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Too Hot not to Handle

Resilient Cooling Policy and Strategy Toolkit

AUTUMN BURTON, MEGAN HUSTED, AND GRACE WICKERSON
FEDERATION OF AMERICAN SCIENTISTS

Executive Summary

Every region in the U.S. is experiencing year after year of record-breaking heat. More households now require home cooling solutions to maintain safe and liveable indoor temperatures. Over the last two decades, U.S. consumers and the private sector have leaned heavily into purchasing and marketing conventional air conditioning (AC) systems, such as central air conditioning, window units and portable ACs, to cool down overheating homes.

While AC can offer immediate relief, the rapid scaling of AC has created dangerous vulnerabilities: rising energy bills are straining people's wallets and increasing utility debt, while surging electricity demand increases reliance on high-polluting power infrastructure and mounts pressure on an aging power grid increasingly prone to blackouts. There is also an increasing risk of elevated demand for electricity during a heat wave, overloading the grid and triggering prolonged blackouts, causing whole regions to lose their sole cooling strategy. This disruption could escalate into a public health emergency as homes and people overheat, leading to hundreds of deaths.

What Americans need to be prepared for more extreme temperatures is a **resilient cooling strategy**. Resilient cooling is an approach that works across **three interdependent systems** — buildings, communities, and the electric grid — to affordably maintain safe indoor temperatures during extreme heat events and reduce power outage risks.

This toolkit introduces a set of **Policy Principles for Resilient Cooling** and outlines a set of actionable policy options and levers for state and local governments to foster broader access to resilient cooling technologies and strategies. For example, states are the primary regulators of public utility commissions, architects of energy and building codes, and distributors of federal and state taxpayer dollars. Local governments are responsible for implementing building standards and zoning codes, enforcing housing and health codes, and operating public housing and retrofit programs that directly shape access to cooling.

The **Policy Principles for Resilient Cooling** for a robust resilient cooling strategy are:

- **Expand Cooling Access and Affordability.** Ensuring that everyone can affordably access cooling will reduce the population-wide risk of heat-related illness and death in communities and the resulting strain on healthcare systems. Targeted financial support tools — such as subsidies, rebates, and incentives — can reduce both upfront and ongoing costs of cooling technologies, thereby lowering barriers and enabling broader adoption.
- **Incorporate Public Health Outcomes as a Driver of Resilience.** Indoor heat exposure and heat-driven factors that reduce indoor air quality — such as pollutant accumulation and mold-promoting humidity — are health risks. Policymakers should embed heat-related health risks into building codes, energy standards, and guidelines for energy system planning, including establishing minimum indoor temperature and air quality requirements, integrating health considerations into energy system planning standards, and investing in multi-solving community system interventions like green infrastructure.
- **Advance Sustainability Across the Cooling Lifecycle.** Rising demand for air conditioning is intensifying the problem it aims to solve by increasing electricity consumption, prolonging reliance on high-polluting power plants, and leaking refrigerants that release powerful greenhouse gases. Policymakers can adopt codes and standards that reduce reliance on high-emission energy sources and promote low-global warming potential (GWP) refrigerants and passive cooling strategies.
- **Promote Solutions for Grid Resilience.** The U.S. electric grid is struggling to keep up with rising demand for electricity, creating potential risks to communities' cooling systems. Policymakers can proactively identify potential vulnerabilities in energy systems' ability to sustain safe indoor temperatures. Demand-side management strategies, distributed energy resources, and grid-enhancing technologies can prepare the electric grid for increased energy demand and ensure its reliability during extreme heat events.
- **Build a Skilled Workforce for Resilient Cooling.** Resilient cooling provides an opportunity to create pathways to good-paying jobs, reduce critical workforce gaps, and bolster the broader economy. Investing in a workforce

that can design, install, and maintain resilient cooling systems can strengthen local economies, ensure preparedness for all kinds of risks to the system, and bolster American innovation.

By adopting a resilient cooling strategy, state and local policymakers can address today's overlapping energy, health, and affordability crises, advance American-made innovation, and ensure their communities are prepared for the hotter decades ahead.

About FAS

The **Federation of American Scientists (FAS)** is an independent, nonpartisan think tank that brings together members of the science and policy communities to collaborate on mitigating global catastrophic threats. Founded in November 1945 as the Federation of Atomic Scientists by scientists who built the first atomic bombs during the Manhattan Project, FAS is devoted to the belief that scientists, engineers, and other technically trained people have the ethical obligation to ensure that the technological fruits of their intellect and labor are applied to the benefit of humankind. In 1946, FAS rebranded as the Federation of American Scientists to broaden its focus to prevent global catastrophes.

Since its founding, FAS has served as an influential source of information and rigorous, evidence-based analysis of issues related to national security. Specifically, FAS works to reduce the spread and number of nuclear weapons, prevent nuclear and radiological terrorism, promote high standards for the safety and security of nuclear energy, illuminate government secrecy practices, and prevent the use of biological and chemical weapons.

FAS can be reached at 1150 18th St. NW. Suite 1000, Washington, DC, 20036, **fas@fas.org**, or through **fas.org.**

About This Report

This report was prepared by **Autumn Burton** with significant support from **Grace Wickerson** and **Megan Husted** at the **Federation of American Scientists (FAS)**. In the development of this report, Autumn Burton and Megan Husted consulted a variety of experts whose insights helped shape the insights and recommendations included in this report. This list of stakeholders is available upon request.

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Introduction: A Nation in Need of Cooling

The Limits of Air Conditioning

Since 1970, 97% of 240 U.S. locations surveyed by the nonprofit Climate Central have experienced increases in cooling degree days (CDD), a measure of demand for cooling to maintain a safe indoor environment. To meet this growing need, consumers have purchased conventional air conditioning (AC) systems en masse, and the private sector has focused on increasing AC purchases and installations. The most commonly installed air conditioners include central split systems, window units, and portable ACs, all of which rely on electrically powered compressors and refrigerants to cool indoor air. State and local policymakers have also prioritized AC distribution to ensure cooling access. According to the Energy Information Agency, air conditioning use in U.S. households surged to 90% of households in 2020, one of the highest rates in the world. Energy for air conditioning is projected to increase more than any other end use in residential buildings through 2050.

This surge in energy use during periods of peak demand places considerable stress on the nation's already overstrained, aging power grid, threatening grid stability and increasing the likelihood of blackouts. Electricity generation capacity is critical to keeping the power on, yet many places are seeing demand rise faster than supply. Keeping the power on is a matter of life and death. When the power goes out during extreme heat events, indoor temperatures can reach dangerous levels within hours. During Hurricane Beryl in 2024, more than 2 million Texans lost power during a heatwave, resulting in significant public health and business impacts, stress to emergency services and the public health sector, and at least twelve deaths from overheating.

At the same time, running AC is driving up household costs and becoming a financial burden on households. This is especially true for low-income households living in older, inefficient buildings that are more expensive to cool. Compounded by rising electricity prices, this growing expense is intensifying the cost burden for the 1 in 6 U.S. households already behind on utility payments and at risk of disconnection. Many families are forced to limit their use of air conditioning due to cost or even avoid it altogether, resulting in hazardous living conditions. As a result, indoor heat deaths are on the rise across the country.

AC alone cannot meet the system or complexity of today's cooling challenge. As average temperatures continue to rise, state and local policymakers are on the front lines of defense: protecting residents by ensuring access to safe, reliable, and affordable cooling. **Policymakers need a systems-level integrated approach that meets cooling needs effectively, accessibly, and reliably**.

Defining Resilient Cooling and the Technology Landscape

Resilient design seeks to ensure that human-made surroundings – buildings, critical infrastructure, and public spaces – are capable of withstanding and recovering from various disruptions while maintaining essential functions that support human well-being. Thus, *resilient cooling* refers to cooling systems that affordably maintain safe indoor temperatures and occupant health while also anticipating, withstanding, and rapidly recovering from disruptions caused by extreme heat events, such as power outages.

Resilient cooling solutions must be systems-based and applied across three integrated systems: **building, communities, and the electric grid**. Specific recommended technologies and strategies for each of these systems are detailed in the Appendix 1.2. They span active cooling technologies, which use energy to reduce indoor temperatures, passive cooling strategies, which utilize design features that reduce heat gain or enhance natural ventilation without relying on electricity, and integrated approaches that combine active and passive cooling, as well as the grid improvements needed to support them all. The technology systems are:

- **Buildings** are the front line of defense, and must be designed to maintain comfortable indoor temperatures. Homes and other buildings also need to be designed to or retrofitted to (i) reduce and shift grid loads to lower blackout risks, and (ii) enhance passive survivability, a building's ability to maintain safe indoor temperatures in the event of an extended power loss. This needs to be achieved affordability to ensure broader access to technologies that support those two goals. To achieve this means **combining active, energy-efficient, low-emissions technologies,** such as heat pumps and super-efficient AC systems with **passive cooling infrastructure,** such as cool roofs, operable shading, and building envelope materials designed for passive cooling**.**
- **Communities** comprise the physical environment around and between buildings, where shared infrastructure can cool spaces and reduce ambient temperatures. Community infrastructure can have a collectively lower upfront cost and lower community-wide energy consumption and costs of cooling. Interventions include active cooling measures like **thermal energy networks** (including networked geothermal and district cooling) and passive cooling measures like **smart surfaces** (including cool pavements, shade structures, porous and permeable pavements, solar PV, and green infrastructure).
- **Electric Grids** are the backbone of mechanical cooling, and ensure that buildings and neighborhoods have the power needed to stay safe under extreme conditions. Investments in **distributed energy resources**, **energy storage systems**, **grid-enhancing technologies**, and **demand response programs** can help reduce strain during peak demand, lowering the risk of power outages. Technologies that improve building-level energy efficiency and passive survivability also ease grid load and delay the need for expensive grid upgrades.

Given the interconnectedness across these systems, state and local governments need to coordinate their efforts to design, fund, and implement technologies and strategies that address both the immediate risks and long-term system needs for cooling. The tools for doing so already exist; this toolkit identifies pathways to integrate them for maximum public benefit.

Key Outcomes of Resilient Cooling

This toolkit introduces **a resilient cooling policy framework** for state and local officials who are seeking to:

- Lower peak electricity demand and mitigate grid strain.
- Enhance indoor passive survivability and ensure communities remain safe during extreme heat events and power outages.
- Address rising utility and housing costs.
- Reduce heat-related health risks.

Resilient cooling delivers a multitude of public benefits. These outcomes are made possible by applying resilient cooling solutions in ways that reflect the following **Policy Principles for Resilient Cooling**. Together, these five principles provide a practical approach to ensure that solutions are responsive to the broader social, economic, and infrastructural challenges of cooling.

Expand Access & Affordability

Millions of households live in buildings that are difficult and expensive to cool. As energy burdens rise, energy-efficient, resilient cooling technologies and passive design measures can offer essential relief by reducing cooling loads, long-term energy consumption, and overall operating costs, thereby helping to prevent utility shut-offs during periods of peak cooling need.

Incorporate Public Health Outcomes as a Driver of Resilience

Sustained exposure to high indoor temperatures is a serious health risk that poses both direct and indirect health impacts. Integrated resilient cooling systems offer a solution that can also improve indoor ventilation and thereby enhance indoor air quality.

Advance Sustainability Across the Lifecycle

Resilient cooling supports environmental and air quality goals by reducing peak demand, enabling clean energy integration, decreasing emissions from inefficient systems, and reducing reliance on high global warming potential (GWP) refrigerants.

Promote Solutions for Grid Resilience

Grid system resilient cooling strategies (demand side-management, distributed energy resources, and grid-enhancing technologies) equip the grid to better withstand extreme heat by reducing peak demand, improving load shifting capabilities, providing backup power during outages, and increasing transmission capacity and efficiency in high temperature conditions. These strategies reduce blackout risk, support clean energy integration, and strengthen overall grid resilience.

Build a Skilled Workforce for Resilient Cooling

Resilient cooling provides an opportunity for more good-paying local jobs in the installation, maintenance, and design of cooling solutions, and reduces economic losses tied to business disruptions during heat events. For example, the nationwide transition to low-GWP refrigerants alone is projected to create 33,000 new manufacturing jobs and sustain 138,400 existing jobs through 2027, while increasing direct manufacturing output by $12.5 billion.

Finally, critical to economic development and growth, state and local government support for resilient cooling accelerates innovation in the private sector. For example, standards and incentives can help stimulate market interest and adoption of advanced cooling systems, passive cooling solutions, and smart grid-ready equipment. This growing market stimulates research and development, drives competition, and opens opportunities for U.S.-based manufacturing and technology exports, bolstering the U.S. economy.

Resilient Cooling Policy Toolkit for State and Local Governments

The **Policy Principles for Resilient Cooling** can guide state and local decision-makers, public sector agencies, utilities, housing providers, and other relevant stakeholders in planning, investment, and regulatory decisions.

This toolkit explores a menu of state and local policies and strategies that provide options to accelerate innovation, development, deployment, market uptake, and broad accessibility of resilient cooling technologies (summarized in Appendix 1.1). By aligning building, community, and grid systems under a single strategy, policymakers can ensure that efforts across agencies, jurisdictions, and sectors are coordinated and maximize impact, and facilitate the transition to adapted, safer communities.

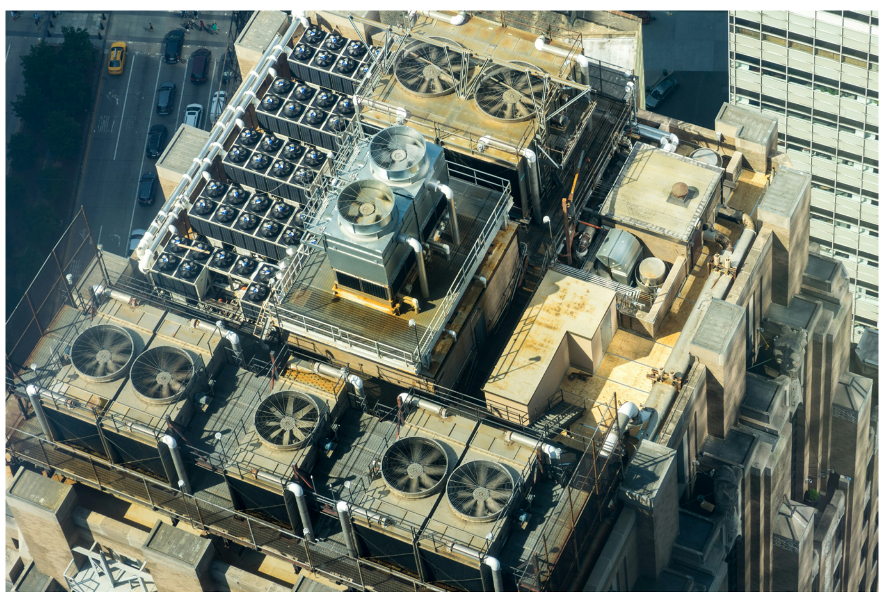
Principle 1. Expand Access and Affordability

The Challenge

Access to adequately weatherized homes and AC is unequal across income levels, housing types, and building ages. Across all metropolitan areas, the lowest-income households and renters are the least likely to have AC. Because housing codes typically do not require landlords to provide cooling, many tenants have to decide between paying out-of-pocket for AC or living without. Further, nearly 1 in 10 renter-occupied homes and over 1 in 20 homes overall were found to be moderately or severely inadequate due to structural deficiencies. Older homes have increased needs for critical maintenance, renovations, and upgrades, compounding the costs on families. For example, heating, ventilation, and air conditioning units and electrical wiring in older buildings often struggle to cope with increased cooling demands and are therefore more likely to fail.

The high cost of running AC can be prohibitively expensive, stacking on top of the cost of purchasing and maintaining AC systems. A 2020 report from the American Council for an Energy-Efficient Economy found that 67% of low-income households nationwide face high energy burdens and spend up to 10% of their income on energy bills. Household cooling costs are rising nationwide as electricity prices skyrocket. For summer 2025, electricity bills were projected to reach an average of $784. Because of rising energy costs, a growing number of Americans are in energy debt and at risk of experiencing a shut-off due to non-payment. Due to these higher energy cost burdens, low-income households tend to delay turning on their air conditioning and maintain unsafe indoor temperatures.

For millions of Americans, the combination of poor building conditions, outdated infrastructure,


MILLIONS OF AMERICANS RELY ON AIR CONDITIONING TO KEEP THEIR HOMES CONFORTABLE AND LIVABLE. VIA UNSPLASH.

and rising summer temperatures is creating a cycle of debt and disconnection in the absence of affordable energy and protections from energy shutoffs. These higher energy bills are an often overlooked factor perpetuating the national housing affordability crisis.

The Opportunity

It is essential that policymakers prioritize strategies that expand access to resilient cooling technologies and mitigate the long-term financial burdens associated with operating them. To address the access and affordability gaps, policymakers can pursue a range of policy tools that lower upfront costs, reduce ongoing energy burdens, and incentivize private sector investment.

Building system

State and Local Tax Credits and Rebates. These financial incentives can improve resilient cooling access and should be designed to prioritize efficiency. For example, Colorado's SB 22-051 established a 10% state tax credit and sales tax exemption for heat pumps and supporting equipment, while HB 23-1272 created a state tax credit of $1,500 for air source heat pumps and $3,000 for geothermal heat pumps. Notably, SB 22-051 includes a point-of-sale sales tax exemption to reduce up-front costs, and the HB 23-1272 tax credit is fully refundable, allowing low-income households and small businesses without the tax liability and cash flow to take advantage of these tax credits. HB 23-1272 also directs contractors to make at least 33% of the tax credit a discount for customers in order to further expand access to low-income households. Along with tax credits, rebates can make it easier for residents to afford resilient cooling technologies. The City and County of Denver, for example, offers rebates of up to $3,500 for new heat pump installations.

State and Local Grant Programs. Grant programs are a crucial mechanism to expand access to resilient cooling technologies by providing much needed resources to low to moderate income households and building operators to perform building assessments and upgrades. San Antonio's Under 1 Roof program, for example, provides a one-time grant to eligible homeowners to replace worn or damaged roofs with new, cool roofs, and the program prioritizes heat-vulnerable communities. New York State's Climate Friendly Homes Fund makes awards to owners of multifamily rental properties to perform energy audits to increase energy efficiency and identify the most impactful upgrades, and then directs the building managers to financing to perform those building retrofits. Boston's Healthy and Green Retrofit Pilot Program invests in similar whole-building evaluations while also stipulating upgrades should not displace tenants or raise rents, ensuring lower income people can benefit from the resilient cooling upgrades.

Utility Rebates. Rebates can be offered by investor-owned, municipal, and co-op utilities to expand accessibility to technologies for customers, benefiting the utility by reducing energy demand. In California, utility rebates were used before building codes were enacted to encourage the installation of cool roofs. Once codes were in place, the qualifications for the rebates were increased to encourage building owners to install roofs above code requirements.

Innovative Utility Financing Models. State public service commissions, which regulate utilities, can use innovative financing models to increase access to cooling measures that are affordable and efficient. On-bill financing (OBF), for instance, is an established method to make financing for energy efficiency improvements more accessible to utility customers. Typically, these programs enable utilities to lend customers the funds needed for energy improvements, with the utility bill serving as the vehicle for collecting loan payments. OBF has been implemented since the 1970s, with over 110 utility jurisdictions across the country offering some form of OBF today. Tariffed-on-bill financing models (TOBF) are a special type of OBF that states can pursue via public utility regulation to lower capital cost barriers of resilient cooling technologies. Unlike other forms of OBF, TOBF programs are structured as utility investments: the utility provides the upfront capital and recovers the cost through a tariffed charge on the recipient customer's bill, rather than through a loan repaid by the customer. Through TOBF, utilities can finance energy-efficient building upgrades, like heat pump installation or cool roofs, and recover the costs through tariffs on electricity bills.

Weatherization Assistance Programs (WAPs). Administered by states, tribal governments, and territories, WAPs leverage federal funding to provide grants to low-income households. These grants can be used to fund home retrofits that increase energy efficiency and reduce excess energy usage. Weatherization audits conducted as part of WAPs should be expanded to include assessments of property cooling efficiency and identification of recommended upgrades such as energy-efficient cooling systems (e.g., heat pumps and the electric panel upgrades needed to support them) and building envelope improvements that offer passive cooling (e.g., window upgrades, reflective roofs, and cool walls). WAP program managers should also explore ways to overcome weather readiness challenges — that is, structural and safety issues like envelope issues, outdated electricity panels, leaks, or mold — that make it difficult to weatherize older homes. For example, Philadelphia Energy Authority's "Built to Last" program braids federal, state, local, and utility funds and convenes service providers to provide a "one stop stop" for home repairs and energy efficiency upgrades.

Integrating and Braiding Federal Rebates With State and Local Programs. The Inflation Reduction Act (IRA) established two rebate programs to support home energy efficiency and electrification projects: the Home Efficiency Rebates Opportunity Program (HERO) for qualifying whole-home energy efficiency upgrades that reduce energy use by at least 20% and the Home Electrification & Appliance Rebates Program (HEAR) for electrifying appliances. As of the time of writing, these programs remain in place and are being administered at the state level, and can be used to support heat pump installations and other eligible energy-efficient mechanical cooling systems and building envelope improvements. State policymakers should consider designating 40% of rebate benefits to low-income and disadvantaged households, even in the absence of federal mandates.

Community system

Bulk Purchasing. Bulk purchasing is a financial incentive that lets building owners take advantage of volume discounts for resilient cooling technologies and strategies in their buildings, lowering prices for individual households. Solarize initiatives offer a model for bulk purchasing programs that can be applied by local governments to advance resilient cooling. These initiatives are designed to expand access to distributed energy technologies by reducing upfront costs and simplifying procurement. In 2021, installations via this program were estimated to save customers more than $8 million over their 25-year lifespan. Bulk purchasing models also promote stakeholder engagement as local governments work with nonprofit coalitions to coordinate community outreach, facilitate installer selection through a competitive bid process, and ensure quality assurance in program delivery. Bulk purchasing can also create entirely new technologies; New York State Energy Research and Development Authority's 'Clean Heat for All Challenge' led to the development of the first-ever window heat pump.

Zoning Codes. Local governments can leverage zoning codes to scale up community-level resilient cooling technologies, such as green infrastructure and shade structures. Potential zoning strategies for exploration include requirements, overlay zoning, and density bonuses for green infrastructure. For requirements, local governments can require developments to include community cooling technologies in new developments. For example, all new developments in Phoenix are required to include open space that is at least 50% shaded. For overlay zoning, local governments can establish special zoning districts layered over existing zones and impose additional standards to protect natural resources and promote green infrastructure. For density bonuses, local governments can create incentives, like allowing for more units or reduced parking minimums, in exchange for incorporating smart surfaces and other community cooling technologies, such as solar PV panels, green roofs, and cool surfaces, into new developments.

Grid system

Rate Design: Rate design is an important factor for the operating costs of electric equipment. Flat annual kilowatt-hour (kWh) charges may be relatively unfavorable for households with rooftop solar or energy-efficient appliances, as they reduce the financial value of reducing consumption or generating excess electricity. For distributed energy resource systems, a rate design that combats this is net metering, which allows consumers to receive credits for the excess electricity they generate that can then go back onto the grid and allow utilities to better manage peak electricity demand. Time-of-use rates are more beneficial than flat rates, as they reward customers for shifting energy use to off-peak hours. Consumers can leverage demand-side management technologies like smart thermostats to take advantage of when energy is cheapest, lowering their bills while still maintaining thermally safe indoor temperatures. Finally, rising electricity prices are increasingly tied to the costs of distribution from an aging and inefficient grid. When upgrading the grid to better handle increasing temperatures, it is critical to balance how much of these costs are passed onto consumers versus required to be assumed by the utility.

Principle 2. Incorporate Public Health Outcomes as a Driver of Resilience

The Challenge

Millions of Americans live in homes that are too hot during extreme heat events. People exposed to unsafe indoor heat levels experience heat-related illnesses such as heat edema, cramps, fainting, rash, stress, exhaustion, and stroke. While extreme heat can impact everyone, certain populations face higher risks, including children, elderly adults, pregnant mothers, people with chronic health conditions, and outdoor workers.

In addition to direct health impacts, extreme heat also makes indoor environments more hazardous by exacerbating poor indoor air quality, aggravating respiratory diseases. For one, higher outdoor temperatures increase the formation of ground-level ozone and other air pollutants, which can infiltrate indoor spaces, especially in buildings with unoptimized ventilation or leaky envelopes. Additionally, extreme heat forces people to keep windows closed to maintain cooler indoor temperatures, trapping ozone and other pollutants inside. In poorly maintained or aging buildings, elevated humidity from heat can promote mold growth. Extreme heat also accelerates material degradation: roofing, insulation, and building envelopes can deteriorate faster under prolonged high temperatures, creating additional pollutants that can impact health.

Lastly, the current energy sources used to power conventional air conditioning systems can generate harmful emissions. Fossil-fueled power plants contribute to particulate matter and ozone precursors that further degrade air quality and drive respiratory and cardiovascular health burdens, especially for communities located near power generation infrastructure.

The Opportunity

Addressing the escalating risks of indoor overheating requires instituting safeguards that protect health across technology systems. Policymakers can advance this shift by updating housing and building codes, setting health-based standards for indoor conditions, investing in multi-solving technologies like green infrastructure, and raising the bar for clean energy generation.

Building system

Standards for Indoor Health and Habitable Spaces. Depending on authorities, state and local policymakers can adjust and revise health codes to name cooling as an essential service for habitability. Oregon's proposed Senate Bill 54 provides an example of model legislation in this regard, as it would have required landlords to provide tenants access to effective cooling on days where temperatures exceed 80°F. Additionally, numerous cities and counties have adopted some form of a maximum indoor air temperature standard. In each of these localities, rental housing is required to have cooling equipment capable of keeping the temperature at an established safe maximum indoor temperature (location dependent, but typically between 80°F and 88°F). Pairing these standards could establish a pathway to implement a *legal right to cooling*, which could encourage the development of resilient cooling technologies. Utility regulation can further support building codes and standards in securing a health-based right to cooling, by preventing electrical utility disconnections during heat season in the same way utilities are prevented from disconnecting customers from heating utility services.

Incorporating Ventilation and Air Quality Standards into Building Codes. State and local governments can strengthen indoor air quality by updating building codes to require cooling systems that meet or exceed American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standards 62.1 and 62.2 for acceptable indoor air quality. These requirements can be paired with high-efficiency filtration in both new construction and retrofits. This combination can reduce occupant exposure to indoor pollutants, ozone, mold, and wildfire smoke, while also supporting cooling load reduction through energy-efficient ventilation.

Community system

Expanding Green Infrastructure through Grant Programs. Using the federal Urban and Community Forestry program as a model, states can develop competitive grant programs for urban forestry and other types of green infrastructure, which not only lower temperatures but also improve community health and well-being. For example, in late 2024, New York launched its Community Reforestation (CoRe) Grant Program, which provides $15 million in competitive grant funds for municipalities, nonprofits, and state agencies to plant and expand forests in urban communities. Also in 2024, Washington State's Department of Natural Resources (DNR) announced it allocated over $8 million for urban forestry projects through the Community Forestry Grant Assistance Program. This funding, comprising a combination of $5 million in USDA Forest Service pass-through funds and $3 million in state dollars, supported more than 40 projects statewide. The grants aimed to enhance urban forest resilience, improve community health, and mitigate urban heat islands by expanding tree canopy coverage.

VOLUNTEERS HELP PLANT A TREE DURING THE TREE EQUITY COLLABORATIVE LAUNCH EVENT MAY 2023 IN SEATTLE. WASHINGTON STATE ALLOCATED OVER $8M FOR URBAN FORESTRY PROJECTS. VIA WA.GOV.

Grid system

Integrating Health into Integrated Resource Plans (IRPs) and Renewable Portfolio Standards (RPS). Many states require utilities to submit IRPs to their public utility commissions (PUCs) in order to ensure utilities have plans for cost-effectively meeting future energy demand. IRPs can be used as a tool to help incorporate health considerations into energy resources and broader grid planning, such as incentivizing technologies that reduce overall air pollution and enable affordability. For example, in 2020, the Governor of Michigan passed an executive order requiring utilities to account for health impacts when completing their IRPs. To meet this requirement, utilities will be encouraged to deploy clean sources of energy, such as geothermal and solar, and reduce energy use through passive cooling strategies like cool roofs, green roofs, solar shading, and natural ventilation. On the other hand, RPSs, used in 30 states and Washington, D.C., mandate that certain percentages of utility electricity come from renewable energy sources. By naming the importance of health and safety in RPSs, utilities can be incentivized to prioritize investments in clean energy resources that reduce overall air pollution, bettering air quality and improving public health, and supporting tactics that lower the overall cost of energy for consumers so they can keep their homes at safe indoor temperatures.

Principle 3. Advance Sustainability Across the Cooling Lifecycle

The Challenge

Expanding access to cooling is crucial for public health and safety, **yet the increased use of and overreliance on AC systems contribute to the very problem it seeks to solve: increased ambient heat.** Many older AC models contain refrigerants with high global warming potential (GWP) such as chlorofluorocarbons (CFCs) and hydrofluorocarbons (HFCs). When released through leaks or improper disposal, high-GWP refrigerants trap heat more effectively than carbon dioxide, causing more atmospheric warming. Additionally, AC systems emit waste heat back outside, which can increase the urban heat island effect, making the impacts of extreme heat more acute for entire communities. Finally, many communities' air conditioning systems are powered by electricity generated from high-emission energy sources that release heat-trapping carbon dioxide (CO2) into the air.

The Opportunity

State and local policymakers should design their approaches to resilient cooling with low-emission and no-emission passive technologies and clean energy sources at the forefront. They can do this by adopting building codes that require low-GWP refrigerants, implementing clean cooling standards and efficiency standards that incentivize passive cooling, preferential permitting, introducing legislation that authorizes public utility commissions (PUCs) to regulate thermal energy, and renewable portfolio standards.

Building system

Adopt Building Codes Requiring Low-GWP Refrigerants in Alignment with the American Innovation and Manufacturing Act (AIM) Act. The AIM Act authorizes the Environmental Protection Agency to phase down hydrofluorocarbons (HFCs) 85% by 2036 via three main mechanisms: minimizing HFC emissions, managing HFCs and their substitutes, and facilitating the transition to next-generation technologies. Should states and localities not update their building codes with the latest ASHRAE and Underwriters Laboratory (UL) safety standards for refrigerants by January 2026, they risk not having legal products available to their constituents. Thus, in alignment with the implementation of the AIM Act, state and local governments can mandate or strongly recommend the use of Heating, Ventilation, and Air Conditioning (HVAC) systems with low-GWP refrigerants, such as R-32 and R-454B, and natural refrigerants, such as ammonia and hydrocarbons. For building systems, this can incentivize broader adoption of heat pumps and ACs that use low-GWP refrigerants.

Clean Cooling Standards. A clean heat standard (CHS) is a performance standard that applies to wholesale providers of gas, propane, and other high-emissions fuel sources and requires the provider to deliver a gradually increasing percentage of low-emission "clean heat" resources to customers, promoting the adoption of cleaner and more efficient alternatives such as heat pumps. Legislation like Colorado's SB 21-264 has established a statewide CHS encouraging additional utility investments in heat pumps and energy efficiency measures. States can take a similar approach to establish "Clean Cooling Standards" to incentivize investments into low-carbon and low- or zero-emission resilient cooling technologies.

Removing Fuel Switching and Substitution Restrictions. State and local incentives can help shape the market and expand the customer base for resilient cooling technologies. Removing barriers such as restrictions on fuel switching will ensure that utility funds or incentives can be used to transition appliances from gas to electric. For example, when homeowners replace a gas furnace with an electric heat pump, they gain both high-efficiency heating and cooling capacity. In the San Francisco Bay Area, for example, air regulators voted to phase out the sale of new gas heating appliances starting in 2029, which could lay the groundwork for a widespread transition to electric heat pumps in homes.

Passive Cooling Standards in State Building and Energy Codes. Passive cooling infrastructure reduces the need for active cooling, reducing energy usage, emissions, and waste heat generation. With respect to cool roofs, for example, states can integrate minimum solar reflectance standards into residential and commercial roofing codes. California's Title 24 establishes building energy efficiency standards that require all new or replacement low-slope roofs to be cool roofs (this requirement extends to steep-slope roofs in several climate zones). States can use this approach as a model for passive cooling at both the building and community systems.

PAINTING A ROOF WHITE REDUCES ENERGY USE AND COMBATS URBAN HEAT ISLAND EFFECTS. VIA FLICKR.

Community system

Update Utility Regulations to Align with the AIM Act. States can justify expanding the development of networked geothermal systems and thermal energy networks as a part of AIM Act implementation. With the exception of New York and Massachusetts, most state utility statutes do not clearly define thermal energy as a regulated utility service, and without explicit authority, public utility commissions (PUCs) may be unable to approve rates, authorize cost recovery, or oversee thermal energy network (TEN) providers. To address this challenge, states can pass legislation authorizing PUCs to regulate thermal energy, enabling utilities and third-party providers to invest in networked geothermal and broader thermal energy network infrastructure.

Preferential Permitting. Local governments can offer priority or preferential permitting for buildings and community development projects designed with passive cooling technologies like cool roofs or pavements or shade infrastructure. Preferential permitting is valuable because it can significantly reduce construction or retrofitting process timelines.

Grid system

Recognize Extreme Heat's Impact on Integrated Resource Plans (IRPs) and Renewable Portfolio Standards (RPS). The increased demand for cooling will require energy infrastructure buildout, which is important for utilities to plan for as warming trends continue. Further, risks to the grid also require IRPs and RPSs to encourage energy resilience practices that can supply power to critical facilities even if the grid goes down. Further, RPSs have also traditionally focused on electricity generation. Some states are starting to incorporate thermal energy networks into their RPS to encourage investment in these technologies as a cooling solution.

Principle 4. Promote Solutions for Grid Resilience

The Challenge

Air conditioning can represent over 70% of peak residential demand on high-temperature days. This spike in load can exceed available generation or transmission capacity. According to the North American Electric Reliability Corporation's (NERC) 2025 Summer Reliability Assessment, some areas of the United States are more vulnerable than others to this issue. For example, the Midwest, New England, and the West-South-Central regions face higher risks of grid reliability issues because of insufficient energy supply.

When supply margins are eroded, grid operators may be forced to deploy emergency measures, such as rotating outages, to maintain system reliability. If emergency measures fail to restore balance, widespread grid failure or blackouts can occur. This translates to loss of access to many people's sole cooling strategy, their AC. Without backup power, homes and critical facilities immediately lose cooling capacity during an outage, and can quickly overheat.

Thus, households would benefit from cooling solutions that do not require a continuous electricity supply to function. Further, battery storage, virtual power plants, and microgrids are all technologies and tools that can provide uninterrupted power to critical facilities during widespread grid outages. Beyond these technologies, networked geothermal and community solar can enable cooling with minimal reliance on the grid, decreasing the load during hot days.

The Opportunity

States and local governments, utilities, and public service commissions need to tackle the issues of extreme heat and cooling demand. Policymakers will need to focus on (i) cooling strategies for building and community systems that are less or non energy-intensive and can keep spaces cool when the power is off, (ii) alternative sources of cooling, such as through geothermal energy and thermal energy networks, and (iii) a reliable electric grid that can withstand the increase in high temperatures and support the increase in energy demand.

Building system

State and Local Building Codes and Standards. Building codes can require that commercial and residential buildings be built for passive survivability and power backups. For example, the new LEED code includes credits for passive survivability: the ability to maintain thermally safe conditions during a power outage. States and local governments can incorporate passive resilient cooling requirements, like deployment of cool roofs and walls, in state and local building codes to achieve passive survivability. Building codes can also be designed to recognize the need to reduce strain on the grid, such as the 2025 California code update that prioritizes reducing grid strain.

Community system

Public Utility Regulation to Expand Thermal Energy Networks (TENs). As previously acknowledged, legislation is needed to create regulatory structures that enable utilities to sell and engage in ratemaking around thermal energy, as well as construct, own, and operate TENs. California, Colorado, Maryland, Massachusetts, Minnesota, New York, and Washington have all enacted enabling legislation for gas utilities, electric utilities, dual-fuel utilities, and public utility districts. These actions can be spurred by a growing political consensus around the need for grid resilience in the face of extreme weather and increasing demand.

Leveraging Federal Tax Credits. The Clean Energy Investment Tax Credit (ITC) program, 48E, could provide the incentive tax credit for thermal energy network technologies and distributed energy resources for community and grid systems, like microgrids, battery storage systems, and geothermal heat pumps. However, the Fiscal Year 2025

THERMAL ENERGY NETWORKS PROVIDE THERMAL ENERGY TO CUSTOMERS WHILE REDUCING GREENHOUSE GAS DEPENDENCE. VIA NY.GOV.

Reconciliation Law has expedited the phase-out of this credit for certain projects.

Utility Investment Incentives. States can direct PUCs to allow regulated utilities to own and recover costs for thermal energy networks using rate riders and performance-based ratemaking. By covering upfront loop installation costs and recovering expenses through small rate riders and monthly participant fees, utilities can significantly lower barriers to systems with higher upfront costs and generate long-term financial gains without incurring debt. States can also support electric co-ops and municipal utilities in adopting similar models through technical assistance and incentive programs. For example, rural electric co-operative CKEnergy has successfully deployed this approach to expand access to geothermal energy, improving customer satisfaction and savings while reducing system peak demand and enhancing rate stability.

Grid system

State Regulatory Frameworks. States and utilities promote grid resilience by implementing regulatory frameworks and utility programs that prioritize the use of grid resilience strategies, including demand-side management (DSM), distributed energy resources (DERs), and grid-enhancing technologies (GETs). For example, states can encourage or require investor-owned utilities to establish DSM and Virtual Power Plant programs. The state of New York recently launched a Program Opportunity Notice to solicit ideas on how to address challenges of grid modernization through GETs, while North Carolina passed a bill in 2025 to prioritize the use of advanced conductors and GETs for grid resilience.

Energy Efficiency Resource Standards (EERS). State-led EERS can encourage or require electric utilities to reduce their customers' electricity use by targeted amounts according to a defined timeline or schedule, encouraging the use of DSMs. As of 2025, 26 states and the District of Columbia have mandatory statewide EERS. EERS policies may also have separate reduction targets for electricity sales and peak electricity demand. Thus, EERS policies can create regulatory drivers for utilities to invest in high-efficiency cooling technology and building retrofits.

Utility Pilot Programs. Utilities have established pilot programs to drive uptake of DSMs. These programs create structured opportunities to evaluate new technologies for DSM, rate designs, and customer engagement methods before long-term implementation. For example, smart thermostat company ecobee and San Diego Gas & Electric (SDG&E) completed a pilot program in 2022 to demonstrate how utilities can expand their pool of resources to improve grid resilience and stability while lowering consumer energy bills. The pilot resulted in positive customer response and load shifting that achieved ecobee's and SDG&E's demand response goals.

Principle 5. Build a Skilled Workforce for Resilient Cooling

The Challenge

Workforce development is essential to scaling both active and passive resilient cooling technologies. These technologies require specialized skills for installation, maintenance, and integration with other systems. The skilled professions implicated in implementing a resilient cooling strategy are broad, including electricians, HVAC engineers, roofers, maintenance personnel, code officials, architects, building science educators, weatherization technicians, arborists, urban planners, and grid technicians. There is also a need for professionals who can think systemically to coordinate all of these practitioners and ensure compliance with multiple complex goals. These roles fit into the broader landscape of **green jobs:** employment pathways that reduce energy use and emissions and/or strengthen community resilience to climate impacts.

Realizing this potential will require targeted efforts to address existing workforce development challenges, which include the following:

- **Lack of technicians to deploy emerging technologies.** The availability of adequately trained engineers and technicians with the skillsets necessary for designing and deploying resilient cooling technologies is critical to facilitating widespread adoption. Yet, there is a deficit of contractors who are familiar with and invested in the procedures to correctly install active and passive resilient cooling systems. For example, passive cooling systems, such as those used in Passive House construction, require specialized knowledge and training beyond traditional building methods that many construction professionals and workers are not yet familiar with. Partnerships among stakeholders like training centers, installers, as well as state and local governments are essential for developing workforce training programs that can graduate and place enough skilled workers to meet the demand for resilient cooling.
- **Skilled labor shortage in the home-building sector.** The National Association of Home Builders has estimated that a broader shortage of skilled laborers in the home-building sector has cost the national economy over $10 billion per year due to longer construction time. While addressing this broader shortage, policymakers must ensure that the workforce is equipped with the skillsets in passive cooling design to ensure the resilience of new and retrofitted homes by spearheading strategic workforce development programs.
- **Utility talent gap**. For utilities in particular, expanding the resilient cooling workforce is both a necessity and a challenge. Nearly half of the current utility workforce is expected to retire within the next 10 years, while non-retirement turnover surges. To address these challenges, utilities should consider new approaches to talent acquisition and workforce development, such as structured mentorship and training programs on adaptability, resilience, and emerging technologies.
- **Stakeholder Outreach and Education.** Ongoing education is needed for all stakeholders, including project developers and consumers, to raise awareness of the benefits of resilient cooling access, facilitate behavioral change, and increase the uptake of systems thinking in cooling systems design.

The Opportunity

Preparing the workforce for resilient cooling is a critical enabler for implementing the strategies described in previous sections. By coordinating public funding, creating partnerships with utilities and private employers, and aligning licensing and certification requirements, states can ensure that workforce readiness keeps pace with technology deployment. Doing so unlocks opportunities to strengthen state and local economies and expand access to stable, well-paying green jobs in an array of industries. For example, in 2023 alone, the clean energy sector in the United States added approximately 149,000 jobs, accounting for the majority of all new energy sector jobs. This growth rate of 4.9% was more than double that of the overall U.S. economy that year.

State and Local Green Job Accelerators. State and local governments can build the residential resilient cooling workforce through accelerator programs that provide career pathways for occupations involving resilient technologies, such as electricians, HVAC installers, and weatherization workers.

Public-Private Partnerships for Training. State and local governments can also help build partnerships with the private sector to expand standardized technical training and industry-recognized certification and to bolster the capacity of community-based organizations to offer support services. The Clean Energy Jobs Program, a partnership between the New Jersey Department of Labor (NJDOL) and the utility company PSE&G, provides an example of how states can work with utilities to expand paid on-the-job training and support for workers to develop the necessary skills to install and maintain energy-efficient, resilient cooling technologies. The NJDOL provided an initial $1 million to establish the program, with PSE&G providing grant funding to nonprofits, governmental agencies, for-profit trainers, and community organizations for training. The program is industry-recognized for its comprehensive guidance on careers in energy efficiency and advancement opportunities.

Another example, the NYC CoolRoofs program, is a workforce development training initiative that includes on-the-job training in building efficiency practices and project management, as well as additional certifications and competencies needed to enter the green jobs market. This initiative is a partnership between the NYC Department of Small Business Services, the Mayor's Office of Climate and Environmental Justice, and The HOPE Program. By the end of 2025, this effort is expected to have helped train 500 New Yorkers — who will be prepared for jobs promoting passive resilient cooling and broader energy efficiency in buildings — and generate $1 million in annual energy cost savings. To further expand access, New York City will continue to prioritize small and mid-sized buildings that would otherwise not have the resources to take advantage of the benefits of cool roofs.

Technical Navigator Programs. To support consumer education, local governments can fund community technical navigators or "cooling coaches": trained individuals who guide households through the selection, financing, and installation of resilient cooling technologies. These navigators and coaches can be based on existing energy efficiency models, such as that of the Southern Maine Energy Navigator Program. This program leveraged funds from the Maine Department of Energy Energy Efficiency and Conservation Block Grant to support low-income households in navigating complex application and installation processes for clean energy upgrades, while offering young adults a new career pathway as skilled energy professionals through the Americorps program.

Aligning Interstate Licensing Requirements. Skilled trades face challenges transferring or seeking jobs outside of their respective state due to varying licensing requirements. State and local governments, especially those in neighboring regions, can minimize challenges faced by businesses or workers moving to seek job opportunities by allowing credential transferability or aligning licensing requirements. Doing so would help enable contractors to take on more jobs in different regions and alleviate critical labor shortages. This would also ease job transitions as well as provide a pathway for businesses to expand their services.

Utility Workforce Development Programs. Some utilities have workforce development programs that provide training to become an electrical engineer, HVAC technician, or solar technician, among other jobs. For example, the District of Columbia Sustainable Energy Utility offers a workforce development program to help prepare residents for shifting job markets and emerging green careers while increasing the capacity of local contractors and organizations working in the clean energy sector. These programs can extend beyond the utility and be state-sponsored, as in New York's Clean Energy Workforce Development Program.

Appendix: Resilient Cooling Technology Landscape

Building Scale Technologies and Strategies

Resilient cooling technology solutions at the building and community scales can be broadly classified into three categories: active, passive, and integrated. The focus of the following sections is technology solutions and strategies across these three categories that provide a high level of resilience against heat waves and power outages by reducing peak loads, increasing cooling efficiency, enabling grid-resilient cooling, and increasing passive survivability.

Active Building-Scale Technologies

Active cooling strategies (Table 2) rely on mechanical equipment such as energy-efficient air conditioners, heat pumps, chillers, and fans to regulate indoor temperature and humidity. While these solutions require energy input and may be more vulnerable to power outages, active cooling solutions can provide more precise and consistent control over indoor conditions. Ideally, active resilient cooling technologies provide efficiency and grid flexibility services, including during peak demand periods. As these technologies help reduce demand load, they lower energy supply and grid constraints and, thus, decrease the risk of power system failures.

TABLE 2. ACTIVE BUILDING-SCALE RESILIENT COOLING TECHNOLOGIES

TYPE	HOW IT WORKS	ACCESS	COSTS	HEALTH & COMFORT	ENERGY & GRID IMPACT
AIR-SOURCE HEAT PUMPS (ASHP)	In cooling mode, ASHPs transfer heat from inside to outside the building to cool the air.	ASHPs are suitable in most residential applications. Ducted ASHP systems can use existing AC ductwork. Ductless systems require minimal construction and are ideal for smaller homes and apartments with non-ducted heating systems.	ASHPs have moderate upfront costs (particularly with rebates) and significant long-term savings given the energy efficiency.	If a building has good insulation, the ASHP will need less energy to maintain comfort levels and will maintain those levels for a longer period. Also, heat pumps typically include filters that reduce indoor pollutants.	ASHPs can significantly reduce energy use compared to conventional cooling systems. This higher efficiency and lower energy use translate to less additional strain on the grid during periods of higher cooling demand.
GROUND-SOURCE HEAT PUMPS (GSHP)	To cool, this technology uses a ground source heat pump running in reverse to take advantage of the relatively constant temperature of the ground a few feet below the surface.	GSHP are suitable for both small homes and large multifamily buildings. However, these systems require land or a shared loop system and are less common in retrofits.	These systems have high upfront costs compared to other technologies, but very low operating costs and significant savings over time. They can reduce energy consumption by 45.1% and save up to 48.2% in energy costs in single-family homes. The energy savings and longer life spans can help cancel out initial costs after five to ten years.	Geothermal heat pumps are long-lasting systems (up to 24 years for the inside components and 50+ years for the ground loop) that involve no indoor combustion while providing good humidity control.	GSHPs significantly reduce energy consumption compared to traditional AC units. This higher efficiency and lower energy use translate to less additional strain on the grid during periods of higher cooling demand.
INVERTER-DRIVEN ACS	Unlike conventional AC units, inverter driven ACs can control the speed of their compressor motors to match the required cooling needs indoors.	Inverter-driven ACs are suitable for large homes and multifamily buildings. There are also newer window AC inverter units available for apartment dwellers. These systems are easy to install in existing homes with AC systems.	These systems have slightly higher upfront costs, but yield lower utility bills than standard AC due to reduced energy usage.	These systems can help avoid humidity spikes that contribute to mold or dust mites; air filters are common in high-efficiency systems.	Inverter ACs avoid the energy-intensive on/off cycling of conventional ACs, leading to reduced electricity consumption. This means more cooling with less power, and therefore less potential grid strain during peak demand.
RADIANT COOLING SYSTEMS	Radiant cooling systems work by circulating chilled water through panels in the floors or ceilings and absorbing heat to create a cooler indoor environment.	These systems are very efficient in homes in dry climates like the Southwest, but less so in humid climates due to condensation. These systems are best suited for new construction or high-performance retrofits.	Significant upfront costs as the panels cover most of the ceiling and water lines must be laid. In most climates, an additional AC system is often needed to control humidity, which further adds to the overall expense. Additionally, operating costs tend to be lower in efficient buildings.	These systems eliminate air recirculation and duct-based dust transport. They can also reduce airborne contaminants and, therefore, improve IAQ.	Radiant cooling can offer significant energy efficiency benefits. When combined with thermal energy storage, radiant cooling systems can facilitate load shifting from off-peak to peak hours in places with large differences between daytime and nighttime rates. This reduces peak demand on electric utilities, potentially lowering energy costs.
EVAPORATIVE COOLING SYSTEMS	Evaporative cooling systems cool air through water evaporation, either by direct contact or via a heat exchanger	Best suited for homes and low-rise buildings in dry climates, such as those of the Southwest.	Compared to central AC, these systems tend to cost less than half the price to install and operate. However, they do require regular maintenance.	Per the Centers for Disease Control and Prevention, evaporative coolers can help protect people indoors from the transmission of airborne viruses because they increase ventilation with outside air to cool indoor spaces.	These systems use about 25% as much energy as central AC, thus reducing the strain on the grid.
PERSONAL COMFORT SYSTEMS (PCS)	A personal comfort system for cooling is a device to cool individuals directly or their immediate thermal environment without affecting the thermal environment of other occupants. Standing fans, micro-air-conditioning units, and fan-ventilated wearables are a few examples.	PCS devices are applicable in all climate zones, and many devices are commercially available.	Costs vary, but PCSs tend to be significantly less expensive than standard AC and offer an opportunity to save energy in buildings. Because these devices allow people to feel comfortable even when the central room temperature isn't "perfect," owners and building operators can set the thermostat a little higher in summer.	PCSs allow people to personally adjust their thermal micro-environments to satisfy their individual comfort needs.	PCSs use very small amounts of energy, making them inherently suitable and adaptable for use during energy emergencies.

Passive Building-Scale Technologies

Passive cooling strategies (Table 3) do not involve any energy or mechanical input. Instead, they rely on design features like natural ventilation, shading, and insulation to minimize heat gain and maximize heat dissipation. Examples of passive cooling strategies include cool roofs, green roofs, solar shading, and natural ventilation. **Passive cooling strategies are essential for fostering passive survivability and increased energy efficiency**.

TABLE 3. PASSIVE BUILDING-SCALE RESILIENT COOLING TECHNOLOGIES

TYPE	HOW IT WORKS	ACCESS	COSTS	HEALTH & COMFORT	ENERGY & GRID IMPACT
REFLECTIVE SURFACES	Cool roofs and cool walls reflect sunlight and cools itself by efficiently emitting any heat that was absorbed. This reduces the amount of heat conducted into the building.	According to the Department of Energy, cool roofing products usually cost no more than comparable conventional roofing products. However, retrofitting roofs with reflective coatings will incur extra material and labor costs.	Cool roofs and cool walls can reduce costs by lowering the need for AC and extending the life of other active cooling equipment. This can lower net annual energy use by 10-20%, up to $1,665 in savings over the roof's lifetime.	Cool roofs and cool walls increase occupant comfort and enhance overall passive survivability.	Cool roofs can reduce peak electricity demand, thereby lowering peak electricity costs and helping to prevent power outages.
GREEN ROOFS	Green roofs provide a net cooling benefit for buildings through evapotranspiration from the vegetation and reducing heat gain.	Green roofs can require high upfront costs due to permitting costs and setting up the watering systems. Green roofs also require a roof that can handle the additional weight.	Green roofs result in energy savings by reducing the need for energy for cooling. Additional costs for green roofs include costs to maintain the plants and water systems.	Green roofs improve indoor comfort, and lower the incidence of heat stress associated with heat waves as well as incorporate green spaces into the built environment.	Reductions in energy load can benefit the grid during periods of peak demand.
INSULATION	Insulation reduces heat transfer through walls, roofs, and floors by slowing heat flow. This strategy minimizes unwanted heat gain in summer and heat loss in winter. New super insulating materials, like vacuum insulation panels and silica aerogel, can be five times more efficient than traditional insulation.	Insulation is more cost-effective to add during construction than to retrofit it after the house is finished, although that can be achieved through weatherization programs.	Homeowners can save an average of 15% on heating and cooling costs by air sealing their homes and adding insulation. Super insulating materials help save additional money and can create additional usable space and therefore increase the financial value of the building.	Insulation helps maintain comfortable indoor temperatures with less energy use for cooling. However, excessive insulation can compromise a building's ability to maintain comfortable thermal conditions during heat waves.	Well insulated buildings require less energy to cool the building, leading to decreased demand for energy.
SHADING AND NATURAL VENTILATION	Shading devices, like overhangs, louvers, or vegetation, block direct sunlight, while operable windows and vents enable cross-breezes that expel warm air and draw in cooler outdoor air, improving thermal comfort and energy efficiency.	Of the different types of shading techniques, exterior operable shading is the cheapest and most effective method to increase passive survivability.	Exterior operable shading is highly suitable for lower-cost retrofits	Buildings that used shading and ventilation at the right times were shown to be able to eliminate hours in dangerous heat index levels and significantly reduce indoor temperatures.	The combined use of shading and natural ventilation can reduce the building energy demand.
FENESTRATION	Fenestration entails energy-efficient windows, doors, and skylights designed to limit heat transfer and maximize daylight. Further, natural ventilation from openable windows has been shown in many studies to provide a thermally comfortable indoor environment.	Costs and applications vary by the type of fenestration technology. Most can be installed when replacing previous technologies.	Efficient fenestration reduces solar heat gain, thus reducing the need for active cooling technologies, contributing to overall building energy savings. However, they can also reduce energy efficiency due to their relatively low thermal resistance compared to opaque surfaces.	Windows as a fenestration strategy admit natural light to a building's interior, reducing the need for artificial lighting, which has been shown to improve mood and happiness.	Effectively designed fenestration strategies can reduce peak electrical demand.
PHASE CHANGE MATERIALS	At the cutting edge, Phase Change Materials (PCMs) can be incorporated into building materials and thermal energy storage systems (TES). They are designed to absorb and release heat, thereby reducing peak cooling demand.	These materials are appropriate for applications in high-performance homes and large multifamily buildings. Given the emergent market, there are limited products available.	TES systems can provide cost savings by shifting the energy demand to low-rate periods. PCMs can potentially save up to 30% in total building energy consumption.	Some studies report up to 50% reductions in heating discomfort hours. The resiliency during power outages highly depends on the time and duration of a power outage, PCM properties, and climate.	PCMs and other TESs releasing the stored energy during periods of high demand can reduce the strain on the grid.

Integrated Building-Scale Technologies

Integrated cooling systems (Table 4) combine passive and active components to achieve a balance between energy efficiency, performance, and resilience. These solutions can leverage the strengths of both passive and active strategies, such as using solar shading and evaporative cooling to reduce the grid load.

TABLE 4. INTEGRATED BUILDING-SCALE RESILIENT COOLING TECHNOLOGIES

TYPE	HOW IT WORKS	ACCESS	COSTS	HEALTH & COMFORT	ENERGY & GRID IMPACT
BIOSOLAR ROOFS	Biosolar roofs are combined green roof-solar photovoltaic (PV) systems.	These systems are suitable for large multifamily buildings. Not all existing residential roofs can support both green roof substrate and PV mounting systems. There are limited incentives targeting the application of these systems.	Increased savings from the energy generated by the solar PV system can offset the additional costs of a green roof. Solar PV panels need to be moved for reroofing less often, which saves money.	Solar PV panels protect the plants and growing media from direct exposure to sunlight and wind, which enhances plant growth and creates microhabitats that encourage species variety.	The reduced ambient temperature from the evapotranspiration caused by green roofs increases the efficiency of solar PV panels. This can result in up to 20% increased power generation capacity for a building.
ADAPTIVE DYNAMIC BUILDING ENVELOPE SYSTEMS	Adaptive dynamic building envelope systems (ADBEs) strategically harness the combined benefits of passive design and active resilient cooling technologies.	Varies by the combination of technologies used.	Varies by the combination of technologies used.	ADBEs have been demonstrated to be effective in reducing building thermal loads and improving thermal comfort levels, enhancing thermal resilience of buildings, and reducing incidences of heat stress.	The specific benefits vary by the combination of technologies used. But, on the whole, ADBEs improve grid resilience by reducing peak electricity demand.

Community Scale Technologies and Strategies

As building-scale resilient cooling interventions rely on individual ownership, upfront capital, or single building-specific conditions, community-scale systems offer unique advantages for broader access, as they facilitate neighborhood-wide access to resilient cooling. These systems distribute resources efficiently across multiple buildings and reduce per-unit energy demand. All buildings on a street segment or people in the neighborhood gain access at the same time, and renters and low- and moderate-income customers do not have to pay for the upfront costs or maintenance of the system. By leveraging shared infrastructure, community-scale strategies help entire neighborhoods remain livable during extreme heat and power disruptions. Community-scale strategies can also be broken down into active and technologies

Active Community-Scale Technologies

Thermal energy networks (TENs) (Table 5) are active systems that can include networked geothermal, district cooling, and others that use water in pipes to capture, re-use, and share thermal energy between buildings. TENs extract thermal energy from a range of readily available sources, which can include traditional ground-source energy from boreholes, bodies of water, or underutilized sources like waste heat from data centers, and use no or minimal electricity. Recognizing the benefits and the barriers of TENs, several states are pursuing approaches to using this technology at the neighborhood scale. Eight states have passed innovative legislation either allowing or mandating that their largest gas utilities file plans to pilot TENs. Moreover, in June 2024, Eversource Energy launched the nation's first gas utility-installed networked geothermal system. Located in Framingham, MA, the system provides heating and cooling to 140 customers, which include both homes and businesses.

TABLE 5. ACTIVE COMMUNITY-SCALE RESILIENT COOLING TECHNOLOGIES

TYPE	HOW IT WORKS	ACCESS	COSTS	HEALTH & COMFORT	ENERGY & GRID IMPACT
NETWORKED GEOTHERMAL	Networked geothermal uses shallow boreholes to access the earth's ambient temperature to heat and cool. The system is made of a network of pipes, where a water-based solution that transfers heat energy within the pipes, and geothermal heat pumps, which disperse it to buildings.	Geothermal heat pumps have high upfront and installation costs compared to other technologies on the market, but energy savings and longer life span help cancel out these initial costs after five to ten years.	Geothermal heat pumps can help lower household electricity bills by up to 60% before factoring in the added benefits of thermal sharing between buildings in a TEN. In some cases, end users (households) each pay a fixed, affordable monthly geothermal service fee in lieu of energy bills.	Unlike conventional AC systems that release heat into outdoor air, geothermal systems return it below ground, which can reduce ambient temperatures and rates of heat-related illnesses.	These systems store excess thermal energy for use later. Additionally, the more buildings that get integrated into the network, the more energy efficient the network becomes. Higher energy efficiency translates to less strain on the electric grid.
DISTRICT COOLING SYSTEMS	District cooling systems systems provide cooling from a central source through a network of pipes carrying cold water underground. This approach can be integrated with a nature-based solution, such as a large body of water, to source cold water for cooling.	These systems have high upfront capital costs and district cooling systems are more commonly used in urban areas. There is a limited number of technical experts to maintain these systems, as district cooling systems are not as common nor as extensive as district heating systems.	These systems can be more cost-effective in the long run due to lower operating costs. This can save money for both building owners and the city as a whole.	District cooling has the same benefit of reducing the heat island effects by removing the impact of large numbers of AC units expelling hot air into the neighborhood.	The centralized plants of district cooling systems can use energy-efficient technologies such as absorption chillers or cooling towers, which are more efficient than individual air conditioning units. This means that district cooling systems can reduce energy consumption and grid load.
ICE-STORAGE SYSTEMS	Ice storage systems freeze water in a tank overnight using off-peak electricity. During the day, the ice is used to cool the building, drastically reducing the energy required for air conditioning during peak hours.	Installation costs and space requirements can be high. This can increase the costs of these systems for developers and retrofitters.	When integrated into new construction, these systems also allow one to design a building without AC equipment, saving costs. Retrofitting existing buildings with ice storage can yield a return on investment between three and five years.	Ice storage helps maintain stable, comfortable indoor temperatures, which can reduce heat-related illnesses.	These systems provide a way to reduce peak demand and grid strain by generating cold during off-peak periods and using the stored cold for cooling during peak periods.

Passive Community-Scale Technologies

Smart surfaces (Table 6) are light-colored, reflective and green surfaces that can combat extreme heat and create cooler, more livable communities. They include reflective surfaces, green infrastructure, solar PV, and bioretention. When these passive cooling interventions are integrated with active systems, they can maximize the benefits from a single area in the community. For example, when cool pavements are combined with bifacial solar PV, more energy can be produced by the solar PV cells while simultaneously reflecting sunlight and heat away from buildings and the surrounding air.

TABLE 6. PASSIVE COMMUNITY-SCALE RESILIENT COOLING TECHNOLOGIES

TYPE	HOW IT WORKS	ACCESS	COSTS	HEALTH & COMFORT	ENERGY & GRID IMPACT
REFLECTIVE SURFACES	Reflective surfaces, such as cool pavements are light-colored and engineered to provide a net cooling benefit by increasing solar reflectance and thermal emittance.	The costs to install reflective surfaces are generally on par with their darker, non-reflective counterparts.	Cool pavement products are typically priced similarly to comparable pavement products.	Cool pavements help reduce the outside air temperature in the area and improve air quality by slowing smog formation.	Reflective surfaces decrease cooling costs and energy consumption.
GREEN INFRASTRUCTURE AND SHADE INFRASTRUCTURE	Green infrastructure for cooling includes green roofs, trees and forestry, permeable pavements, green roofs, and bioretention. Mechanical shade can compliment green infrastructure to add additional cooling benefits.	Many local governments seeking to establish green infrastructure and shade infrastructure programs face budget constraints. However, an array of state as well private financing options exists nationwide for green infrastructure. There is less financing for shade infrastructure.	Urban forestry is cost-effective: for every $1 spent on urban tree management, benefits are estimated to be valued at $1.37 to $3.09. The value of shade infrastructure is still being determined.	Trees, for example, can reduce air temperatures by up to 10°F and surface temperatures up to 25°F and provide billions in ecosystem services benefits. Another example, porous and permeable pavements lower temperatures through evaporative cooling.	Urban forestry, green infrastructure, and shade infrastructure can help reduce energy use and grid stress.
SOLAR PHOTOVOLTAICS (PV)	Solar PV provides shading for buildings and outdoor public areas and generates electricity from sunlight. In the case of community solar, this electricity flows through a meter to the utility grid.	Community solar is an instrumental way to expand access by enabling all households and businesses in a community to access the electricity cost-reduction benefits of solar energy without needing to host a PV system on their own roof.	Community solar customers pay for a share of the electricity generated, often in the form of a monthly subscription fee.	Solar panels provide outdoor heat protection in the form of shade for buildings and outdoor public areas.	Solar PV reduces energy demand from buildings and fossil fuel power plants. This offers additional co-benefits, including reduced emissions and improved air quality.

Grid Scale Technologies and Strategies

Load reductions from passive and active cooling technologies and systems at the building and community scales can be enhanced and supercharged with the deployment of grid resilience and reliability strategies. This is especially important as extreme heat causes strain on the entire electric grid system, affecting the efficiency of energy generation, grid transmission and distribution, and the electrical infrastructure itself. Grid strategies (Table 7) include the following: demand side management strategies, distributed energy resources, and grid enhancing technologies.

TABLE 7. GRID SCALE RESILIENT COOLING TECHNOLOGIES

STRATEGY	TECHNOLOGY	HOW IT WORKS	BENEFITS
DEMAND SIDE MANAGEMENT	SMART THERMOSTATS	Smart thermostats allow for real-time adjustment to energy demand by consumers and automatic adjustments from the utility based on grid signals.	This technology can help the utility to proactively lower consumer energy consumption to avoid blackouts or brownouts.
	GRID INTERACTIVE EFFICIENT BUILDINGS (GEBS)	GEBs utilize distributed energy resources, smart technology, and energy-efficient appliances to be an asset in achieving grid reliability and energy affordability. GEBs monitor and change energy usage based on grid signals. This can reduce energy costs by automatically shifting energy consumption to cheaper hours of the day.	GEBs can make buildings into a flexible energy resource by combining energy efficiency and demand flexibility.
DISTRIBUTED ENERGY RESOURCES	VIRTUAL POWER PLANTS (VPPS)	VPPs are a network of households and businesses that offer their thermostats, appliances, batteries, and solar arrays to support the grid in times of peak demand. When these devices are aggregated and coordinated, they can provide the same energy services as a traditional power plant.	State utilities are deploying VPPs and seeing results. For example, Utah's Rocky Mountain Power's WattSmart Battery program is one of the most robust VPPs in the country, utilizing 3,200 customer-owned batteries with approximately 20 megawatts of load available for real-time dispatch.
	MICROGRIDS	Microgrids use local energy resources, such as solar panels and batteries, to serve local loads and can operate autonomously and independently from the larger grid. This means that if the power in a certain community were to go out due to an extreme heat event, a community connected to a microgrid would continue to have electricity and be able to operate their cooling technology.	The deployment of microgrids can mitigate grid disturbance and dangerous health impacts of losing power during extreme heat while also keeping critical infrastructure running, such as homes, hospitals, and grocery stores.
	ENERGY STORAGE	Battery storage is a critical component for grid reliability and resilience. As more clean energy is deployed and connected to the grid, batteries are able to make sure the energy that consumers need can be used even when the sun isn't shining or when the wind is not blowing. Flow batteries are an example of an emerging technique for grid-scale storage.	Grid-scale battery storage can be used by utilities to support peak load management to enhance system resilience and reliability by storing energy and then providing it back to the grid when it is needed.
GRID ENHANCING TECHNOLOGIES	ADVANCED CONDUCTORS	Advanced conductors increase line capacity on existing rights of way while maintaining better performance at higher operating temperatures and managing thermal sag.	Advanced conductors can carry more power than traditional conductors.This allows for more power to be used during peak cooling demand times without building new power lines.
	DYNAMIC LINE RATING (DLR)	DLR can give real-time calculations of a transmission line's electric capacity based on local conditions, such as temperature, weather conditions, wind, and line sag.	Since the transmission line's ability to carry electricity is limited by heat, DLR can help keep power moving efficiently on transmission lines during extreme heat events. For example, if an electric line is becoming congested due to an increase in energy demand, grid operators can utilize DLR to lower the amount of energy passing through the line.

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