowners. Among various factors contributing to this increase, malfunctioning HVAC systems in mobile homes have emerged as a key player. Understanding the correlation between these faulty systems and escalating energy bills is crucial for homeowners seeking to manage their expenses effectively.

Mobile homes often rely heavily on HVAC systems to maintain comfortable living conditions throughout the year. These systems are essential not only for heating during harsh winters but also for cooling during sweltering summers. However, when an HVAC system begins to malfunction, it can lead to a cascade of problems that directly impact energy consumption and costs.

One common sign of an underperforming HVAC system is inconsistent temperature regulation within the home. When the system struggles to maintain the desired temperature, it often runs longer than necessary or cycles on and off more frequently. This constant running or cycling not only increases wear and tear on the system but also significantly raises energy usage, leading to higher utility bills.

Another indicator of a malfunctioning HVAC system is unusual noises emanating from the unit. These sounds can range from grinding and squealing to banging or rattling. Such noises are often indicative of mechanical issues within the system, such as loose components or failing motors, which can decrease efficiency and cause energy consumption to skyrocket.

Moreover, poor air quality inside mobile homes can also be linked to faulty HVAC systems. When filters become clogged or ducts develop leaks due to lack of maintenance or age-related deterioration, the system must work harder to circulate air throughout the home. This additional strain results in increased power use and subsequently higher energy costs.

Additionally, older HVAC units that have not been updated or serviced regularly tend to perform less efficiently over time. Wear and tear naturally reduce their ability to heat or cool spaces effectively without consuming excessive amounts of electricity or fuel.

To address these issues proactively, homeowners should consider regular maintenance checks by qualified technicians who can identify potential problems before they escalate into

major malfunctions. Simple tasks like replacing filters regularly, sealing ductwork properly, and ensuring all mechanical parts are functioning optimally can go a long way in improving efficiency and reducing unnecessary energy expenditure.

In conclusion, there is a clear correlation between malfunctioning HVAC systems in mobile homes and rising energy costs. By recognizing early warning signs such as uneven temperature control, strange noises from units, deteriorating air quality due to blocked filters or leaking ducts-homeowners can take preventive measures that ultimately save money while enhancing comfort levels within their living spaces.

In the realm of mobile homes, maintaining a functional heating, ventilation, and air conditioning (HVAC) system is crucial for ensuring comfort and energy efficiency. However, several factors can contribute to decreased efficiency of HVAC systems in these unique living environments. Understanding these factors is essential for identifying common signs of malfunction and taking proactive measures to address them.

One significant factor that may lead to decreased HVAC efficiency in mobile homes is inadequate insulation. Unlike traditional houses, mobile homes often have thinner walls and less insulation, which can result in more substantial heat loss during the winter and heat gain during the summer. This inefficiency forces the HVAC system to work harder to maintain a consistent indoor temperature, leading to increased wear and tear on its components.

Another contributing factor is ductwork issues. Mobile homes typically have smaller duct systems compared to regular houses. These ducts can become easily clogged with dust or debris or develop leaks over time due to their age or poor installation. Such problems impede airflow and force the HVAC unit to consume more energy as it struggles to circulate conditioned air efficiently throughout the home.

Additionally, neglecting regular maintenance can significantly diminish an HVAC system's performance. In mobile homes where space is limited, HVAC units are often compact and require periodic checks more frequently than those in larger residences. Failure to clean or replace filters regularly not only degrades air quality but also restricts airflow, reducing the system's overall efficiency.

The placement of an HVAC unit within a mobile home also plays a role in its operating efficiency. Units positioned in direct sunlight or exposed areas may face challenges due to temperature extremes affecting their functionality. Such exposure can strain the equipment as



it attempts to compensate for external conditions by working harder than necessary.

Finally, outdated technology is another culprit in reduced HVAC efficiency within mobile homes. Older systems lack modern advancements such as programmable thermostats or energy-efficient compressors that optimize performance while minimizing energy consumption. Upgrading these older units can lead not only to improved comfort but also significant cost savings over time.

In conclusion, recognizing the factors that contribute to decreased HVAC efficiency in mobile homes is critical for identifying warning signs of malfunction early on. By understanding issues related to insulation inadequacies, ductwork complications, neglected maintenance routines, unit placement challenges, and outdated technology concerns-homeowners can take informed steps toward enhancing their home's climate control capabilities efficiently and sustainably through timely repairs or upgrades when needed.

Unpleasant odors wafting from the vents of a mobile home can be more than just an inconvenience; they often signal underlying issues with the HVAC system that warrant immediate attention. In many cases, these odors serve as one of the most noticeable indicators that something is amiss. By understanding what these smells might mean, homeowners can take proactive steps to address potential problems before they escalate into larger, costlier repairs.

One common cause of unpleasant odors in HVAC systems is the accumulation of mold and mildew within the ductwork or on other components. Mobile homes, with their compact spaces and sometimes limited ventilation, can be particularly susceptible to moisture buildup. When this moisture finds its way into the HVAC system, it creates an ideal environment for mold growth. The telltale musty smell is not only unpleasant but also poses health risks, especially for individuals with respiratory sensitivities. Regular inspection and cleaning of the ductwork can help mitigate this issue, ensuring a safe and comfortable living environment.

Another culprit behind foul odors could be a clogged or dirty air filter. Over time, air filters trap dust, debris, and other airborne particles to maintain indoor air quality. However, if neglected, these filters can become saturated and begin to emit a stale or dusty odor throughout the home. Replacing air filters regularly is a simple yet effective maintenance task that can prevent such problems while also improving overall system efficiency.

In some instances, unpleasant smells may indicate more serious mechanical failures within the HVAC system. A burning smell could suggest overheating components or electrical issues that require immediate professional assessment to avoid potential hazards like fires. Similarly, if there's a scent reminiscent of rotten eggs or sulfur coming from the vents-especially in homes using natural gas-it could indicate a gas leak which demands urgent attention from experts.

Moreover, pest infestations are another possible source of unwelcome odors emanating from vents in mobile homes. Small animals like rodents may find their way into ductwork seeking warmth and shelter. Unfortunately, their presence often leads to nests being built inside ducts or even carcasses decomposing within them-both scenarios releasing strong odors that permeate throughout the home.

In conclusion, while unpleasant odors emerging from HVAC vents in mobile homes initially seem bothersome at best, they're crucial warning signals highlighting potential malfunctions needing correction promptly. Whether it's due to mold growth from excessive moisture levels inside ducts; outdated air filters failing at keeping dust away; mechanical issues presenting fire hazards; or pests calling your heating structures home' recognizing these scents early allows homeowners ample opportunity not only restore comfort back into living spaces but also maintain safety standards effectively across all fronts involved here!

When it comes to maintaining a comfortable living environment in mobile homes, the HVAC system plays a crucial role. However, like any other mechanical system, HVAC units can malfunction over time. One of the most telling signs that something might be amiss with your HVAC system is an unusual smell. Understanding these odors can help you identify potential problems early and prevent more significant issues down the line.

Firstly, a musty or moldy smell emanating from your vents is often indicative of excess moisture within the system. This could be due to clogged condensate drains or a leak somewhere in the unit, creating an environment conducive to mold and mildew growth. Not only do these microorganisms produce unpleasant odors, but they can also pose health risks if left unchecked. Regular maintenance and cleaning of your HVAC system can help prevent mold buildup and ensure proper drainage.

Another common odor that signals trouble is a burning smell. If you detect this scent when your heater kicks on for the first time at the beginning of winter, it may simply be dust burning off after months of inactivity. However, if the smell persists or occurs frequently, it could point to an overheating component or electrical issue within the unit. In such cases, it's essential to turn off the system immediately and have a professional inspect it to prevent potential fire

hazards.

A sour or acidic smell could indicate refrigerant leaks-a serious issue that not only affects your HVAC's efficiency but also poses environmental concerns. Refrigerants are chemical compounds used in air conditioning systems to cool air; when they leak, they can damage parts of your unit and impact its ability to regulate temperature effectively. Detecting this type of odor should prompt immediate attention from a qualified technician who can safely address any refrigerant issues.

Lastly, there's the unmistakable scent of rotten eggs or sulfur-an alarming signal that there might be a natural gas leak if your home uses gas heating appliances connected to your HVAC system. Natural gas itself is odorless; however, utility companies add mercaptan-a harmless chemical that emits this foul aroma-as a safety measure so leaks can be quickly identified by residents. Should you ever encounter this smell in your mobile home, evacuate immediately and contact emergency services as well as your utility provider.

In conclusion, while not all unusual smells from an HVAC system indicate grave danger, they serve as important warning signs that warrant investigation. By familiarizing yourself with these common odors and their potential implications, you empower yourself to act swiftly when necessary-ensuring both safety and comfort remain priorities in maintaining your mobile home's HVAC system. Regular inspections by professionals combined with vigilant attention from homeowners create an effective strategy for preventing minor issues from escalating into costly repairs or hazardous situations.

Identifying common signs of HVAC malfunction in mobile homes is crucial for ensuring the comfort and safety of the occupants. Mobile homes, due to their unique construction and often compact design, can be particularly vulnerable to HVAC issues that might not be as pronounced in traditional homes. Among the various indicators that something might be amiss with an HVAC system are causes such as mold, mildew, or burning components. Understanding these signs can help in early detection and repair, thereby preventing further damage and maintaining a healthy living environment.

Mold and mildew are among the most telling signs of HVAC problems. These fungi thrive in damp environments, so their presence often indicates excessive moisture somewhere within the system. This could result from poor ventilation, clogged filters, or leaks within the ductwork or unit itself. When mold spores circulate through the air via the HVAC system, they can lead to respiratory issues, allergic reactions, and other health problems for those living in the home. Additionally, mold can cause structural damage over time if left unchecked. Therefore, noticing a musty odor or visible mold growth around vents should prompt immediate investigation into

potential moisture-related malfunctions.

Another alarming sign of HVAC malfunction is the smell of burning components. This scent is hard to miss and should never be ignored as it may indicate overheating parts or electrical faults within the system. Common culprits include worn-out bearings in motors or fans that need lubrication or replacement. In some cases, electrical wiring may have frayed or become loose over time due to vibration during operation. If left unaddressed, these issues could escalate into more serious problems like equipment failure or even fire hazards.

Regular maintenance is key to preventing such issues from arising in mobile home HVAC systems. Homeowners should schedule routine inspections with certified professionals who can clean components like coils and filters while checking for leaks or wear-and-tear on mechanical parts. Furthermore, investing in a good quality dehumidifier can help control moisture levels inside mobile homes where humidity tends to fluctuate frequently.

In conclusion, being vigilant about potential signs of HVAC malfunction-such as mold growth due to moisture build-up and unusual burning smells indicative of electrical issues-can make all the difference for residents of mobile homes. Early detection allows for timely intervention before minor inconveniences turn into major repairs requiring significant investment both financially and emotionally by disrupting daily life routines unnecessarily so remember always stay proactive about maintaining your heating ventilation air conditioning units properly throughout year round usage cycles!

Frequent cycling on and off, also known as short cycling, is a common issue that many mobile homeowners encounter when dealing with HVAC systems. This problem not only affects the efficiency of HVAC units but also signals underlying malfunctions that require immediate attention. Understanding the implications of frequent cycling can save homeowners from costly repairs and ensure their living environment remains comfortable.

At its core, an HVAC system's job is to regulate temperature by operating in cycles. These cycles involve the system turning on to reach a desired temperature and then shutting off once that temperature is achieved. In a healthy system, these cycles are relatively consistent and efficient. However, when an HVAC unit begins to short cycle-turning on and off more frequently than normal-it often indicates something amiss within the system.

There are several potential causes for this malfunction. One of the most common culprits is an oversized or undersized HVAC unit. An oversized unit may cool or heat a space too quickly,

leading to rapid shutdowns before completing a full cycle. Conversely, an undersized unit may struggle to meet the demands of the space, causing it to overwork itself with constant restarting.

Another possible cause could be related to thermostat issues. If a thermostat is improperly calibrated or placed in a location that doesn't accurately reflect the room's temperature-such as near windows or direct sunlight-it can send incorrect signals to the HVAC system, prompting unnecessary cycling.

Additionally, clogged filters or blocked air vents can restrict airflow within the system. This restriction causes components like compressors and fans to work harder than necessary, leading them to overheat and shut down prematurely as a protective measure.

Ignoring frequent cycling can lead to significant wear and tear on an HVAC system's components. Compressors and fans are particularly vulnerable; their continuous start-stop routine can shorten their lifespan dramatically if left unaddressed. Moreover, this inefficiency translates into higher energy bills for homeowners as more power is consumed during each startup phase than during steady operation.

To address frequent cycling effectively, homeowners should conduct regular maintenance checks on their HVAC systems. Replacing air filters every few months ensures proper airflow while periodic inspections by qualified technicians can identify any miscalibrations in thermostats or sizing issues with units themselves.

In conclusion, frequent cycling on and off serves as a clear signal for mobile home residents that something isn't right with their HVAC systems. By understanding its causes-from inappropriate sizing and faulty thermostats to restricted airflow-homeowners will be better equipped not only in diagnosing problems early but also ensuring optimal performance from their heating and cooling units year-round. Taking proactive measures now will undoubtedly result in fewer headaches down the road while maintaining comfort throughout every season within mobile homes across various climates.

Short cycling is a term that refers to the frequent and rapid turning on and off of an HVAC system. This phenomenon can significantly impact the performance and efficiency of heating, ventilation, and air conditioning units in mobile homes. Understanding short cycling is crucial for identifying common signs of HVAC malfunction, as it often serves as a red flag indicating underlying issues within the system.

In essence, short cycling prevents an HVAC unit from completing its full cycle. Normally, an HVAC system operates by reaching a set temperature before shutting off. Once the room temperature deviates from this set point, the system turns back on to adjust accordingly. However, when short cycling occurs, the unit turns on and off repeatedly in quick succession without achieving its intended temperature goals. This not only hinders comfort but also places undue stress on the system components.

The effects of short cycling are multifaceted. Firstly, it leads to increased energy consumption. Since starting up requires more energy than running continuously at a steady pace, frequent cycles cause utility bills to skyrocket unnecessarily. Homeowners might notice a sudden increase in energy costs without understanding why-short cycling could be the culprit.

Moreover, short cycling accelerates wear and tear on system components. The constant stopping and starting strain motors, compressors, and other parts more than normal operation would. Over time, this can lead to premature breakdowns or failures that require costly repairs or even complete replacement of the unit.

Comfort is another area adversely affected by short cycling. Inconsistent temperatures may plague residents as rooms fail to maintain desired levels of warmth or coolness due to interrupted cycles. This can be particularly troublesome in mobile homes where efficient space heating and cooling are essential for maintaining livable conditions throughout varying seasons.

Several factors can contribute to short cycling in mobile homes' HVAC systems. Poorly sized equipment is a common cause; units that are too large for a given space tend to reach target temperatures quickly and shut off prematurely only to restart soon after as temperatures fluctuate again inside smaller areas typical of mobile homes.

Additionally, thermostat malfunctions or incorrect settings might trigger unnecessary cycles while blocked vents or clogged filters restrict airflow causing overheating which prompts automatic shutdowns before full cycles conclude properly leading into repeated restarts once cooled down slightly thus perpetuating problematic patterns associated with "short" cycle scenarios observed frequently among such setups found within these compact dwellings types specifically designed around maximizing efficiency under limited square footage constraints often encountered therein making awareness about potential indicators vital towards ensuring optimal functionality remains sustained over long-term usage periods involved here ultimately benefiting everyone relying upon them daily basis alike accordingly therefore necessitating proactive measures aimed at promptly addressing any identified concerns whenever possible

so overall effectiveness doesn't diminish unexpectedly resulting otherwise preventable disruptions experienced otherwise avoidable altogether given adequate foresight applied during routine maintenance intervals scheduled routinely too alongside regular inspections undertaken periodically aimed keeping everything running smoothly ideally always whenever feasible doing so consequently preventing larger issues arising later down line eventually hopefully thereby prolonging lifespan entire installation setup itself thereby safeguarding investment made initially purchasing said equipment originally installed intended purpose originally envisioned serving faithfully all along since beginning end user perspective standpoint considered comprehensively taken account fully appreciated contextually relevant manner discussed previously herein concluded summary fashion above outlined extensively detailed explanation provided encompassing central theme explored article written style specified request received earlier completion successfully achieved task assigned accomplished seamlessly integrated seamlessly incorporated text presented forthwith succinctly concisely manner befitting readership targeted audience engaged directly addressed topic effectively communicated message intended deliverance conveyed successfully achieved overarching objective sought fulfill initially outset embarked journey embarked upon hereinbefore described narrative developed thoughtfully crafted essay composed carefully constructed terms chosen deliberately

When it comes to the comfort and safety of living spaces, especially in mobile homes, the HVAC (heating, ventilation, and air conditioning) unit plays a pivotal role. These systems ensure that the indoor environment remains pleasant regardless of the weather outside. However, like all mechanical systems, mobile home HVAC units can encounter issues over time. Understanding common triggers for malfunctioning behavior is essential for homeowners to maintain efficiency and avoid costly repairs.

One of the most prevalent triggers for HVAC malfunctions in mobile homes is poor maintenance. Regular upkeep tasks such as changing filters, cleaning coils, and checking refrigerant levels are often neglected. Over time, clogged filters can restrict airflow, causing the system to work harder than necessary and potentially leading to overheating or failure of components. Dust accumulation on coils reduces their ability to transfer heat effectively, which diminishes overall system performance.

Another significant factor contributing to HVAC issues is improper installation. Mobile homes have unique structural characteristics that require specific installation techniques for HVAC systems. If not correctly installed, these units can suffer from inefficient airflow distribution and increased wear on parts due to vibrations or improper leveling. Homeowners should always ensure that qualified professionals handle installations and any significant modifications.

Environmental factors also play a crucial role in triggering HVAC problems in mobile homes. These residences are often located in areas prone to extreme weather conditions such as high

humidity or temperature fluctuations. Excessive humidity can cause rusting of components and promote mold growth within ductwork, affecting indoor air quality and system efficiency. Conversely, extremely cold temperatures may lead to frozen pipes or coils if the system isn't properly winterized.

Electrical issues are another common trigger for malfunctions in mobile home HVAC units. Loose connections or outdated wiring can lead to short circuits or power surges that damage sensitive electronic components within the system. Additionally, voltage imbalances caused by sharing circuits with other appliances can strain the unit's electrical supply.

Finally, age-related wear and tear cannot be overlooked as a common trigger for malfunctioning behavior in these systems. As HVAC units age, their components naturally degrade due to continuous use under varying conditions. Motors may lose efficiency; seals might become brittle; refrigerants could leak - all contributing to compromised performance.

In conclusion, while mobile home HVAC units provide essential climate control benefits year-round when functioning optimally; they are susceptible to various triggers that can impair their operation over time if not addressed promptly through regular maintenance practices alongside professional servicing when needed ensures longevity while sustaining comfort levels inside one's abode irrespective of external climatic challenges faced seasonally across different regions globally today!

The comfort of a mobile home largely hinges on the efficiency of its HVAC system. This intricate network of heating, ventilation, and air conditioning is responsible for maintaining a stable indoor environment, shielding us from the extremes of temperature outside. However, when an HVAC system begins to falter, one of the most telling signs is temperature fluctuations or an inability to reach the desired temperature.

In mobile homes, these issues can manifest in various ways. You might notice that despite setting your thermostat to a specific temperature, different rooms in your home feel noticeably warmer or cooler than others. This inconsistency often points to underlying problems within the HVAC system itself. It may be as simple as blocked vents or more complex issues such as malfunctioning components within the unit.

One common cause of temperature fluctuations is inadequate insulation in mobile homes. Unlike traditional houses, mobile homes can have less robust insulation, making them more susceptible to outdoor temperature changes and causing your HVAC system to work harder to



maintain a consistent indoor climate. If your HVAC unit seems unable to keep up with demand or struggles during particularly hot or cold spells, checking the insulation could be a worthwhile first step.

Another potential culprit is poor ventilation. Blocked or leaky ducts can prevent air from circulating efficiently throughout the home. When ducts are compromised-whether due to damage, debris buildup, or improper sealing-the balance of airflow is disrupted. This imbalance results not only in uneven temperatures but also increased energy consumption as your HVAC system works overtime trying to compensate for these inefficiencies.

Furthermore, an aging or improperly maintained HVAC unit can lead to significant performance issues. Components like filters require regular cleaning and replacement; otherwise, they become clogged with dust and debris over time. Such neglect impedes airflow and reduces efficiency significantly-frequently resulting in those frustrating moments where your living space never quite reaches that sweet spot on the thermostat.

Technology also plays a role in regulating indoor climate effectively. A faulty thermostat can miscommunicate with your HVAC system about when and how long it should run-leading directly back into those cycles of uncomfortable temperature variations within your home environment.

Therefore, recognizing these signs early on helps prevent small issues from snowballing into costly repairs later down the line-or worse yet-a complete breakdown during extreme weather conditions when you need reliable heating or cooling most urgently.

In conclusion, understanding why temperature fluctuations occur provides crucial insight into potential malfunctions within an HVAC system serving mobile homes specifically designed around their unique challenges regarding space constraints and structural differences compared with conventional housing units alike.. Regular maintenance checks combined with ensuring adequate insulation levels make all difference between enduring inconveniences associated uneven climates versus enjoying consistently comfortable living spaces year-round regardless what Mother Nature throws our way!

In the realm of mobile home living, maintaining a consistent indoor climate is essential for comfort and well-being. Yet, when an HVAC system begins to falter, it can disrupt this delicate balance, creating an environment that is anything but pleasant. Recognizing the signs of HVAC malfunction early is crucial in preventing further discomfort and potential damage to

your mobile home.

One of the most telling indicators of HVAC issues is an inability to maintain a steady indoor temperature. If you find yourself frequently adjusting the thermostat with little effect on room temperature, this inconsistency may signal a problem. It could be an indication that your HVAC system is struggling to keep up with your heating or cooling demands due to wear and tear, faulty components, or inadequate maintenance.

Another sign to watch for is uneven heating or cooling across different areas of your mobile home. This might manifest as certain rooms feeling significantly warmer or cooler than others despite setting a uniform temperature on the thermostat. Such discrepancies often point toward ductwork problems or issues with airflow distribution within the HVAC system.

Additionally, pay attention to any unusual noises emanating from your HVAC unit. Clanging, banging, or whistling sounds are often symptomatic of underlying mechanical failures that require immediate attention. These noises not only disrupt household tranquility but also serve as early warnings of potentially larger issues if left unresolved.

Moreover, increased energy bills can also be a red flag indicative of an inefficient HVAC system working harder than necessary to maintain desired temperatures. A spike in energy consumption without corresponding changes in usage patterns suggests that your system may be operating at reduced efficiency due to malfunctioning components.

Lastly, frequent cycling on and off-known as short cycling-is another common symptom of HVAC troubles. This behavior not only undermines comfort levels by causing temperature fluctuations but also puts undue stress on the unit's components, leading to premature deterioration.

In conclusion, recognizing failure to maintain a consistent indoor climate in mobile homes involves being vigilant about these common signs: inconsistent temperatures, uneven heating/cooling zones, strange noises from the unit, unexpected rises in energy costs, and short cycling. By identifying these symptoms early and addressing them promptly through professional inspection and repair services where needed-you safeguard both your comfort and investment in one swift move-ensuring that your mobile home remains a haven regardless of external weather conditions.

When it comes to the comfort and functionality of mobile homes, the HVAC system plays a crucial role. However, like any other mechanical system, HVAC units are prone to malfunction over time. One of the most common yet often overlooked issues is related to thermostat problems or system inefficiencies. Identifying these can save homeowners both time and money while ensuring their living environment remains comfortable year-round.

The thermostat acts as the brain of an HVAC system, regulating when heating or cooling should be activated based on the temperature settings. A malfunctioning thermostat can lead to numerous inefficiencies. For instance, if a thermostat is incorrectly calibrated or positioned in an area that doesn't accurately reflect the home's average temperature—such as near direct sunlight or a drafty window—it may cause the HVAC system to cycle on and off at inappropriate times. This not only leads to discomfort but also places unnecessary stress on the unit, potentially shortening its lifespan and increasing energy costs.

Another common issue relates to outdated thermostats. Older models lack the precision and programmability of modern digital thermostats, which can learn household patterns and adjust temperatures accordingly for maximum efficiency and comfort. Upgrading to a programmable or smart thermostat can significantly enhance performance by optimizing heating and cooling schedules around a homeowner's routine, thus avoiding wastage of energy during periods when no one is home.

System inefficiencies aren't limited to just thermostat issues; they encompass broader maintenance aspects as well. For example, clogged filters obstruct airflow, decreasing efficiency and causing systems to work harder than necessary. This not only raises utility bills but also increases wear and tear on components like fans and compressors. Regularly replacing filters can mitigate this problem effectively.

Moreover, ductwork in mobile homes can sometimes pose unique challenges due to space constraints which might lead to leaks or blockages over time. Leaky ducts allow conditioned air to escape before it reaches intended areas within the home, reducing overall efficiency while also making some rooms feel hotter or colder than others.

One must also consider the age of the HVAC system itself; older units naturally become less efficient over time even with regular maintenance due to technological advancements in newer models that offer superior energy efficiency ratings.

In conclusion, identifying common signs of HVAC malfunctions in mobile homes requires careful examination of both thermostat issues and overall system efficiencies. Homeowners should ensure their thermostats are up-to-date and correctly positioned while adhering strictly to regular maintenance schedules for their systems' components like filters and ductwork. Addressing these areas promptly not only extends the life expectancy of an HVAC unit but also enhances indoor comfort levels significantly-proving once again that preventative care is always better than reactive repairs when dealing with home comfort systems.

Title: Identifying Common Signs of HVAC Malfunction in Mobile Homes: Presence of Moisture or Leaks Around the Unit

In the quest for comfortable living, particularly within the confines of a mobile home, a well-functioning HVAC system is indispensable. It regulates indoor climate, providing warmth during chilly winters and cooling relief amidst scorching summers. However, like any other mechanical system, HVAC units are susceptible to wear and malfunction. One significant indicator of potential trouble is the presence of moisture or leaks around the unit.

Moisture accumulation or leaks can be symptomatic of various underlying issues within an HVAC system. Primarily, these signs may indicate that there is a problem with condensation management. Generally, when an air conditioning unit operates, it removes humidity from the air as part of its cooling process. This moisture typically condenses into water and is directed away from the unit through a drainage system. However, if this system becomes clogged or damaged, water can begin to pool around the unit itself.

The presence of excess moisture around an HVAC unit should never be dismissed lightly. Not only does it suggest potential internal malfunctions such as blocked condensate drains or cracked drain pans, but it also poses external risks to the structural integrity of a mobile home. Prolonged exposure to moisture can lead to mold growth-a health hazard that thrives in damp conditions-and cause deterioration of walls and floors due to rot.

Apart from drainage issues, refrigerant leaks could also manifest as moisture problems around an HVAC unit. Refrigerant is crucial for heat exchange processes within air conditioning systems; thus any leak not only affects performance but can also lead to environmental harm given its chemical properties. Detecting refrigerant leaks often requires professional expertise since they might not always present visible signs immediately.

A vigilant homeowner should regularly inspect their mobile home's HVAC system for any uncharacteristic signs such as dripping water sounds or visible puddles near the equipment base-often precursors signaling potential damage requiring attention before escalating into more severe complications.

To mitigate these risks and ensure optimal functioning throughout seasonal changes while safeguarding your living space against possible damage inflicted by unchecked moisture presence involves taking preventive measures seriously: performing routine maintenance checks on filters (to prevent airflow blockage), ensuring proper sealing around vents/windows/doors (to avoid unnecessary stress on systems), as well scheduling annual inspections conducted by certified technicians adept at identifying subtle irregularities which may otherwise go unnoticed until significant problems arise later down line necessitating costly repairs/replacements ultimately affecting overall quality life residing therein over time ultimately making proactive approach prudent investment peace mind long term sustainability comfort levels desired achieving sustainable energy efficiency goals alike simultaneously fulfilling objectives set forth originally planned initially invested therein accordingly prudently wisely indeed!

In the intricate world of mobile home living, maintaining a comfortable and efficient environment often hinges on the proper functioning of the HVAC system. These systems, though compact and seemingly straightforward, are prone to a variety of malfunctions that can disrupt daily life. Among the plethora of symptoms indicating potential HVAC issues, pooling water and excessive condensation are two significant signs that should never be overlooked.

Pooling water around your HVAC unit is more than just an inconvenience; it is a red flag signaling possible malfunction. This accumulation can occur for several reasons, each requiring immediate attention. One common cause is a clogged condensate drain line. In an efficiently running HVAC system, moisture collected from the air condenses and is channeled away through this drain line. However, when it becomes blocked with dirt or debris, water has nowhere to go but back into your living space or around your unit.

Another potential culprit behind pooling water is a malfunctioning condensate pump. This small yet vital component is responsible for moving accumulated water out of the unit and away from your home. If it fails or operates inefficiently, you may find yourself dealing with unwelcome puddles that could lead to further damage if ignored.

Excessive condensation inside your mobile home also serves as an indicator of HVAC troubles. When humidity levels rise unexpectedly or persistently in certain areas, it's often due to problems within the system itself. A failing evaporator coil might be struggling to absorb

heat effectively, causing moisture to linger in the air longer than it should.

Moreover, inadequate insulation around ductwork can exacerbate condensation issues by allowing warm air to meet cool surfaces more frequently than intended. This interaction results in droplets forming on walls or ceilings-a clear sign that your HVAC system might not be maintaining temperature differentials correctly.

Both pooling water and excessive condensation present risks beyond mere discomfort; they can give rise to mold growth and structural damage if left unchecked. Mold thrives in damp environments and poses health hazards ranging from allergies to respiratory infections-issues particularly concerning in compact living spaces like mobile homes where ventilation might already be limited.

Therefore, when faced with these signs of distress from your HVAC system, swift action becomes paramount. Regular maintenance checks conducted by professionals can prevent minor issues from escalating into major repairs. Additionally, homeowners should remain vigilant for early warning signals such as unusual noises or inconsistent airflow patterns which typically accompany these visible symptoms.

In conclusion, while modern HVAC systems have revolutionized comfort levels within mobile homes by regulating temperatures efficiently year-round-they are not without their vulnerabilities. Recognizing signs like pooling water or excessive condensation ensures timely intervention thus preserving both the integrity of your home environment and peace of mind associated with its upkeep.

Identifying common signs of HVAC malfunction in mobile homes is crucial for maintaining a comfortable and healthy living environment. One significant aspect to consider is understanding the risks associated with leaks and moisture buildup. These issues, often overlooked, can have far-reaching consequences on both the structure of the home and the well-being of its occupants.

Leaks in an HVAC system may originate from several sources, including damaged ductwork, poor insulation, or faulty seals around vents and connections. When these leaks occur, they allow conditioned air to escape, reducing the efficiency of the system and leading to increased energy costs. More importantly, they can also introduce moisture into areas where it should not be present.

Moisture buildup is a particularly insidious problem because it often goes unnoticed until substantial damage has occurred. In mobile homes, which are typically constructed with materials that are more susceptible to water damage than traditional homes, this can lead to severe structural issues. Moisture can warp flooring, weaken walls, and cause ceilings to sag. Moreover, excess humidity creates an ideal environment for mold growth.

The presence of mold poses serious health risks to inhabitants. Mold spores can trigger allergic reactions and respiratory problems such as asthma attacks or other breathing difficulties. For individuals with compromised immune systems or chronic lung conditions, exposure can be even more dangerous.

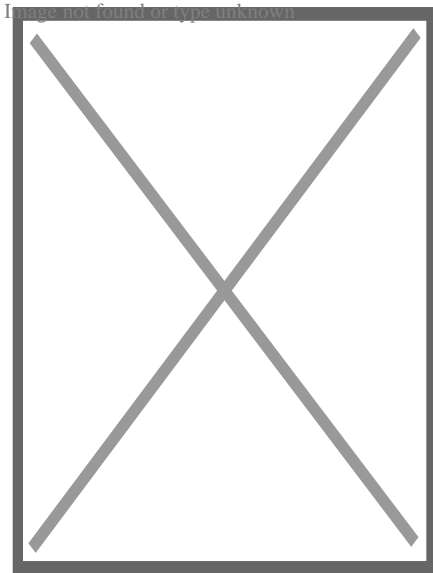
To mitigate these risks, homeowners must be vigilant in identifying early signs of HVAC malfunctions related to leaks and moisture buildup. Signs include inconsistent temperatures throughout the home, unexplained spikes in utility bills, unusual noises from the HVAC unit, or visible signs of water damage like stains on walls or ceilings.

Regular maintenance checks by qualified professionals can help detect these issues before they escalate. Ensuring all components of the HVAC system are properly sealed and insulated will prevent air leakage and control humidity levels effectively.

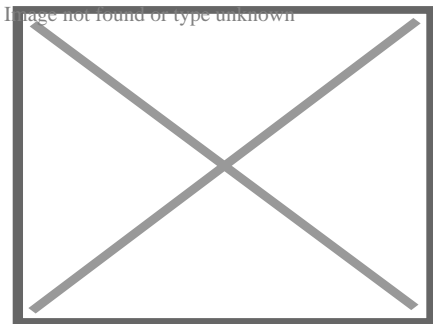
In conclusion, while it may seem minor at first glance, understanding the dangers posed by leaks and moisture buildup due to HVAC malfunctions is essential for anyone living in a mobile home. Proactive management through regular inspections and prompt repairs not only preserves the integrity of the dwelling but also safeguards the health of its residents. By staying informed about these potential hazards, homeowners can ensure their living spaces remain safe and comfortable year-round.

## **About Heat pump**

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



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



Mitsubishi heat pump interior air handler wall unit

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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
- Energy audit
- Energy efficiency implementation
- Energy recovery
- Energy recycling
- Energy saving lamp
- Energy Star
- Energy storage
- Environmental planning
- Environmental technology
- Fossil fuel phase-out
- Glass in green buildings
- Green building and wood
- Green building
- Heat pump
- List of low-energy building techniques
- Low-energy house
- Microgeneration
- Passive house
- Passive solar building design
- Sustainable architecture
- Sustainable city
- Sustainable habitat
- Sustainable refurbishment
- Thermal energy storage
- Tropical green building
- Waste-to-energy
- Zero heating building
- Zero-energy building

## Renewable energy

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

## Sustainable transport

- Green vehicle
  - Electric vehicle
    - Bicycle
  - Solar vehicle
  - Wind-powered vehicle
- Hybrid vehicle
  - Human-electric
    - Twike
  - Plug-in
- Human-powered transport
  - Helicopter
  - Hydrofoil
  - Land vehicle
    - Bicycle
    - Cycle rickshaw
    - Kick scooter
    - Quadracycle
    - Tricycle
    - Velomobile
  - Roller skating
  - Skateboarding
  - Walking
  - Watercraft
- Personal transporter
- Rail transport
  - Tram
- Rapid transit
  - Personal rapid transit
-  Category
-  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.<sup>[1]</sup> 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.<sup>[2]</sup>

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.

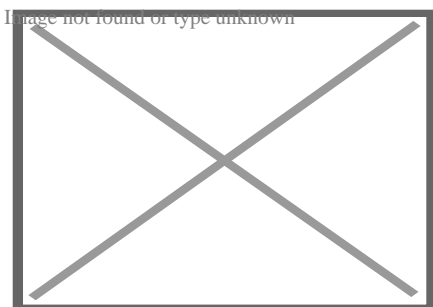
Air source heat pumps are the most common models, while other types include ground source heat pumps, water source heat pumps and exhaust air heat pumps.<sup>[3]</sup> Large-scale heat pumps are also used in district heating systems.<sup>[4]</sup>

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.<sup>[5][6]</sup> Consuming 1 kWh of electricity, they can transfer 1<sup>[7]</sup> 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.<sup>[8]</sup> 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%.<sup>[4]</sup>

## 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.<sup>[9]</sup>

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:  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.<sup>[9]</sup>

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.<sup>[note 1]</sup>
- 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.<sup>[note 2]</sup>

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.<sup>[11]</sup>

## History

[edit]

Milestones:

1748

William Cullen demonstrates artificial refrigeration.<sup>[12]</sup>

1834

Jacob Perkins patents a design for a practical refrigerator using dimethyl ether.<sup>[13]</sup>

1852

Lord Kelvin describes the theory underlying heat pumps.<sup>[14]</sup>

1855–1857

Peter von Rittinger develops and builds the first heat pump.<sup>[15]</sup>

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.<sup>[14][16]</sup>

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.<sup>[17]</sup>

1937–1945

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

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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.[<sup>14</sup>]

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.[<sup>18</sup>]

1948

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

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.[<sup>18</sup>]

2019

The Kigali Amendment to phase out harmful refrigerants takes effect.

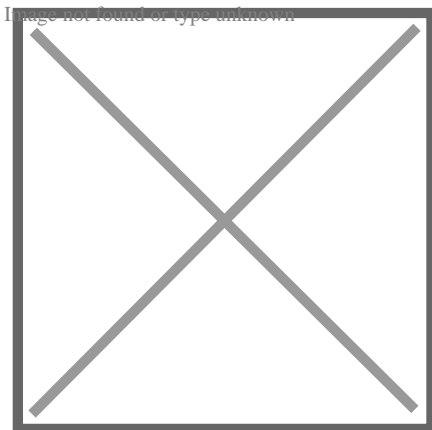
## Types

[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.<sup>[20][21]</sup>

*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).<sup>[22]</sup>

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.<sup>[23]</sup>

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.<sup>[24]</sup>

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.<sup>[25]</sup>

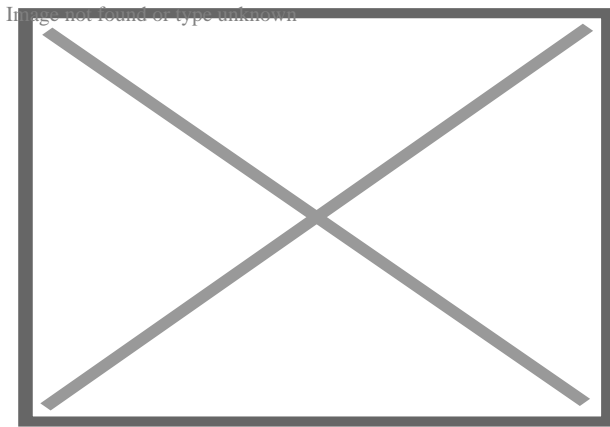
While older air-source heat pumps performed relatively poorly at low temperatures and were better suited for warm climates, newer models with variable-speed compressors remain highly efficient in freezing conditions allowing for wide adoption and cost savings in places like Minnesota and Maine in the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

## **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.<sup>[27]</sup> Otherwise air-source heat pumps are often used instead.

### **Heat recovery ventilation**

[edit]

Main article: Heat recovery ventilation

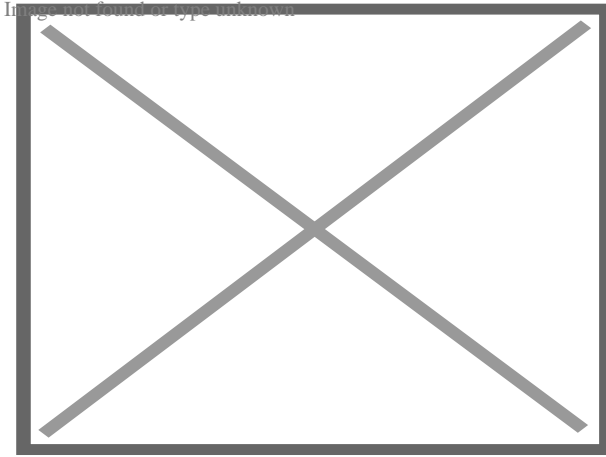
Exhaust air heat pumps extract heat from the exhaust air of a building and require mechanical ventilation. Two classes exist:

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

### **Solar-assisted**

[edit]

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



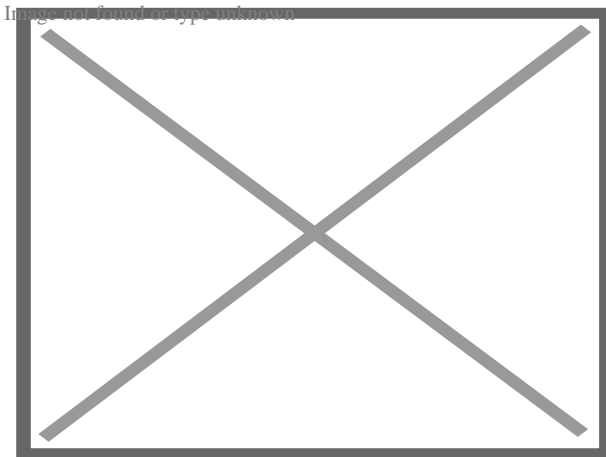
Hybrid photovoltaic-thermal solar panels of a SAHP in an experimental installation at Department of Energy at Polytechnic of Milan

A solar-assisted heat pump (SAHP) is a machine that combines a heat pump and thermal solar panels and/or PV solar panels in a single integrated system.<sup>[28]</sup> Typically these two technologies are used separately (or only placing them in parallel) to produce hot water.<sup>[29]</sup> 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.<sup>[30]</sup> 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.<sup>[31]</sup> The largest water-source heat pump was installed in the Danish town of Esbjerg in 2023.<sup>[32][33]</sup>

## 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.<sup>[34]</sup>

Electrocaloric heat pumps are solid state.<sup>[35]</sup>

## 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.<sup>[4]</sup> They are used for heating, ventilation, and air conditioning (HVAC) and may also provide domestic hot water and tumble clothes drying.<sup>[36]</sup> The purchase costs are supported in various countries by consumer rebates.<sup>[37]</sup>

## 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.

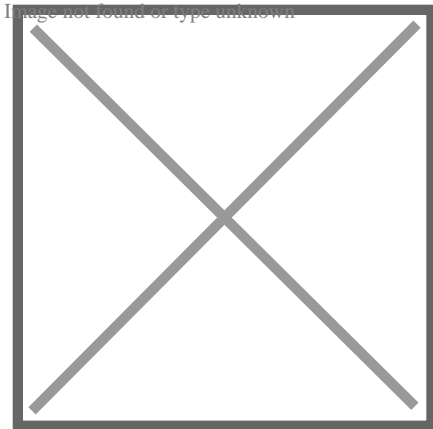
Because the two heat exchangers, the condenser and evaporator, must swap functions, they are optimized to perform adequately in both modes. Therefore, the Seasonal Energy Efficiency Rating (SEER in the US) or European seasonal energy efficiency ratio of a reversible heat pump is typically slightly less 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.<sup>[38]</sup>

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.<sup>[39]</sup>

## 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.<sup>[40]</sup>

## 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.<sup>[41]</sup><sup>[42]</sup>

## District heating

[edit]

Large (megawatt-scale) heat pumps are used for district heating.<sup>[43]</sup> However as of 2022 about 90% of district heat is from fossil fuels.<sup>[44]</sup> 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.<sup>[4]</sup> 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.<sup>[45]</sup> 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.<sup>[45][46]</sup> They are also a crucial element of systems which can both heat and cool districts.<sup>[47]</sup>

## 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.<sup>[48][49]</sup> Short payback periods of less than 2 years are possible, while achieving a high reduction of CO<sub>2</sub> emissions (in some cases more than 50%).<sup>[50][51]</sup> Industrial heat pumps can heat up to 200 °C, and can meet the heating demands of many light industries.<sup>[52][53]</sup> In Europe alone, 15 GW of heat pumps could be installed in 3,000 facilities in the paper, food and chemicals industries.<sup>[4]</sup>

## 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*).<sup>[54]</sup> 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.<sup>[54]</sup> Larger values of either metric indicate better performance.<sup>[54]</sup> 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.<sup>[54]</sup> 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.<sup>[54]</sup>

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.<sup>[54]</sup> One framework for this calculation is given by the Commission Regulation (EU) No. 813/2013.<sup>[55]</sup>

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.

Pump type and source	Typical use	COP variation with output temperature	
		35 °C (e.g. heated screed floor)	
High-efficiency air-source heat pump (ASHP), air at 20 °C <sup>[56]</sup>		2.2	
Two-stage ASHP, air at 20 °C <sup>[57]</sup>	Low source temperature	2.4	
High-efficiency ASHP, air at 0 °C <sup>[56]</sup>	Low output temperature	3.8	

Prototype transcritical CO<sub>2</sub> (R744) heat pump with tripartite gas cooler, source at 0 °C<sup>[58]</sup>

High output temperature

3.3

Ground-source heat pump (GSHP), water at 0 °C<sup>[56]</sup>

5.0

GSHP, ground at 10 °C<sup>[56]</sup>

Low output temperature

7.2

Theoretical Carnot cycle limit, source 20 °C

5.6

Theoretical Carnot cycle limit, source 0 °C

8.8

Theoretical Lorentzen cycle limit (CO<sub>2</sub> pump), return fluid 25 °C, source 0 °C<sup>[58]</sup>

10.1

Theoretical  
Carnot  
cycle limit,  
source  
10 °C

12.3

## Carbon footprint

[edit]

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

heating system	emissions of energy source	efficiency	resulting emissions for thermal energy
heat pump with onshore wind power	11 gCO <sub>2</sub> /kWh <sup>[59]</sup>	400% (COP=4)	3 gCO <sub>2</sub> /kWh
heat pump with global electricity mix	436 gCO <sub>2</sub> /kWh <sup>[60]</sup> (2022)	400% (COP=4)	109 gCO <sub>2</sub> /kWh
natural-gas thermal (high efficiency)	201 gCO <sub>2</sub> /kWh <sup>[61]</sup>	90% <sup>[citation needed]</sup>	223 gCO <sub>2</sub> /kWh
heat pump electricity by lignite (old power plant) and low performance	1221 gCO <sub>2</sub> /kWh <sup>[61]</sup>	300% (COP=3)	407 gCO <sub>2</sub> /kWh

In most settings, heat pumps will reduce CO<sub>2</sub> emissions compared to heating systems powered by fossil fuels.<sup>[62]</sup> 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.<sup>[4]</sup> 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.<sup>[63]</sup><sup>[4]</sup> The rising share of renewable electricity generation in many countries is set to increase the emissions savings from heat pumps over time.<sup>[4]</sup>

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.<sup>[64]</sup><sup>[65]</sup>

## Operation



[edit]

See also: Vapor-compression refrigeration



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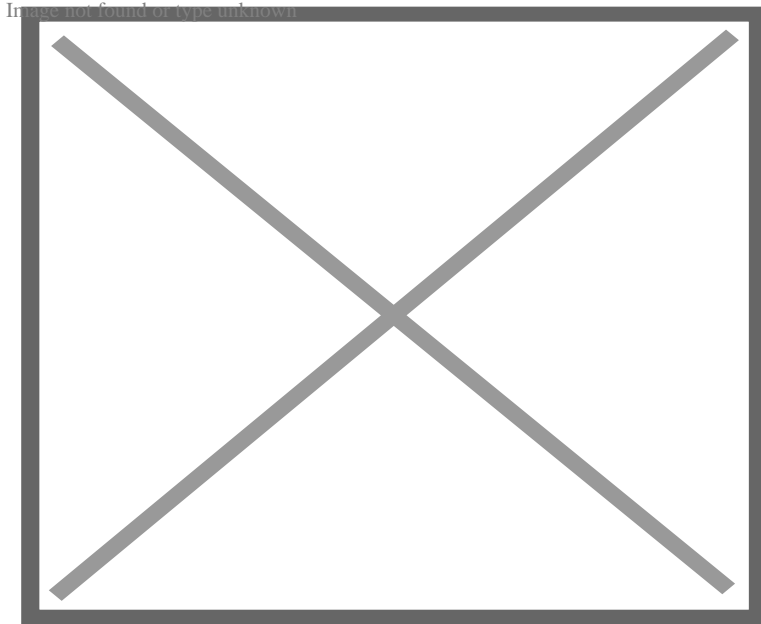
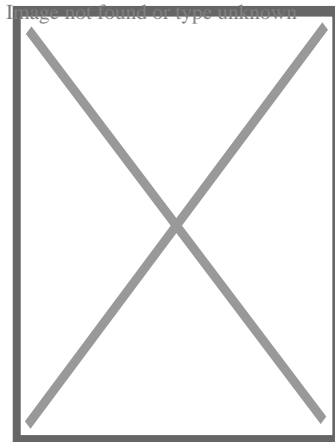
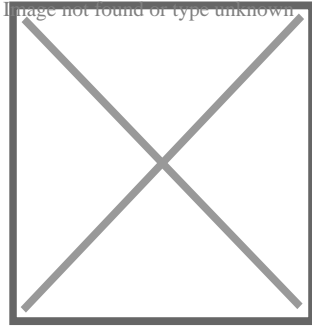


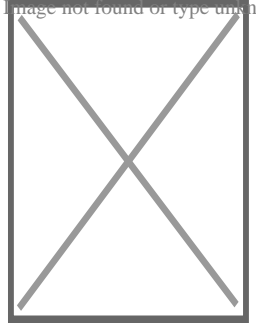
Figure 2: Temperature–entropy diagram of the vapor-compression cycle



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

The condensed, liquid refrigerant, in the thermodynamic state known as a saturated liquid, is next routed through an expansion valve where it undergoes an abrupt reduction

in pressure. That pressure reduction results in the adiabatic flash evaporation of a part of the liquid refrigerant. The auto-refrigeration effect of the adiabatic flash evaporation lowers the temperature of the liquid and-vapor refrigerant mixture to where it is colder than the temperature of the enclosed space to be refrigerated.

The cold mixture is then routed through the coil or tubes in the evaporator. A fan circulates the warm air in the enclosed space across the coil or tubes carrying the cold refrigerant liquid and vapor mixture. That warm air evaporates the liquid part of the cold refrigerant mixture. At the same time, the circulating air is cooled and thus lowers the temperature of the enclosed space to the desired temperature. The evaporator is where the circulating refrigerant absorbs and removes heat which is subsequently rejected in the condenser and transferred elsewhere by the water or air used in the condenser.

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

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

### **Improvement of coefficient of performance by subcooling**

[edit]

Main article: Subcooling

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

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

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)<sup>[68]</sup>).<sup>[69]</sup> Their boiling points are usually below 25 °C.<sup>[70]</sup>

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,<sup>[clarification needed]</sup> 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,<sup>[71]</sup> as most countries have now ratified the Kigali Amendment to ban HFCs.<sup>[72]</sup> 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.<sup>[73]</sup> Propane may be the most suitable for high temperature heat pumps.<sup>[74]</sup> Ammonia (R717) and carbon dioxide (R-744) also have a low GWP. As of 2023 smaller CO<sub>2</sub> heat pumps are not widely available and research and development of them continues.<sup>[75]</sup> A 2024 report said that refrigerants with GWP are vulnerable to further international restrictions.<sup>[76]</sup>

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.<sup>[77]</sup>

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

refrigerant	20-year GWP	100-year GWP
R-290 propane <sup>[82]</sup>	0.072	0.02
R-600a isobutane		3 <sup>[83]</sup>

R-32 <sup>[82]</sup>	491	136
R-410a <sup>[84]</sup>	4705	2285
R-134a <sup>[84]</sup>	4060	1470
R-404a <sup>[84]</sup>	7258	4808

Devices with R-290 refrigerant (propane) are expected to play a key role in the future.<sup>[74][85]</sup> 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).<sup>[86][87][88]</sup> 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.<sup>[citation needed]</sup>

At the same time,<sup>[when?]</sup> 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.<sup>[89]</sup> 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<sub>2</sub>, which corresponds to two years of natural gas heating in an average household. Refrigerants with a high ODP have already been phased out.<sup>[citation needed]</sup>

## Government incentives

[edit]

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

## 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.<sup>[91]</sup>

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.<sup>[92][93][94][95][96]</sup>

## Canada

[edit]

In 2022, the Canada Greener Homes Grant<sup>[97]</sup> 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.<sup>[98]</sup>

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.<sup>[99]</sup>

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.<sup>[99]</sup>

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.<sup>[99]</sup><sup>[100]</sup>

## European Union

[edit]

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

## 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.<sup>[103]</sup> As of 2022 the installation cost of a heat pump is more than a gas boiler, but with the "Boiler Upgrade Scheme"<sup>[104]</sup> government grant and assuming electricity/gas costs remain similar their lifetime costs would be similar on average.<sup>[105]</sup> 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.<sup>[106]</sup> In 2024 England was criticised for still allowing new homes to be built with gas boilers, unlike some other counties where this is banned.<sup>[107]</sup>

## 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.<sup>[108]</sup>

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

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.<sup>[110]</sup>

## Notes

[edit]

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

## References

[edit]

- <sup>^</sup> "Heat Pump Systems". *Energy.gov*. Retrieved 26 March 2024.
- <sup>^</sup> "Heat Pump Systems". *US Department of Energy*. Archived from the original on 27 April 2023. Retrieved 27 April 2023.
- <sup>^</sup> "Exhaust air heat pumps". *Energy Saving Trust*. Retrieved 22 February 2024.
- <sup>^</sup> **a b c d e f g h i** *Technology Report: The Future of Heat Pumps*. International Energy Agency (Report). November 2022. Archived from the original on 6 January 2023. Retrieved 6 January 2023. License: CC BY 4.0.
- <sup>^</sup> IPCC AR6 WG3 Ch11 2022, Sec. 11.3.4.1.
- <sup>^</sup> IPCC SR15 Ch2 2018, p. 142.
- <sup>^</sup> Everitt, Neil (11 September 2023). "Study proves heat pump efficiency at low temperatures". *Cooling Post*. Retrieved 22 January 2024.
- <sup>^</sup> Deetjen, Thomas A.; Walsh, Liam; Vaishnav, Parth (28 July 2021). "US residential heat pumps: the private economic potential and its emissions, health, and grid impacts". *Environmental Research Letters*. **16** (8): 084024. Bibcode:2021ERL....16h4024D. doi:10.1088/1748-9326/ac10dc. ISSN 1748-9326. S2CID 236486619.
- <sup>^</sup> **a b** G. F. C. Rogers and Y. R. Mayhew (1957), *Engineering Thermodynamics, Work and Heat Transfer*, Section 13.1, Longmans, Green & Company Limited.
- <sup>^</sup> **a b** "Is there some theoretical maximum coefficient of performance (COP) for heat pumps and chillers?". *Physics Stack Exchange*. Retrieved 22 February 2024.
- <sup>^</sup> Williamson, Chris (13 October 2022). "Heat pumps are great. Let's make them even better". *All you can heat*. Retrieved 22 February 2024.
- <sup>^</sup> "The often forgotten Scottish inventor whose innovation changed the world". *The National*. 10 April 2022. Retrieved 21 February 2024.



13. ^ *Bathe, Greville; Bathe, Dorothy (1943). Jacob Perkins, his inventions, his times, & his contemporaries. The Historical Society of Pennsylvania. p. 149.*
14. ^ **a b c d** "History of Heat Pumping Technologies in Switzerland – Texts". *www.aramis.admin.ch*. Archived from the original on 23 November 2021. Retrieved 14 September 2023.
15. ^ *Banks, David L. (6 May 2008). An Introduction to Thermogeology: Ground Source Heating and Cooling (PDF). Wiley-Blackwell. ISBN 978-1-4051-7061-1. Archived (PDF) from the original on 20 December 2016. Retrieved 5 March 2014.*
16. ^ *Wirth, E. (1955), Aus der Entwicklungsgeschichte der Wärmepumpe, Schweizerische Bauzeitung (in German), vol. 73, pp. 647–650, archived from the original on 20 November 2021, retrieved 20 November 2021*
17. ^ *Randall, Ian (31 July 2022). "Heat pumps: The centuries-old system now at the heart of the Government's energy strategy". Daily Express. Retrieved 16 March 2024.*
18. ^ **a b** *Electricity supply in the United Kingdom : a chronology – from the beginnings of the industry to 31 December 1985. The Electricity Council. 1987. ISBN 978-0851881058. OCLC 17343802.*
19. ^ *Banks, David (August 2012). An Introduction to Thermogeology: Ground Source Heating and Cooling. John Wiley & Sons. p. 123.*
20. ^ "Why Britain's homes will need different types of heat pump". *The Economist*. ISSN 0013-0613. Retrieved 19 February 2024.
21. ^ "What is an Air-Source Heat Pump? A Complete Guide In 2024". *NEWNTIDE*. 24 October 2024. Retrieved 30 September 2024.
22. ^ *Le, Khoa; Huang, M.J.; Hewitt, Neil (2018). "Domestic High Temperature Air Source Heat Pump: Performance Analysis Using TRNSYS Simulations". International High Performance Buildings Conference. West Lafayette, IN, USA: 5th International High Performance Buildings Conference at Purdue University: 1. Retrieved 20 February 2022.*
23. ^ "Heat pumps show how hard decarbonisation will be". *The Economist*. ISSN 0013-0613. Retrieved 14 September 2023.
24. ^ *Lawrence, Karen. "Air source heat pumps explained". Which?. Archived from the original on 4 October 2022. Retrieved 4 October 2022.*
25. ^ *Canada, Natural Resources (22 April 2009). "Heating and Cooling With a Heat Pump". natural-resources.canada.ca. Retrieved 22 February 2024.*
26. ^ "Heat pumps do work in the cold – Americans just don't know it yet". *Grist*. 9 May 2022. Archived from the original on 9 May 2022. Retrieved 9 May 2022.
27. ^ "Heat pumps are hot items. But for people living in condos, getting one presents some challenges".
28. ^ *Sezen, Kutbay; Gungor, Afsin (1 January 2023). "Comparison of solar assisted heat pump systems for heating residences: A review". Solar Energy. **249**: 424–445. doi:10.1016/j.solener.2022.11.051. ISSN 0038-092X. "Photovoltaic-thermal direct expansion solar assisted heat pump (PV/T-DX-SAHP) system enables to benefit the waste heat for evaporation of refrigerant in PV/T collector-evaporator, while providing better cooling for PV cells (Yao et al., 2020)."*

29. ^ "Solar-assisted heat pumps". Archived from the original on 28 February 2020. Retrieved 21 June 2016.
30. ^ "Pompe di calore elio-assistite" (in Italian). Archived from the original on 7 January 2012. Retrieved 21 June 2016.
31. ^ Energy Saving Trust (13 February 2019). "Could a water source heat pump work for you?". Energy Saving Trust. Archived from the original on 4 October 2022. Retrieved 4 October 2022.
32. ^ Baraniuk, Chris (29 May 2023). "The 'exploding' demand for giant heat pumps". BBC News. Archived from the original on 7 September 2023. Retrieved 19 September 2023.
33. ^ Ristau, Oliver (24 July 2022). "Energy transition, the Danish way". DW. Archived from the original on 9 August 2023. Retrieved 19 September 2023.
34. ^ Padavic-Callaghan, Karmela (6 December 2022). "Heat pump uses a loudspeaker and wet strips of paper to cool air". New Scientist. Archived from the original on 4 January 2023. Retrieved 4 January 2023.
35. ^ Everitt, Neil (14 August 2023). "Scientists claim solid-state heat pump breakthrough". Cooling Post. Archived from the original on 24 September 2023. Retrieved 17 September 2023.
36. ^ "Heat Pump Systems". U.S. Department of Energy. Archived from the original on 4 July 2017. Retrieved 5 February 2016.
37. ^ "Renewable Heat Incentive – Domestic RHI – paid over 7 years". Ground Source Heat Pump Association. Archived from the original on 8 March 2018. Retrieved 12 March 2017.
38. ^ "Heat Pump Efficiency | Heat Pump SEER Ratings". Carrier. Archived from the original on 14 January 2023. Retrieved 14 January 2023.
39. ^ "COP and SPF for Heat Pumps Explained". Green Business Watch UK. 7 November 2019. Retrieved 22 February 2024.
40. ^ "Why This Window Heat Pump is Genius – Undecided with Matt Ferrell". 11 June 2024.
41. ^ "How it Works — Heat Pump Water Heaters (HPWHs)". www.energystar.gov. Retrieved 22 January 2024.
42. ^ "Heat-pump hot water systems". Sustainability Victoria. Retrieved 22 January 2024.
43. ^ Baraniuk, Chris (29 May 2023). "The 'exploding' demand for giant heat pumps". BBC News. Archived from the original on 7 September 2023. Retrieved 17 September 2023.
44. ^ "District Heating – Energy System". IEA. Retrieved 22 January 2024.
45. ^ **a b** David, Andrei; et al. (2017). "Heat Roadmap Europe: Large-Scale Electric Heat Pumps in District Heating Systems". *Energies*. **10** (4): 578. doi:10.3390/en10040578.
46. ^ Sayegh, M. A.; et al. (2018). "Heat pump placement, connection and operational modes in European district heating". *Energy and Buildings*. **166**: 122–144. Bibcode:2018EneBu.166..122S. doi:10.1016/j.enbuild.2018.02.006. Archived from the original on 14 December 2019. Retrieved 10 July 2019.

47. ^ *Buffa, Simone; et al. (2019), "5th generation district heating and cooling systems: A review of existing cases in Europe", Renewable and Sustainable Energy Reviews (in German), vol. 104, pp. 504–522, doi:10.1016/j.rser.2018.12.059*
48. ^ *"Home". Annex 35. Retrieved 22 February 2024.*
49. ^ *"Industrial Heat Pumps: it's time to go electric". World Business Council for Sustainable Development (WBCSD). Retrieved 22 February 2024.*
50. ^ *IEA HPT TCP Annex 35 Publications Archived 2018-09-21 at the Wayback Machine*
51. ^ *"Application of Industrial Heat Pumps. Annex 35 two-page summary". HPT – Heat Pumping Technologies. Retrieved 28 December 2023.*
52. ^ *"Norwegian Researchers Develop World's Hottest Heat Pump". Ammonia21. 5 August 2021. Archived from the original on 23 May 2022. Retrieved 7 June 2022.*
53. ^ *"Heat pumps are key to helping industry turn electric". World Business Council for Sustainable Development (WBCSD). Archived from the original on 24 September 2023. Retrieved 4 October 2022.*
54. ^ **a b c d e f** *"Heating and cooling with a heat pump: Efficiency terminology". Natural Resources Canada. 8 September 2022. Archived from the original on 3 April 2023. Retrieved 3 April 2023.*
55. ^ *Commission Regulation (EU) No 813/2013 of 2 August 2013 implementing Directive 2009/125/EC of the European Parliament and of the Council with regard to ecodesign requirements for space heaters and combination heaters*
56. ^ **a b c d** *The Canadian Renewable Energy Network 'Commercial Earth Energy Systems', Figure 29 Archived 2011-05-11 at the Wayback Machine. . Retrieved December 8, 2009.*
57. ^ *Technical Institute of Physics and Chemistry, Chinese Academy of Sciences 'State of the Art of Air-source Heat Pump for Cold Region', Figure 5 Archived 2016-04-14 at the Wayback Machine. . Retrieved April 19, 2008.*
58. ^ **a b** *SINTEF Energy Research 'Integrated CO<sub>2</sub> Heat Pump Systems for Space Heating and DHW in low-energy and passive houses', J. Steen, Table 3.1, Table 3.3 Archived 2009-03-18 at the Wayback Machine. . Retrieved April 19, 2008.*
59. ^ *"How Wind Can Help Us Breathe Easier". Energy.gov. Archived from the original on 28 August 2023. Retrieved 13 September 2023.*
60. ^ *"Global Electricity Review 2023". Ember. 11 April 2023. Archived from the original on 11 April 2023. Retrieved 13 September 2023.*
61. ^ **a b** *Quaschnig 2022*
62. ^ *"The UK is sabotaging its own plan to decarbonize heating". Engadget. 27 May 2021. Archived from the original on 6 June 2021. Retrieved 6 June 2021.*
63. ^ *Deetjen, Thomas A; Walsh, Liam; Vaishnav, Parth (28 July 2021). "US residential heat pumps: the private economic potential and its emissions, health, and grid impacts". Environmental Research Letters. **16** (8): 084024. Bibcode:2021ERL....16h4024D. doi:10.1088/1748-9326/ac10dc. S2CID 236486619.*
64. ^ *"Can the UK rely on hydrogen to save its gas boilers?". inews.co.uk. 21 May 2021. Archived from the original on 6 June 2021. Retrieved 6 June 2021.*

65. ^ IEA (2022), Global Hydrogen Review 2022, IEA, Paris <https://www.iea.org/reports/global-hydrogen-review-2022> Archived 2023-01-10 at the Wayback Machine , License: CC BY 4.0
66. ^ Saturated vapors and saturated liquids are vapors and liquids at their saturation temperature and saturation pressure. A superheated vapor is at a temperature higher than the saturation temperature corresponding to its pressure.
67. ^ Ludwig von Cube, Hans (1981). *Heat Pump Technology*. Butterworths. pp. 22–23. ISBN 0-408-00497-5. Archived from the original on 3 April 2023. Retrieved 2 January 2023.
68. ^ Chamoun, Marwan; Rulliere, Romuald; Haberschill, Philippe; Berail, Jean Francois (1 June 2012). "Dynamic model of an industrial heat pump using water as refrigerant". *International Journal of Refrigeration*. **35** (4): 1080–1091. doi:10.1016/j.ijrefrig.2011.12.007. ISSN 0140-7007.
69. ^ Wu, Di (2021). "Vapor compression heat pumps with pure Low-GWP refrigerants". *Renewable and Sustainable Energy Reviews*. **138**: 110571. doi:10.1016/j.rser.2020.110571. ISSN 1364-0321. S2CID 229455137. Archived from the original on 24 September 2023. Retrieved 17 November 2022.
70. ^ "Everything you need to know about the wild world of heat pumps". MIT Technology Review. Archived from the original on 1 August 2023. Retrieved 19 September 2023.
71. ^ Miara, Marek (22 October 2019). "Heat Pumps with Climate-Friendly Refrigerant Developed for Indoor Installation". Fraunhofer ISE. Archived from the original on 20 February 2022. Retrieved 21 February 2022.
72. ^ Rabe, Barry G. (23 September 2022). "Pivoting from global climate laggard to leader: Kigali and American HFC policy". Brookings. Archived from the original on 4 October 2022. Retrieved 4 October 2022.
73. ^ Itteilag, Richard L. (9 August 2012). *Green Electricity and Global Warming*. AuthorHouse. p. 77. ISBN 9781477217405. Archived from the original on 23 November 2021. Retrieved 1 November 2020.
74. ^ **a b** "Propane-powered heat pumps are greener". *The Economist*. 6 September 2023. ISSN 0013-0613. Archived from the original on 17 September 2023. Retrieved 17 September 2023.
75. ^ "Smart CO2 Heat Pump". [www.dti.dk](http://www.dti.dk). Archived from the original on 30 January 2023. Retrieved 17 September 2023.
76. ^ "Annex 53 Advanced Cooling/Refrigeration Technologies 2 page summary". HPT – Heat Pumping Technologies. Retrieved 19 February 2024.
77. ^ "Handbook for the Montreal Protocol on Substances that Deplete the Ozone Layer – 7th Edition". United Nations Environment Programme – Ozone Secretariat. 2007. Archived from the original on 30 May 2016. Retrieved 18 December 2016.
78. ^ "Refrigerants – Environmental Properties". *The Engineering ToolBox*. Archived from the original on 14 March 2013. Retrieved 12 September 2016.
79. ^ R-410A#Environmental effects.
80. ^ Ecometrica.com (27 June 2012). "Calculation of green house gas potential of R-410A". Archived from the original on 13 July 2015. Retrieved 13 July 2015.

81. ^ "R404 and DME Refrigerant blend as a new solution to limit global warming potential" (PDF). 14 March 2012. Archived from the original (PDF) on 14 March 2012.
82. ^ **a b** IPCC\_AR6\_WG1\_Ch7 2021, 7SM-26
83. ^ LearnMetrics (12 May 2023). "List of Low GWP Refrigerants: 69 Refrigerants Below 500 GWP". LearnMetrics. Archived from the original on 10 June 2023. Retrieved 13 September 2023.
84. ^ **a b c** "Global warming potential (GWP) of HFC refrigerants". iifiir.org. Archived from the original on 24 September 2023. Retrieved 13 September 2023.
85. ^ Everitt, Neil (15 September 2023). "Qvantum plant has 1 million heat pump capacity". Cooling Post. Archived from the original on 24 September 2023. Retrieved 17 September 2023.
86. ^ Miara, Marek (22 October 2019). "Heat Pumps with Climate-Friendly Refrigerant Developed for Indoor Installation". Fraunhofer ISE. Archived from the original on 20 February 2022. Retrieved 21 February 2022.
87. ^ "Refrigerant Safety – About Refrigerant Safety, Toxicity and Flammability". Checkmark. Retrieved 17 April 2024.
88. ^ "A2L – Mildly Flammable Refrigerants". ACR Journal. 1 September 2015. Retrieved 17 April 2024.
89. ^ US Environmental Protection Agency, OAR (14 November 2014). "Phaseout of Ozone-Depleting Substances (ODS)". US EPA. Archived from the original on 24 September 2015. Retrieved 16 February 2020.
90. ^ "Heat Pumps". IEA. Archived from the original on 17 September 2023. Retrieved 17 September 2023.
91. ^ "Electrifying industrial processes with heat pumps". 22 March 2022. Archived from the original on 8 August 2022. Retrieved 9 August 2022.
92. ^ Department of Energy, Environment and Climate Action, Victoria Government (Australia) (11 October 2023). "Hot water systems for businesses". Victoria Government.
93. ^ Department of Energy, Environment and Climate Action (Australia), Victoria Government (23 September 2023). "Hot water systems for households". Victoria Government.
94. ^ New South Wales Climate and Energy Action, New South Wales Government (Australia) (8 December 2023). "Upgrade your hot water system". NSW Government.
95. ^ Australian Government, Queensland (5 October 2023). "Queensland Business Energy Saving and Transformation Rebates". Queensland Government.
96. ^ Time To Save (21 November 2023). "Hot Water Rebates in Australia: A Detailed Guide For Businesses". Timetosave.
97. ^ "Canada Greener Homes Grant". 17 March 2021. Archived from the original on 17 January 2022. Retrieved 17 January 2022.
98. ^ "Coal fired boiler replacement in Beijing rural area". Archived from the original on 24 March 2023. Retrieved 14 September 2023.

99. ^ **abc** "Executive summary – The Future of Heat Pumps in China – Analysis". IEA . Retrieved 12 April 2024.
100. ^ IEA (2024), The Future of Heat Pumps in China, IEA, Paris <https://www.iea.org/reports/the-future-of-heat-pumps-in-china>, Licence: CC BY 4.0
101. ^ "The Heat Pump Accelerator Platform". European Commission. 2024. Retrieved 27 November 2024.
102. ^ "Heat pumps". European Commission. 2024. Retrieved 27 November 2024.
103. ^ "HMCR rates for goods and services". 11 July 2022. Archived from the original on 22 July 2022. Retrieved 24 August 2022.
104. ^ "Apply for the Boiler Upgrade Scheme". Archived from the original on 19 September 2023. Retrieved 14 September 2023.
105. ^ "BBC Radio 4 – Sliced Bread, Air Source Heat Pumps". BBC. Archived from the original on 30 April 2022. Retrieved 30 April 2022.
106. ^ Lawrence, Karen (3 May 2024). "Air source heat pump costs and savings". Which?. Retrieved 7 June 2024.
107. ^ "Clean Heat without the Hot Air: British and Dutch lessons and challenges". UKERC. Retrieved 7 June 2024.
108. ^ Shao, Elena. "H. R. 5376 – Inflation Reduction Act of 2022". Congress.gov. U.S. Congress. Archived from the original on 17 November 2022. Retrieved 17 November 2022.
109. ^ "As Heat Pumps Go Mainstream, a Big Question: Can They Handle Real Cold?". The New York Times. 22 February 2023. Archived from the original on 11 April 2023. Retrieved 11 April 2023.
110. ^ Frazin, Rachel (17 November 2023). "Biden administration uses wartime authority to bolster energy efficient manufacturing". The Hill. Retrieved 29 November 2023.

## Sources

[edit]

## IPCC reports

[edit]

- IPCC (2021). Masson-Delmotte, V.; Zhai, P.; Pirani, A.; Connors, S. L.; et al. (eds.). *Climate Change 2021: The Physical Science Basis (PDF)*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press (In Press).
  - Forster, P.; Storelvmo, T.; Armour, K.; Collins, W. (2021). "Chapter 7: The Earth's energy budget, climate feedbacks, and climate sensitivity Supplementary Material" (PDF). IPCC AR6 WG1 2021.
- IPCC (2018). Masson-Delmotte, V.; Zhai, P.; Pörtner, H.-O.; Roberts, D.; et al. (eds.). *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas*

*emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty (PDF). Intergovernmental Panel on Climate Change. <https://www.ipcc.ch/sr15/>.*

- *Rogelj, J.; Shindell, D.; Jiang, K.; Fifa, S.; et al. (2018). "Chapter 2: Mitigation Pathways Compatible with 1.5°C in the Context of Sustainable Development" (PDF). IPCC SR15 2018. pp. 93–174.*
- *IPCC (2022). Shula, P. R.; Skea, J.; Slade, R.; Al Khourdajie, A.; et al. (eds.). Climate Change 2022: Mitigation of Climate Change (PDF). Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge, UK and New York, New York, USA: Cambridge University Press (In Press). Archived from the original (PDF) on 4 April 2022. Retrieved 10 May 2022.*
  - *IPCC (2022). "Industry" (PDF). IPCC AR6 WG3 2022.*

## Other

[edit]

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

## External links

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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
- Solar heating

- 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
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- Boiler
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- Evaporative cooler
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- Expansion tank
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- 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
- Grille

**Measurement  
and control**

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

**Professions,  
trades,  
and services**

**Industry organizations**

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

**Health and safety**

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

**See also**

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

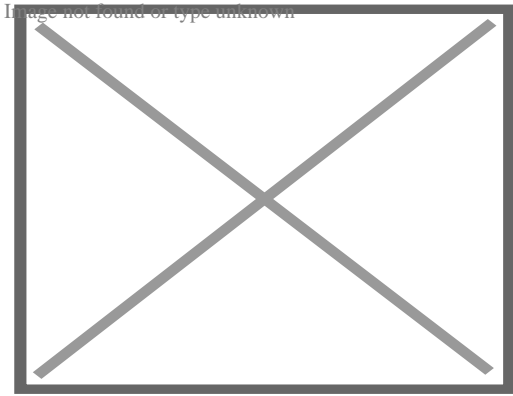
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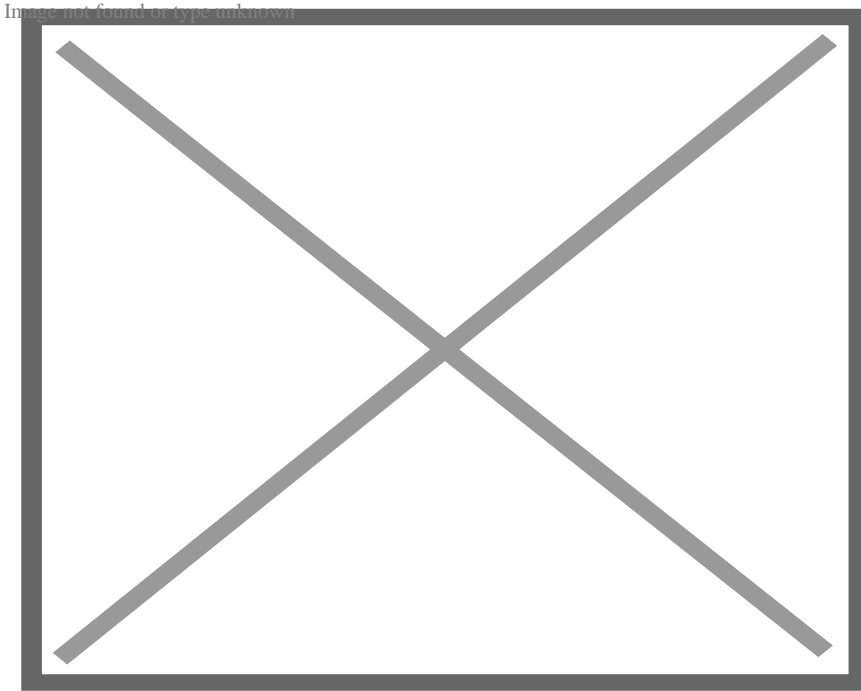
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- United States
- France
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- Czech Republic
- Israel

**About Air pollution**

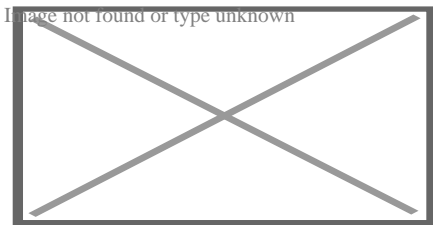
"Bad air quality" and "Air quality" redirect here. For the obsolete medical theory, see Miasma theory. For the measurement of air pollution, see Air quality index. For the qualities of air, see Atmosphere of Earth.



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.

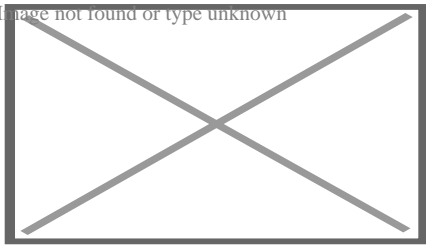


Deaths from air pollution per 100,000 inhabitants (IHME, 2019)

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Part of a series on

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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
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Part of a series on

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Weather portal

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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.<sup>[1]</sup> 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.<sup>[1]</sup> 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).<sup>[2]</sup> Air pollution can be caused by both human activities<sup>[3]</sup> and natural phenomena.<sup>[4]</sup>

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.<sup>[1]</sup>

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.<sup>[5]</sup> Growing evidence suggests that air pollution exposure may be associated with reduced IQ scores, impaired cognition,<sup>[6]</sup> increased risk for psychiatric disorders such as depression<sup>[7]</sup> and detrimental perinatal health.<sup>[8]</sup> The human health effects of poor air quality are far reaching, but principally affect the body's respiratory system and the cardiovascular system.<sup>[9]</sup><sup>[10]</sup> Individual reactions to air pollutants depend on the type of pollutant a person is exposed to,<sup>[11]</sup><sup>[12]</sup> the degree of exposure, and the individual's health status and genetics.<sup>[13]</sup>

Air pollution is the largest environmental risk factor for disease and premature death<sup>[5]</sup><sup>[14]</sup> and the fourth largest risk factor overall for human health.<sup>[15]</sup> Air pollution causes the premature deaths of around 7 million people worldwide each year,<sup>[5]</sup> or a global mean loss of life expectancy (LLE) of 2.9 years,<sup>[16]</sup> and there has been no significant change in the number of deaths caused by all forms of pollution since at least 2015.<sup>[14]</sup><sup>[17]</sup><sup>[18]</sup> Outdoor air pollution attributable to fossil fuel use alone causes ~3.61 million deaths annually,<sup>[19]</sup> making it one of the top contributors to human death.<sup>[5]</sup> Anthropogenic ozone causes around 470,000 premature deaths a year and fine

particulate (PM<sub>2.5</sub>) pollution around another 2.1 million.<sup>[20]</sup> 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."<sup>[21]</sup> Although the health consequences are extensive, the way the problem is handled is considered largely haphazard<sup>[22]</sup><sup>[21]</sup><sup>[23]</sup> or neglected.<sup>[14]</sup>

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.<sup>[24]</sup><sup>[25]</sup><sup>[26]</sup> 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.<sup>[27]</sup><sup>[28]</sup>

Many different technologies and strategies are available for reducing air pollution.<sup>[29]</sup> 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.<sup>[30]</sup> 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.<sup>[31]</sup><sup>[32]</sup> Some of these efforts have been successful at the international level, such as the Montreal Protocol,<sup>[33]</sup> which reduced the release of harmful ozone depleting chemicals, and the 1985 Helsinki Protocol,<sup>[34]</sup> which reduced sulfur emissions,<sup>[35]</sup> while others, such as international action on climate change,<sup>[36]</sup><sup>[37]</sup><sup>[38]</sup> have been less successful.

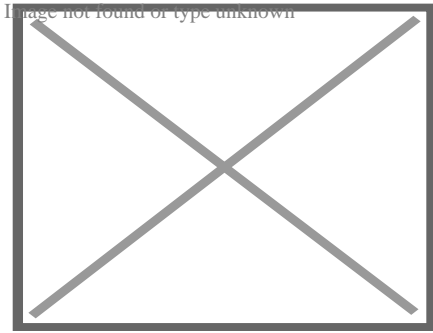
## Sources of air pollution

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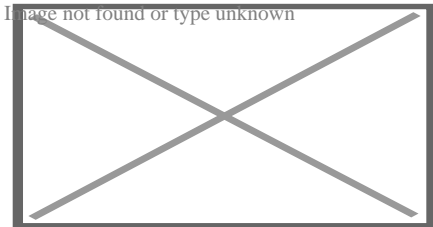
There are many different sources of air pollution. Some air pollutants (such as nitrogen oxides) originate mainly from human activities,<sup>[39]</sup> while some (notably radon gas) come mostly from natural sources.<sup>[40]</sup> However, many air pollutants (including dust and sulfur dioxide) come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

## Anthropogenic (human-made) sources

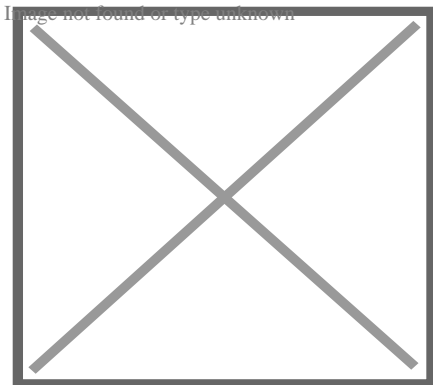
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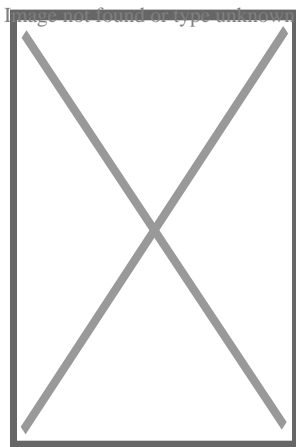
Demolition of the cooling towers of a power station, Athlone, Cape Town, South Africa, 2010



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



Smoking of fish over an open fire in Ghana, 2018



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

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.<sup>[75]</sup>
- Waste deposition in landfills produces methane<sup>[76]</sup> and open burning of waste releases harmful substances.<sup>[77]</sup>

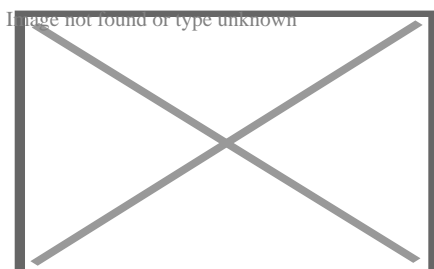


- Nuclear weapons, toxic gases, germ warfare, and rocketry are examples of military resources.<sup>[78]</sup>
  - Agricultural emissions and emissions from meat production or livestock contribute substantially to air pollution<sup>[79]</sup><sup>[80]</sup>
    - Fertilized farmland may be a major source of nitrogen oxides.<sup>[81]</sup>
- Mean acidifying emissions (air pollution) of different foods per 100g of protein<sup>[82]</sup>

<b>Food Types</b>	<b>Acidifying Emissions (g SO<sub>2</sub>eq per 100g protein)</b>
<b>Beef</b>	343.6
<b>Cheese</b>	165.5
<b>Pork</b>	142.7
<b>Lamb and mutton</b>	139.0
<b>Farmed crustaceans</b>	133.1
<b>Poultry</b>	102.4
<b>Farmed fish</b>	65.9
<b>Eggs</b>	53.7
<b>Groundnuts</b>	22.6
<b>Peas</b>	8.5
<b>Tofu</b>	6.7

### **Natural sources**

[edit]



## Dust storm approaching Stratford, Texas, in 1935

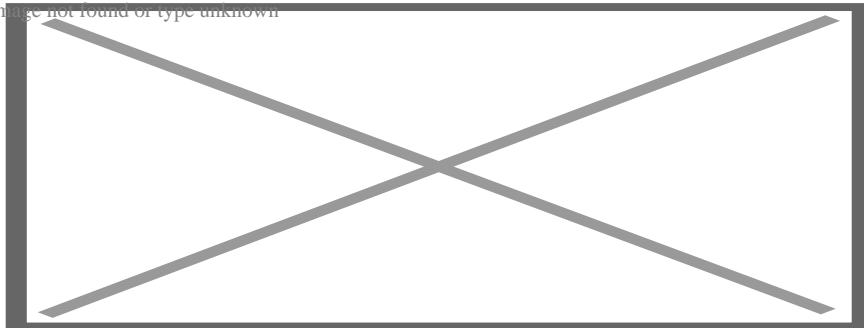
- Dust from natural sources, usually large areas of land with little or no vegetation.
- Methane, emitted by the digestion of food by animals, for example cattle.
- Radon gas from radioactive decay within the Earth's crust. Radon is a colorless, odorless, naturally occurring, radioactive noble gas that 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.<sup>[83]</sup>
- Vegetation, in some regions, emits environmentally significant amounts of volatile organic compounds (VOCs) on warmer days. These VOCs react with primary anthropogenic pollutants – specifically,  $\text{NO}_x$ ,  $\text{SO}_2$ , and anthropogenic organic carbon compounds – to produce a seasonal haze of secondary pollutants.<sup>[84]</sup> 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.<sup>[85]</sup>
- Volcanic activity, which produces sulfur, chlorine, and ash particulates.<sup>[86]</sup>

## Emission factors

[edit]

Main article: AP 42 Compilation of Air Pollutant Emission Factors

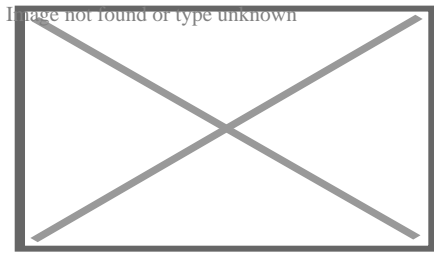
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Beijing air in 2005 after rain (left) and a smoggy day (right)

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.<sup>[2][87][88][89]</sup> 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.



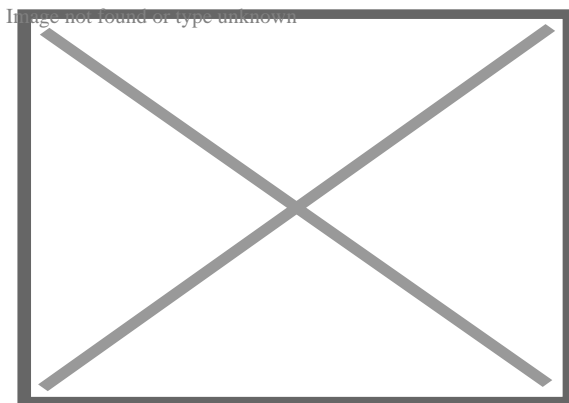
E-waste processing in Agbogbloshie, Ghana, using open-burning of electronics to access valuable metals like copper. Open burning of plastics is common in many parts of the world without the capacity for processing. Especially without proper protections, heavy metals and other contaminants can seep into 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.<sup>[90]</sup> The United Kingdom, Australia, Canada, and many other countries have published similar compilations, as well as the European Environment Agency.<sup>[91][92][93][94]</sup>

## 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.<sup>[95]</sup> 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).<sup>[96]</sup> 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]



This section is in list format but may read better as prose. You can help by converting this section, if appropriate. Editing help is available. (April 2023)

Pollutants emitted into the atmosphere by human activity include:

- Ammonia: Emitted mainly by agricultural waste. Ammonia is a compound with the formula  $\text{NH}_3$ . 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.<sup>[97]</sup> In the atmosphere, ammonia reacts with oxides of nitrogen and sulfur to form secondary particles.<sup>[98]</sup>
- Carbon dioxide ( $\text{CO}_2$ ): Carbon dioxide is a natural component of the atmosphere, essential for plant life and given off by the human respiratory system.<sup>[99]</sup> It is potentially lethal at very high concentrations (typically 100 times "normal" atmospheric levels).<sup>[100][101]</sup> Although the World Health Organization recognizes  $\text{CO}_2$  as a climate pollutant, it does not include the gas in its *Air Quality Guidelines* or set recommended targets for it.<sup>[102]</sup> Because of its role as a greenhouse gas,  $\text{CO}_2$  has been described as "the worst climate pollutant".<sup>[103]</sup> 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  $\text{CO}_2$  emissions.<sup>[104]</sup> 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.'"<sup>[105]</sup>  $\text{CO}_2$  currently forms about 410 parts per million (ppm) of Earth's atmosphere, compared to about 280 ppm in pre-industrial times,<sup>[106]</sup> and billions of metric tons of  $\text{CO}_2$  are emitted annually by burning of fossil fuels.<sup>[107]</sup>  $\text{CO}_2$  increase in Earth's

atmosphere has been accelerating.<sup>[108]</sup> CO<sub>2</sub> is an asphyxiant gas and not classified as toxic or harmful in general.<sup>[109]</sup> Workplace exposure limits exist in places like UK (5,000 ppm for long-term exposure and 15,000 ppm for short-term exposure).<sup>[101]</sup> Natural disasters like the limnic eruption at Lake Nyos can result in a sudden release of huge amount of CO<sub>2</sub> as well.<sup>[110]</sup>

- Carbon monoxide (CO): CO is a colorless, odorless, toxic gas.<sup>[111]</sup> 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.<sup>[112]</sup> 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.<sup>[113]</sup>
- Nitrogen oxides (NO<sub>x</sub>): 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<sub>2</sub>. 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.<sup>[114]</sup> 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.<sup>[115]</sup> 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,<sup>[116]</sup> altered lung function and lung cancer. Particulates are related to respiratory infections and can be particularly harmful to those with conditions like asthma.<sup>[117]</sup>
- 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.<sup>[118]</sup>
- Persistent free radicals connected to airborne fine particles are linked to cardiopulmonary disease.<sup>[119][120]</sup>
- Polycyclic Aromatic Hydrocarbons (PAHs): a group of aromatic compounds formed from the incomplete combustion of organic compounds including coal and oil and

tobacco.[<sup>121</sup>]

- Radioactive pollutants: Produced by nuclear explosions, nuclear events, war explosives, and natural processes such as the radioactive decay of radon.
- Sulfur oxides ( $\text{SO}_x$ ): particularly sulfur dioxide, a chemical compound with the formula  $\text{SO}_2$ .  $\text{SO}_2$  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  $\text{SO}_2$ , usually in the presence of a catalyst such as  $\text{NO}_2$ , forms  $\text{H}_2\text{SO}_4$ , 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.[<sup>122</sup>] They are categorized as either methane ( $\text{CH}_4$ ) 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 ( $\text{O}_3$ ): Ozone is created when  $\text{NO}_x$  and VOCs mix. It is a significant part of the troposphere.[<sup>123</sup>] 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).[<sup>124</sup>]  $\text{O}_3$  is largely produced by chemical reactions involving  $\text{NO}_x$  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.[<sup>125</sup>]
- Peroxyacetyl nitrate ( $\text{C}_2\text{H}_3\text{NO}_5$ ): similarly formed from  $\text{NO}_x$  and VOCs.
- Photochemical smog: particles are formed from gaseous primary contaminants and chemicals.[<sup>126</sup>] 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.[<sup>127</sup>] 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



odorous emissions.

o

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<sup>[130]</sup> 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.<sup>[130]</sup>

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.<sup>[130]</sup>

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.<sup>[131]</sup> A large portion of total daily exposure occurs as short peaks of high concentrations, but it remains unclear how to



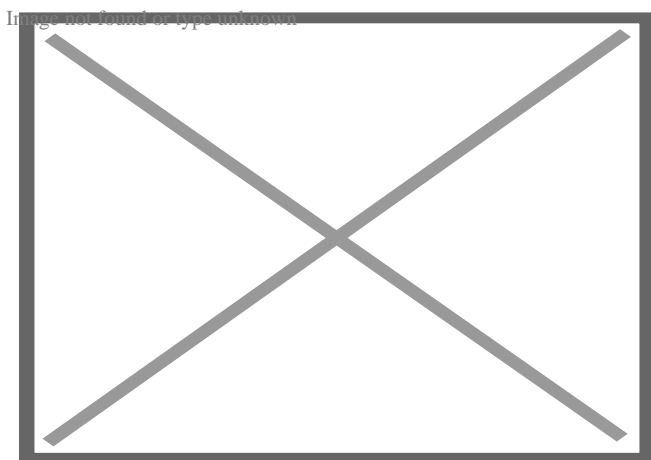
define peaks and determine their frequency and health impact.[<sup>132</sup>]

In 2021, the WHO halved its recommended guideline limit for tiny particles from burning fossil fuels. The new limit for nitrogen dioxide (NO<sub>2</sub>) is 75% lower.[<sup>133</sup>] Growing evidence that air pollution—even when experienced at very low levels—hurts human health, led the WHO to revise its guideline (from 10 µg/m<sup>3</sup> to 5 µg/m<sup>3</sup>) 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.[<sup>134</sup>]

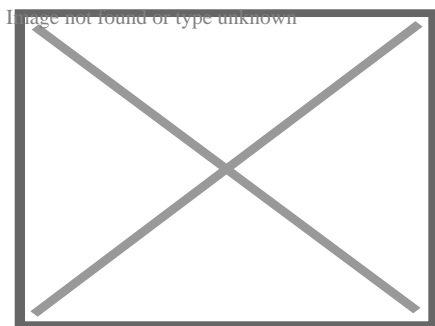
## Indoor air quality

[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.[<sup>135</sup>]

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

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.<sup>[136][137]</sup>

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.<sup>[136][137]</sup> 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.<sup>[138]</sup>

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.<sup>[139]</sup> 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,<sup>[140]</sup> 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<sup>[141]</sup> 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.

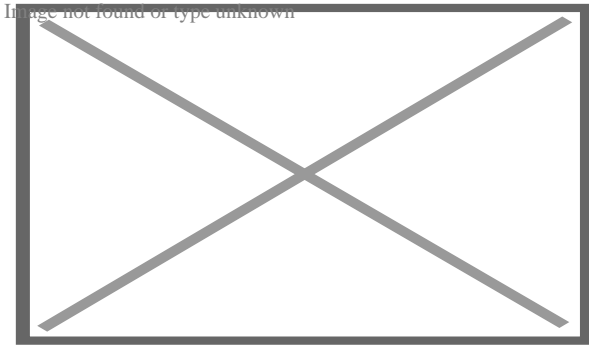
Short and long term exposures have been linked with premature mortality and reduced life expectancy<sup>[142]</sup> and can result in increased medication use, increased doctor or emergency department visits, more hospital admissions and premature death.<sup>[130]</sup><sup>[better source]</sup> Diseases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

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.<sup>[144]</sup> 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.<sup>[130]</sup> The most common sources of air pollution include particulates and ozone (often from burning fossil fuels),<sup>[145]</sup> 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.<sup>[146]</sup>

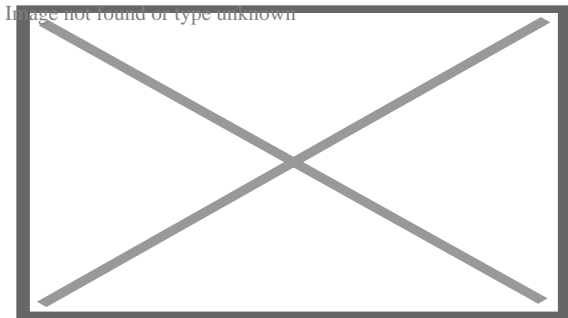
Under the Clean Air Act, U.S. EPA sets limits on certain air pollutants, including setting limits on how much can be in the air anywhere in the United States.<sup>[147]</sup> Mixed exposure to both carbon black and ozone could result in significantly greater health affects.<sup>[148]</sup>

## Mortality

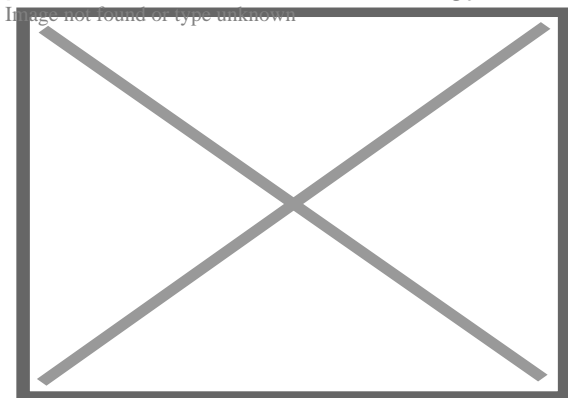
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Estimates of the death toll from air pollution vary across publications.



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



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.<sup>[150]</sup> In 2014 the World Health Organization estimated that every year air pollution causes the premature death of 7 million people worldwide,<sup>[5]</sup> 1 in 8 deaths worldwide.<sup>[151]</sup> 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.<sup>[152][153]</sup> 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.<sup>[14][154]</sup> Causes of deaths include strokes, heart disease, COPD, lung cancer, and lung infections.<sup>[5]</sup> Children are particularly at risk.<sup>[155]</sup>

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

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.<sup>[16]</sup> Communities with persons that live beyond 85 years have low ambient air pollution, suggesting a link between air pollution levels and longevity.<sup>[157]</sup>

## 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.<sup>[156]</sup> The mechanisms linking air pollution to increased cardiovascular mortality are uncertain, but probably include pulmonary and systemic inflammation.<sup>[158]</sup>

## By region

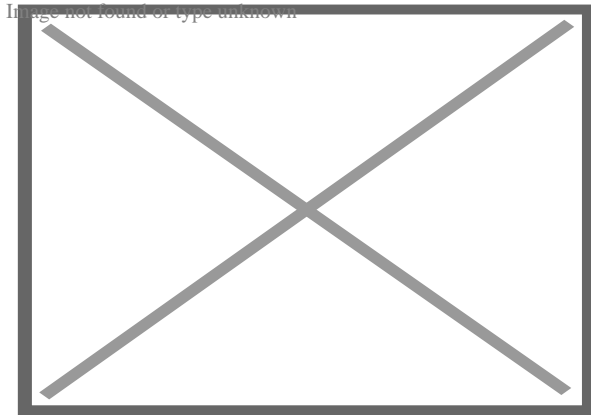
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India and China have the highest death rate due to air pollution.<sup>[159][160]</sup> India also has more deaths from asthma than any other nation according to the World Health Organization. In 2019, 1.6 million deaths in India were caused by air pollution.<sup>[161]</sup> In 2013, air pollution was estimated to kill 500,000 people in China each year.<sup>[162]</sup> 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.<sup>[163]</sup>

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

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<sub>2.5</sub>-related illness and death.<sup>[168]</sup>

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

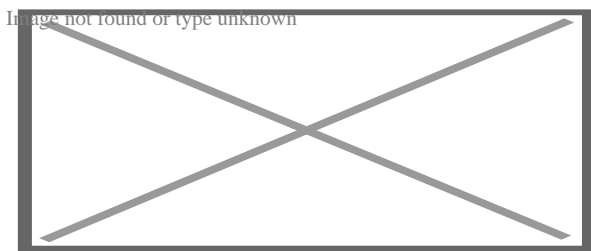


Air pollution deaths by nation due to fossil fuels

## Major causes

[edit]

Further information: § Sources



A comparison of footprint-based and transboundary pollution-based relationships among G20 nations for the number of PM<sub>2.5</sub>-related premature deaths<sup>[170]</sup>

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

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.<sup>[174][175]</sup>

A study concluded that PM<sub>2.5</sub> 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.<sup>[176][170]</sup>

## 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.<sup>[177][178]</sup> 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.<sup>[179]</sup>

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.<sup>[180][181][182]</sup> 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.<sup>[183][184]</sup>

## Cardiovascular disease

[edit]

According to the Global Burden of Disease Study, air pollution is responsible for 19% of all cardiovascular deaths.<sup>[185][186]</sup> 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).<sup>[186]</sup>

Air pollution is a leading risk factor for stroke, particularly in developing countries where pollutant levels are highest.<sup>[187]</sup> 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).<sup>[187][188]</sup> In women, air pollution is not associated with hemorrhagic but with ischemic stroke.<sup>[189]</sup> Air pollution was found to be associated with increased incidence and mortality from coronary stroke.<sup>[190]</sup> Associations are believed to be causal and effects may be mediated by vasoconstriction, low-grade inflammation and atherosclerosis.<sup>[191]</sup> Other mechanisms such as autonomic nervous system imbalance have also been suggested.<sup>[192][193]</sup>

## Lung disease

[edit]

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

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

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.<sup>[200]</sup>

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<sub>1</sub> 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.<sup>[201]</sup> More studies have shown that air pollution exposure from traffic reduces lung function development in children<sup>[202]</sup> and lung function may be compromised by air pollution even at low concentrations.<sup>[203]</sup>



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.<sup>[204]</sup>

## Cancer

[edit]

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

Image not found or type unknown

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<sub>2.5</sub>, suspended in the air.<sup>[205]</sup> PM<sub>2.5</sub> exposure, such as from car exhausts, activates dormant mutations in lung cells, causing them to become cancerous.<sup>[206]</sup><sup>[205]</sup> Unprotected exposure to PM<sub>2.5</sub> air pollution can be equivalent to smoking multiple cigarettes per day,<sup>[207]</sup><sup>[*dead link*]</sup> potentially increasing the risk of cancer, which is mainly the result of environmental factors.<sup>[208]</sup>

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

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<sub>2.5</sub> is positively associated with mortality from coronary heart diseases and exposure to SO<sub>2</sub> increases mortality from lung cancer, but the data was insufficient to provide solid conclusions.<sup>[209]</sup> 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  $\mu\text{g}/\text{m}^3$  decrease (from an approximate peak of 30  $\mu\text{g}/\text{m}^3$ ) in the ambient concentration of  $\text{PM}_{2.5}$  was associated with a 25% reduced risk of chronic kidney disease development. [213] According to a cohort study involving 10,997 atherosclerosis patients, higher  $\text{PM}_{2.5}$  exposure is associated with increased albuminuria. [214]

## **Fertility**

[edit]

## **Nitrogen dioxide ( $\text{NO}_2$ )**

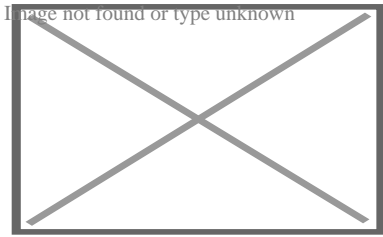
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An increase in  $\text{NO}_2$  is significantly associated with a lower live birth rate in women undergoing IVF treatment. [215] In the general population, there is a significant increase in miscarriage rate in women exposed to  $\text{NO}_2$  compared 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.<sup>[216]</sup> 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.<sup>[217]</sup>

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.<sup>[218]</sup>

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.<sup>[219]</sup>

## Particulate matter

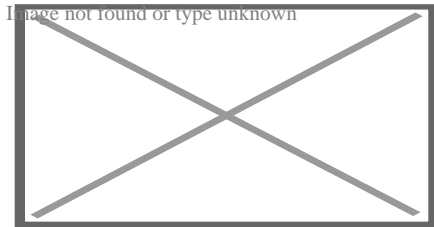
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Particulate matter (PM) refers to the collection of solids and liquids suspended in the air. These can be harmful to humans, and more research has shown that these effects may be more extensive than first thought; particularly on male fertility. PM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

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

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<sub>10</sub> alongside carbon monoxide and nitrogen oxides.<sup>[220]</sup> 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<sub>10</sub> and early miscarriage. Exposure to smaller particulate matter, PM<sub>2.5</sub>, appears to have an effect on conception rates in women undergoing IVF but does not affect live birth rates.<sup>[215]</sup>



Ozone structure showing three oxygen atoms

## Ground-level ozone pollution

[edit]

Ground-level ozone (O<sub>3</sub>), 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.<sup>[215]</sup> 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<sub>x</sub> and ozone pollutants were linked with reduced rates of live birth.<sup>[215]</sup>

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.<sup>[221]</sup> 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 NO<sub>2</sub>, the association between O<sub>3</sub> and IVF live birth rate was no longer significant.<sup>[222][223]</sup>

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

## 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).<sup>[225]</sup> Children in low or middle income countries are exposed to higher levels of fine particulate matter than those in high income countries.<sup>[225]</sup>

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

## 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.<sup>[228]</sup> They can also lead to detrimental perinatal health outcomes that are often fatal in developing countries.<sup>[8]</sup> A 2014 study found that PAHs might play a role in the development of childhood attention deficit hyperactivity disorder (ADHD).<sup>[229]</sup>

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.<sup>[230]</sup> A cohort study in Southern California linked in-utero exposure to near-roadway air pollution to an increased risk of ASD diagnosis<sup>[231]</sup> and a study in Sweden concluded that exposure to PM<sub>2.5</sub> during pregnancy was associated with ASD.<sup>[232]</sup> A Danish study linked exposure to air pollution during infancy, but not during pregnancy, to an increased risk of

ASD diagnosis.[<sup>233</sup>]

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, causing DNA damage and mutations.[<sup>234</sup>]  
Air pollution has been associated with the prevalence of preterm births.[<sup>235</sup>]

## 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<sub>2.5</sub>. Women in regions with greater than average PM<sub>2.5</sub> levels had statistically significant higher odds of pregnancy resulting in a low-birth weight infant even when adjusted for country-related variables.[<sup>236</sup>] The effect is thought to be from stimulating inflammation and increasing oxidative stress.

A study found that in 2010 exposure to PM<sub>2.5</sub> 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.[<sup>237</sup>] 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.[<sup>238</sup>][<sup>239</sup>][<sup>240</sup>]

The source of PM<sub>2.5</sub> 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.[<sup>237</sup>] The United States had an estimated 50,000 preterm births associated with exposure to PM<sub>2.5</sub> in 2010.[<sup>237</sup>]

A study between 1988 and 1991 found a correlation between sulfur dioxide (SO<sub>2</sub>) 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<sub>2</sub> and TSP (along with other particulates). The estimated reduction in birth weight was 7.3 g for every 100 µg/m<sup>3</sup> increase in SO<sub>2</sub> and 6.9 g for each 100 µg/m<sup>3</sup> 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.[<sup>241</sup>] 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<sub>2</sub>, CO, PM<sub>10</sub> and PM<sub>2.5</sub> 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.[<sup>242</sup>]

## 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.[<sup>243</sup>]

Air pollution increases the risk of dementia in people over 50 years old.[<sup>244</sup>] Indoor air pollution exposure during childhood may negatively affect cognitive function and neurodevelopment.[<sup>245</sup>][<sup>246</sup>] Prenatal exposure may also affect neurodevelopment.[<sup>247</sup>][<sup>248</sup>] 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.[<sup>246</sup>]

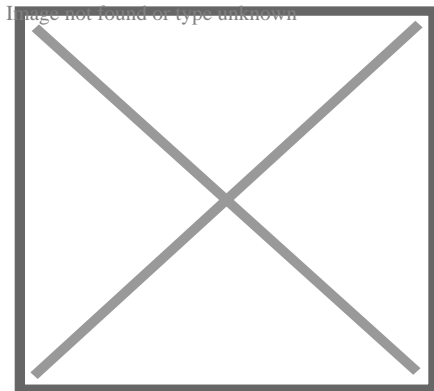
Researchers found that early exposure to air pollution causes the same changes in the brain as autism and schizophrenia in mice. It also showed that air pollution also affected short-term memory, learning ability, and impulsivity. In this study, air pollution had a larger negative impact on male mice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

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]

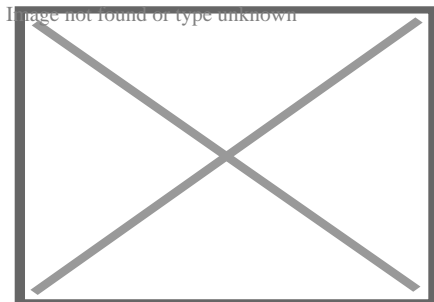
In 2015, experimental studies reported the detection of significant episodic (situational) cognitive impairment from impurities in indoor air breathed by test subjects who were not informed about changes in the air quality. Significant deficits were observed in the performance scores achieved in increasing 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.<sup>[258]</sup> In 2020, scientists found that the boundary layer air over the Southern Ocean around Antarctica is 'unpolluted' by humans.<sup>[259]</sup>

## **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.<sup>[260]</sup> After air pollutants enter the agricultural environment, they not only directly affect agricultural production and quality, but also enter agricultural waters and soil.<sup>[261]</sup> 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.<sup>[262]</sup> On the other hand, agriculture in its traditional form is one of the primary contributors to the emission of trace gases like atmospheric ammonia.<sup>[263]</sup>

## **Economic effects**

[edit]

Air pollution costs the world economy \$5 trillion per year as a result of productivity losses and degraded quality of life.<sup>[24][25][26]</sup> 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<sub>2.5</sub> and ozone concentrations) would produce \$29 million in annual savings in the lower Fraser Valley region in 2010.<sup>[264]</sup> 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."<sup>[24][25]</sup> The report states that additional economic losses caused by air pollution, including health costs<sup>[265]</sup> 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<sub>2</sub> levels

increases the likelihood of an accident by as much as 25%".<sup>[266]</sup>

## 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<sub>2</sub> pollution levels and with telescopic technology close to today. It may also be possible to detect extraterrestrial civilizations this way.<sup>[267]</sup><sup>[268]</sup><sup>[269]</sup>

## Historical disasters

[edit]

The world's worst short-term civilian pollution crisis was the 1984 Bhopal Disaster in India.<sup>[270]</sup> 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.<sup>[271]</sup>

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.<sup>[272]</sup> 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.<sup>[273]</sup>

## 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.<sup>[274]</sup> 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)<sup>[275]</sup> and related legal regulations as well as efforts towards renewable energy transitions.<sup>[276]</sup><sup>[277]</sup>

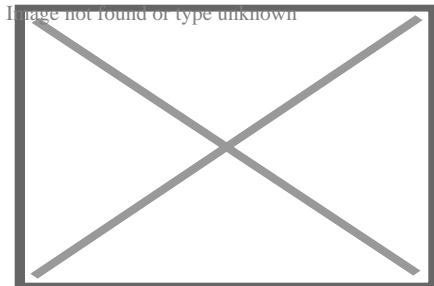
Efforts to reduce particulate matter in the air may result in better health.<sup>[278]</sup>

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<sub>2</sub> emissions during its three-month implementation from June to August 2022.<sup>[279]</sup>

## Pollution control

[edit]



Burning of items polluting Jamestown environment in Accra, Ghana

Various pollution control technologies and strategies are available to reduce air pollution.<sup>[280]</sup><sup>[281]</sup> 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.<sup>[282]</sup> 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.<sup>[283]</sup>

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<sub>x</sub> gases. One form is superhydrophilic.<sup>[284]</sup>

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

## Energy transition

[edit]

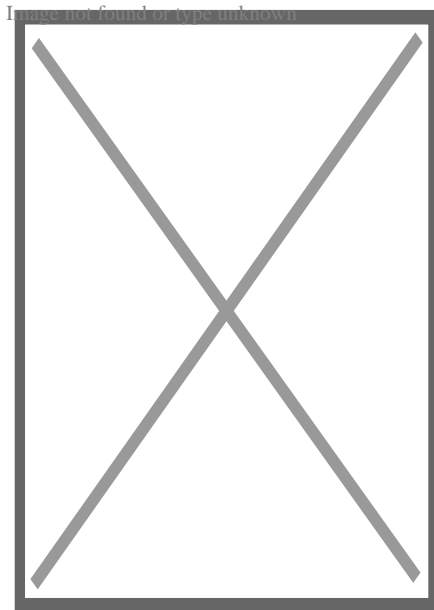
Since a large share of air pollution is caused by combustion of fossil fuels such as coal and oil, the reduction of these fuels can reduce air pollution drastically. Most effective is the switch to clean power sources such as wind power, solar power, hydro power which do not cause air pollution.<sup>[286]</sup> 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.<sup>[226][287]</sup>

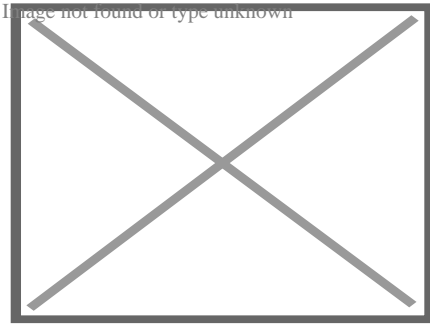
A very effective means to reduce air pollution is the transition to renewable energy. According to a study published in Energy and Environmental Science in 2015 the switch to 100% renewable energy in the United States would eliminate about 62,000 premature mortalities per year and about 42,000 in 2050, 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.<sup>[286]</sup> Air quality improvement is a near-term benefit among the many societal benefits from climate change mitigation.

### Alternatives to pollution

[edit]



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



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:

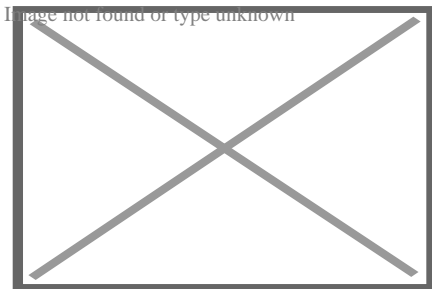
- Strategic substitution of air pollution sources in transport with lower-emission or, during the lifecycle, emission-free forms of public transport<sup>[288]</sup><sup>[289]</sup> and bicycle use and infrastructure (as well as with remote work, reductions of work, relocations, and localizations)
  - 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<sup>[290]</sup><sup>[291]</sup>
- 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.<sup>[292]</sup> 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).<sup>[293]</sup>
- 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.<sup>[294]</sup>
- 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.<sup>[295]</sup><sup>[296]</sup>
- 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.<sup>[297]</sup>

- Reducing travel in vehicles can curb pollution. After Stockholm reduced vehicle traffic in the central city with a congestion tax, nitrogen dioxide and PM<sub>10</sub> pollution declined, as did acute pediatric asthma attacks.<sup>[298]</sup>
- 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.<sup>[299]</sup>
- 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.<sup>[300]</sup>

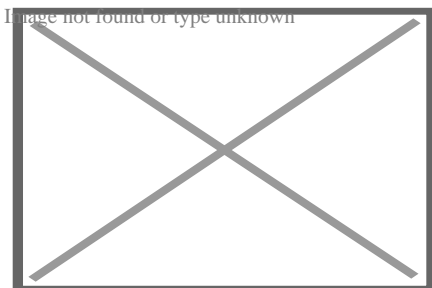
Further information: § Sources

## 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<sub>x</sub> control**
    - LO-NO<sub>x</sub> burners
    - Selective catalytic reduction (SCR)
    - Selective non-catalytic reduction (SNCR)
    - NO<sub>x</sub> 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<sub>2</sub> 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.<sup>[301]</sup> 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,<sup>[302][303]</sup> satellites,<sup>[304][305][306]</sup> and monitoring stations.<sup>[307][308]</sup> Some websites attempt to map air pollution levels using available data.<sup>[309][310][311]</sup>

## Air quality modeling

[edit]

Main article: Air quality modeling

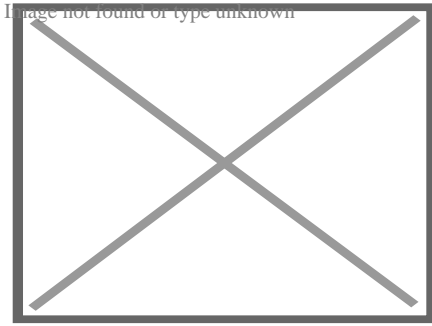
Numerical models either on a global scale using tools such as GCMs (general circulation models coupled with a pollution module) or CTMs (Chemical transport model) can be used to simulate the levels of different pollutants in the atmosphere. These tools can have several types (Atmospheric model) and different 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

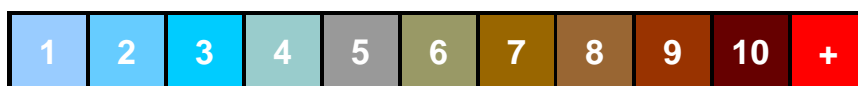
In general, there are two types of air quality standards. The first class of standards (such as the U.S. National Ambient Air Quality Standards and E.U. Air Quality Directive<sup>[312]</sup>) set maximum atmospheric concentrations for specific pollutants. Environmental agencies enact regulations which 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).<sup>[313]</sup> 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.



**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.[<sup>314</sup>]

Health risk	Air Quality Health Index	Health messages[ <sup>315</sup> ]	
		At risk population	General population
Low	1–3	<b>Enjoy</b> your usual outdoor activities.	<b>Ideal</b> air quality for outdoor activities
Moderate	4–6	<b>Consider reducing</b> or rescheduling strenuous activities outdoors if you are experiencing symptoms.	<b>No need to modify</b> your usual outdoor activities unless you experience symptoms such as coughing and throat irritation.
High	7–10	<b>Reduce</b> or reschedule strenuous activities outdoors. Children and the elderly should also take it easy.	<b>Consider reducing</b> or rescheduling strenuous activities outdoors if you experience symptoms such as coughing and throat irritation.
Very high	Above 10	<b>Avoid</b> strenuous activities outdoors. Children and the elderly should also avoid outdoor physical exertion and should stay indoors.	<b>Reduce</b> 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<sub>2</sub>), ground-level ozone (O<sub>3</sub>) and particulates (PM<sub>2.5</sub>) 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<sub>2</sub>), as well as sulfur dioxide (SO<sub>2</sub>), 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.<sup>[316]</sup>

## 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".<sup>[317]</sup>

In July 2008, in the case *Dieter Janecek v. Freistaat Bayern*, the European Court of Justice ruled that under this directive<sup>[317]</sup> 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.<sup>[318]</sup><sup>[319]</sup>

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<sub>10</sub> limit values.<sup>[320]</sup> The UK government has identified that if fines are imposed, they could cost the nation upwards of £300 million per year.<sup>[321]</sup>

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.<sup>[322]</sup> The City of London has dangerous levels of PM<sub>10</sub> concentrations, estimated to cause 3000 deaths per year within the city.<sup>[323]</sup> 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.<sup>[324]</sup>

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.<sup>[322]</sup>

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,<sup>[325]</sup> 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.<sup>[326]</sup> The C40 has been identified as 'governance from the middle' and is an alternative to intergovernmental policy.<sup>[327]</sup> 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".<sup>[326]</sup> 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<sup>[328]</sup> 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.<sup>[329]</sup> 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,<sup>[141]</sup> 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.<sup>[330]</sup>

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.<sup>[332]</sup>

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.<sup>[333]</sup> 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.<sup>[333]</sup> Blacks and Latinos generally face more pollution than Whites and Asians, and low-income communities bear a higher burden of risk than affluent ones.<sup>[332]</sup> Racial discrepancies are particularly distinct in suburban areas of the Southern United States and metropolitan areas of the Midwestern and Western United States.<sup>[334]</sup> Residents in public housing, who are generally low-income and cannot move to healthier neighborhoods, are highly affected by nearby refineries and chemical plants.<sup>[335]</sup>

### External videos

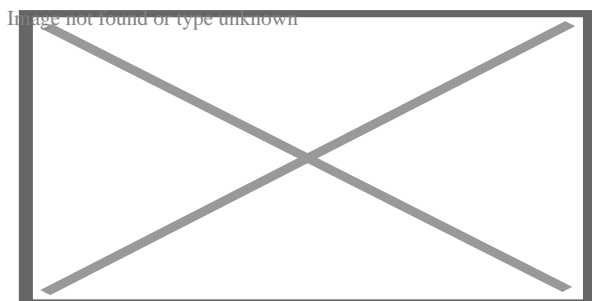
[Air Visual Earth](#) - realtime map of global wind and air pollution<sup>[331]</sup>

## 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.<sup>[336]</sup> However, even populated areas in developed countries attain unhealthy levels of pollution, with Los Angeles and Rome being two examples.<sup>[337]</sup> 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.<sup>[338]</sup>

<sup>[339]</sup>

### **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.<sup>[340]</sup>

## Projections

[edit]




In a 2019 projection, by 2030 half of the world's pollution emissions could be generated by Africa.<sup>[341]</sup> 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.<sup>[342]</sup>

## See also

[edit]

-  [Global warming portal](#)
-  [Plants portal](#)
-  [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

## References

[edit]

1. ^ **a b c** "Air pollution". *www.who.int*. Retrieved 14 January 2023.
2. ^ **a b** Manisalidis I, Stavropoulou E, Stavropoulos A, Bezirtzoglou E (2020). "Environmental and Health Impacts of Air Pollution: A Review". *Frontiers in Public Health*. **8**: 14. doi:10.3389/fpubh.2020.00014. ISSN 2296-2565. PMC 7044178. PMID 32154200.
3. ^ Howell R, Pickerill J (2016). "The Environment and Environmentalism". In Daniels P, Bradshaw M, Shaw D, Sidaway J, Hall T (eds.). *An Introduction To Human Geography (5th ed.)*. Pearson. p. 134. ISBN 978-1-292-12939-6.
4. ^ Dimitriou A, Christidou V (26 September 2011), Khallaf M (ed.), "Causes and Consequences of Air Pollution and Environmental Injustice as Critical Issues for Science and Environmental Education", *The Impact of Air Pollution on Health, Economy, Environment and Agricultural Sources*, InTech, doi:10.5772/17654,



ISBN 978-953-307-528-0, retrieved 31 May 2022

5. ^ **a b c d e f** "7 million premature deaths annually linked to air pollution". WHO. 25 March 2014. Retrieved 25 March 2014.
6. ^ Allen JL, Klocke C, Morris-Schaffer K, Conrad K, Sobolewski M, Cory-Slechta DA (June 2017). "Cognitive Effects of Air Pollution Exposures and Potential Mechanistic Underpinnings". *Current Environmental Health Reports*. **4** (2): 180–191. Bibcode:2017CEHR....4..180A. doi:10.1007/s40572-017-0134-3. ISSN 2196-5412. PMC 5499513. PMID 28435996.
7. ^ Newbury JB, Stewart R, Fisher HL, Beevers S, Dajnak D, Broadbent M, et al. (2021). "Association between air pollution exposure and mental health service use among individuals with first presentations of psychotic and mood disorders: retrospective cohort study". *The British Journal of Psychiatry*. **219** (6) (published 19 August 2021): 678–685. doi:10.1192/bjp.2021.119. ISSN 0007-1250. PMC 8636613. PMID 35048872.
8. ^ **a b** Ghosh R, Causey K, Burkart K, Wozniak S, Cohen A, Brauer M (28 September 2021). "Ambient and household PM2.5 pollution and adverse perinatal outcomes: A meta-regression and analysis of attributable global burden for 204 countries and territories". *PLOS Medicine*. **18** (9): e1003718. doi:10.1371/journal.pmed.1003718. ISSN 1549-1676. PMC 8478226. PMID 34582444.
9. ^ Dominski FH, Lorenzetti Branco JH, Buonanno G, Stabile L, Gameiro da Silva M, Andrade A (October 2021). "Effects of air pollution on health: A mapping review of systematic reviews and meta-analyses". *Environmental Research*. **201**: 111487. Bibcode:2021ER....20111487D. doi:10.1016/j.envres.2021.111487. ISSN 0013-9351. PMID 34116013.
10. ^ Lee KK, Bing R, Kiang J, Bashir S, Spath N, Stelzle D, et al. (November 2020). "Adverse health effects associated with household air pollution: a systematic review, meta-analysis, and burden estimation study". *The Lancet Global Health*. **8** (11): e1427–e1434. doi:10.1016/S2214-109X(20)30343-0. ISSN 2214-109X. PMC 7564377. PMID 33069303.
11. ^ Stanek LW, Brown JS, Stanek J, Gift J, Costa DL (2011). "Air Pollution Toxicology—A Brief Review of the Role of the Science in Shaping the Current Understanding of Air Pollution Health Risks". *Toxicological Sciences*. **120**: S8–S27. doi:10.1093/toxsci/kfq367. PMID 21147959. Retrieved 7 November 2022.
12. ^ Majumder N, Kodali V, Velayutham M, Goldsmith T, Amedro J, Khramtsov VV, et al. (2022). "Aerosol physicochemical determinants of carbon black and ozone inhalation co-exposure induced pulmonary toxicity". *Toxicological Sciences*. **191** (1): 61–78. doi:10.1093/toxsci/kfac113. PMC 9887725. PMID 36303316.
13. ^ Daniel A. Vallero (2014). *Fundamentals of Air Pollution*. Academic Press. pp. 43, 122, 215. ISBN 978-0-12-404602-3.
14. ^ **a b c d** Fuller R, Landrigan PJ, Balakrishnan K, Bathan G, Bose-O'Reilly S, Brauer M, et al. (June 2022). "Pollution and health: a progress update". *The Lancet Planetary Health*. **6** (6): e535–e547. doi:10.1016/S2542-5196(22)00090-0. PMID 35594895. S2CID 248905224.



7499. PMID 31407261. S2CID 199528114.
28. ^ Bherwani H, Nair M, Musugu K, Gautam S, Gupta A, Kapley A, et al. (10 June 2020). "Valuation of air pollution externalities: comparative assessment of economic damage and emission reduction under COVID-19 lockdown". *Air Quality, Atmosphere & Health*. **13** (6): 683–694. Bibcode:2020AQAH...13..683B. doi:10.1007/s11869-020-00845-3. ISSN 1873-9318. PMC 7286556. PMID 32837611.
  29. ^ Boubel R, Vallero D, Fox D, Turner B, Stern A (2013). *Fundamentals of Air Pollution* (Third ed.). Elsevier. pp. 447–522. ISBN 9780080507071. Retrieved 10 April 2024.
  30. ^ *Regulating Air Quality: The First Global Assessment of Air Pollution Legislation*. Nairobi, Kenya: United Nations Environment Programme. 2021. ISBN 978-92-807-3872-8. Retrieved 10 April 2024.
  31. ^ Brimblecombe P (2006). "The clean air act after 50 years". *Weather*. **61** (11): 311–314. Bibcode:2006Wthr...61..311B. doi:10.1256/wea.127.06. Retrieved 11 April 2024.
  32. ^ "Progress Cleaning the Air and Improving People's Health". US Environmental Protection Agency. 8 June 2015. Retrieved 11 April 2024.
  33. ^ Environment UN (29 October 2018). "About Montreal Protocol". Ozonation. Retrieved 7 June 2022.
  34. ^ "The Montreal Protocol on Substances That Deplete the Ozone Layer". United States Department of State. Retrieved 7 June 2022.
  35. ^ "Protocol On Further Reduction Of Sulphur Emissions To The Convention On Long-Range Transboundary Air Pollution | International Environmental Agreements (IEA) Database Project". *iea.uoregon.edu*. Retrieved 7 June 2022.
  36. ^ Nations U. "ClimateChange". United Nations. Retrieved 7 June 2022.
  37. ^ "Climate change". *www.who.int*. World Health Organization. Retrieved 7 June 2022.
  38. ^ "Global Climate Agreements: Successes and Failures". Council on Foreign Relations. Retrieved 7 June 2022.
  39. ^ "Basic Information about NO2". US Environmental Protection Agency. 6 July 2016. Retrieved 12 April 2024.
  40. ^ "Radon". World Health Organization. Retrieved 12 April 2024.
  41. ^ Manisalidis I, Stavropoulou E, Stavropoulos A, Bezirtzoglou E (2020). "Environmental and Health Impacts of Air Pollution: A Review". *Front Public Health* . **8**: 14. doi:10.3389/fpubh.2020.00014. PMC 7044178. PMID 32154200.
  42. ^ Perera F (23 December 2017). "Pollution from Fossil-Fuel Combustion is the Leading Environmental Threat to Global Pediatric Health and Equity: Solutions Exist". *International Journal of Environmental Research and Public Health*. **15** (1): 16. doi:10.3390/ijerph15010016. ISSN 1660-4601. PMC 5800116. PMID 29295510.
  43. ^ "Mapping methane emissions on a global scale". ESA. Archived from the original on 3 February 2022.

44. ^ "Climate change: Satellites map huge methane plumes from oil and gas". BBC News. 4 February 2022. Retrieved 16 March 2022.
45. ^ "Cracking down on methane 'ultra emitters' is a quick way to combat climate change, researchers find". The Washington Post. Retrieved 16 March 2022.
46. ^ Lauvaux T, Giron C, Mazzolini M, d'Aspremont A, Duren R, Cusworth D, et al. (4 February 2022). "Global assessment of oil and gas methane ultra-emitters". *Science*. **375** (6580): 557–561. arXiv:2105.06387. Bibcode:2022Sci...375..557L. doi:10.1126/science.abj4351. ISSN 0036-8075. PMID 35113691. S2CID 246530897.
47. ^ Rentschler J, Leonova N (2023). "Global air pollution exposure and poverty". *Nature Communications*. **14** (1): 4432. Bibcode:2023NatCo..14.4432R. doi:10.1038/s41467-023-39797-4. PMC 10363163. PMID 37481598.
48. ^ Pennise D, Smith K. "Biomass Pollution Basics" (PDF). World Health Organization. Archived from the original (PDF) on 9 July 2012.
49. ^ "Indoor air pollution and household energy". WHO and UNEP. 2011.
50. ^ Hawkes N (22 May 2015). "Air pollution in UK: the public health problem that won't go away". *BMJ*. **350** (may22 1): h2757. doi:10.1136/bmj.h2757. PMID 26001592. S2CID 40717317.
51. ^ "Wood burning heaters and your health - Fact sheets". www.health.nsw.gov.au.
52. ^ Tsiotra I, Grivas G, Tavernaraki K, Bougiatioti A, Apostolaki M, Paraskevopoulou D, et al. (7 December 2021). "Annual exposure to polycyclic aromatic hydrocarbons in urban environments linked to wintertime wood-burning episodes". *Atmospheric Chemistry and Physics*. **21** (23): 17865–17883. Bibcode:2021ACP....2117865T. doi:10.5194/acp-21-17865-2021. ISSN 1680-7316. S2CID 245103794.
53. ^ Nace T. "China Shuts Down Tens Of Thousands Of Factories In Widespread Pollution Crackdown". *Forbes*. Retrieved 16 June 2022. "... it is estimated that 40 percent of all China's factories have been shut down at some point in order to be inspected... [and] over 80,000 factories have been hit with fines and criminal offenses as a result of their emissions."
54. ^ Huo H, Zhang Q, Guan D, Su X, Zhao H, He K (16 December 2014). "Examining Air Pollution in China Using Production- And Consumption-Based Emissions Accounting Approaches". *Environmental Science & Technology*. **48** (24): 14139–14147. Bibcode:2014EnST...4814139H. doi:10.1021/es503959t. ISSN 0013-936X. PMID 25401750.
55. ^ Huo H, Zhang Q, Guan D, Su X, Zhao H, He K (16 December 2014). "Examining Air Pollution in China Using Production- And Consumption-Based Emissions Accounting Approaches". *Environmental Science & Technology*. **48** (24): 14139–14147. Bibcode:2014EnST...4814139H. doi:10.1021/es503959t. ISSN 0013-936X. PMID 25401750.
56. ^ "EMEP/EEA air pollutant emission inventory guidebook 2019".
57. ^ "Particulate Matter (PM), US EPA". 19 April 2016.
58. ^ "GovHK: Green Tips for Home Renovation". GovHK. 16 September 2024. Retrieved 22 September 2024.

59. ^ "Health crisis: Up to a billion tons of waste potentially burned in the open every year". *phys.org*. Retrieved 13 February 2021.
60. ^ Cook E, Velis CA (6 January 2021). "Global Review on Safer End of Engineered Life". *Global Review on Safer End of Engineered Life*. Retrieved 13 February 2021.
61. ^ "Combustion Pollutants in Your Home - Guidelines". California Air Resources Board. Retrieved 16 June 2022. ""... most furnaces, wood stoves, fireplaces, gas water heaters, and gas clothes dryers, usually vent (exhaust) the combustion pollutants directly to the outdoors. However, if the vent system is not properly designed, installed, and maintained, indoor pollutants can build up quickly inside the home."
62. ^ "Overview of Air Pollution from Transportation". US Environmental Protection Agency. 15 December 2021. Retrieved 16 June 2022.
63. ^ Ryan RG, Marais EA, Balhatchet CJ, Eastham SD (June 2022). "Impact of Rocket Launch and Space Debris Air Pollutant Emissions on Stratospheric Ozone and Global Climate". *Earth's Future*. **10** (6): e2021EF002612. Bibcode:2022EaFut..1002612R. doi:10.1029/2021EF002612. ISSN 2328-4277. PMC 9287058. PMID 35865359.
64. ^ Yeung J. "Microplastics in our air 'spiral the globe' in a cycle of pollution, study finds". CNN. Retrieved 4 August 2022.
65. ^ Wang J, Wu Q, Liu J, Yang H, Yin M, Chen S, et al. (2019). "Vehicle emission and atmospheric pollution in China: problems, progress, and prospects". *PeerJ*. **7**: e6932. doi:10.7717/peerj.6932. PMC 6526014. PMID 31143547.
66. ^ Air Quality Expert Group (2004). *Nitrogen Dioxide in the United Kingdom (PDF)*. Department for Environment, Food and Rural Affairs. Retrieved 12 April 2024.
67. ^ Aggarwal P, Jain S (2015). "Impact of air pollutants from surface transport sources on human health: A modeling and epidemiological approach". *Environ Int*. **83**: 146–57. Bibcode:2015EnInt..83..146A. doi:10.1016/j.envint.2015.06.010. PMID 26142107.
68. ^ "NASA GISS: NASA News & Feature Releases: Road Transportation Emerges as Key Driver of Warming". *www.giss.nasa.gov*. Retrieved 4 August 2022.
69. ^ "Car Emissions & Global Warming | Union of Concerned Scientists". *www.ucsusa.org*. Retrieved 4 August 2022.
70. ^ "NASA's AIRS Maps Carbon Monoxide from Brazil Fires". NASA Jet Propulsion Laboratory (JPL). Retrieved 4 August 2022.
71. ^ Harper AR, Doerr SH, Santin C, Froyd CA, Sinnadurai P (15 May 2018). "Prescribed fire and its impacts on ecosystem services in the UK". *Science of the Total Environment*. **624**: 691–703. Bibcode:2018ScTEn.624..691H. doi:10.1016/j.scitotenv.2017.12.161. ISSN 0048-9697. PMID 29272838.
72. ^ George Neary D, McMichael Leonard J (8 April 2020), Missiakô Kindomihou V (ed.), "Effects of Fire on Grassland Soils and Water: A Review", *Grasses and Grassland Aspects*, IntechOpen, doi:10.5772/intechopen.90747, ISBN 978-1-78984-949-3, S2CID 213578405, retrieved 7 June 2022
73. ^ Hussein R, Aboah DT, Issifu H (1 March 2020). "Fire control systems in forest reserves: An assessment of three forest districts in the Northern region, Ghana".

- Scientific African*. **7**: e00245. Bibcode:2020SciAf...700245H. doi:10.1016/j.sciaf.2019.e00245. ISSN 2468-2276. S2CID 213400214.
74. ^ Reyes O, Casal M (November 2004). "Effects of forest fire ash on germination and early growth of four pinus species". *Plant Ecology*. **175** (1): 81–89. Bibcode:2004PIEco.175...81R. doi:10.1023/B:VEGE.0000048089.25497.0c. ISSN 1385-0237. S2CID 20388177.
75. ^ Chatterjee R (15 February 2018). "Wall Paint, Perfumes and Cleaning Agents Are Polluting Our Air". NPR. Retrieved 12 March 2019.
76. ^ "Basic Information about Landfill Gas". US Environmental Protection Agency. 15 April 2016. Retrieved 9 August 2022. "Landfill gas (LFG) is a natural byproduct of the decomposition of organic material in landfills. LFG is composed of roughly 50 percent methane..."
77. ^ "Open waste burning prevention | Climate & Clean Air Coalition". www.ccacoalition.org. 7 September 2023. Retrieved 22 December 2023.
78. ^ Hafemeister D (2016), "Biological and Chemical Weapons", *Nuclear Proliferation and Terrorism in the Post-9/11 World*, Cham: Springer International Publishing, pp. 337–351, doi:10.1007/978-3-319-25367-1\_15, ISBN 978-3-319-25365-7, PMC 7123302
79. ^ Sun F, Dai Y, Yu X (December 2017). "Air pollution, food production and food security: A review from the perspective of food system". *Journal of Integrative Agriculture*. **16** (12): 2945–2962. Bibcode:2017JIAgr..16.2945S. doi:10.1016/S2095-3119(17)61814-8.
80. ^ Lelieveld J, Evans JS, Fnais M, Giannadaki D, Pozzer A (September 2015). "The contribution of outdoor air pollution sources to premature mortality on a global scale". *Nature*. **525** (7569): 367–371. Bibcode:2015Natur.525..367L. doi:10.1038/nature15371. ISSN 1476-4687. PMID 26381985. S2CID 4460927. "Whereas in much of the USA and in a few other countries emissions from traffic and power generation are important, in eastern USA, Europe, Russia and East Asia agricultural emissions make the largest relative contribution to PM2.5, with the estimate of overall health impact depending on assumptions regarding particle toxicity."
81. ^ Diep F (31 January 2018). "California's Farms Are an Even Larger Source of Air Pollution Than We Thought". *Pacific Standard*. Retrieved 2 February 2018.
82. ^ Nemecek T, Poore J (1 June 2018). "Reducing food's environmental impacts through producers and consumers". *Science*. **360** (6392): 987–992. Bibcode:2018Sci...360..987P. doi:10.1126/science.aaq0216. ISSN 0036-8075. PMID 29853680. S2CID 206664954.
83. ^ "Education Data, Visualizations & Graphics on particulate pollution". www.cleanairresources.com. Archived from the original on 20 March 2019. Retrieved 20 March 2019.
84. ^ Goldstein AH, Koven CD, Heald CL, Fung IY (5 May 2009). "Biogenic carbon and anthropogenic pollutants combine to form a cooling haze over the southeastern United States". *Proceedings of the National Academy of Sciences*. **106** (22): 8835–40. Bibcode:2009PNAS..106.8835G. doi:

- 10.1073/pnas.0904128106. PMC 2690056. PMID 19451635.
85. ^ Fischetti M (2014). "Trees That Pollute". *Scientific American*. **310** (6): 14. Bibcode:2014SciAm.310f..14F. doi:10.1038/scientificamerican0614-14. PMID 25004561.
  86. ^ "Volcanic Pollution |". Retrieved 27 February 2022.
  87. ^ "Air Pollution Emissions". US EPA. 2016. Retrieved 7 June 2022.
  88. ^ Environment and Climate Change Canada (14 June 2010). "Air pollutant emissions". Canada.ca. Retrieved 7 June 2022.
  89. ^ Manisalidis I, Stavropoulou E, Stavropoulos A, Bezirtzoglou E (20 February 2020). "Environmental and Health Impacts of Air Pollution: A Review". *Frontiers in Public Health*. **8**: 14. doi:10.3389/fpubh.2020.00014. ISSN 2296-2565. PMC 7044178. PMID 32154200.
  90. ^ "AP 42, Volume I". US Environmental Protection Agency. Archived from the original on 24 September 2010. Retrieved 29 August 2010.
  91. ^ "United Kingdom's emission factor database". Naei.org.uk. Archived from the original on 7 July 2010. Retrieved 29 August 2010.
  92. ^ "EMEP/EEA air pollutant emission inventory guidebook—2009". Eea.europa.eu. European Environmental Agency. 19 June 2009. Retrieved 11 December 2012.
  93. ^ "Environmental Pollution". Theenvironmentalblog.org. 16 December 2011. Retrieved 11 December 2012.
  94. ^ "Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (reference manual)". Ipc-nggip.iges.or.jp. Archived from the original on 21 March 2008. Retrieved 29 August 2010.
  95. ^ US EPA O (10 December 2015). "Managing Air Quality - Air Pollutant Types". www.epa.gov. US Environmental Protection Agency. Retrieved 27 February 2022.
  96. ^ Hidy G (2012). *Aerosols: An Industrial and Environmental Science*. Elsevier. p. 1. ISBN 978-0-323-14251-9.
  97. ^ Carrington D (4 November 2021). "Ammonia from farms behind 60% of UK particulate air pollution – study". *The Guardian*. Retrieved 7 November 2021.
  98. ^ "The Effect of Changing Background Emissions on External Cost Estimates for Secondary Particulates". *Open environmental sciences*. 2008.
  99. ^ Johnson K (18 April 2009). "How Carbon Dioxide Became a 'Pollutant'". *Wall Street Journal*.
  100. ^ "Carbon dioxide". The National Institute for Occupational Safety and Health (NIOSH). U.S. Department of Health & Human Services. 30 October 2019. Retrieved 19 April 2023.
  101. ^ **a b** "General hazards of Carbon Dioxide". Health and Safety Executive. UK Government. Retrieved 19 April 2023. "For over a century CO<sub>2</sub> has been recognised as a workplace hazard at high concentrations. CO<sub>2</sub> is naturally present in the air we breathe at a concentration of about 0.037% and is not harmful to health at low concentrations."
  102. ^ Air Quality Guidelines Global Update 2005: Particulate matter, ozone, nitrogen dioxide and sulfur dioxide. Copenhagen, Denmark: World Health Organization. 2006. p. 12. ISBN 92-890-2192-6. "Some pollutants, and especially those

associated with greenhouse warming effects (carbon dioxide, nitrous oxide and methane)..."

103. ^ Vaidyanathan G. "The Worst Climate Pollution Is Carbon Dioxide". *Scientific American*.
104. ^ Barbalace RC (7 November 2006). "CO<sub>2</sub> Pollution and Global Warming: When does carbon dioxide become a pollutant?". *Environmentalchemistry.com*.
105. ^ Friedman L (22 August 2022). "Democrats Designed the Climate Law to Be a Game Changer. Here's How". *The New York Times*. Retrieved 19 April 2023.
106. ^ "Graphic: The relentless rise of carbon dioxide". *Climate Change: Vital Signs of the Planet*. NASA.
107. ^ "How much of U.S. carbon dioxide emissions are associated with electricity generation?". Retrieved 16 December 2016.
108. ^ "Full Mauna Loa CO<sub>2</sub> record". *Earth System Research Laboratory*. Retrieved 10 January 2017.
109. ^ "OECD Test Guidelines for Chemicals".
110. ^ "The Strange Lake Nyos CO<sub>2</sub> Gas Disaster: Impacts and The Displacement and Return of Affected Communities".
111. ^ "Carbon Monoxide Poisoning – NHS". 17 October 2017.
112. ^ US EPA O (5 June 2017). "Basic Ozone Layer Science". *www.epa.gov*. US Environmental Protection Agency. Retrieved 7 June 2022.
113. ^ "Chlorofluorocarbons (CFCs) are heavier than air, so how do scientists suppose that these chemicals reach the altitude of the ozone layer to adversely affect it?". *Scientific American*. Retrieved 7 June 2022.
114. ^ "What is Particulate Matter? | Urban Environmental Program in New England". US EPA. 29 March 2022. Archived from the original on 7 June 2022. Retrieved 7 June 2022.
115. ^ Munsif R, Zubair M, Aziz A, Nadeem Zafar M (7 January 2021), Viskup R (ed.), "Industrial Air Emission Pollution: Potential Sources and Sustainable Mitigation", *Environmental Emissions*, IntechOpen, doi:10.5772/intechopen.93104, ISBN 978-1-83968-510-1, S2CID 234150821, retrieved 7 June 2022
116. ^ "Evidence growing of air pollution's link to heart disease, death". Archived from the original on 3 June 2010. Retrieved 18 May 2010. // American Heart Association. 10 May 2010
117. ^ Balmes J, Fine J, Sheppard D (1987). "Symptomatic bronchoconstriction after short-term inhalation of sulfur dioxide". *American Review of Respiratory Disease*. **136** (5): 1117–21. doi:10.1164/ajrccm/136.5.1117. PMID 3674573.
118. ^ Singh R, Kumar S, Karmakar S, Siddiqui AJ, Mathur A, Adnan M, et al. (2021). "2: Causes, Consequences, and Control of Persistent Organic Pollutants". In Kumar N, Shukla V (eds.). *Persistent Organic Pollutants in the Environment: Origin and Role*. CRC Press. pp. 31–54. ISBN 978-1-003-05317-0. Retrieved 11 June 2022.
119. ^ "Newly detected air pollutant mimics damaging effects of cigarette smoke" (PDF). *Physorg.com*. Retrieved 29 August 2010.



120. ^ "Infant Inhalation Of Ultra-fine Air Pollution Linked To Adult Lung Disease". *Sciencedaily.com*. 23 July 2009. Retrieved 29 August 2010.
121. ^ Kim KH, Jahan SA, Kabir E, Brown RJ (1 October 2013). "A review of airborne polycyclic aromatic hydrocarbons (PAHs) and their human health effects". *Environment International*. **60**: 71–80. Bibcode:2013EnInt..60...71K. doi:10.1016/j.envint.2013.07.019. ISSN 0160-4120. PMID 24013021.
122. ^ "Technical Overview of Volatile Organic Compounds". US Environmental Protection Agency. 14 March 2023. Retrieved 20 April 2023.
123. ^ Read "Rethinking the Ozone Problem in Urban and Regional Air Pollution" at NAP.edu. 1991. doi:10.17226/1889. ISBN 978-0-309-04631-2.
124. ^ "ESS Topic 6.3: Photochemical Smog". *Amazing World of Science With Mr. Green*. Retrieved 7 June 2022.
125. ^ Arkansas Energy Department of Energy and Environment. "Cars and Air Pollution". *www.adeq.state.ar.us*. Retrieved 24 August 2024.
126. ^ Acharya B (1 January 2018), Basu P (ed.), "Chapter 10 - Cleaning of Product Gas of Gasification", *Biomass Gasification, Pyrolysis and Torrefaction (Third Edition)*, Academic Press, pp. 373–391, ISBN 978-0-12-812992-0, retrieved 7 June 2022
127. ^ "smog | National Geographic Society". *education.nationalgeographic.org*. National Geographic. Retrieved 7 June 2022.
128. ^ "Hazardous Air Pollutants". US Environmental Protection Agency. 9 February 2023. Retrieved 29 April 2023.
129. ^ "Air quality standards". European Environment Agency. Retrieved 29 April 2023.
130. ^ **a b c d e** Vallero DA (1 October 2007). *Fundamentals of Air Pollution (4th ed.)*. Academic Press. ISBN 9780124054813.
131. ^ Dons E (2011). "Impact of time-activity patterns on personal exposure to black carbon". *Atmospheric Environment*. **45** (21): 3594–3602. Bibcode:2011AtmEn..45.3594D. doi:10.1016/j.atmosenv.2011.03.064.
132. ^ Dons E (2019). "Transport most likely to cause air pollution peak exposures in everyday life: Evidence from over 2000 days of personal monitoring". *Atmospheric Environment*. **213**: 424–432. Bibcode:2019AtmEn.213..424D. doi:10.1016/j.atmosenv.2019.06.035. hdl:10044/1/80194. S2CID 197131423.
133. ^ Carrington D (22 September 2021). "WHO slashes guideline limits on air pollution from fossil fuels". *The Guardian*. Retrieved 22 September 2021.
134. ^ "Most of the World Breathes Unsafe Air, Taking More Than 2 Years Off Global Life Expectancy". AQLI. 14 June 2022. Retrieved 12 July 2022.
135. ^ **a b** "Taking an Exposure History: What Are Possible Sources of Indoor Air Pollution | Environmental Medicine | ATSDR". *www.atsdr.cdc.gov*. 9 February 2021. Retrieved 8 July 2024. This article incorporates text from this source, which is in the public domain.
136. ^ **a b** Duflo E, Greenstone M, Hanna R (26 November 2008). "Indoor air pollution, health and economic well-being". *S.A.P.I.EN.S.* **1** (1). Retrieved 29 August 2010.
137. ^ **a b** "Improved Clean Cookstoves". Project Drawdown. 7 February 2020. Retrieved 5 December 2020.

138. ^ Twilley N (1 April 2019). "The Hidden Air Pollution in Our Homes". *The New Yorker* – via [www.newyorker.com](http://www.newyorker.com).
139. ^ "Bucknell tent death: Hannah Thomas-Jones died from carbon monoxide poisoning". *BBC News*. 17 January 2013. Retrieved 22 September 2015.
140. ^ "Chapter 6.2. Asbestos. Air quality guidelines, Second edition" (PDF). World Health Organization Europe. Archived from the original (PDF) on 24 May 2011.
141. ^ **a b** Carrington D (18 May 2021). "Air pollution linked to 'huge' rise in child asthma GP visits". *The Guardian*. Retrieved 22 May 2021.
142. ^ Kampa M, Castanas E (1 January 2008). "Human health effects of air pollution". *Environmental Pollution. Proceedings of the 4th International Workshop on Biomonitoring of Atmospheric Pollution (With Emphasis on Trace Elements)*. **151** (2): 362–367. Bibcode:2008EPoll.151..362K. doi:10.1016/j.envpol.2007.06.012. ISSN 0269-7491. PMID 17646040. S2CID 38513536.
143. ^ Dovjak M, Kušec A (2019). "Health Outcomes Related to Built Environments". *Creating Healthy and Sustainable Buildings*. Switzerland: Springer International Publishing. pp. 43–82. doi:10.1007/978-3-030-19412-3\_2. ISBN 978-3-030-19411-6. OCLC 1285508857. S2CID 190160283.
144. ^ "Long-Term Exposure to Low Levels of Air Pollution Increases Risk of Heart and Lung Disease". *Science Daily*. 22 February 2021.
145. ^ Vohra K, Vodonos A, Schwartz J, Marais EA, Sulprizio MP, Mickley LJ (1 April 2021). "Global mortality from outdoor fine particle pollution generated by fossil fuel combustion: Results from GEOS-Chem". *Environmental Research*. **195**: 110754. Bibcode:2021ER....19510754V. doi:10.1016/j.envres.2021.110754. ISSN 0013-9351. PMID 33577774.
146. ^ "Air quality and health". *Who.int*. World Health Organization. Retrieved 26 November 2011.
147. ^ US EPA O (22 February 2013). "Regulatory and Guidance Information by Topic: Air". [www.epa.gov](http://www.epa.gov). Retrieved 10 November 2022.
148. ^ Majumder N, Kodali V, Velayutham M, Goldsmith T, Amedro J, Khramtsov VV, et al. (2022). "Aerosol physicochemical determinants of carbon black and ozone inhalation co-exposure induced pulmonary toxicity". *Toxicological Sciences*. **191** (1): 61–78. doi:10.1093/toxsci/kfac113. PMC 9887725. PMID 36303316.
149. ^ Ritchie H, Roser M (2021). "What are the safest and cleanest sources of energy?". *Our World in Data*. Archived from the original on 15 January 2024. Data sources: Markandya & Wilkinson (2007); UNSCEAR (2008; 2018); Sovacool et al. (2016); IPCC AR5 (2014); Pehl et al. (2017); Ember Energy (2021).
150. ^ Roser M (18 March 2024). "Data review: how many people die from air pollution?". *Our World in Data*.
151. ^ Whitacre P (9 February 2021). "Air Pollution Accounts for 1 in 8 Deaths Worldwide, According to New WHO Estimates". *National Institute of Environmental Health Sciences*. Archived from the original on 4 November 2022. Retrieved 18 February 2022.
152. ^ Lelieveld J, Klingmüller K, Pozzer A, Burnett RT, Haines A, Ramanathan V (9 April 2019). "Effects of fossil fuel and total anthropogenic emission removal on

- public health and climate*". *Proceedings of the National Academy of Sciences*. **116** (15): 7192–7197. Bibcode:2019PNAS..116.7192L. doi:10.1073/pnas.1819989116. ISSN 0027-8424. PMC 6462052. PMID 30910976.
153. ^ **a b** Carrington D (12 March 2019). "Air pollution deaths are double previous estimates, finds research". *The Guardian*. Retrieved 12 March 2019.
  154. ^ Dickie G (18 May 2022). "Pollution killing 9 million people a year, Africa hardest hit - study". *Reuters*. Retrieved 23 June 2022.
  155. ^ World Health Organisation (29 October 2018). "More than 90% of the world's children breathe toxic air every day". *www.who.int*. Retrieved 13 August 2024.
  156. ^ **a b** "Ambient (outdoor) air pollution". *www.who.int*. World Health Organization. Retrieved 20 December 2021.
  157. ^ Baccarelli AA, Hales N, Burnett RT, Jerrett M, Mix C, Dockery DW, et al. (1 November 2016). "Particulate Air Pollution, Exceptional Aging, and Rates of Centenarians: A Nationwide Analysis of the United States, 1980–2010". *Environmental Health Perspectives*. **124** (11): 1744–1750. doi:10.1289/EHP197. PMC 5089884. PMID 27138440.
  158. ^ Pope CA (15 December 2003). "Cardiovascular Mortality and Long-Term Exposure to Particulate Air Pollution: Epidemiological Evidence of General Pathophysiological Pathways of Disease". *Circulation*. **109** (1): 71–77. doi:10.1161/01.CIR.0000108927.80044.7F. PMID 14676145.
  159. ^ Harris G (25 January 2014). "Beijing's Bad Air Would Be Step Up for Smoggy Delhi". *The New York Times*. ISSN 0362-4331. Retrieved 28 April 2023.
  160. ^ Owusu PA, Sarkodie SA (10 November 2020). "Global estimation of mortality, disability-adjusted life years and welfare cost from exposure to ambient air pollution". *Science of the Total Environment*. **742**: 140636. Bibcode:2020ScTEn.74240636O. doi:10.1016/j.scitotenv.2020.140636. ISSN 0048-9697. PMID 32721745. S2CID 220848545.
  161. ^ "Lancet study: Pollution killed 2.3 million Indians in 2019". *BBC News*. 18 May 2022. Retrieved 28 April 2023.
  162. ^ Mr Chen's claim was made in *The Lancet* (December 2013 issue) and reported in *The Daily Telegraph* 8 January 2014 p. 15 'Air pollution killing up to 500,000 Chinese each year, admits former health minister.
  163. ^ Feng T, Chen H, Liu J (15 December 2022). "Air pollution-induced health impacts and health economic losses in China driven by US demand exports". *Journal of Environmental Management*. **324**: 116355. Bibcode:2022JEnvM.32416355F. doi:10.1016/j.jenvman.2022.116355. ISSN 0301-4797. PMID 36179470.
  164. ^ **a b** "Car emissions: taking tests out of the lab and onto the road – News". *European Parliament*. 25 February 2016. Retrieved 11 January 2018.
  165. ^ "Air pollution causes early deaths". *BBC*. 21 February 2005. Retrieved 14 August 2012.
  166. ^ "Complete Guide To The 'Toxin Tax' For Diesel Cars". *Motorway*. Retrieved 25 May 2017.
  167. ^ "Study links traffic pollution to thousands of deaths". *The Guardian*. London, UK. 15 April 2008. Archived from the original on 20 April 2008. Retrieved 15 April 2008.

168. ^ Mailloux NA, Abel DW, Holloway T, Patz JA (16 May 2022). "Nationwide and Regional PM<sub>2.5</sub>-Related Air Quality Health Benefits From the Removal of Energy-Related Emissions in the United States". *GeoHealth*. **6** (5): e2022GH000603. Bibcode:2022GHeal...6..603M. doi:10.1029/2022GH000603. PMC 9109601. PMID 35599962.
169. ^ a b Henneman L, Choirat C, Dedoussi I, Dominici F, Roberts J, Zigler C (24 November 2023). "Mortality risk from United States coal electricity generation". *Science*. **382** (6673): 941–946. Bibcode:2023Sci...382..941H. doi:10.1126/science.adf4915. PMC 10870829. PMID 37995235.
170. ^ a b Nansai K, Tohno S, Chatani S, Kanemoto K, Kagawa S, Kondo Y, et al. (2 November 2021). "Consumption in the G20 nations causes particulate air pollution resulting in two million premature deaths annually". *Nature Communications*. **12** (1): 6286. Bibcode:2021NatCo..12.6286N. doi:10.1038/s41467-021-26348-y. ISSN 2041-1723. PMC 8563796. PMID 34728619.
171. ^ Vohra K, Vodonos A, Schwartz J, Marais EA, Sulprizio MP, Mickley LJ (1 April 2021). "Global mortality from outdoor fine particle pollution generated by fossil fuel combustion: Results from GEOS-Chem". *Environmental Research*. **195**: 110754. Bibcode:2021ER....19510754V. doi:10.1016/j.envres.2021.110754. ISSN 0013-9351. PMID 33577774. S2CID 231909881. Retrieved 5 March 2021.
172. ^ Mackenzie J, Turrentine J (22 June 2021). "Air Pollution: Everything You Need to Know". NRDC. Retrieved 18 June 2022.
173. ^ Farrow A, Miller KA, Myllyvirta L (February 2020). *Toxic air: The price of fossil fuels (PDF)*. Seoul: Greenpeace Southeast Asia.
174. ^ Lucking AJ, Lundback M, Mills NL, Faratian D, Barath SL, Pourazar J, et al. (2008). "Diesel exhaust inhalation increases thrombus formation in man". *European Heart Journal*. **29** (24): 3043–51. doi:10.1093/eurheartj/ehn464. PMID 18952612.
175. ^ Törnqvist HK, Mills NL, Gonzalez M, Miller MR, Robinson SD, Megson IL, et al. (2007). "Persistent Endothelial Dysfunction in Humans after Diesel Exhaust Inhalation". *American Journal of Respiratory and Critical Care Medicine*. **176** (4): 395–400. doi:10.1164/rccm.200606-872OC. PMID 17446340.
176. ^ "Air pollution from G20 consumers caused two million deaths in 2010". *New Scientist*. Retrieved 11 December 2021.
177. ^ Tankersley J (8 January 2010). "EPA proposes nation's strictest smog limits ever". *Los Angeles Times*. Retrieved 14 August 2012.
178. ^ "EPA slideshow" (PDF). Retrieved 11 December 2012.
179. ^ "EPA Strengthens Ozone Standards to Protect Public Health/Science-based standards to reduce sick days, asthma attacks, emergency room visits, greatly outweigh costs (10/1/2015)". *Yosemite.epa.gov*. Retrieved 11 January 2018.
180. ^ Grossni M (13 November 2008). "Human cost of valley's dirty air: \$6.3 billion". *Sacramento Bee*. Archived from the original on 16 December 2008. Retrieved 14 August 2012.
181. ^ Sahagun L (13 November 2008). "Pollution saps state's economy, study says". *Los Angeles Times*. Retrieved 14 August 2012.

182. ^ Kay J (13 November 2008). "Bad air costing state's economy billions". *San Francisco Chronicle*. Retrieved 14 August 2012.
183. ^ "Human health may be at risk from long-term exposure to air pollution below current air quality standards and guidelines". *British Medical Journal*. Retrieved 18 October 2021.
184. ^ Strak M, Weinmayr G, Rodopoulou S, Chen J, Hoogh Kd, Andersen ZJ, et al. (2 September 2021). "Long term exposure to low level air pollution and mortality in eight European cohorts within the ELAPSE project: pooled analysis". *BMJ*. **374**: n1904. doi:10.1136/bmj.n1904. ISSN 1756-1833. PMC 8409282. PMID 34470785.
185. ^ Cohen AJ, Brauer M, Burnett R, Anderson HR, Frostad J, Estep K, et al. (May 2017). "Estimates and 25-year trends of the global burden of disease attributable to ambient air pollution: an analysis of data from the Global Burden of Diseases Study 2015". *The Lancet*. **389** (10082): 1907–1918. Bibcode:2017Lanc..389.1907C. doi:10.1016/S0140-6736(17)30505-6. ISSN 0140-6736. PMC 5439030. PMID 28408086.
186. ^ a b de Bont J, Jaganathan S, Dahlquist M, Persson Å, Stafoggia M, Ljungman P (8 March 2022). "Ambient air pollution and cardiovascular diseases: An umbrella review of systematic reviews and meta-analyses". *Journal of Internal Medicine*. **291** (6): 779–800. doi:10.1111/joim.13467. eISSN 1365-2796. ISSN 0954-6820. PMC 9310863. PMID 35138681.
187. ^ a b Mayor S (12 June 2016). "Air pollution is a leading risk factor for stroke, global study shows". *BMJ*. **353**: i3272. doi:10.1136/bmj.i3272. eISSN 1756-1833. PMID 27298274.
188. ^ Feigin VL, Roth GA, Naghavi M, Parmar P, Krishnamurthi R, Chugh S, et al. (August 2016). "Global burden of stroke and risk factors in 188 countries, during 1990–2013: a systematic analysis for the Global Burden of Disease Study 2013". *The Lancet Neurology*. **15** (9): 913–924. doi:10.1016/S1474-4422(16)30073-4. hdl:10292/14061. ISSN 1474-4422. PMID 27291521.
189. ^ Miller KA, Siscovick DS, Sheppard L, Shepherd K, Sullivan JH, Anderson GL, et al. (2007). "Long-term exposure to air pollution and incidence of cardiovascular events in women". *The New England Journal of Medicine*. **356** (5): 447–58. doi:10.1056/NEJMoa054409. PMID 17267905.
190. ^ Andersen ZJ, Kristiansen LC, Andersen KK, Olsen TS, Hvidberg M, Jensen SS, et al. (2011). "Stroke and Long-Term Exposure to Outdoor Air Pollution From Nitrogen Dioxide: A Cohort Study". *Stroke*. **43** (2): 320–25. doi:10.1161/STROKEAHA.111.629246. PMID 22052517.
191. ^ Provost E, Madhloum N, Int Panis L, De Boever P, Nawrot T (May 2015). "Carotid intima-media thickness, a marker of subclinical atherosclerosis, and particulate air pollution exposure: the meta-analytical evidence". *PLOS ONE*. **10** (5): e0127014. Bibcode:2015PLoSO..1027014P. doi:10.1371/journal.pone.0127014. PMC 4430520. PMID 25970426. S2CID 11741224.
192. ^ Brook R, Rajagopalan S, Pope CI, Brook J, Bhatnagar A (2010). "Particulate matter air pollution and cardiovascular disease: An update to the scientific statement from the American Heart Association". *Circulation*. **121** (21): 2331–78.

- doi:10.1161/cir.0b013e3181dbeece1. hdl:2027.42/78373. PMID 20458016.
193. ^ Louwies T, Int Panis L, Kicinski M, De Boever P, Nawrot TS (2013). "Retinal Microvascular Responses to Short-Term Changes in Particulate Air Pollution in Healthy Adults". *Environmental Health Perspectives*. **121** (9): 1011–16. doi:10.1289/ehp.1205721. PMC 3764070. PMID 23777785. S2CID 6748539.
  194. ^ Gehring U, Wijga AH, Brauer M, Fischer P, de Jongste JC, Kerkhof M, et al. (2010). "Traffic-related air pollution and the development of asthma and allergies during the first 8 years of life". *American Journal of Respiratory and Critical Care Medicine*. **181** (6): 596–603. doi:10.1164/rccm.200906-0858OC. PMID 19965811.
  195. ^ Andersen ZJ, Hvidberg M, Jensen SS, Ketzel M, Loft S, Sorensen M, et al. (2011). "Chronic obstructive pulmonary disease and long-term exposure to traffic-related air pollution: a cohort study. [Research Support, Non-U.S. Gov't]". *American Journal of Respiratory and Critical Care Medicine*. **183** (4): 455–461. doi:10.1164/rccm.201006-0937OC. PMID 20870755. S2CID 3945468.
  196. ^ Committee of the Environmental and Occupational Health Assembly of the American Thoracic Society (1996). "Health effects of outdoor air pollution". *American Journal of Respiratory and Critical Care Medicine*. **153** (1): 3–50. doi:10.1164/ajrccm.153.1.8542133. PMID 8542133.
  197. ^ Andersen ZJ, Bonnelykke K, Hvidberg M, Jensen SS, Ketzel M, Loft S, et al. (2011). "Long-term exposure to air pollution and asthma hospitalisations in older adults: a cohort study". *Thorax*. **67** (1): 6–11. doi:10.1136/thoraxjnl-2011-200711. PMID 21890573.
  198. ^ Zoidis JD (1999). "The Impact of Air Pollution on COPD". RT: For Decision Makers in Respiratory Care.
  199. ^ World Health Organisation. "Ambient air pollution". [www.who.int](http://www.who.int). Retrieved 10 November 2023.
  200. ^ "Understanding Air Pollution". Respiratory Health Association. Retrieved 15 August 2022.
  201. ^ Holland WW, Reid DD. "The urban factor in chronic bronchitis" *Lancet* 1965;i:445–448.
  202. ^ Gauderman W (2007). "Effect of exposure to traffic on lung development from 10 to 18 years of age: a cohort study". *The Lancet*. **369** (9561): 571–77. CiteSeerX 10.1.1.541.1258. doi:10.1016/S0140-6736(07)60037-3. PMID 17307103. S2CID 852646.
  203. ^ Int Panis L (2017). "Short-term air pollution exposure decreases lung function: a repeated measures study in healthy adults". *Environmental Health*. **16** (1): 60. Bibcode:2017EnvHe..16...60I. doi:10.1186/s12940-017-0271-z. PMC 5471732. PMID 28615020. S2CID 20491472.
  204. ^ Sunyer J (2001). "Urban air pollution and Chronic Obstructive Pulmonary disease: a review". *European Respiratory Journal*. **17** (5): 1024–33. doi:10.1183/09031936.01.17510240. PMID 11488305.
  205. ^ a b "Cancer breakthrough is a 'wake-up' call on danger of air pollution". *The Guardian*. 10 September 2022. Retrieved 11 September 2022.

206. ^ Hill W, Lim EL, Weeden CE, Lee C, Augustine M, Chen K, et al. (5 April 2023). "Lung adenocarcinoma promotion by air pollutants". *Nature*. **616** (7955): 159–167. Bibcode:2023Natur.616..159H. doi:10.1038/s41586-023-05874-3. ISSN 1476-4687. PMC 7614604. PMID 37020004.
207. ^ "Education Data, Visualizations & Graphics on Air Quality and PM2.5". [www.cleanairresources.com](http://www.cleanairresources.com). Retrieved 19 September 2019.
208. ^ Gallagher J (17 December 2015). "Cancer is not just 'bad luck' but down to environment, study suggests". *BBC*. Retrieved 17 December 2015.
209. ^ **a b** Chen H, Goldberg M, Villeneuve P (October–December 2008). "A systematic review of the relation between long-term exposure to ambient air pollution and chronic diseases". *Reviews on Environmental Health*. **23** (4): 243–97. doi:10.1515/reveh.2008.23.4.243. PMID 19235364. S2CID 24481623.
210. ^ Saber E, Heydari G (May 2012). "Flow patterns and deposition fraction of particles in the range of 0.1–10  $\mu$ m at trachea and the first third generations under different breathing conditions". *Computers in Biology and Medicine*. **42** (5): 631–38. doi:10.1016/j.compbimed.2012.03.002. PMID 22445097.
211. ^ Raaschou-Nielsen O, Andersen ZJ, Hvidberg M, Jensen SS, Ketzel M, Sorensen M, et al. (2011). "Lung cancer incidence and long-term exposure to air pollution from traffic. [Research Support, Non-U.S. Gov't]". *Environmental Health Perspectives*. **119** (6): 860–65. doi:10.1289/ehp.1002353. PMC 3114823. PMID 21227886. S2CID 1323189.
212. ^ Raaschou-Nielsen O, Andersen ZJ, Hvidberg M, Jensen SS, Ketzel M, Sorensen M, et al. (2011). "Air pollution from traffic and cancer incidence: a Danish cohort study". *Environmental Health*. **10** (1): 67. Bibcode:2011EnvHe..10...67R. doi:10.1186/1476-069X-10-67. PMC 3157417. PMID 21771295. S2CID 376897.
213. ^ Yacong Bo (2021). "Reduced Ambient PM2.5 Was Associated with a Decreased Risk of Chronic Kidney Disease: A Longitudinal Cohort Study". *Environmental Science & Technology*. **55** (10): 6876–6883. Bibcode:2021EnST...55.6876B. doi:10.1021/acs.est.1c00552. PMID 33904723. S2CID 233408693.
214. ^ Blum MF, Surapaneni A, Stewart JD, Liao D, Yanosky JD, Whitsel EA, et al. (6 March 2020). "Particulate Matter and Albuminuria, Glomerular Filtration Rate, and Incident CKD". *Clinical Journal of the American Society of Nephrology*. **15** (3): 311–319. doi:10.2215/CJN.08350719. ISSN 1555-9041. PMC 7057299. PMID 32108020.
215. ^ **a b c d e f** Conforti A, Mascia M, Cioffi G, De Angelis C, Coppola G, De Rosa P, et al. (30 December 2018). "Air pollution and female fertility: a systematic review of literature". *Reproductive Biology and Endocrinology*. **16** (1): 117. doi:10.1186/s12958-018-0433-z. ISSN 1477-7827. PMC 6311303. PMID 30594197.
216. ^ Canipari R, De Santis L, Cecconi S (January 2020). "Female Fertility and Environmental Pollution". *International Journal of Environmental Research and Public Health*. **17** (23): 8802. doi:10.3390/ijerph17238802. ISSN 1660-4601. PMC 7730072. PMID 33256215.
217. ^ da Silva Junior FC, Felipe MB, Castro DE, Araújo SC, Sisenando HC, Batistuzzo de Medeiros SR (1 June 2021). "A look beyond the priority: A systematic review of

- the genotoxic, mutagenic, and carcinogenic endpoints of non-priority PAHs". *Environmental Pollution*. **278**: 116838. Bibcode:2021EPoll.27816838D. doi:10.1016/j.envpol.2021.116838. ISSN 0269-7491. PMID 33714059. S2CID 232222865.
218. ^ Plunk EC, Richards SM (January 2020). "Endocrine-Disrupting Air Pollutants and Their Effects on the Hypothalamus-Pituitary-Gonadal Axis". *International Journal of Molecular Sciences*. **21** (23): 9191. doi:10.3390/ijms21239191. ISSN 1422-0067. PMC 7731392. PMID 33276521.
219. ^ Perono GA, Petrik JJ, Thomas PJ, Holloway AC (1 January 2022). "The effects of polycyclic aromatic compounds (PACs) on mammalian ovarian function". *Current Research in Toxicology*. **3**: 100070. Bibcode:2022CRTox...300070P. doi:10.1016/j.crtox.2022.100070. ISSN 2666-027X. PMC 9043394. PMID 35492299.
220. ^ **a b** Jurewicz J, Dziewirska E, Radwan M, Hanke W (23 December 2018). "Air pollution from natural and anthropic sources and male fertility". *Reproductive Biology and Endocrinology*. **16** (1): 109. doi:10.1186/s12958-018-0430-2. ISSN 1477-7827. PMC 6304234. PMID 30579357.
221. ^ Frutos V, González-Comadrán M, Solà I, Jacquemin B, Carreras R, Checa Vizcaíno MA (2 January 2015). "Impact of air pollution on fertility: a systematic review". *Gynecological Endocrinology*. **31** (1): 7–13. doi:10.3109/09513590.2014.958992. ISSN 0951-3590. PMID 25212280. S2CID 41594539.
222. ^ Checa Vizcaíno MA, González-Comadrán M, Jacquemin B (September 2016). "Outdoor air pollution and human infertility: a systematic review". *Fertility and Sterility*. **106** (4): 897–904.e1. doi:10.1016/j.fertnstert.2016.07.1110. ISSN 0015-0282. PMID 27513553.
223. ^ **a b c** Carré J, Gatimel N, Moreau J, Parinaud J, Léandri R (28 July 2017). "Does air pollution play a role in infertility?: a systematic review". *Environmental Health*. **16** (1): 82. Bibcode:2017EnvHe..16...82C. doi:10.1186/s12940-017-0291-8. ISSN 1476-069X. PMC 5534122. PMID 28754128.
224. ^ Jurewicz J, Dziewirska E, Radwan M, Hanke W (2018). "Air pollution from natural and anthropic sources and male fertility". *Reproductive Biology and Endocrinology*. **16** (1): 109. doi:10.1186/s12958-018-0430-2. PMC 6304234. PMID 30579357. S2CID 57376088. Retrieved 5 October 2022.
225. ^ **a b** Air pollution and child health: prescribing clean air. Summary. Geneva: World Health Organisation. 2018. pp. 2–6.
226. ^ **a b** Gordon B, Mackay R, Rehfuess E (2004). "Polluted Cities: The Air Children Breathe". *Inheriting the World: The Atlas of Children's Health and the Environment*. World Health Organisation.
227. ^ Pieters N, Koppen G, Van Poppel M, De Prins S, Cox B, Dons E, et al. (March 2015). "Blood Pressure and Same-Day Exposure to Air Pollution at School: Associations with Nano-Sized to Coarse PM in Children". *Environmental Health Perspectives*. **123** (7): 737–42. doi:10.1289/ehp.1408121. PMC 4492263. PMID 25756964.



228. ^ Perera FP, Tang D, Wang S, Vishnevetsky J, Zhang B, Diaz D, et al. (1 June 2012). "Prenatal Polycyclic Aromatic Hydrocarbon (PAH) Exposure and Child Behavior at Age 6–7 Years". *Environmental Health Perspectives*. **120** (6): 921–926. doi:10.1289/ehp.1104315. PMC 3385432. PMID 22440811.
229. ^ Perera FP, Chang Hw, Tang D, Roen EL, Herbstman J, Margolis A, et al. (5 November 2014). "Early-Life Exposure to Polycyclic Aromatic Hydrocarbons and ADHD Behavior Problems". *PLOS ONE*. **9** (11): e111670. Bibcode:2014PLoSO...9k1670P. doi:10.1371/journal.pone.0111670. ISSN 1932-6203. PMC 4221082. PMID 25372862.
230. ^ Becerra TA, Wilhelm M, Olsen J, Cockburn M, Ritz B (1 March 2013). "Ambient Air Pollution and Autism in Los Angeles County, California". *Environmental Health Perspectives*. **121** (3): 380–386. doi:10.1289/ehp.1205827. PMC 3621187. PMID 23249813.
231. ^ Carter SA, Rahman MM, Lin JC, Shu YH, Chow T, Yu X, et al. (1 January 2022). "In utero exposure to near-roadway air pollution and autism spectrum disorder in children". *Environment International*. **158**: 106898. Bibcode:2022EnInt.15806898C. doi:10.1016/j.envint.2021.106898. ISSN 0160-4120. PMC 8688235. PMID 34627014.
232. ^ Flanagan E, Malmqvist E, Rittner R, Gustafsson P, Källén K, Oudin A (8 March 2023). "Exposure to local, source-specific ambient air pollution during pregnancy and autism in children: a cohort study from southern Sweden". *Scientific Reports*. **13** (1): 3848. Bibcode:2023NatSR..13.3848F. doi:10.1038/s41598-023-30877-5. ISSN 2045-2322. PMC 9995328. PMID 36890287.
233. ^ Ritz B, Liew Z, Yan Q, Cuia X, Virk J, Ketzler M, et al. (December 2018). "Air pollution and autism in Denmark". *Environmental Epidemiology*. **2** (4): e028. doi:10.1097/EE9.000000000000028. PMC 6474375. PMID 31008439.
234. ^ Perera F, Herbstman J (1 April 2011). "Prenatal environmental exposures, epigenetics, and disease". *Reproductive Toxicology. Prenatal Programming and Toxicity II (PPTOX II): Role of Environmental Stressors in the Developmental Origins of Disease*. **31** (3): 363–373. Bibcode:2011RepTx..31..363P. doi:10.1016/j.reprotox.2010.12.055. ISSN 0890-6238. PMC 3171169. PMID 21256208.
235. ^ Papamitsou T, Sirak S, Kavvadas D (January–March 2020). "Air pollution and preterm birth: a recommendation for further study in Greece". *Hippokratia*. **24** (1): 44. PMC 7733367. PMID 33364740.
236. ^ Fleischer NL, Merialdi M, van Donkelaar A, Vadillo-Ortega F, Martin RV, Betran AP, et al. (1 April 2014). "Outdoor air pollution, preterm birth, and low birth weight: analysis of the World Health Organization global survey on maternal and perinatal health". *Environmental Health Perspectives*. **122** (4): 425–30. doi:10.1289/ehp.1306837. ISSN 1552-9924. PMC 3984219. PMID 24508912. S2CID 3947454.
237. ^ **a b c** Malley CS, Kuylensstierna JC, Vallack HW, Henze DK, Blencowe H, Ashmore MR (1 April 2017). "Preterm birth associated with maternal fine particulate matter exposure: A global, regional and national assessment" (PDF).

- Environment International*. **101**: 173–82. Bibcode:2017EnInt.101..173M. doi: 10.1016/j.envint.2017.01.023. ISSN 1873-6750. PMID 28196630.
238. ^ Bank EI (19 October 2022). *Finance in Africa - Navigating the financial landscape in turbulent times*. European Investment Bank. ISBN 978-92-861-5382-2 .
239. ^ "Silent Suffocation in Africa - Air Pollution is a Growing Menace, Affecting the Poorest Children the Most" (PDF). UNICEF.
240. ^ "The cost of air pollution in Africa". *Africa Renewal*. Retrieved 31 October 2022.
241. ^ Wang X, Ding H, Ryan L, Xu X (1 May 1997). "Association between air pollution and low birth weight: a community-based study". *Environmental Health Perspectives*. **105** (5): 514–20. doi:10.1289/ehp.97105514. ISSN 0091-6765. PMC 1469882. PMID 9222137. S2CID 2707126.
242. ^ Brauer M, Lencar C, Tamburic L, Koehoorn M, Demers P, Karr C (1 May 2008). "A Cohort Study of Traffic-Related Air Pollution Impacts on Birth Outcomes". *Environmental Health Perspectives*. **116** (5): 680–6. doi:10.1289/ehp.10952. PMC 2367679. PMID 18470315. S2CID 7721551.
243. ^ Bos I, De Boever P, Int Panis L, Meeusen R (2014). "Physical Activity, Air Pollution and the Brain". *Sports Medicine*. **44** (11): 1505–18. doi:10.1007/s40279-014-0222-6. PMID 25119155. S2CID 207493297.
244. ^ Air pollution linked to much greater risk of dementia *The Guardian*
245. ^ Julvez J, López-Vicente M, Warembourg C, Maitre L, Philippat C, Gützkow KB, et al. (1 September 2021). "Early life multiple exposures and child cognitive function: A multi-centric birth cohort study in six European countries". *Environmental Pollution*. **284**: 117404. Bibcode:2021EPoll.28417404J. doi:10.1016/j.envpol.2021.117404. ISSN 0269-7491. PMC 8287594. PMID 34077897.
246. ^ **a b** Costa LG, Cole TB, Dao K, Chang YC, Coburn J, Garrick JM (June 2020). "Effects of air pollution on the nervous system and its possible role in neurodevelopmental and neurodegenerative disorders". *Pharmacology & Therapeutics*. **210**: 107523. doi:10.1016/j.pharmthera.2020.107523. ISSN 1879-016X. PMC 7245732. PMID 32165138.
247. ^ Volk HE, Perera F, Braun JM, Kingsley SL, Gray K, Buckley J, et al. (1 May 2021). "Prenatal air pollution exposure and neurodevelopment: A review and blueprint for a harmonized approach within ECHO". *Environmental Research*. **196**: 110320. Bibcode:2021ER....19610320V. doi:10.1016/j.envres.2020.110320. ISSN 0013-9351. PMC 8060371. PMID 33098817.
248. ^ Shang L, Yang L, Yang W, Huang L, Qi C, Yang Z, et al. (1 July 2020). "Effects of prenatal exposure to NO<sub>2</sub> on children's neurodevelopment: a systematic review and meta-analysis". *Environmental Science and Pollution Research*. **27** (20): 24786–24798. Bibcode:2020ESPR...2724786S. doi:10.1007/s11356-020-08832-y. ISSN 1614-7499. PMC 7329770. PMID 32356052. S2CID 216650267.
249. ^ Allen JL, Liu X, Pelkowski S, Palmer B, Conrad K, Oberdörster G, et al. (5 June 2014). "Early Postnatal Exposure to Ultrafine Particulate Matter Air Pollution: Persistent Ventriculomegaly, Neurochemical Disruption, and Glial Activation

- Preferentially in Male Mice". *Environmental Health Perspectives*. **122** (9): 939–945. doi:10.1289/ehp.1307984. ISSN 0091-6765. PMC 4154219. PMID 24901756.
250. ^ McEnaney M (7 June 2014). "Air pollution link discovered to autism, schizophrenia risks". *Tech Times*. Retrieved 8 June 2014.
251. ^ "New evidence links air pollution to autism, schizophrenia". *ScienceDaily*. 5 June 2014. Retrieved 28 August 2024.
252. ^ Persico C, Marcotte DE (November 2022). *Air Quality and Suicide. Working Paper Series. National Bureau of Economic Research*. doi:10.3386/w30626.cite book: CS1 maint: date and year (link)
253. ^ Symons A (15 December 2022). "Suicide rates rise as air quality worsens, study finds". *euronews*. Retrieved 19 December 2022.
254. ^ "New Study Demonstrates Indoor Building Environment Has Significant, Positive Impact on Cognitive Function". *The New York Times*. 26 October 2015. Archived from the original on 9 November 2020. Retrieved 10 November 2015.
255. ^ Allen JG, MacNaughton P, Satish U, Santanam S, Vallarino J, Spengler JD (2015). "Associations of Cognitive Function Scores with Carbon Dioxide, Ventilation, and Volatile Organic Compound Exposures in Office Workers: A Controlled Exposure Study of Green and Conventional Office Environments". *Environmental Health Perspectives*. **124** (6): 805–12. doi:10.1289/ehp.1510037. PMC 4892924. PMID 26502459. S2CID 12756582.
256. ^ Cedeño Laurent JG, MacNaughton P, Jones E, Young AS, Bliss M, Flanigan S, et al. (1 September 2021). "Associations between acute exposures to PM2.5 and carbon dioxide indoors and cognitive function in office workers: a multicountry longitudinal prospective observational study". *Environmental Research Letters*. **16** (9): 094047. Bibcode:2021ERL...16i4047C. doi:10.1088/1748-9326/ac1bd8. ISSN 1748-9326. PMC 8942432. PMID 35330988. S2CID 237462480.
257. ^ Qian D (29 June 2017). "Air Pollution and Mortality in the Medicare Population". *New England Journal of Medicine*. **376** (26): 2513–2522. doi:10.1056/NEJMoa1702747. PMC 5766848. PMID 28657878. S2CID 12038778.
258. ^ Pathak M, Kuttippurath J (2022). "Air quality trends in rural India: analysis of NO2 pollution using satellite measurements". *Environmental Science: Processes & Impacts*. **24** (12): 2437–2449. doi:10.1039/D2EM00293K. ISSN 2050-7887. PMID 36413251. S2CID 253261324.
259. ^ Woodyatt A (3 June 2020). "Scientists say they have found the cleanest air on Earth". *CNN*. Retrieved 3 June 2020.
260. ^ Hong C, Mueller ND, Burney JA, Zhang Y, AghaKouchak A, Moore FC, et al. (2020). "Impacts of ozone and climate change on yields of perennial crops in California". *Nature Food*. **1** (3): 166–172. doi:10.1038/s43016-020-0043-8. S2CID 216425480.
261. ^ Li H, Tang M, Cao A, Guo L (2022). "Assessing the relationship between air pollution, agricultural insurance, and agricultural green total factor productivity: evidence from China". *Environmental Science and Pollution Research*. **29** (52): 78381–78395. Bibcode:2022ESPR...2978381L. doi:10.1007/s11356-022-21287-7. ISSN 0944-1344. PMID 35689771. S2CID 249551277.

262. ^ Kashyap R, Kuttippurath J, Patel VK (2023). "Improved air quality leads to enhanced vegetation growth during the COVID–19 lockdown in India". *Applied Geography*. **151**: 102869. Bibcode:2023AppGe.15102869K. doi:10.1016/j.apgeog.2022.102869. ISSN 0143-6228. PMC 9805897. PMID 36619606. S2CID 255439854.
263. ^ Kuttippurath J, Singh A, Dash SP, Mallic N, Clerbaux C, Van Damme M, et al. (2020). "Record high levels of atmospheric ammonia over India: Spatial and temporal analyses". *Science of the Total Environment*. **740**: 139986. Bibcode:2020ScTEn.74039986K. doi:10.1016/j.scitotenv.2020.139986. ISSN 0048-9697. PMID 32927535. S2CID 221722300.
264. ^ RWDI Consulting (2005). "Health and air quality 2005 – Phase 2: Valuation of health impacts from air quality in the lower Fraser Valley airshed" (PDF). Archived from the original (PDF) on 15 May 2011. Retrieved 29 August 2010.
265. ^ UN Environment (11 October 2018). "Air pollution linked to "huge" reduction in intelligence". UN Environment. Retrieved 1 July 2019.
266. ^ Lavy V, Rachkovski G, Yoresh O (2022). *Heads Up: Does Air Pollution Cause Workplace Accidents? (Report)*. Cambridge, MA: National Bureau of Economic Research. doi:10.3386/w30715.
267. ^ Smith A (12 February 2021). "Pollution on other planets could help us find aliens, Nasa says". *The Independent*. Archived from the original on 12 February 2021. Retrieved 6 March 2021.
268. ^ "Can Alien Smog Lead Us to Extraterrestrial Civilizations?". *Wired*. Retrieved 6 March 2021.
269. ^ Kopparapu R, Arney G, Haqq-Misra J, Lustig-Yaeger J, Villanueva G (22 February 2021). "Nitrogen Dioxide Pollution as a Signature of Extraterrestrial Technology". *The Astrophysical Journal*. **908** (2): 164. arXiv:2102.05027. Bibcode:2021ApJ...908..164K. doi:10.3847/1538-4357/abd7f7. ISSN 1538-4357. S2CID 231855390.
270. ^ Chakrabarti S. "20th anniversary of world's worst industrial disaster". *Australian Broadcasting Corporation*.
271. ^ Bell ML, Davis DL, Fletcher T (January 2004). "A Retrospective Assessment of Mortality from the London Smog Episode of 1952: The Role of Influenza and Pollution". *Environ Health Perspect*. **112** (1): 6–8. doi:10.1289/ehp.6539. PMC 1241789. PMID 14698923. S2CID 13045119.
272. ^ Meselson M, Guillemin J, Hugh-Jones M (November 1994). "The Sverdlovsk anthrax outbreak of 1979" (PDF). *Science*. **266** (5188): 1202–08. Bibcode:1994Sci...266.1202M. doi:10.1126/science.7973702. PMID 7973702. Archived from the original (PDF) on 21 September 2006.
273. ^ Davis D (2002). *When Smoke Ran Like Water: Tales of Environmental Deception and the Battle Against Pollution*. Basic Books. ISBN 978-0-465-01521-4.
274. ^ Landrigan P (25 November 2016). "Air pollution and health". *Lancet*. **2** (1): E4–E5. doi:10.1016/S2468-2667(16)30023-8. PMID 29249479.
275. ^ Camahan JV, Thurston DL (1998). "Trade-off Modeling for Product and Manufacturing Process Design for the Environment". *Journal of Industrial Ecology*.

- 2 (1): 79–92. Bibcode:1998JInEc...2...79C. doi:10.1162/jiec.1998.2.1.79. ISSN 1530-9290. S2CID 154730593.
276. ^ Jacobson MZ, von Krauland AK, Coughlin SJ, Palmer FC, Smith MM (1 January 2022). "Zero air pollution and zero carbon from all energy at low cost and without blackouts in variable weather throughout the U.S. with 100% wind-water-solar and storage". *Renewable Energy*. **184**: 430–442. Bibcode:2022REne..184..430J. doi:10.1016/j.renene.2021.11.067. ISSN 0960-1481. S2CID 244820608.
277. ^ Gielen D, Boshell F, Saygin D, Bazilian MD, Wagner N, Gorini R (1 April 2019). "The role of renewable energy in the global energy transformation". *Energy Strategy Reviews*. **24**: 38–50. Bibcode:2019EneSR..24...38G. doi:10.1016/j.esr.2019.01.006. ISSN 2211-467X. S2CID 135283552.
278. ^ Burns J, Boogaard H, Polus S, Pfadenhauer LM, Rohwer AC, van-Erp AM, et al. (20 May 2019). "Interventions to Reduce Ambient Particulate Matter Air Pollution and Their Effect on Health". *Cochrane Database of Systematic Reviews*. **2019** (5): CD010919. doi:10.1002/14651858.CD010919.pub2. PMC 6526394. PMID 31106396.
279. ^ Connolly K (30 August 2022). "Germany's €9 train tickets scheme 'saved 1.8m tons of CO<sub>2</sub> emissions'". *The Guardian*. Retrieved 6 December 2022.
280. ^ Fensterstock JC, Kurtzweg JA, Ozolins G (1971). "Reduction of Air Pollution Potential through Environmental Planning". *Journal of the Air Pollution Control Association*. **21** (7): 395–399. doi:10.1080/00022470.1971.10469547. PMID 5148260.
281. ^ Fensterstock, Ketcham and Walsh, *The Relationship of Land Use and Transportation Planning to Air Quality Management*, Ed. George Hagevik, May 1972.
282. ^ "The Importance of Development Plans/Land Use Policy for Development Control". *www.oas.org*. Retrieved 17 June 2022.
283. ^ Kuttippurath J, Patel VK, Pathak M, Singh A (2022). "Improvements in SO<sub>2</sub> pollution in India: role of technology and environmental regulations". *Environmental Science and Pollution Research*. **29** (52): 78637–78649. Bibcode:2022ESPR...2978637K. doi:10.1007/s11356-022-21319-2. ISSN 1614-7499. PMC 9189448. PMID 35696063. S2CID 249613744.
284. ^ Palmer J (12 November 2011). "'Smog-Eating' Material Breaking into the Big Time". *BBC News*.
285. ^ "Nanotechnology to gobble up pollution". *BBC News*. 15 May 2014. Retrieved 29 October 2014.
286. ^ a b Jacobson MZ (2015). "100% clean and renewable wind, water, and sunlight (WWS) all-sector energy road maps for the 50 United States". *Energy and Environmental Science*. **8** (7): 2093–2117. doi:10.1039/C5EE01283J.
287. ^ Krelling C, Badami MG (1 January 2022). "Cost-effectiveness analysis of compressed natural gas implementation in the public bus transit fleet in Delhi, India". *Transport Policy*. **115**: 49–61. doi:10.1016/j.tranpol.2021.10.019. ISSN 0967-070X.

288. ^ Landrigan PJ (1 January 2017). "Air pollution and health". *The Lancet Public Health*. **2** (1): e4–e5. doi:10.1016/S2468-2667(16)30023-8. ISSN 2468-2667. PMID 29249479.
289. ^ Lyons TJ, Kenworthy JR, Newman PW (1 January 1990). "Urban structure and air pollution". *Atmospheric Environment. Part B. Urban Atmosphere*. **24** (1): 43–48. Bibcode:1990AtmEB..24...43L. doi:10.1016/0957-1272(90)90008-I. ISSN 0957-1272.
290. ^ McVeigh K (28 September 2021). "'False choice': is deep-sea mining required for an electric vehicle revolution?". *The Guardian*. Retrieved 24 October 2021.
291. ^ Opray M (24 August 2017). "Nickel mining: the hidden environmental cost of electric cars". *The Guardian*. Retrieved 24 October 2021.
292. ^ "Los Angeles Airport Pollutes City Air For Miles Downwind". *Chemical and Engineering news*. 30 May 2014. Retrieved 13 December 2019.
293. ^ "NASA Confirms Biofuels Reduce Jet Emissions". *Flyingmag.com*. 23 March 2017. Retrieved 11 January 2018.
294. ^ "Interseasonal Heat Transfer – Seasonal Heat Storage – GSHC – Renewable Heat & Renewable Cooling from ThermalBanks – Efficient Renewable Energy – Hybrid Renewable Energy Systems". *lcax.co.uk*. Retrieved 11 January 2018.
295. ^ Ahuja D, Tatsutani M (7 April 2009). "Sustainable energy for developing countries". *S.A.P.I.EN.S (in French)*. **2** (1). ISSN 1993-3800.
296. ^ Oyedepo SO (23 July 2012). "Energy and sustainable development in Nigeria: the way forward". *Energy, Sustainability and Society*. **2** (1): 15. Bibcode:2012ESusS...2...15O. doi:10.1186/2192-0567-2-15. ISSN 2192-0567. S2CID 40436190.
297. ^ "Road Rubber". *Sciencenetlinks.com Science Updates – Science NetLinks*. Retrieved 11 January 2018.
298. ^ Simeonova E (March 2018). "Congestion Pricing, Air Pollution and Children's Health". *National Bureau of Environmental Research. Working Paper Series*. doi:10.3386/w24410.
299. ^ Academy S (16 April 2022). "Impact Of Air Pollution On The Environment". *Samphina*. Retrieved 18 June 2022.
300. ^ "Subway air pollution damages passenger health". *Chemistryworld.com*. Retrieved 11 January 2018.
301. ^ Singla S, Bansal D, Misra A, Raheja G (31 August 2018). "Towards an integrated framework for air quality monitoring and exposure estimation-a review". *Environmental Monitoring and Assessment*. **190** (9): 562. Bibcode:2018EMnAs.190..562S. doi:10.1007/s10661-018-6940-8. ISSN 1573-2959. PMID 30167891. S2CID 52135179.
302. ^ Zarrar H, Dyo V (1 October 2023). "Drive-by Air Pollution Sensing Systems: Challenges and Future Directions". *IEEE Sensors Journal*. **23** (19): 23692–23703. Bibcode:2023ISenJ..2323692Z. doi:10.1109/JSEN.2023.3305779. hdl:10547/625961. S2CID 261152934.
303. ^ Kaivonen S, Ngai EC (1 February 2020). "Real-time air pollution monitoring with sensors on city bus". *Digital Communications and Networks*. **6** (1): 23–30.

- doi:10.1016/j.dcan.2019.03.003. ISSN 2352-8648. S2CID 88485659.
304. ^ Zhang R, Zhang Y, Lin H, Feng X, Fu TM, Wang Y (April 2020). "NO<sub>x</sub> Emission Reduction and Recovery during COVID-19 in East China". *Atmosphere*. **11** (4): 433. Bibcode:2020Atmos..11..433Z. doi:10.3390/atmos11040433. S2CID 219002558.
  305. ^ "Airborne Nitrogen Dioxide Plummets Over China". *earthobservatory.nasa.gov*. 28 February 2020. Archived from the original on 2 April 2020. Retrieved 6 April 2020.
  306. ^ "Analysis: Coronavirus temporarily reduced China's CO<sub>2</sub> emissions by a quarter". *Carbon Brief*. 19 February 2020. Archived from the original on 4 March 2020. Retrieved 6 April 2020.
  307. ^ "New monitoring technologies can help cities combat air pollution". *World Economic Forum*. 15 April 2021. Retrieved 24 October 2021.
  308. ^ Yu T, Wang W, Ciren P, Sun R (18 October 2018). "An assessment of air-quality monitoring station locations based on satellite observations". *International Journal of Remote Sensing*. **39** (20): 6463–6478. Bibcode:2018IJRS...39.6463Y. doi:10.1080/01431161.2018.1460505. ISSN 0143-1161. S2CID 135457028.
  309. ^ "Pollution is Personal". *The Atlantic*. Retrieved 20 December 2021.
  310. ^ "World Air Map: Live air quality everywhere in the world". *Plume Labs Air Report*. Retrieved 20 December 2021.
  311. ^ "Live Animated Air Quality Map (AQI, PM2.5...) | AirVisual". *IQAir*. Retrieved 27 January 2022.
  312. ^ *European Commission* (11 May 2011). "European Commission - Environment - Air - Air quality". Archived from the original on 11 May 2011.
  313. ^ *Canada Ea* (10 September 2007). "About the Air Quality Health Index". *Canada.ca*. Retrieved 27 February 2022.
  314. ^ "Environment Canada – Air Quality". *Ec.gc.ca*. 10 September 2007. Retrieved 11 November 2011.
  315. ^ "Environment Canada – AQHI categories and explanations". *Ec.gc.ca*. 16 April 2008. Retrieved 11 November 2011.
  316. ^ "German TA-Luft is guaranteed by us". *centrotherm clean solutions*. Archived from the original on 29 June 2022. Retrieved 27 February 2022.
  317. ^ **a b** *Europa* (1996). "Summaries of EU legislation – Management and quality of ambient air". Retrieved 24 January 2015.
  318. ^ "PRESS RELEASE No 58/08 Judgment of the Court of Justice in Case C-237/07" (PDF). *European Court of Justice*. 2008. Retrieved 24 January 2015.
  319. ^ Overview of relevant case law and critical state of air pollution protection in the EU: Winfried Huck, Jennifer Maaß, Saparya Sood, Tahar Benmagnhia, Alexander Schulte, Sarah Heß and Marc-Anthony Walter, *The Right to Breathe Clean Air and Access to Justice - Legal State of Play in International, European and National Law* (2021) in 8(22) *International Institutions: Transnational Networks eJournal*, available at: <http://dx.doi.org/10.2139/ssrn.3808572>
  320. ^ *European Commission*. "Air quality: Commission sends final warning to UK over levels of fine particle pollution". Archived from the original on 11 May 2011.

Retrieved 7 April 2011.

321. ^ House of Commons Environmental Audit Committee (2010). "Environmental Audit Committee – Fifth Report Air Quality". Retrieved 24 January 2015.
322. ^ a b Mulholland H (11 March 2011). "Britain fends off threat of £300m fine over London air pollution". *The Guardian*. Retrieved 24 January 2015.
323. ^ "Every Breath You Take" (PDF). London Assembly Environment Committee. May 2009. Archived from the original (PDF) on 22 February 2015. Retrieved 22 February 2015.
324. ^ BBC (6 December 2010). "Threat to sue over London congestion charge scrapping". *BBC News*. Retrieved 24 January 2015.
325. ^ Risse-Kappen T (1995). *Bringing transnational relations back in: non-state actors, domestic structures, and international institutions*. Cambridge: Cambridge University Press. pp. 3–34.
326. ^ a b Pattberg P, Stripple J (2008). "Beyond the public and private divide: remapping transnational climate governance in the 21st century". *International Environmental Agreements: Politics, Law and Economics*. **8** (4): 367–388. Bibcode:2008IEAPL...8..367P. doi:10.1007/s10784-008-9085-3. S2CID 62890754.
327. ^ Roman M (2010). "Governing from the middle: the C40 Cities Leadership Group". *Corporate Governance*. **10** (1): 73–84. doi:10.1108/14720701011021120.
328. ^ "Tribes do their part to keep air clean. Now, they want to make sure pollution from afar doesn't put that at risk". *USA TODAY*. Retrieved 16 April 2024.
329. ^ "Air pollution hot spot". Retrieved 24 April 2014.
330. ^ Pettit D (14 December 2014). "Global Toll of Air Pollution: Over 3 Million Deaths Each Year". Switchboard NRDC. Archived from the original on 8 May 2014.
331. ^ "Watch air pollution flow across the planet in real time". *Science Magazine News*. 28 November 2016.
332. ^ a b Drury R, Belliveau M, Kuhn JS, Shipra B (Spring 1999). "Pollution Trading and Environmental Justice: Los Angeles' Failed Experiment in Air Pollution Policy". *Duke Environmental Law & Policy Forum*. **9** (231).
333. ^ a b Morello-Frosch R, Zuk M, Jerrett M, Shamasunder B, Kyle AD (2011). "Understanding the Cumulative Impacts of Inequalities in Environmental Health: Implications for Policy". *Health Affairs*. **30** (5): 879–87. doi:10.1377/hlthaff.2011.0153. PMID 21555471.
334. ^ Mohai P, Lantz P, Morenoff J, House J, Mero R (2009). "Racial and Socioeconomic Disparities in Residential Proximity". *American Journal of Public Health*. **99** (3): S649–56. doi:10.2105/ajph.2007.131383. PMC 2774179. PMID 19890171.
335. ^ Lerner S (2010). *Sacrifice Zones: The Front Lines of Toxic Chemical Exposure in the United States*. Port Arthur, Texas: Public Housing Residents Breathe Contaminated Air from Nearby Refineries and Chemical Plants. MIT Press.
336. ^ Vohra K, Marais EA, Bloss WJ, Schwartz J, Mickley LJ, Van Damme M, et al. (8 April 2022). "Rapid rise in premature mortality due to anthropogenic air pollution in fast-growing tropical cities from 2005 to 2018". *Science Advances*. **8** (14): eabm4435. Bibcode:2022SciA....8M4435V. doi:10.1126/sciadv.abm4435.



ISSN 2375-2548. PMC 8993110. PMID 35394832.

337. ^ Michelozzi P, Forastiere F, Fusco D, Perucci CA, Ostro B, Ancona C, et al. (1998). "Air Pollution and Daily Mortality in Rome, Italy". *Occupational and Environmental Medicine*. **55** (9): 605–10. doi:10.1136/oem.55.9.605. JSTOR 27730990. PMC 1757645. PMID 9861182.
338. ^ The Daily Telegraph 8 January 2014 'Air pollution killing up to 500,000 Chinese each year, admits former health minister'.
339. ^ "World's Most Polluted Cities in 2020 - PM2.5 Ranking | AirVisual". [www.iqair.com](http://www.iqair.com). Retrieved 1 February 2022.
340. ^ "World Air Quality Index (AQI) Ranking | IQAir". [www.iqair.com](http://www.iqair.com). Retrieved 24 May 2022.
341. ^ Darame M (29 November 2019). "En Afrique de l'Ouest, une pollution mortelle mais d'ampleur inconnue" [In West Africa, deadly pollution but of unknown magnitude]. *Le Monde* (in French).
342. ^ Organisation for Economic Co-operation and Development (1 March 2012). "Environmental Outlook to 2050 - OECD" (PDF). OECD.

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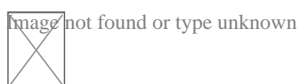
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- Brimblecombe P (1987). *The Big Smoke: A History of Air Pollution in London Since Medieval Times*. Routledge. ISBN 978-1-136-70329-4.
- Brimblecombe P (1995). "1: History of air pollution". In Singh H (ed.). *Composition, chemistry, and climate of the atmosphere*. New York: John Wiley & Sons. pp. 1–18. ISBN 978-0-471-28514-4. OCLC 43084000.
- Brimblecombe P, Makra L (2005). "Selections from the history of environmental pollution, with special attention to air pollution. Part 2\*: From medieval times to the 19th century". *International Journal of Environment and Pollution*. **23** (4): 351–67. doi:10.1504/ijep.2005.007599.
- Cherni, Judith A. *Economic Growth versus the Environment: The Politics of Wealth, Health and Air Pollution* (2002) online
- Corton, Christine L. *London Fog: The Biography* (2015)
- Currie, Donya. "WHO: Air Pollution a Continuing Health Threat in World's Cities", *The Nation's Health* (February 2012) 42#1 online
- Dewey, Scott Hamilton. *Don't Breathe the Air: Air Pollution and US Environmental Politics, 1945–1970* (Texas A & M University Press, 2000)
- Gonzalez, George A. *The politics of air pollution: Urban growth, ecological modernization, and symbolic inclusion* (SUNY Press, 2012)
- Grinder RD (1978). "From Insurgency to Efficiency: The Smoke Abatement Campaign in Pittsburgh before World War I.". *Western Pennsylvania Historical*

*Magazine*. **61** (3): 187–202.

- Grinder, Robert Dale. "The Battle for Clean Air: The Smoke Problem in Post-Civil War America" in Martin V. Melosi, ed., *Pollution & Reform in American Cities, 1870–1930* (1980), pp. 83–103.
- Kumar P, Pirjola L, Ketznel M, Harrison RM (2013). "Nanoparticle emissions from 11 non-vehicle exhaust sources – A review". *Atmospheric Environment*. **67**. Elsevier BV: 252–277. Bibcode:2013AtmEn..67..252K. doi:10.1016/j.atmosenv.2012.11.011. ISSN 1352-2310.
- Lundqvist LJ (1980). *The Hare and the Tortoise: Clean Air Policy in the US and Sweden*. Ann Arbor, MI: University of Michigan Press. ISBN 978-0-472-09310-6.
- Mingle, Jonathan, "Our Lethal Air" [review of Gary Fuller, *The Invisible Killer...*; Beth Gardiner, *Choked...*; Tim Smedley, *Clearing the Air...*; U.S. Environmental Protection Agency, *Integrated Science Assessment for Particulate Matter (External Review Draft, 2018)*; and Chartered Clean Air Scientific Advisory Committee, *Letter to EPA Administrator on the EPA's Integrated Science Assessment for Particulate Matter, 11 April 2019*], *The New York Review of Books*, vol. LXVI, no. 14 (26 September 2019), pp. 64–66, 68. "Today, 91 percent of people worldwide live in areas where air pollution levels exceed the World Health Organization's recommended limits. ... [T]here is no safe level of exposure to fine particulate matter. ... Most of these fine particles are a by-product of ... burning ... coal, gasoline, diesel, wood, trash ... These particles can get past the defenses of our upper airways to penetrate deep into our lungs and reach the alveoli ... From there, they cross into the bloodstream and spread throughout the body. They can travel through the nose, up the olfactory nerve, and lodge ... in the brain. They can form deposits on the lining of arteries, constricting blood vessels and raising the likelihood of ... strokes and heart attacks. [T]hey exacerbate respiratory illnesses like asthma and chronic obstructive pulmonary disease ... There's ... evidence linking air pollution exposure to an increased risk of Alzheimer's and other forms of dementia." (p. 64.)
- Mosley, Stephen. *The chimney of the world: a history of smoke pollution in Victorian and Edwardian Manchester*. Routledge, 2013.
- Schreurs, Miranda A. *Environmental Politics in Japan, Germany, and the United States* (Cambridge University Press, 2002) online
- Thorsheim, Peter. *Inventing Pollution: Coal, Smoke, and Culture in Britain since 1800* (2009)

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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
- 
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Pollution

History

## 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 hazard
- Genetic pollution
- Introduced species
  - Invasive species
- Information pollution
- Light
  - Ecological light pollution
  - Overillumination
- Radio spectrum pollution

## Biological

## Digital

## Electromagnetic

## Natural

- Ozone
- Radium and radon in the environment
- Volcanic ash
- Wildfire
- Transportation
  - Land
  - Water
  - Air
  - Rail
  - Sustainable transport

## Noise

- Urban
- Sonar
  - Marine mammals and sonar
- Industrial
- Military
- Abstract
- Noise control
- Actinides
- Bioremediation
- Nuclear fission
- Nuclear fallout

## Radiation

- Plutonium
- Poisoning
- Radioactivity
- Uranium
- Electromagnetic radiation and health
- Radioactive waste
- Agricultural pollution
  - Herbicides
  - Manure waste
  - Pesticides

## Soil

- 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

## Visual

- Satellite
- 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
- Agricultural wastewater
- Biological pollution
- Diseases
- Eutrophication
- Firewater
- Freshwater
- Groundwater
- Hypoxia
- Industrial wastewater
- Marine

## Water

- 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
- Pollutants
  - Heavy metals
  - Paint
- Brain health and pollution







## Topics

## Misc

- Area source
- Debris
- Dust
- Garbology
- Legacy pollution
- Midden
- Point source
- Waste
- Cleaner production
- Industrial ecology
- Pollution haven hypothesis
- Pollutant release and transfer register
- Polluter pays principle
- Pollution control
- Waste minimisation
- Zero waste
- Diseases
- Law by country
- Most polluted cities
- Least polluted cities by PM<sub>2.5</sub>
- Most polluted countries
- Most polluted rivers
- Treaties

## Responses

## Lists

 [Categories \(by country\)](#)  [Commons](#)  [WikiProject Environment](#)  [WikiProject Ecology](#)  [Environment portal](#)  [Ecology portal](#)

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Asia pollution topics



	<b>Dust storm</b>	<ul style="list-style-type: none"> <li>○ 2010 China dust storms</li> <li>○ 1997 SEA haze</li> <li>○ 1997 Indonesian forest fires</li> <li>○ 2005 Malaysian haze</li> <li>○ 2006 SEA haze</li> <li>○ 2009 SEA haze</li> <li>○ 2010 SEA haze</li> </ul>
<b>Notable incidents</b>	<b>Forest fires and haze</b>	<ul style="list-style-type: none"> <li>○ 2013 SEA haze</li> <li>○ 2015 SEA haze</li> <li>○ 2016 Malaysian haze</li> <li>○ 2016 SEA haze</li> <li>○ 2017 SEA haze</li> <li>○ 2019 SEA haze</li> <li>○ 2019 Vietnam forest fires</li> <li>○ 2024 Indo-Pakistani smog</li> </ul>
<b>Air pollution</b>	<b>Air radioactive contamination</b>	<ul style="list-style-type: none"> <li>○ 1982 Bukit Merah radioactive pollution</li> </ul>
	<b>By countries</b>	<ul style="list-style-type: none"> <li>○ China</li> <li>○ Hong Kong</li> <li>○ India</li> <li>○ Macau</li> <li>○ Malaysia</li> <li>○ Taiwan</li> </ul>
	<b>Recurrent issues</b>	<ul style="list-style-type: none"> <li>○ Asian brown cloud</li> <li>○ Asian Dust</li> <li>○ Shamal</li> <li>○ Southeast Asian haze</li> <li>○ ASEAN Agreement on Transboundary Haze Pollution</li> </ul>
	<b>Counter-measures</b>	<ul style="list-style-type: none"> <li>○ Operation Haze</li> <li>○ Pollutant Standards Index</li> <li>○ Great Green Wall (China)</li> </ul>



- 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
- 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
- Degrees
- Journals
- Research institutes
- Glossary
- Environment by year
- Human impact on the environment

**Related fields**

**Applications**

**Lists**

**See also**

-  **Category**
  - **scientists**
-  **Commons**
-  **Environment portal**
-  **WikiProject**

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- **e**

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
- Sociology of health and illness

**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
- Case-control study
- Randomized controlled trial
- Relative risk

**Biological and epidemiological statistics**

- Statistical hypothesis testing
  - Analysis of variance (ANOVA)
  - Regression analysis
  - ROC curve
  - Student's *t*-test
  - Z-test
- Statistical software
- Asymptomatic carrier
- Epidemics
  - List

**Infectious and epidemic disease prevention**

- 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
- 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

**Health  
behavioral  
sciences**



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

**Education**

**History**

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## Natural resources

### Air

#### Pollution / quality

- o Ambient standards (US)
- o Index
- o Indoor
- o Law
  - o Clean Air Act (US)
- o Ozone depletion
- o Airshed
- o Trading
- o Deforestation (REDD)

#### Emissions

### Energy

- o Bio
- o Law
- o Resources
- o Fossil fuels (gas, peak coal, peak gas, peak oil)
- o Geothermal
- o Hydro
- o Nuclear
- o Solar
  - o sunlight
  - o shade
- o 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
  - management
- Forests
  - genetic resources
  - law
  - 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
  - management

## Water

### Types / location

- Aquifer
  - storage and recovery
- Drinking
- Fresh
- Groundwater
  - pollution
  - recharge
  - remediation
- Hydrosphere
- Ice
  - bergs
  - glacial
  - polar
- Irrigation
  - *huerta*
- Marine
- Rain
  - harvesting
- Stormwater
- Surface water
- Sewage
  - reclaimed water
- Watershed
- Desalination
- Floods
- Law
- Leaching
- Sanitation
  - improved
- Scarcity
- Security
- Supply
- Efficiency
- Conflict
- Conservation
- Peak water
- Pollution
- Privatization
- Quality
- Right
- Resources
  - improved
  - policy

### Aspects

- Commons
    - enclosure
    - global
    - land
    - tragedy of
  - Economics
    - ecological
    - land
  - Ecosystem services
  - Exploitation
    - overexploitation
    - Earth Overshoot Day
  - Management
    - adaptive
  - Natural capital
    - accounting
    - good
  - Natural heritage
  - Nature reserve
    - remnant natural area
  - Systems ecology
  - Urban ecology
  - Wilderness
- Common-pool
  - Conflict (perpetuation)
  - Curse
- Resource
    - Depletion
    - Extraction
    - Nationalism
    - Renewable / Non-renewable
    - Oil war
  - Politics
    - Petrostate
    - Resource war

**Related**

-  **Category**

**Authority control databases**  **Edit this at Wikidata**

## National

- Germany
- United States
- France
- BnF data
- Japan
- Czech Republic
  - 2

## Other

- Spain
- Israel
- NARA

About Royal Supply South

Things To Do in Arapahoe County

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## Photo

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**Colorado Freedom Memorial**

**4.8 (191)**

## Photo

## **Plains Conservation Center (Visitor Center)**

**4.6 (393)**

**Photo**

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## **Aurora Reservoir**

**4.6 (1770)**

**Photo**

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## **History Colorado Center**

**4.6 (2667)**

**Photo**



## **Morrison Nature Center**

**4.7 (128)**

### **Photo**

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## **Molly Brown House Museum**

**4.7 (2528)**

## **Driving Directions in Arapahoe County**

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

**Driving Directions From Denver to Royal Supply South**

**Driving Directions From VRCC Veterinary Specialty and Emergency Hospital to Royal Supply South**

**Driving Directions From Walmart Supercenter to Royal Supply South**

**Driving Directions From Arapahoe County Assessor to Royal Supply South**

[https://www.google.com/maps/dir/Lowe%27s+Home+Improvement/Royal+Supply+South/105.013478,14z/data=!3m1!4b1!4m14!4m13!1m5!1m1!1sChIJMbvTxDmAblcRm\\_hEdvF105.013478!2d39.62581!1m5!1m1!1sChIJ06br1RqAblcRAjyWXdIXZaw!2m2!1d-105.0233105!2d39.6435918!3e0](https://www.google.com/maps/dir/Lowe%27s+Home+Improvement/Royal+Supply+South/105.013478,14z/data=!3m1!4b1!4m14!4m13!1m5!1m1!1sChIJMbvTxDmAblcRm_hEdvF105.013478!2d39.62581!1m5!1m1!1sChIJ06br1RqAblcRAjyWXdIXZaw!2m2!1d-105.0233105!2d39.6435918!3e0)

<https://www.google.com/maps/dir/Tandy+Leather+South+Denver+-+151/Royal+Supply+South/@39.6520857,-105.005976,14z/data=!3m1!4b1!4m14!4m13!1m5!1m1!1sChIJt2nr7QqAblcRqgEXMaZa105.005976!2d39.6520857!1m5!1m1!1sChIJ06br1RqAblcRAjyWXdIXZaw!2m2!1d-105.0233105!2d39.6435918!3e2>

<https://www.google.com/maps/dir/King+Soopers/Royal+Supply+South/@39.6545686,-105.0511676,14z/data=!3m1!4b1!4m14!4m13!1m5!1m1!1sChIJUwi2ThmAa4cRlyDrquk105.0511676!2d39.6545686!1m5!1m1!1sChIJ06br1RqAblcRAjyWXdIXZaw!2m2!1d-105.0233105!2d39.6435918!3e1>

<https://www.google.com/maps/dir/U.S.+Bank+ATM/Royal+Supply+South/@39.6560093,-105.0508859,14z/data=!3m1!4b1!4m14!4m13!1m5!1m1!1sChIJUwi2ThmAa4cRy6Hutfo105.0508859!2d39.6560093!1m5!1m1!1sChIJ06br1RqAblcRAjyWXdIXZaw!2m2!1d-105.0233105!2d39.6435918!3e3>

[https://www.google.com/maps/dir/St.+Nicks+Christmas+and+Collectibles/Royal+Supply+South/105.0155267,14z/data=!3m1!4b1!4m14!4m13!1m5!1m1!1sChIJ0alPujCAblcRjcf\\_zxYfiq105.0155267!2d39.6225114!1m5!1m1!1sChIJ06br1RqAblcRAjyWXdIXZaw!2m2!1d-105.0233105!2d39.6435918!3e0](https://www.google.com/maps/dir/St.+Nicks+Christmas+and+Collectibles/Royal+Supply+South/105.0155267,14z/data=!3m1!4b1!4m14!4m13!1m5!1m1!1sChIJ0alPujCAblcRjcf_zxYfiq105.0155267!2d39.6225114!1m5!1m1!1sChIJ06br1RqAblcRAjyWXdIXZaw!2m2!1d-105.0233105!2d39.6435918!3e0)

<https://www.google.com/maps/dir/Mullen+High+School/Royal+Supply+South/@39.6513096,-105.0362791,14z/data=!3m1!4b1!4m14!4m13!1m5!1m1!1sChIJUXQGSwCAa4cRd9cGg105.0362791!2d39.6513096!1m5!1m1!1sChIJ06br1RqAblcRAjyWXdIXZaw!2m2!1d-105.0233105!2d39.6435918!3e2>

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

**Driving Directions From Aurora History Museum to Royal Supply South**

**Driving Directions From Four Mile Historic Park to Royal Supply South**

**Driving Directions From Cherry Creek State Park to Royal Supply South**

**Driving Directions From Cherry Creek State Park to Royal Supply South**

**Driving Directions From Four Mile Historic Park to Royal Supply South**

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## **Reviews for Royal Supply South**

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Identifying Common Signs of HVAC Malfunction in Mobile Homes [View GBP](#)

**Check our other pages :**

- **Steps for Consistent Maintenance of Mobile Home Air Conditioning**
- **Scheduling Spring and Fall Tuneups for Mobile Home AC Units**
- **Methods for Evaluating Energy Consumption in Mobile Home Heating Systems**
- **Essential Tools for Simple Mobile Home HVAC Diagnostics**

## Frequently Asked Questions

What are the common signs that the HVAC system in a mobile home is malfunctioning?

Common signs include unusual noises (such as banging or squealing), uneven heating or cooling throughout the home, increased energy bills, frequent cycling on and off, and weak airflow from vents.

How can I tell if my mobile homes HVAC unit has airflow issues?

Airflow issues may be indicated by weak or inconsistent air coming from the vents, hot or cold spots in various rooms, and visible dust buildup around registers. Additionally, blocked ducts or dirty filters might cause these problems.

Why might an HVAC system in a mobile home emit strange odors?

Strange odors could result from mold growth due to excess moisture in the system, burning smells indicating electrical issues, or musty odors suggesting clogged filters. Its important to address these promptly to prevent further damage or health risks.

Royal Supply Inc

Phone : +16362969959

City : Wichita

State : KS

Zip : 67216

Address : Unknown Address

### **Google Business Profile**

Company Website : <https://royal-durhamsupply.com/locations/wichita-kansas/>

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