NOT PASSING ON PASSIVE COOLING:

HOW PHILANTHROPY CAN HELP ACCELERATE PASSIVE COOLING SOLUTIONS AND THEIR CLIMATE BENEFITS

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Cool Coalition

KIGALI
COOLING EFFICIENCY PROGRAM

SUSTAINABLE ENERGY FOR ALL

CEA CONSULTING

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About the Cool Coalition

The Cool Coalition is a global multi-stakeholder network that connects a wide range of key actors from government, cities, international organizations, businesses, finance, academia, and civil society groups to facilitate knowledge exchange, advocacy, and joint action towards a rapid global transition to efficient and climate-friendly cooling. The Cool Coalition promotes an 'avoid-shift-improve-protect' holistic and cross-sectoral approach to meet the cooling needs of both industrialized and developing countries through urban form, better building design, energy efficiency, renewables, and thermal storage as well as phasing down HFCs.

About the Kigali Cooling Efficiency Program

The Kigali Cooling Efficiency Program (K-CEP) is a philanthropic collaboration to support the Kigali Amendment to the Montreal Protocol and the transition to efficient, climate-friendly cooling solutions for all. K-CEP works in over 50 countries in support of ambitious action by governments, businesses, and civil society.

About Sustainable Energy for All

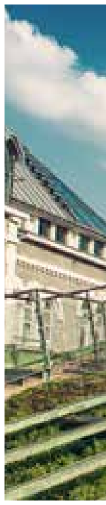
Sustainable Energy for All (SEforALL) is an international organization that works in partnership with the United Nations and leaders in government, the private sector, financial institutions, civil society, and philanthropies to drive faster action towards the achievement of Sustainable Development Goal 7—access to affordable, reliable, sustainable, and modern energy for all by 2030—in line with the Paris Agreement on climate.

About CEA Consulting

Since 1984, CEA Consulting has helped transform business practices, public policies, nonprofit organizations, and philanthropic strategies to improve environmental outcomes. Their work is guided by a deep knowledge of the scientific, regulatory, political, social, and economic underpinnings of our most pressing environmental problems.

EXECUTIVE SUMMARY

Passive cooling—the practice of using non-mechanical technology, design elements, and/or naturebased solutions (NbS) to keep a space cool without using energy—is fundamental to ensuring climatefriendly cooling for all. Many passive cooling solutions can be incorporated into building, container, or environmental design and adapted to local climates. These measures can be simple passive technology additions like external shading or cool roofs on buildings to increase solar reflectance, or NbS such as green roofs and corridors, urban parks, or plants on and around buildings that reduce ambient temperatures. Building designs that feature improved ventilation, insulated walls, low-solar heat gain windows, intentional orientation to minimize heat gain from the sun, or biomaterials with low thermal capacity and high insulation qualities can provide thermal comfort. In turn, these features can drastically reduce the amount of energy used and greenhouse gas (GHG) emissions produced by mechanical cooling. Reducing the heat gain of buildings, sidewalks, and streets, and the resulting urban heat island (UHI) effect in cities through cool roofs and NbS can also increase the comfort, health, and safety of community residents. These benefits are greatest for the most vulnerable populations who lack access to cooling.



Passive cooling is a key component in addressing the challenge of providing equitable access to cooling while reducing the sector's GHG emissions. Passive cooling is relatively inexpensive compared to active solutions and is broadly applicable to a wide variety of buildings and communities. Philanthropy has an important role to play in scaling up the adoption of passive cooling solutions, in order to realize its fullest potential with regards to emissions reductions, improved health, and economic development.

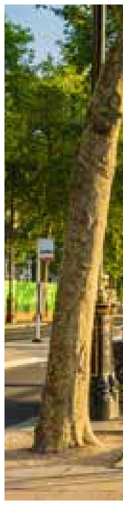
Philanthropy is uniquely positioned to intervene at several levels to help scale passive cooling beyond a business-as-usual trajectory, including:

- supporting the development of building codes that incorporate passive design elements;
- promoting access to cooling through passive cooling solutions focusing on heatwaves and netzero cold chains;
- raising awareness of passive cooling solutions through awards, challenges, and education;
- establishing and building the capacity of local champions to accelerate implementation;
- proving the business case for passive cooling solutions; and,
- creating financial mechanisms to fund and de-risk passive cooling projects.

These interventions can be bottom-up (e.g., encouraging demonstrations of an integrated set of passive solutions in a variety of contexts to influence national policy), top-down (e.g., national policy that trickles down to individual building or environment design), or market-based. The most effective interventions will likely incorporate a mix of these elements.

This brief frames passive cooling within the broader context of climate-friendly cooling; summarizes the environmental, economic, and health benefits of passive cooling; provides case studies for passive cooling at the building, city, national, and global level; addresses barriers to scaling passive cooling; and provides recommendations on how philanthropy can advance the sector.

INTRODUCTION

Passive cooling is the practice of using non-mechanical technology, design elements, and/or naturebased solutions (NbS) to keep a space cool without using energy. Passive cooling is a subset of passive design, which focuses on reducing the overall energy demand for buildings, containers, and surrounding environments. Many passive cooling solutions can be adapted to local climates. These can be simple passive technology additions—such as installing external shading or a cool roof on buildings to increase solar reflectance—or construction that prioritizes ventilation, insulated walls, building envelope improvements, low-solar heat gain windows, night flush cooling[1], or building orientation to minimize heat gain from the sun.

NbS are a subset of passive cooling that utilize natural features to provide cooling benefits that enhance human well-being and biodiversity. Such solutions can be integrated into building design (e.g., green roofs, water sinks, or living walls) or into the broader community design (e.g., urban greening or natural heat sinks) to decrease the urban heat island (UHI) effect, which, if unaddressed, can raise the mean air temperature of a city by 1–3°C.[2]

Building materials that have high insulation qualities and low thermal capacity are also important elements of passive cooling. Light colored materials can help reduce heat retention. Biomaterials, traditionally used in lightweight constructions, can be used to create innovate designs and building techniques to reduce the need of mechanical cooling. Traditional materials used in the past by communities in hot climates also present climate-specific solutions that are typically in plentiful supply and sourced locally, further reducing energy demand, embodied carbon of buildings, and environmental impacts of construction. For example, in arid and semi-arid climatic conditions, traditionally used biobased material naturally provides evaporative cooling qualities that yield thermal comfort without needed cooling appliances in buildings. In hot and humid climates, locally sourced construction biomaterials coupled with passive cooling can help with humidity control as many of these local materials have excellent moisture buffering properties.[3]

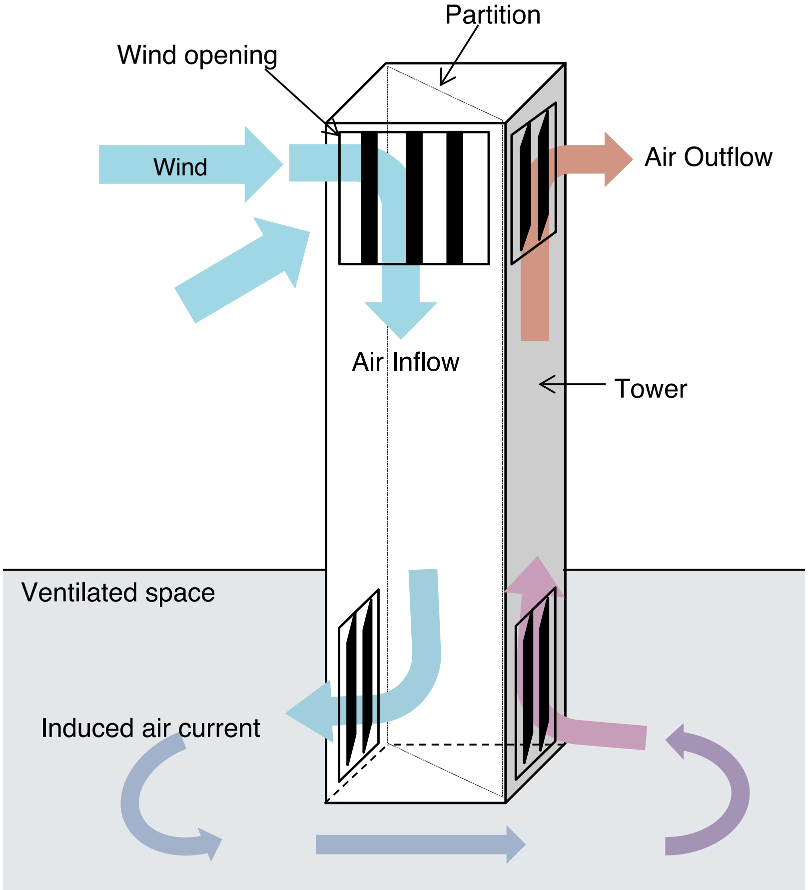
Passive cooling can also be integrated into cold chains to promote food and medicine security in rural areas through insulated boxes and the use of phase change materials that can store cooling energy (which can also be used for space cooling in buildings). Passive cooling can play a vital role in the insulation of vaccines for longer-distance transport, such as the emerging Covid-19 vaccines that require sustained refrigeration.

Passive measures can dramatically decrease greenhouse gas (GHG) emissions from cooling by reducing the demand for mechanical cooling, such as air conditioners (AC). In turn this lowers energy consumption and minimizes the leakage of high-global warming potential (GWP) refrigerants that are used in cooling appliances. This is especially important as demand for cooling is increasing at an alarming level. Demand for space cooling rose by more than 33% between 2010 and 2018, becoming the fastest-growing use of energy in buildings since 2010.[4]

By reducing the heat gain of buildings, sidewalks, and streets, and the resulting UHI effect in cities, it is possible to also increase the comfort, health, and safety of community residents.

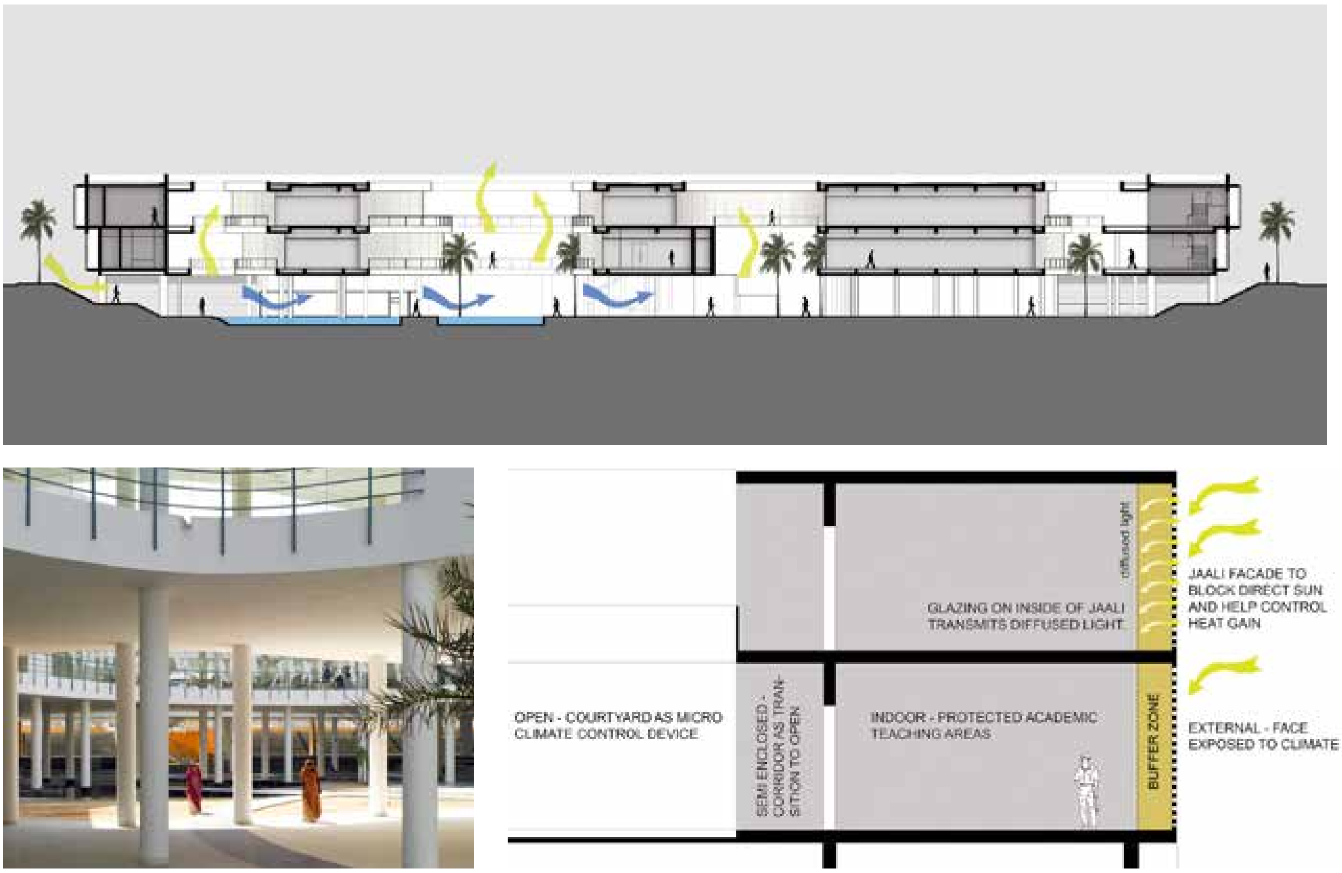
Passive cooling pre-dates mechanical cooling, and there are many historical examples of passively designed buildings. In the Persian Gulf, for example, wind catchers have been used since the fifth century to passively cool the inside of buildings. This is achieved by directing airflow indoors, providing natural ventilation, and decreasing internal temperatures by up to 10°C.[5,6] In India, step wells (pools of water built below building structures) still provide evaporative passive cooling to massive structures, some of which are over 500 years old.[7]

Figure 1: Design of a traditional bi-directional wind catcher (from Kassir 2016)



Passive measures can dramatically decrease greenhouse gas (GHG) emissions from cooling

Figure 2: The building design for the Pearl Academy of Fashion in Jaipur, India includes a traditional step well on the ground floor to provide passive cooling to the building (ArchDaily 2009).



PASSIVE COOLING IN THE CONTEXT OF CLIMATE-FRIENDLY COOLING

INCREASING DEPENDENCE ON MECHANICAL AC

Since the advent of mechanical AC in the 20th century, a growing dependence on such technology has largely displaced other cooling methods. Today, space cooling accounts for around 6% of the overall energy use in buildings. In total, annual cooling-related emissions account for 1,135 Mt CO_2, which is about 12% of global energy-related emissions from buildings.[8] With the global number of AC units in buildings predicted to increase from 1.6 billion today to 5.6 billion by 2050, the energy needs for space cooling could triple, especially in hot and tropical countries, despite expected improvements in product efficiency.[9] By 2050, space cooling is expected to be the second-largest source of global electricity demand, consuming as much electricity as all of China and India today.[10] The 2,500 GW of additional capacity needed to meet the growth in space-cooling demand by 2050 is equivalent to the combined total generating capacity of the U.S., Europe, and India today.[11] Passive cooling solutions are a climatefriendly way of combatting such issues, while still providing cooling for all.

WARMING TEMPERATURES AND HEATWAVES

Warming global land temperatures, including heatwaves and the UHI effect, can cause an uptick in the demand for mechanical AC, which creates a positive feedback that contributes to more warming.[12] The last five years have been the warmest five years on record, with 2019's global temperatures exceeding 0.95°C above average.[13] The distribution of heat gain is not uniform, with Africa, for example, recording a yearly continental average temperature of 1.33°C above average.[14] Heatwaves are also accelerating in intensity, frequency, and duration, and are projected to worsen under continued global warming.[15] For most of human history, humans have lived in climates with mean annual temperatures of 11–15°C, but by 2070 one out of three people will live in climates with mean annual temperatures exceeding 29°C.[16]

Increasing temperatures, especially during record heatwaves, amplify the demand for cooling. On an average day, New York City requires about 10,000 MW/second for electricity, but this number exceeds 13,000 MW/second during a heatwave, driven by increased demand for mechanical AC.[17] In areas fortunate enough to have access to mechanical AC, this uptick in demand can cause a positive feedback in the forces that contribute to climate change. In areas with less access to cooling, increasing temperatures and heatwaves can prove deadly.

Providing passive cooling in both industrialized and developing nations can save lives and provide thermal comfort, while also minimizing environmental impact. The "Protect-Reduce-Shift-Improve-Leverage" approach can support this goal by centering the role of passive cooling.

PROTECT-REDUCE-SHIFT-IMPROVE-LEVERAGE

Providing cooling that is aligned with the Paris Agreement, the Kigali Amendment to the Montreal Protocol, and the United Nations Sustainable Development Goals (SDGs) requires utilizing the "Protect-Reduce-Shift-Improve-Leverage" approach to meeting cooling needs (see Figure 3).[18] Different passive cooling technologies can provide varying benefits within this framework (see Figure 4).

Figure 3: The Protect-Reduce-Shift-Improve-Leverage approach to climate-friendly cooling (adapted from SEforALL 2020 and The Cool Coalition 2020)

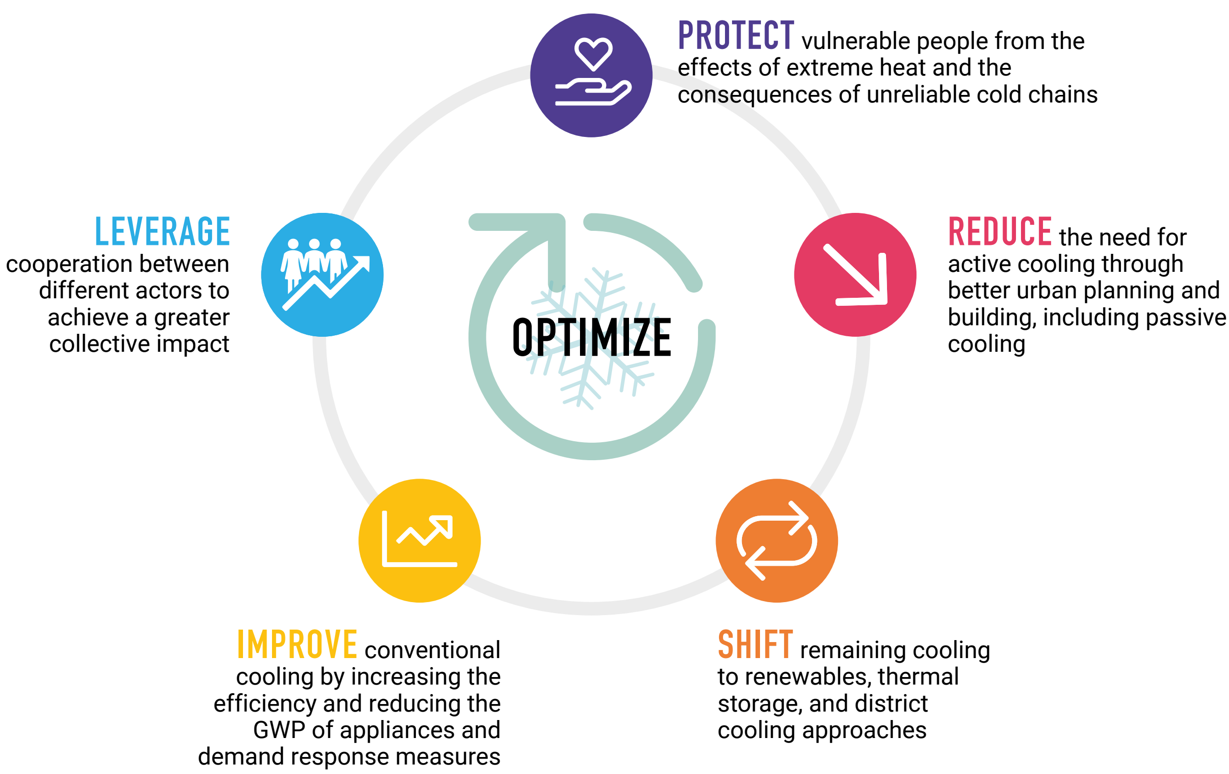


Figure 4: Examples of some nature-based and passive technology solutions with their corresponding elements from the protect-reduce-improve-shift-leverage framework (SEforALL 2020).

NATURE-BASED AND PASSIVE TECHNOLOGY SOLUTIONS

SHADES	Umbrellas, overhangs, fins, external blinds, solar panels and plants as shades
INSULATION	Roof and wall insulation, insulated windows, insulated containers
REFLECTION	Cool roofs, walls, vehicles, containers and other surfaces
AIRFLOW	Natural ventilation, building openings, exhaust
PLANTS	Ground cover, green roofs, green walls, shade trees
THERMAL	Thermal mass, thermal storage
EARTH	Earth tunnel, earth berm, heat sinks
WATER	Flowing water, mist, pools, rivers, lakes, ocean, heat sinks

PROTECT

Passive cooling measures can protect vulnerable people from the effects of extreme heat and the consequences of unreliable medical and agricultural cold chains. The World Health Organization (WHO) estimates that more than 166,000 people have died due to heatwaves between 1998 and 2017.[19] Simple passive cooling approaches to building design, like shading and cool roofs, could save lives and improve the health of those without access to mechanical cooling. At the city or district level, passive cooling can reduce the UHI effect and promote thermal comfort, which can have the largest impact in at-risk communities and least developed countries (LDCs) where heat can be the most damaging to health and productivity. Passive cooling solutions in cold chains can also help distribute food, medicine, and vaccines to vulnerable populations in rural and poorer areas.

REDUCE

Passive cooling, including the implementation of NbS and the use of innovative building materials, can reduce the need for mechanical cooling, thereby decreasing cooling-related energy use and its subsequent emissions. Reducing and even eliminating the demand for mechanical AC decreases the impact on the electricity grid during times of peak demand and can result in lower lifecycle cooling costs.

Mechanical cooling can also be avoided in stages of the cold chain through innovative solutions like dehydration or insulated packaging.

SHIFT AND IMPROVE

While passive cooling technologies predominantly help protect vulnerable populations and reduce the demand for mechanical cooling, they can also be used to maximize the benefits of "shift" and "improve" approaches.

"Shift" technologies—defined as methods to shift the energy used for cooling to renewable sources, district cooling, and/or climate-friendly refrigerants[20]—can be incorporated into building design and urban planning in tandem with passive cooling to further reduce emissions. For example, building codes intended to encourage passive cooling can incentivize the installation of renewable energy sources, such as rooftop solar. Additionally, district cooling solutions at the city level can incorporate nature-based and renewable passive cooling elements, such as using seawater heat exchange as a cooling agent.

Recent research has highlighted the symbiotic interactions between passive cooling measures and other renewable energy and energy efficiency efforts. One study showed solar panels placed above a vegetated roof have an increased solar energy output of about 1.4% relative to solar panels on a conventional black roof.[21]

Passive building design can further improve conventional cooling by facilitating demand-side management (DSM) strategies. Implementing passive cooling measures reduces the need for mechanical AC during times of peak demand, such as in the late afternoon when most electricity grids use the dirtiest mix of fossil fuels. AC alone accounts for 10–30% of peak electricity demand in many countries and is expected to account for more than 40% of peak demand in India and Indonesia in 2050.[22] Reducing this peak energy demand can have both short- and long-term impacts on emissions levels by helping to reduce direct emissions and to facilitate the transition to

renewable energy. This form of demand reduction can also avoid the construction of new fossil-fuel based power stations to meet peak demand, which would likely lock in emissions for several decades.

LEVERAGE

Lastly, the benefits of passive cooling can be further realized through "leverage" approaches, which use partnerships, cooperation, and collective impact to scale up climate-friendly cooling, particularly at the community level. Passive cooling needs to be elevated in tandem with other cooling solutions and technologies. For ways in which philanthropy can help leverage the benefits of passive cooling, see the *'Philanthropy's Added Value to Passive Cooling'* section.

BENEFITS OF PASSIVE COOLING

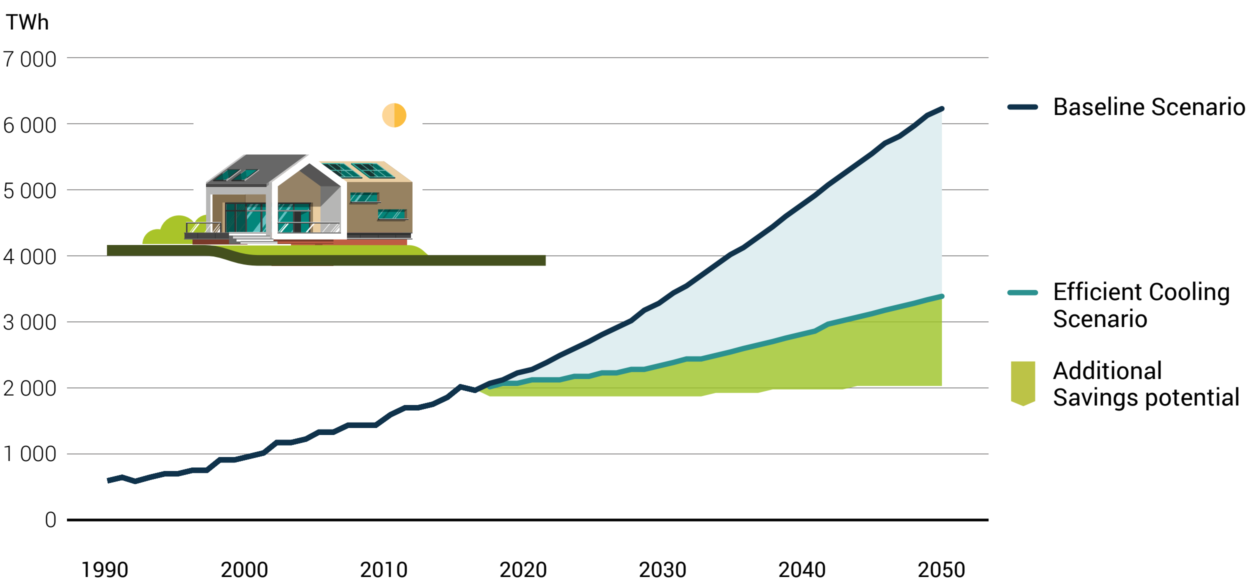
CLIMATE

The primary environmental benefit of passive cooling is seen in the reduction of GHG emissions from mechanical cooling, especially in the building sector. In the U.S. in 2014, the building sector accounted for more than 76% of electricity use, and more than 38% of all energy use and associated GHG emissions.[23] Around the world, cooling currently accounts for nearly 20% of the total electricity used in buildings today, and many countries are heading in the direction of the U.S. as they industrialize and are able to afford more mechanical AC.[24]

Isolating the future mitigation potential of passive cooling solutions at the global level is difficult. This is due to the variety of solutions available and the uncertainty surrounding dependent variables such as future electricity grid mixes and different uptake trajectories for efficient AC. In the International Energy Agency's (IEA) Future of Cooling report, the additional savings potential of improvements to the building envelope are modeled on top of more efficient AC. Improvements to the building envelope, such as through stricter building codes, work in tandem with efficient cooling and could provide an additional 1,300 TWh of energy savings in 2050 (see Figure 5). However, this approach essentially reverses the "Protect-Reduce-Shift-Improve-Leverage" hierarchy by prioritizing improvements to the efficiency of ACs. This means that even greater mitigation savings are possible from passive cooling measures by elevating the priority of passive cooling and avoiding the need for mechanical cooling in the first place.

More efficient ACs in the Efficient Cooling Scenario reduce energy needs for space cooling by more than 45% compared with the Baseline Scenario in 2050, with other measures such as building envelope improvements leading to even greater savings.

Figure 5: Additional energy savings potential from improvements to the building envelope (IEA 2018)



Passive cooling design in buildings can extend energy savings beyond just reductions in the cooling load. For example, buildings constructed to reduce the need for mechanical cooling through window design may deliver additional energy savings from the reduced need for mechanical ventilation or electric lighting. One study looking at the potential for passive cooling in building design in the United Arab Emirates found that applying passive cooling strategies could not only reduce the cooling load by 9%, but it could also reduce the annual energy consumption from buildings by 23.6%.[25] By securing such energy savings, a greater proportion of the carbon-free energy in the electrical grid could become available for mechanical cooling where it is necessary.[26]

Additionally, using reflective surfaces such as cool roofs can increase the albedo of urban areas, which in turn can induce a negative radiative forcing to cool the planet. *Akbari et al.* (2009) estimate that a widespread adoption of cool roofs could cause a one-time reduction in radiative forcing equivalent to offsetting about 44 Gt CO_2.[27]

HEALTH, WELL-BEING, AND COMFORT

Access to climate-friendly cooling is interwoven with many of the 17 SDGs.[28] In addition to the environmentally oriented goals, passive cooling is fundamental to the emerging research area of healthy buildings. Most people spend most of their time inside buildings, and research shows that there is a connection between the built environment and our physical, mental, and social health and well-being. The Harvard T.H. Chan School of Public Health has identified nine foundations of a healthy building: ventilation, air quality, thermal health, moisture, dust and pests, safety and security, water quality, noise, and lighting and views.[29] Passive building design with NbS can help achieve nearly all nine of these foundations. Passive cooling is likely to improve thermal comfort in buildings that are either not connected to the electrical grid or where the price of AC is a barrier. Covid-19 and its subsequent lockdowns have further emphasized the importance of healthy buildings, with some passive coolingrelated solutions, such as increased airflow, being promoted as a mitigation tool for virus transmission.[30]

Urban greening, such as trees, already provide enormous benefits to the health, well-being, and comfort of city dwellers. The Nature Conservancy's "Planting Healthy Air" report (2016), in coordination with the C40 Cities Climate Leadership Group, found that trees currently provide around 68.3 million people with a 0.5–2.0°C reduction in summer maximum air temperatures, coupled with significant reductions in particulate matter ($PM_{2.5}$) concentrations.[31] The report also emphasized that additional investments in urban greening are a cost-effective solution to further reducing temperatures and $PM_{2.5}$ concentrations.

Providing access to green spaces and the associated physical, mental, and productivity benefits can also help to reverse the impacts of redlining and other historically environmentally racist urban planning designs.[32,33] Income levels,

CASE STUDY 1

BUILDING LEVEL – BULLITT CENTER/BULLITT FOUNDATION

Various green building certification programs exist around the world, including the Leadership in Energy and Environment Design (LEED) certifications and the Living Building challenge. These certifications encourage specific performance levels for a variety of environmental indicators including energy, water, and sustainable building material use. A large focus of sustainable buildings is to improve the efficiency of the building envelope, which in turn decreases energy demand internally, including from cooling and heating. The Bullitt Center in Seattle, Washington, is the largest and greenest commercial building in the world and was certified as a living building by the International Living Future Institute in April 2015.[40]

The building is entirely self-sufficient with regards to energy and water and does not produce any emissions from cooling. The Bullitt Center achieves net-zero emissions cooling through a combination of passive cooling solutions and a heat pump, which is operated using renewable energy. The building's temperature is controlled by extracting heat from the radiant flooring during cool months via slabs that are heated or cooled by water captured naturally through stable underground temperature reserves. During warmer months, the Bullitt Center utilizes passive cooling via windows that adjust to provide cross ventilation and open automatically to provide fresh air during times of CO_2 build-up.[41] In total, the system avoids the use of 750 hours of mechanical cooling and therefore the production of its corresponding GHG emissions.[42]

surface temperatures, tree canopy coverage, and heat vulnerability are all closely correlated, especially in cities. A recent study found that in the western region of the U.S., twothirds of urban areas with a history of redlining have land surface temperatures as much as 7°C higher than their non-redlined neighbors.[34] Studies have also shown a direct link between temperatures and learning ability—a 0.55°C hotter school year can reduce that year's learning by 1%—which disproportionately impacts minority students and accounts for roughly 5% of the racial achievement gap.[35]

COLD CHAIN ACCESS

As previously mentioned, passive cooling design can improve the security of food and medicine supply. Elements can be integrated into the cold chain to prevent food waste and insulate vaccines for longerdistance transport, with significant implications for food security and disseminating vaccines during the Covid-19 pandemic.[36] Evaporative coolers, which use water to cool a food-carrying vessel, can be constructed for as little as $2 and can prolong the shelf life of fresh produce for up to 20 days.[37] Clay vessels can also help protect food from perishing in non-electrified areas, providing additional economic value to rural communities that can use passive cold chains to get their produce to market.

A recent discussion document on net zero cold chains for food from Carbon Trust, the Kigali Cooling Efficiency Program (K-CEP), and the Cool Coalition found that many countries may be able to leapfrog to net-zero cold chain infrastructure and significantly reduce the GHG emissions from such assets and the wider food system.[38] Passive cooling technologies can be a part of the larger system of net-zero cold chains, helping to bend the curve on cold chain emissions in industrialized countries and avoid emissions increases in countries where cold chain deployment is expected to grow.[39]

CASE STUDY 2

BUILDING LEVEL – STAR GARMENTS INNOVATION CENTER

The Star Garments Innovation Center is a product development facility in Sri Lanka. By renovating an obsolete building to the performance-based Passive House standards[43], the project dramatically reduced the waste, carbon emissions, and fossil fuels typically required for demolition and a new build. In addition, it maintains high standards in social, environmental, ethical, and safety compliance within the global fashion industry. Monitoring results confirm that annual energy consumption is cut by over 60% compared to a conventional "efficient" modern industrial building.[44] Specific design elements include:

- wall and roof insulation;
- solar protective double glazing and suitable shading;
- the avoidance of thermal bridges;
- improved airtightness;
- use of ventilation units with heat and humidity recovery – preventing around 70% of exterior heat and humidity from entering the building through the fresh air flow; and,
- a wrap-around heat pipe system helps to further reduce the dehumidification demand.[45]

All these solutions enable workers to enjoy year-round comfort in a workspace that provides abundant natural light, low humidity, filtered fresh air, and maintained temperatures near a constant 24°C at low energy expenditure.

BARRIERS AND SOLUTIONS TO PASSIVE COOLING

LIMITED COVERAGE OF NATIONAL BUILDING CODES

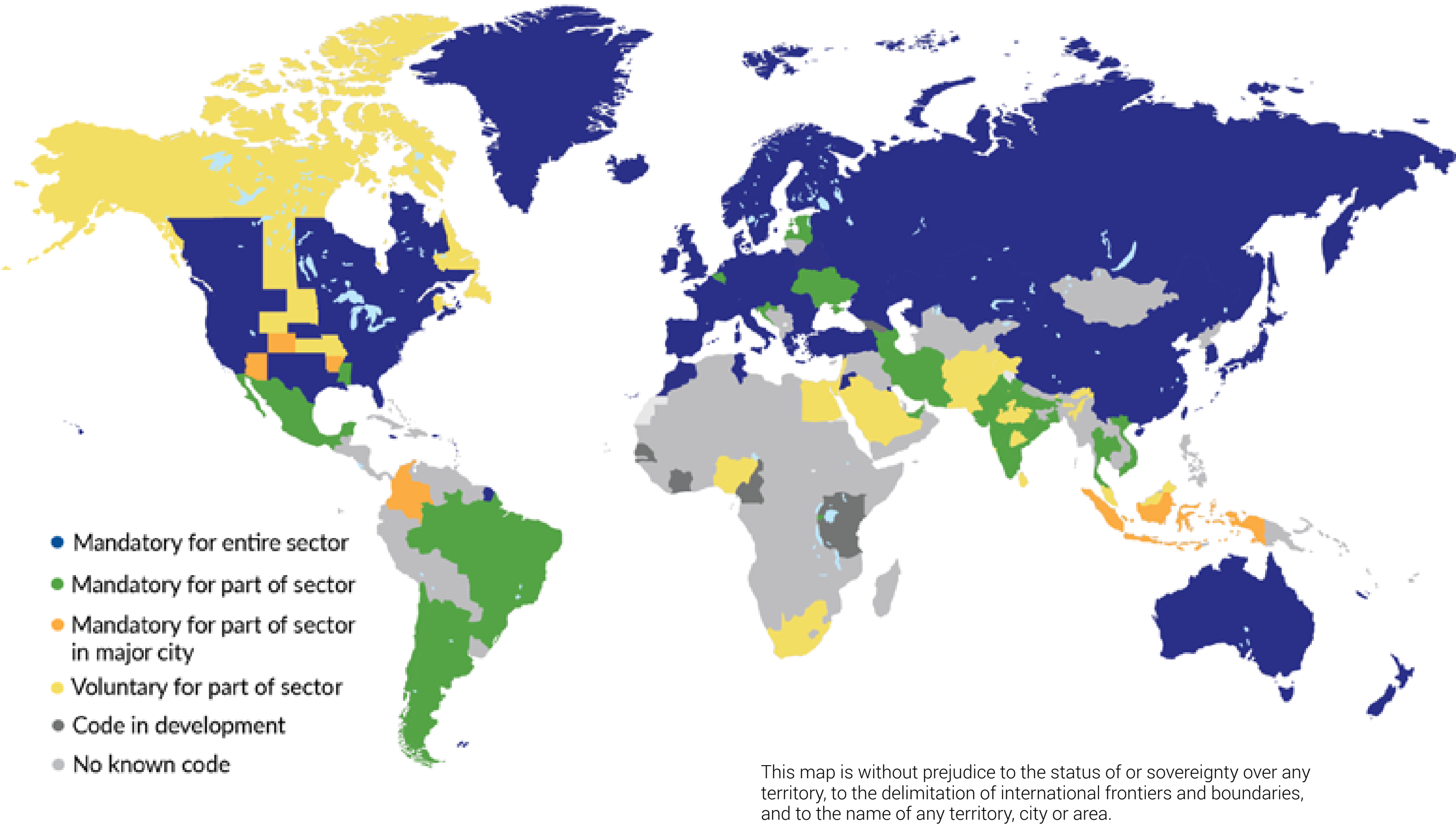
Building codes are a primary policy lever for increasing the adoption of passive cooling solutions, but levels of implementation and enforcement vary. Two-thirds of the 130 billion m^2 of new buildings to be constructed over the next two decades will occur in countries that do not have mandatory building energy codes in place.[56] Local or regional building codes can be an effective policy lever for small-scale change but fall short of the mitigation potential achievable through national regulation.

SLOW BUILDING TURNOVER AND LIMITED ENFORCEMENT OF EXISTING CODES

Many countries are adopting ambitious requirements for energy-efficient buildings, but meeting or enforcing those requirements amongst public and private developers is lagging. Especially in developing countries, informal construction can dominate the residential sector and limit the impact of building codes at the local, regional, or national level. Enforcement of building energy codes often falls on local governments, which can be understaffed and underfunded.[57] A lack of formal training and tools can also undermine both enforcement and compliance for existing codes.[58]

Even in countries with existing and well-enforced building energy codes, the turnover rate of the current building stock can create a bottleneck to rapidly scaling energy savings and passive cooling. The rate of building refurbishment in developed countries is 0.5–2.5%, which can cause lengthy delays between the adoption of a new building energy code with the most up-to-date passive cooling technologies, and when it is ultimately incorporated throughout the building stock.[59] This slow turnover rate can apply to other forms of established infrastructure, such as cold chains, which may have been developed originally without incorporating passive cooling elements.

Figure 6: Map of building energy codes by country, state, and province in 2017 (Global Alliance for Buildings and Construction 2019)



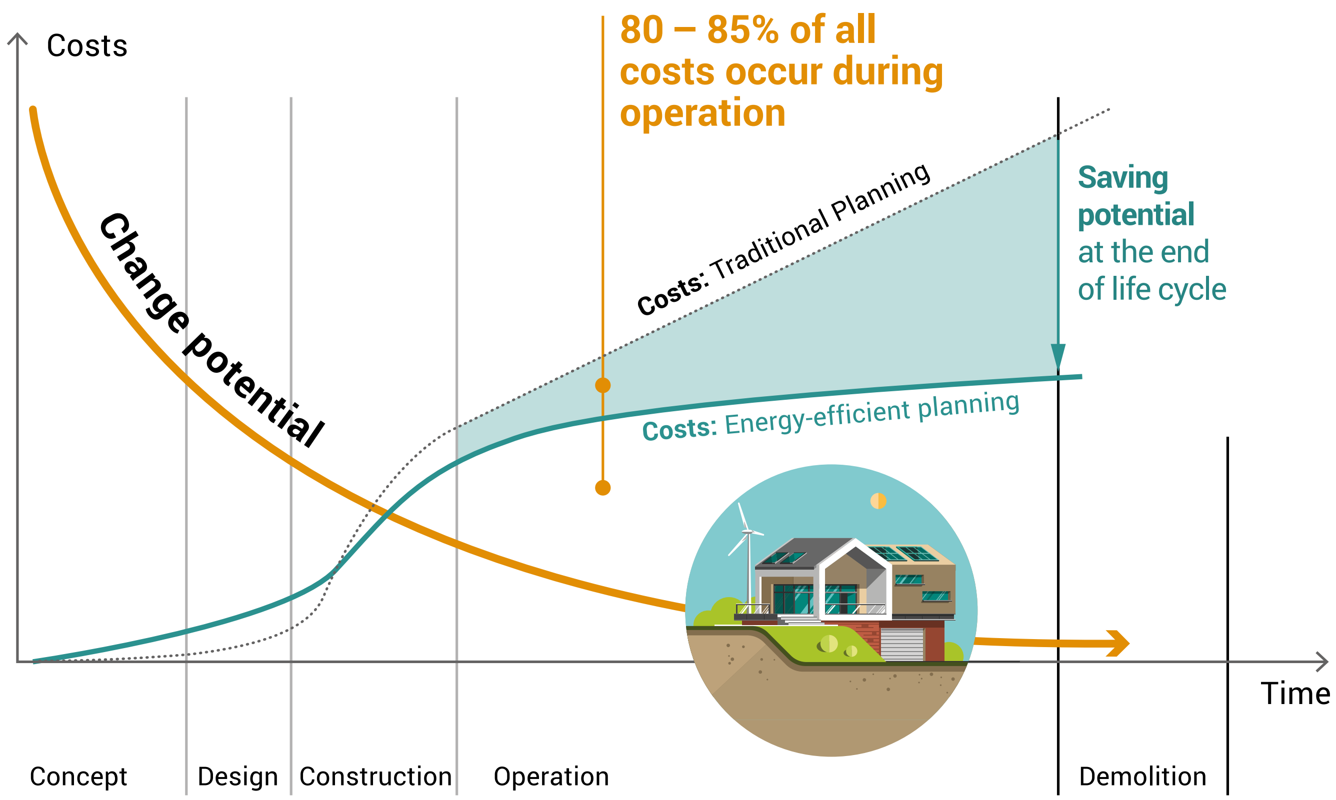
Source: 2019 Global Status Report on Buildings, Global Alliance on Buildings and Construction

UPFRONT COSTS AND SPLIT INCENTIVES

Another barrier to the widespread adoption of passive cooling can be the up-front costs. Even small additional investments for energy-efficient buildings can be a barrier, despite leading to long-term cost and CO2 savings. The extra effort to make buildings more energy and cooling efficient can be minimal during the initial design phase and can correspond to significant savings potential at the end of the building life cycle.[60] The early design decisions of a building can determine up to 80% of a building's long-term operational costs and environmental impact.[61] However, because of low return on investment (ROI), short-term-motivated financiers do not always see passive cooling as a priority investment going forward.

Additionally, since the investors and builders of passively designed buildings are often not the beneficiaries of the long-term savings (e.g., lower monthly energy bills), the existing market structure does not reward frontloading the higher costs. Alternative business models (e.g., design-build-operate instead of building and selling) can help overcome this barrier. Also, continued education and awareness of many of the most affordable passive cooling solutions (e.g., cool roofs and sourcing local building materials with high insulation qualities and low thermal capacity) can encourage developers to integrate passive cooling into building designs from the beginning.

Figure 7: Building design and change potential (Programme for Energy Efficiency in Buildings (PEEB) 2019; based on: Kovacic and Zoller 2015)



Source: Programme for Energy Efficiency in Buildings

KNOWLEDGE AND MINDSETS

Existing knowledge and mindsets on building design and traditional (i.e., mechanical) approaches to cooling can further hinder the mainstreaming of passive cooling technologies. Building design and cooling methods can be influenced by tradition, culture, and standard building practices. Resistance to change and lack of awareness on passive cooling options can be seen in policy makers, building owners, developers, and consumers. Architects and developers need to understand how to integrate passive cooling elements into their projects before scaling up passive cooling solutions. Consumers and owners need to understand and require lower energy intensity for their buildings and cooled spaces. This includes shifting perspectives on the attractivity of building materials and designs. Glass, steel, and concrete used to produce "modern-looking" buildings need to leave space for traditional materials and designs with higher insulation and lower heat retention qualities.

Passive cooling, including well-designed building envelopes, can and should be adapted to the local climate, culture, knowledge, and practices, as well as being incentivized. Knowledge and mindsets must be continually updated as research evolves on passive cooling technologies, such as with emerging research on increasingly sustainable building materials. For example, a recent article in Vox helped highlight the growing trend of using wood as a sustainable building material. Though wood has been used to build structures for thousands of years, an emerging method called "mass timber" – which involves sticking pieces of soft wood together to form larger, sturdier pieces—has been shown to be durable, safe, insulating, and capable of sequestering GHG emissions, thereby re-elevating the use of wood as a preferred building material.[62] Biomaterials such as agricultural waste (also known as agrowaste) derivates can also act as effective construction materials, ensuring intrinsic evaporative cooling and dehumidification in the built environment.[63] This is the case for the coconut fiberboard panel system developed by Willow Technologies Ltd. of Ghana in association with Center for Ecosystems in Architecture (CASE) at Rensselaer Polytechnic Institute, New York.

In some cases, adopting passive cooling involves a partial return to traditional building practices in a particular region. Vernacular technologies have been devised over millennia to adapt to severe climates without the need for mechanical cooling or heating. Returning to these architectural approaches can help bring thermal comfort to buildings.[64]

CASE STUDY 3

CITY LEVEL — MEDELLÍN GREEN CORRIDORS AND OTHER CITIES

Urban greening, a form of NbS, can provide passive cooling at the city level and reduce the UHI effect. Medellín, Colombia's second-largest city, implemented 30 'green corridors' in 2016 to provide cooling and a variety of other benefits. The $16.3 million initiative involved planting 8,300 trees and 350,000 shrubs over 70 hectares of waterways, roads, and paved ground. The green corridors have reduced the city's average temperatures by 2°C, decreasing the need for mechanical cooling in many of the city's residential and commercial buildings. Temperatures along the Avenue Oriental, one of Medellín's main roads, have fallen by up to 3°C. The project won the 2019 Ashden Award for Cooling by Nature, which was supported by K-CEP.[46]

Other cities around the world, including London, Melbourne, Tokyo, and Dhaka, are following Medellín's example by enhancing their green infrastructure to ensure effective passive cooling in and around buildings. The Greening Riyadh project aims at planting 7.5 million trees to reduce ambient temperatures in the Saudi capital by 2°C. The city of Frankfurt am Main, Germany, is also investing in NbS to tackle the cooling challenge by installing mobile green 'rooms' in grey areas of the city. Moreover, the city is enabling fast uptake of NbS by providing co-financing support to businesses seeking to green their building or surrounding areas. It is hoped that these actions will decrease the need for mechanical cooling and enhance the livability of the spaces.

City-level solutions to reduce the UHI effect using NbS are a core component of 'extreme heat planning'. Through the Cool Coalition, Mission Innovation, the Rocky Mountain Institute, the United Nations Environment Programme (UNEP), the Global Covenant of Mayors for Climate and Energy (GCOM), and K-CEP will be supporting cities across Latin America and the Caribbean, Africa, and Asia Pacific to implement NbS as part of a holistic urban cooling approach to tackle growing cooling demands.

PHILANTHROPY'S ADDED VALUE TO PASSIVE COOLING

Passive cooling has enormous mitigation potential and health benefits, but only a small fraction of the technical potential is currently being realized. According to the IEA, "a global 'race to the moon' approach is needed to bring deep energy renovation and 'net-zero' buildings from small-scale demonstration to mass-market penetration."[65] Similar effort is needed to extend the benefits of passive cooling to containers, environments, and throughout the cold chain.

In 2019, less than 2% of global philanthropic giving was dedicated to climate change mitigation.[66] Given the outsize impact that the cooling sector has on global GHG emissions and the role that passive cooling can play in mitigation, philanthropy can better focus its resources on promoting passive cooling as an approach to combatting climate change. Philanthropy is uniquely positioned to intervene at several levels to help scale passive cooling beyond a business-as-usual trajectory by:

- supporting the development of building codes that incorporate passive design elements;
- promoting access to cooling through passive cooling solutions focusing on heatwaves and netzero cold chains;
- raising awareness of passive cooling solutions through awards, challenges, and education programs;
- establishing and building the capacity of local champions to accelerate implementation;
- proving the business case for passive cooling solutions; and
- creating financial mechanisms to fund and de-risk passive cooling projects.

These interventions can be bottom-up (e.g., encouraging demonstrations of an integrated set of passive solutions in a variety of contexts to influence national policy), top-down (e.g., national policy that trickles down to individual building or environment design), or market based. The most effective interventions will likely incorporate a mix of these elements.

SUPPORT THE INTEGRATION OF PASSIVE COOLING SOLUTIONS INTO ENERGY-EFFICIENT BUILDING CODES

Passive cooling requires both short- and long-term investments, but longer-term engagement is necessary to realize major mitigation potential. Quick wins, in the form of financing cheap add-on improvements to the building envelope like cool roofs or shading, are easy to do and can deliver immediate benefits. Lengthier investments, such as redesigning building codes and design standards at a national level, will require long-term partnerships with the right state and private entities for the multiplier effect to take hold. These types of investments would also require strong coordination amongst many stakeholders (e.g., industry, government, public and private builders, and housing occupants).

According to the IEA, improving the adoption and enforcement of mandatory polices for low-energy building construction "is a necessary first step for all countries".[67] India's ENS Code, highlighted in Case Study 4, is an example of how overseas development aid can support the creation of regulatory policies such as building codes. The Swiss Agency for Development and Cooperation (SDC) helped fund BEEP, which provided technical assistance to the Indian BEE in the development of the code. The SDC's funding has also helped test buildings, create design tools, and provide training on the design process, which created an enabling environment for the code to be successful.

The role that building codes play in designing and promoting energy-efficient buildings is well established both in academic literature and within the industry. However, cooling needs are not often prioritized in energy efficiency considerations for building codes, and philanthropy can play a role in pushing for the inclusion of passive cooling elements in baseline building codes around the world. Building codes also generally focus on energy efficiency in terms of technologies and appliances but should be extended to include elements tailored to local climates that emphasize passive cooling. Building codes should also avoid being technology specific by focusing on performance-based standards so that they can continue adopting to state-of-the-art and emerging material, passive, and nature-based solutions. Specifically, philanthropy should push to bring passive cooling elements

into building codes that are tailored to the local climate and can be integrated with the least amount of additional cost. For example, adopting passive cooling technologies can encourage a shift away from using heat-absorbing building materials such as steel and glass, which lead to a dependence on mechanical air conditioning to cool structures. Pushing for the use of sustainable materials in building design may reduce the thermal heat gain of buildings but can be more expensive to adopt compared to measures such as external shadings, which can be applied with very little additional cost.

To facilitate this transition, philanthropy can work to improve the supply of efficient building materials and help develop markets for such products. Sustainable building materials that promote passive cooling have high insulation qualities and low thermal capacity. They include light-colored materials to reduce heat retention, biomaterials, and traditional and local materials that are tailored to hot climates.

Widespread adoption of efficient building materials is limited by market barriers such as supply chain fragmentation and a lack of alignment with the requirements of stakeholders (e.g., contractors, builders, and developers).[68] By using and incentivizing the production of high-performance products, philanthropy can help prepare the market for an increase in both the supply and the demand of building materials used in passive cooling. Specifically, philanthropy should encourage market transformation by:

- targeting the testing, certification, and labelling of products used in passive cooling building design;
- assisting small and medium-sized enterprises (SMEs) to upgrade their production process for approved materials;
- working with the building industry to enhance demand; and
- developing the knowledge and skills of masons, contractors, and builders who work with passive cooling products.

More broadly, passive cooling design elements should be explicit beyond building codes and throughout public-facing documents. This includes National Cooling Action Plans (NCAPs), Nationally Determined Contributions (NDCs), and other national, provincial, and municipal commitments and strategies. Committing at the national and international level to maximizing the benefits of passive cooling can help bind passive cooling as a central element of nations' approaches to addressing the threats of climate change and lack of access to cooling.

PROMOTE ACCESS TO COOLING THROUGH PASSIVE COOLING SOLUTIONS

According to SEforALL's Chilling Prospects 2020 report, 1.02 billion people remain at high risk from a lack of access to cooling.[69] An equitable passive cooling strategy could involve designing passively-cooled buildings for social housing, or prioritizing the construction of passively-cooled buildings in communities with energy poverty. While efficient buildings capture much of the conversation around passive cooling, efforts to scale up other passive cooling measures, such as urban greening, can also have untapped potential. With passive cooling and NbS, cooling can be delivered to the most marginalized communities, including slums and informal or off-grid settlements. These populations are especially atrisk from heatwaves, where extreme heat can pose danger to their health and their livelihoods.

Furthermore, many cities, especially in the developing world, are still yet to be built. With urbanization trends, three billion people – representing 40% of the world's population – will need new housing by 2030, requiring over 300 million new housing units.[70] In India, for example, 75% of the buildings that will be required by 2030 are yet to be built. This creates a massive opportunity to integrate passive cooling elements into building design, providing cooling access to millions of people.[71] Indonesia, another hot climate and high-population country, is considering building an entire new city for their capital, and the winning design – the "Forest Archipelago City" proposal – is surrounded by wetlands and features an artificial lake, which will help keep the surrounding environment cool.[72]

Many countries are addressing massive housing shortages and moving populations out of slums and into subsidized housing, which provides an opportunity to be proactive on passive cooling by "building better" during the original construction. Extending access to cooling in these communities will require building codes that elevate passive cooling solutions, which must be urgently developed, implemented, and enforced in order to incorporate passive cooling into buildings before they are built. There is an urgent need to act swiftly on building codes to see the largest mitigation potential. The construction of new buildings locks in emissions for 30–80 years, so delayed action can result in higher costs down the road – financially, environmentally, and societally.[73] It is a more efficient use of time and financial resources to design buildings with passive measures and highly-efficient cooling technologies in place, rather than retrofitting buildings after construction (see Figure 7).

Philanthropy can influence building codes that promote access to cooling by showcasing and supporting large-scale demonstrations that define best practices for cheap, passively cooled buildings. This role is especially important in the context of extreme heat events, which can often fall between different government departments (e.g., health and environment) and create a critical gap for promoting cooling solutions.[74]

While much of this work may take place in LDCs, cooling poverty extends to regions of some of the wealthiest countries, including the United States. The U.S. Department of Energy's (DOE) Weatherization Assistance Program (WAP) improves the building envelope for low-income households in the U.S. to help increase energy efficiency. So far, since 1976, the program has saved on average $283 per year, per family, for more than seven million families.[75] Additionally, incorporating green spaces into community design can lower ambient temperatures and provide physical, mental, and productivity benefits, which can help to reverse the impacts of redlining and other historically environmentally racist urban planning designs in the U.S.[76,77]

The building materials promoted to increase access to passive cooling can be tailored to locally-available materials, including reused or recycled products. Preference should be given to low-carbon building materials, including natural products such as wood (where feasible and controlled to avoid deforestation) and other biomass. For example, bamboo as a building material can replace other carbon-intensive products and is widely available in tropical areas that often lack universal access to cooling. Local building materials have the additional benefits of promoting local circular economies and using sources that are abundant and can be regenerated.

Access to passive cooling can also involve net-zero cold chains, which serve populations with diversified and safe food, reduce food waste, improve farmer incomes, and help bring vaccines to rural areas. Food loss alone is responsible for 4.4 Gt CO_2e per year and reduces incomes by at least 15% for 470 million smallholders, farmers, and downstream value chain actors.[78] Within cold chains, philanthropy can serve as a systems integrator to reduce GHG emissions while delivering safer food to consumers and higher incomes to farmers.[79] Philanthropy can be most successful in this mission by centering passive cooling solutions in the development of net-zero cold chains and prioritizing cold chain access to the most atrisk populations.

CASE STUDY 4

NATIONAL LEVEL – INDIA ENERGY CONSERVATION BUILDING CODE FOR RESIDENTIAL BUILDINGS: ECO-NIWAS SAMHITA (ENS)

The government of India plans on building 12 million affordable homes in the period 2018 – 2022 and the urban residential floor space is estimated to increase from 5.9 billion m^2 in 2020, to 22.2 billion m^2 in 2050.[47] By which time, 45% of India's peak electricity demand is expected to come from space cooling alone, with the largest share coming from mechanical AC in urban residential buildings.[48]

Without improvements to the building envelope, new construction in India will cause an enormous increase in the energy demand for space cooling. However, simple adjustments to the building envelope in new construction and retrofitting existing buildings can help reduce the space cooling requirement by 30% at little-to-low additional cost.[49]

The Eco-Niwas Samhita (ENS) is a new energy conservation code for residential buildings, which was launched in December 2018 by the Bureau of Energy Efficiency (BEE), with technical support provided by the Indo-Swiss Building Energy Efficiency Program (BEEP). The ENS sets minimum building envelope standards to

minimize heat gain and heat loss, improve natural ventilation, and improve daylighting. It has been designed to be implemented with very little additional expertise or time, and requires simple calculations that can be performed through an online compliance tool.

The ENS was designed with equity in mind, as more than 90% of residents in India currently do not have access to mechanical cooling.[50] The code sets a minimum openable window-to-floor area ratio with respect to custom climate zones; a minimum visible light transmittance; and maximum heat gain values for rooftops and building envelopes.

If there are no improvements made to the building envelope and if all residents have access to thermal comfort, space cooling requirement in urban residential buildings in India is expected to be 2,914 TWh_{th} in 2050 – nearly three times the requirement today. However, moving nearly all existing and new urban residential stock toward complying with the improved ENS standards could reduce the cooling energy requirement to 2,006 TWh_{th}.[51]

While the ENS code is an important technical achievement, continued work is needed to ensure that implementation is expanded. As the federal structure in India places electricity and buildings under the purview of both central and state governments, engagement with local authorities is critical to enforcing the code. The first energy code for commercial buildings in India, the Energy Conservation Building Code (ECBC), was introduced in 2007 and after a decade, only seven of the 35 Indian states and union territories had notified the ECBC. Even within those seven states, implementation was not widespread.[52]

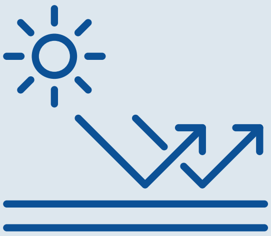
Future work on the ENS code will involve working with states and urban local bodies to make the code provisions mandatory. This can be done by integrating with local building regulations; working with the large private and public sector builders to pilot ENS-compliant housing projects; and transforming the building materials supply chain by incentivizing the production of light-weight insulated bricks, doubleglazed windows, external movable shading, cool roof solutions, and other passive technologies.[53]

CASE STUDY 5

GLOBAL LEVEL – MILLION COOL ROOFS CHALLENGE

Cool roofs are often considered a “win-win” strategy for GHG emissions because of their simplicity, costeffectiveness, and ease of adoption, with relatively inexistent drawbacks. They also offer other health, comfort, and environmental co-benefits due to their contribution to reducing the UHI effect and improving indoor thermal comfort.

The Million Cool Roofs Challenge is a $2 million global competition sponsored by K-CEP in collaboration with the Global Cool Cities Alliance (GCCA), Sustainable Energy for All (SEforALL), and Nesta’s Challenge Prize Centre. The award aims to rapidly scale up the deployment of highly solar-reflective ‘cool roofs’ in developing countries that are suffering heat stress and lacking widespread access to cooling services. Cool roofs are an affordable application that can reduce the heat gain of residential and commercial buildings by increasing the building’s reflectivity and reducing the need for mechanical cooling. According to Project Drawdown, cool roofs can provide a cumulative mitigation potential of 1.0 Gt CO_2e over the period 2020–2050 in a 2°C warming scenario (excluding the effects of negative radiative forcing).[54] In addition to reducing GHG emissions, switching from a dark roof to a cool roof effectively cancels the warming effect of GHGs in the atmosphere. Converting 100 m^2 of roof space to a cool roof would mitigate the warming equivalent of 10 tonnes of atmospheric CO_2.[55]



The challenge awarded $100,000 grants to 10 teams in 2019 to deploy solar reflective coating and/or materials in 10 countries across Africa, North America, and Southeast Asia. In 2021, an additional $1 million will be awarded to the team that has demonstrated the best sustainable and transferable model for rapid deployment of cool roofs. Many of the teams have undertaken pilot projects to demonstrate the local benefits of cool roofs. In Indonesia, a cool roof demonstration at a dairy plant has reduced indoor temperatures by up to 10°C during the workday. In Kenya, a pilot at an orphanage and school has cooled the building enough to allow students to learn indoors on hot afternoons—something they were typically unable to do during summer months.

RAISE AWARENESS OF PASSIVE COOLING SOLUTIONS

The technology for many passive cooling solutions is already available and has been for thousands of years. Raising the profile and highlighting the benefits of these technologies can help elevate passive cooling solutions on the international cooling agenda. Philanthropy can facilitate the growth of passive cooling by targeting the necessary stakeholders at national and subnational governments, architects involved in building design and construction, and key financiers in the cooling space.

Philanthropy could leverage its resources to work on improving the capacity, education, and training necessary to enforce efficiency standards and building energy code compliance. Additionally, design awards (e.g., the Ashden Cooling by Nature Award) or scaling programs (e.g., the Million Cool Roofs Challenge) can help elevate the narrative around passive cooling while encouraging innovative solutions. Such awards and programs can help build a scalable model for different passive cooling solutions, which will further amplify awareness of the importance of these technologies. Demonstrating this work is particularly crucial in developing countries and at the city and regional scale.

One way to further elevate the narrative around passive cooling is to shift the focus away from complex technical solutions (e.g., zero emission buildings) to simple changes that can be implemented without high up-front costs. While complex technical solutions still have an important role in efficient, climatefriendly cooling, promoting simple measures can help scale passive solutions. The Programme for Energy Efficiency in Buildings (PEEB) outlines eight "quick wins" that should be applied to every building in a hot climate zone:[80]

Eight Quick Wins

1 The building **orientation** should be aligned the from **west to east** as far as possible.

2 The **window-to-wall ratio** should be generally low, adapted to the climate zone, while still ensuring enough natural daylight.

3 **External shading** should be installed above all windows, exterior doors, and vents.

4 **Natural ventilation** should be encouraged where possible and adapted to climate zone. In hot and humid climate zones, a ventilation unit with heat and humidity can reduce the amount of heat and humidity entering the building, thus reducing the need for mechanical cooling.

5 **Vegetation** should be provided to shade to the building and provide evaporative cooling.

6 **Roofs and walls** should be built with **thermal insulation**. The suitable insulation thickness will depend on the climate.

7 Light-colored and reflective **coatings** should be applied on **roofs and façades**.

8 Building interiors should be equipped with **ceiling fans**, before considering AC.

The fact that architects and engineers play a key role in building design choices cannot be overlooked. That said, philanthropy can help facilitate a transfer of ideas to them through networks and collaborations, or through targeted campaigns that encourage organizations to publicly commit to action and promote passive principles through their work. Broader awareness campaigns will help build bottom-up demand as users better understand the potential level of comfort, safety, and reduced energy costs that result from passive cooling. Philanthropy can then use its resources to leverage simple and low-cost passive cooling wins globally.

Philanthropy can also raise awareness among governments and development agencies via a targeted campaign to show the importance and vast environmental, health, and long-term economic benefits of passive cooling, especially as the public sector responds to the Covid-19 pandemic. Philanthropic influence should leverage government action to ensure that philanthropy's limited financial resources unlock larger amounts of funding.

BUILD FINANCIAL VEHICLES TO SUPPORT PASSIVE COOLING

Philanthropy has a role to play in supporting new and innovative business models and financing structures that support passive cooling, and in extending existing ones to include passive solutions. Philanthropy can help de-risk investment in passive cooling solutions by providing co-financing with the financial sector, which may otherwise be uninterested in funding large-scale passive cooling projects, though these investments are likely to be smaller and more pilot-project oriented than those provided by multilateral assistance.

Philanthropy can better leverage its financial resources by testing and proving business models that utilize passive cooling, such as energy service companies (ESCOs) with a focus on passive cooling solutions, or 'cooling as a service' (CaaS) models, which integrate NbS in their cooling delivery model.[81] Furthermore, philanthropy can encourage new business models and instruments by launching competitions that drive innovation in passive cooling investments and finance. Philanthropy can also connect all necessary stakeholders in the financial industry, especially where banks and financiers do not have the capacity for small and disconnected workflows.

CONCLUSION

The WHO estimates that climate change will kill 250,000 people each year by 2050 due to increasing temperatures — this can be mitigated with focused support on passive cooling from the philanthropic community.[82] With over one billion people facing risk from a lack of access to cooling, and with AC electric fans already accounting for 20% of the electricity use in buildings, passive cooling can offer a simple and affordable solution to the access and emissions conundrum posed by cooling.

Philanthropy can play a pivotal role in elevating passive cooling into the mainstream of climate-friendly cooling solutions. By supporting passive cooling building codes, promoting access, building awareness, and building financial vehicles, philanthropy can collaborate with governments, development agencies, and the private sector to lock in passive cooling wins. Wins that will protect the environment from the detrimental effects of mechanical cooling, while promoting health, comfort, and long-term economic benefits.

FURTHER READING

For more information on passive cooling and green building design, please consult the following reports:

- **PEEB Working Paper:** Better Design for Cool Buildings (2020)
- **SEforALL Sustainable Cooling Solutions Chapter:** Chilling Prospects: Tracking Sustainable Cooling for All 2020
- **World Bank Report: Primer for Cool Cities:** Reducing Excessive Urban Heat (2020)
- **Cooling Singapore Report:** Strategies for Cooling Singapore (2017)

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