Air conditioning poses a climate conundrum

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This week, much of the US is suffering from yet another heat wave. So far this year, 15 countries have set records for high heat. Last July, the average global temperature, factoring in heat waves in multiple regions around the world, was likely the hottest in 120,000 years. Heat stress already kills about 500,000 people around the world yearly—a number the World Health Organization expects will rise five-fold by 2050.

Because heat can be a life or death issue, air conditioning is essential. But not only is it a necessity for human health; we also need it to refrigerate food and medicines, to cool computers in data centers and in manufacturing processes for electronics and pharmaceuticals, among other reasons. The problem: The more we cool, the more planet-warming global greenhouse gas emissions we pump into the atmosphere.

Why air conditioning is essential

In 2023, 3.8 billion people around the world suffered from extreme heat for at least a day, and over 47,000 people in Europe alone died from heat-related causes.

Air conditioning is no longer just a luxury, but an imperative for human health, as heat stress is the leading weather-related cause of death. When the heat index exceeds 90°F, there is a risk of heat stroke as blood moves from major organs to the skin to cool it; deprived of oxygen, organs can stop functioning properly.

Heat may also cause seizures and cardiovascular failure in people with heart disease, as the heart must work harder to maintain blood pressure when the body is trying to keep cool. Excessive sweating can reduce blood flow to the kidneys, which can damage them. If a pregnant woman is exposed to very high temperatures, her baby might be born preterm, have low birth weight, congenital abnormalities or be stillborn.

Heat also affects cognitive performance and can hamper the ability of children to learn. High temperatures may worsen air pollution, which exacerbates respiratory diseases. Most at risk in high heat are small children, the elderly, those with underlying health issues, pregnant women, outdoor workers and people with low incomes.

High temperatures also affect productivity and GDP. In India, a study found that productivity fell 2% for every 3.6°F increase in temperature. Workers may be more fatigued or get sick, crop yields can be reduced, and energy costs are higher. The decrease in productivity over 30 years may have cost India 1% of its GDP, or $32 billion.

Air conditioning use is increasing

Sustained daily temperatures over 86°F have been shown to increase weekly air conditioner sales by 16%. Today, there are about 2 billion air conditioners in the world. The International Energy Agency (IEA) expects there will be 5.6 billion by 2050. This is equivalent to 10 new air conditioners being bought every second until 2050.

Air conditioning use is increasing because places like the US Pacific Northwest, UK, Germany, Scandinavia, and parts of South America, Africa and Asia that historically never needed it are now getting hotter. Air conditioner sales are also being driven by rising incomes.

According to economists, air conditioning purchases spike after annual household incomes reach $10,000. As incomes rise in developing countries, more and more people will want, and need, access to air conditioning.

The Philippines passed the $10,000 mark in 2022; Ukraine, Algeria, and Mongolia, among others, are gradually approaching the $10,000 mark.

In addition, 56% of the world population currently lives in cities, and urban populations are expected to more than double by 2050. City temperatures tend to be higher than surrounding regions because of the urban heat-island effect, due to the built environment absorbing and retaining heat.

Many large cities in South Asia and Sub-Saharan Africa, countries with tropical or sub-tropical climates, are the world's fastest-growing urban areas. In the US, 40 large cities, including Houston, Pensacola, Charleston and Baton Rouge, face increased heat exposure due to rising temperatures, coupled with growing populations.

If we continue the current warming trend, by 2050, almost 1,000 cities containing 1.6 billion people will experience average high summer temperatures of 95°F.

AI needs more and more cooling

The explosive growth of artificial intelligence, cloud computing and cryptocurrencies is also adding to the cooling demand because servers in data centers must be kept cool to function properly. Data centers account for 2.5 to 3.7 percent of global greenhouse gas emissions, exceeding even those of the aviation industry. Forty percent of their energy use is for cooling.

Moreover, as the capabilities and complexity of AI models rapidly increase over the next few years, their processing and energy consumption needs will too. Because of AI's enormous growth, the IEA projects the energy demands of data centers will increase tenfold by 2026 as more data is stored and processed.

Some data centers are moving towards alternative cooling methods. Microsoft researchers are using a special fluid engineered to boil 90 degrees lower than water's boiling point to cool computer processors.

Servers are submerged in the fluid, which does not harm electronic equipment. Microsoft is also experimenting with underwater data centers that rely on the ocean to cool servers, and ocean currents and nearby wind turbines to generate renewable energy.

Thales Alenia Space is leading a study on the feasibility of building data centers in space, which would run on solar energy. Despite these new and developing approaches, however, most data centers still use air cooling.

Access to cooling is an environmental justice issue

"With the increasing incidence of extreme heat around the world, in particular in the global south communities, as well as in vulnerable communities here, air conditioning has become less of a luxury and more of a necessity, and therefore an arguable human right," said Sheila Foster, professor of climate at the Columbia Climate School.

Heat exacerbates inequality because access to cooling is tied to wealth. 90% of US and Japanese households have air conditioning, as compared to 8% of people in the hottest regions of the world. In Sub-Saharan Africa, less than 4% of homes have cooling and these are almost all the wealthiest households.

In addition, many poor regions and marginalized communities in the US, in particular those that were redlined in the past, have been starved of investment over decades.

"These communities lack green infrastructure, lack tree canopy, lack natural infrastructure that could help them reduce their exposure to heat," said Foster.

"A national study of 37 cities found that formerly redlined areas have about 23% of tree canopy coverage on average, whereas those areas that were the highest rated under the federal government's map have on average 43%. The areas that had the least tree canopy, formerly redlined areas across dozens of cities, are many degrees hotter during heat waves, so the lack of green amenities is another environmental justice issue."

Foster added that the energy transition is not unfolding in a just way. Despite numerous federal and state incentives now available to help households move toward renewable energy, these incentives are not reaching the most vulnerable households.

"You have to be a homeowner," she said.

"To get those incentives, you have to outlay the cash. You have to purchase and install and then claim the credit on your tax filing. The households that can invest and get those credits are going to see their energy costs go down. Those households that cannot, including the most vulnerable ones, are going to see their energy burden continue to go up. The most economically and socially vulnerable are being left behind in this energy transition."

The climate impacts of air conditioning

Cooling is currently responsible for 10% of global electricity consumption, according to the IEA. In some countries with the highest temperatures, it can account for over 70% of peak electricity demand, and the countries where cooling demand is increasing the fastest largely rely on coal-fired power plants. Because about two-thirds of the world's electricity is still produced by fossil fuels—mainly coal and gas—cooling's soaring electricity demand is increasing greenhouse gas emissions.

In 2022, the IEA estimated that electricity for cooling produced 1 billion metric tons of CO_2. This is equal to 238 million gasoline-powered cars driven for one year. In addition, the hydrofluorocarbons (HFCs) used as refrigerants in today's air conditioners have hundreds to thousands of times more global warming potential than CO_2.

When they leak, they produce an additional 720 million metric tons of

CO_2 equivalents each year.

In 2016, over 170 nations agreed to phase out HFCs starting in 2019, and alternatives to HFCs are being developed in many countries. In the US, the EPA's HVAC refrigerant mandate requires manufacturers to use refrigerants with a global warming potential (GWP) below 700 (current refrigerants have a GWP of 2,800) in new air conditioners, refrigeration systems and heat pumps starting January 1, 2025.

The units with the new refrigerants are expected to cost 20 to 25% more, however, which could put them out of reach for lower-income households.

While the new refrigerants will reduce the carbon footprint of air conditioners, 80% of cooling's greenhouse gas emissions comes from the energy it consumes. Air conditioning currently accounts for 7% of global greenhouse gas emissions. If we continue with business as usual, emissions from cooling are expected to double by 2030 and to triple by 2050.

Air conditioning and our net-zero goals

To achieve the world's goal of net-zero emissions by 2050, emissions from cooling must decrease to 40% of today's level by 2030, according to the IEA. And while emissions from air-conditioning units have decreased over the last ten years due to improvements in energy efficiency, they need to be cut three times faster through 2030.

To reach net zero, the IEA says that increased adoption of the highest-efficiency air conditioners must be combined with building and neighborhood designs that incorporate passive cooling, as well as individual behavior changes such as setting thermostats slightly higher.

Solutions to the air conditioning conundrum

Greater energy efficiency

Traditional air conditioners are inefficient because they need to cool the air past the point of comfort to condense water from it and then dehumidify the air. Many companies and researchers are exploring different strategies to improve energy efficiency. Some new designs, including one from Massachusetts-based Transaera, separate the dehumidification and cooling processes, so that overcooling is not necessary.

Others, like cSNAP, do not contain refrigerants, but employ evaporative cooling in a process that is more energy efficient than current air conditioners. Electrocaloric cooling, still another approach, uses an electric field to alter the movement of the atoms in a material, thus causing a temperature change.

In addition, the Global Cooling Prize, a competition with the goal of developing air conditioning with five times less climate impact than today's units, incentivizes manufacturers, startups and companies to come up with new efficient and affordable strategies.

Most of the air conditioners sold everywhere in the world today are less than half as efficient as the most efficient models available. The IEA projects that electricity consumption for cooling will increase from 2,000 TWh today to 6,000 TWh by 2050. If everyone bought the most efficient units, this electricity demand could be reduced 45%, but people in poorer communities are unlikely to choose the most efficient and usually more costly models.

Despite the ongoing developments in more energy efficient cooling, they still may not be enough to offset the extra energy that will be needed to power the increased demand for cooling. Experts say it is critical to minimize the need for cooling in the first place with designs for passive cooling incorporated into urban and building designs.

Passive cooling and smart systems

Before the invention of the air conditioner in the 1920s, cities were designed with narrow streets exposed to the sun only for short periods during the day. Cul-de-sacs created barriers against the heat. Shady squares with fountains gave people places to retreat from the heat.

Today's homes, buildings and cities can be better designed to cope with heat. A building's orientation and layout can improve air flow. There are many possible design strategies, including providing outdoor or indoor shade, or planting trees around a building to decrease solar heat. Incorporating a body of water into a design also helps cool nearby temperatures.

White or green roofs and facades cut down on heat. Open windows or doors on opposite sides of a home can produce cross ventilation. Insulation stems the flow of heat, and reflective panels can reduce the absorption of solar radiation. Open windows at night allow the night air to cool down buildings.

Automated smart systems with thermostats that can reduce the need for continuous air conditioning by regulating cooling based on occupancy, weather, time of day, and the internal heat, are also needed in buildings and homes to reduce energy consumption.

Government policies

Governments can establish and enforce energy codes for buildings—something often lacking in developing countries with the most need for cooling—as well as minimum energy standards for air conditioners. They can provide incentives, such as rebates and subsidies to encourage the purchase of energy-efficient air conditioners or reduce taxes on them.

They also need to provide energy bill assistance for lower-income households to help with higher electricity bills and employ subsidies to support renewable energy resources.

Governments can invest in R&D for new technologies to improve energy efficiency and find alternatives to climate-warming refrigerants. They also must invest in green infrastructure in cities, particularly in marginalized and low-income communities.

To protect the population, federal and state governments can develop heat action plans to raise awareness about heat risks, give advance warnings and prepare communities to deal with increasing temperatures.

By educating the public, governments can encourage individuals to change their behavior by setting thermostats higher so air conditioners don't have to work so hard, and by employing ways to stay cooler without air conditioning.

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