clasp Efficient Appliances for People & the Planet

Powering Thriving Communities

Efficient Appliances for Climate Change Adaptation and Resilience

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CLASP's research aims to bridge the gap between analysis and action to hit net zero emissions in the appliances sector by 2050. Read ***Net Zero Heroes: Scaling Efficient Appliances for Climate Change Mitigation, Adaptation & Resilience*** to learn more about our net zero strategy.

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Increasingly frequent and severe climate hazards are making billions of people more vulnerable, particularly in the Global South. Risks such as heat-related illness and crop loss are only projected to increase. In response, global momentum for an expanded adaptation and resilience toolkit is growing, with a specific demand for people-focused solutions. Efficient appliances and equipment should be a critical part of an expanded adaptation solution set.

Efficient appliances and equipment are essential "microinfrastructure" that can power people's lives. **They are proven to reduce heat risk, bolster food security, and improve livelihoods**, directly helping communities adapt and build resilience to climate shocks, as depicted in the graphic below.

RECOMMENDATIONS

- **How to include efficient appliances and equipment in expanded adaptation measures**

  Taken together, the actions described below would elevate appliances to a core pillar of adaptation policy, finance, and program delivery and ensure that appliances rapidly protect communities, food systems, and livelihoods as climate risks intensify.

- **Develop appliance-specific adaptation metrics**

  Governments should adopt indicators that track adaptation and resilience outcomes from appliance access and use, while donors should consider including these indicators in project proposals. Implementers and researchers should provide practical tools and data to help develop indicators and measure results.

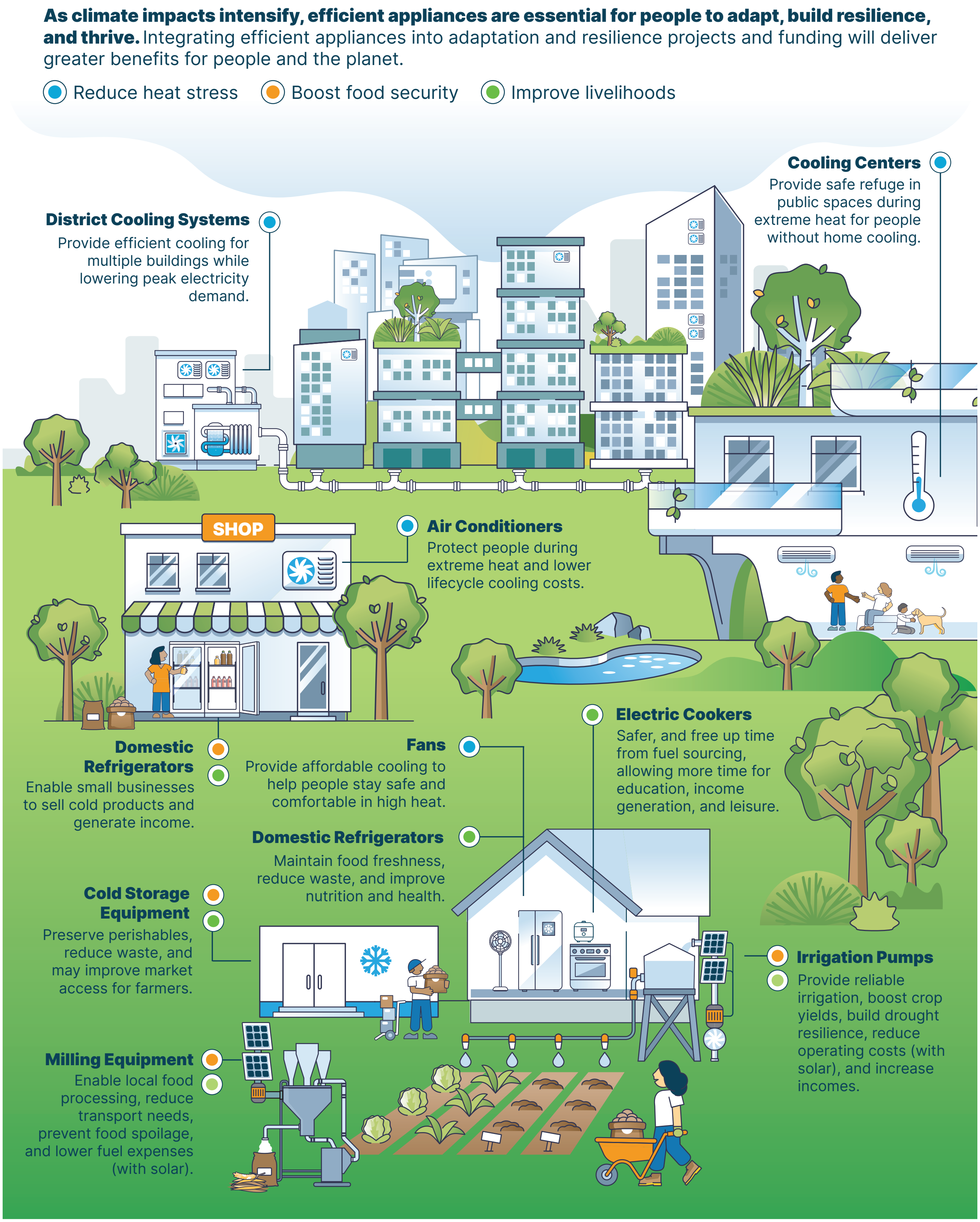
- **Embed appliances in national adaptation policies, roadmaps, and plans**

  Governments should name priority appliances in National Adaptation Plans, Nationally Determined Contributions to the Paris Agreement, and Long-Term Low-Emission Development Strategies. Examples of priority appliances include cooling appliances and equipment, agricultural technologies, and business appliances (see Figure 1 on page 6). Governments should also create roadmaps involving multiple ministries and stakeholders responsible for adaptation delivery.

- **Enable scalable and durable appliance delivery**

  Governments should strengthen markets through standards, subsidies, and incentives, while donors should provide grants and concessional finance for affordable service delivery models. Private-sector partners and implementers should expand local manufacturing and distribution, repair networks, and provide technician training to ensure long-term functionality.

FIGURE 1 How Efficient Appliances Power Climate Adaptation and Resilience



Powering People-Centered Adaptation and Resilience with Efficient Appliances

The world is on the brink of a critical climate threshold.

In 2024, global temperatures surpassed 1.5 degrees Celsius (°C) above preindustrial levels for the first time, a critical scientific and symbolic marker. Scientists warn that we will likely exceed the 1.5°C warming goal of the 2015 Paris Climate Agreement (Paris Agreement) in the near term,[i] with some noting that the 1.5°C warming target could be passed as soon as the late 2020s.[1,2,3]

Under current policies, the world is on track for devastating levels of warming, with temperatures expected to exceed preindustrial levels by 2.7°C during this century.[4] Each additional fraction of a degree of warming increases the urgency, complexity, and expense of climate change adaptation and resilience.[5]

As the effects of climate change intensify, the imperative for adaptation has never been greater.[6] Climate change adaptation refers to the process of adjusting systems, communities, and infrastructure to minimize harm and capitalize on potential benefits in response to current or anticipated climate impacts, while climate change resilience refers to the ability to cope with and recover from climate-related damages and stresses.

Despite their importance, adaptation and resilience plans, finance, and implementation fall alarmingly short. While the number of adaptation and resilience plans has increased, they often lack clear definitions and consistency, which undermine implementation efforts. The United Nations Environment Programme estimates that the current adaptation finance gap is as large as $359 billion USD per year.[7] To date, adaptation investments have often favored large-scale, capital-intensive, no-regret projects like flood management, early warning systems, and large-scale infrastructure projects.[8] However, this narrow focus risks leaving behind the very communities most in need of support.

Efficient appliances and equipment represent precisely the type of underutilized, human-centered adaptation solution needed. Appliances like efficient cooling equipment and agricultural technologies function as microinfrastructure for adaptation, providing essential energy services that enable people to cope with climate stresses in real time. By reducing exposure to extreme heat, preserving food, supporting climate-resilient agriculture, and stabilizing livelihoods, efficient appliances directly strengthen adaptive capacity where climate impacts are felt most acutely. At the same time, improvements in appliance efficiency reduce energy demand, alleviate pressure on energy systems, and constrain emissions growth, helping avoid maladaptive outcomes such as higher energy bills, grid stress, and increased reliance on fossil fuels.

This report focuses specifically on the role of efficient appliances in supporting households, small businesses, and smallholder farmers in the Global South, for whom vulnerability to climate change is highest and adaptation benefits from access are most immediate. In these contexts, first-time access to an efficient appliance can fundamentally change people's ability to respond and adapt to climate change. The report does not explore resilience benefits in the commercial and public buildings sectors, industrial sector, or large-scale agriculture sectors.

Despite the benefits of efficient appliances, they remain largely absent from national adaptation and resilience plans. People-centered, decentralized solutions are often perceived as more difficult to finance and implement because they are fragmented in their delivery, involve diverse stakeholders, and lack the scale typically favored by financiers.[9] Moreover, policymakers, donors, and practitioners typically lack awareness of all the available technologies and techniques for designing enabling policies and programs. As of September 2025, 67 countries had submitted National Adaptation Plans (NAPs),[ii] but just 20 NAPs mention appliances and only seven specifically call out critical technologies like space cooling equipment.[iii]

COP30 in Belém, Brazil, marked the tenth anniversary of the Paris Agreement and a turning point in the global adaptation agenda. The Brazilian government aimed to make 2025 a landmark for climate adaptation, with a stronger focus on implementation and delivery.[10] During the conference, parties reinforced the Global Goal on Adaptation (GGA) as the primary mechanism for defining and tracking progress and developed a set of 59 voluntary indicators covering seven sectors, including health, water, and agriculture, as well as enabling conditions like finance, technology transfer, and capacity building.[11] There were also calls to close gaps in finance and adaptation planning and implementation. The final Belém package called for the tripling of climate finance by 2035, while other initiatives like the NAP Implementation Alliance will connect

i The temperature goals of the Paris Agreement are measured as 20-year averages exceeding a preindustrial baseline.

ii NAPs are a country-led process under the Paris Agreement through which governments identify medium- and long-term priorities to adapt to climate change, reduce vulnerability, and build resilience across key sectors and communities. NAPs integrate adaptation into national development planning and guide coordinated action, investment, and support in response to current and future climate risks.

iii Based on CLASP's own analysis of 50 NAPs in English.

governments, donors, and partners to accelerate country-led adaptation priorities and investable solutions.[12,13]

These outcomes create a timely opportunity to embed efficient appliances and equipment more systematically into adaptation plans, indicators, and finance. As countries pilot indicators, seek to close the adaptation finance gap, and update and implement NAPs, efficient appliances should be recognized as core components of adaptation infrastructure that deliver measurable outcomes at scale, often for the most vulnerable.

This report seeks to elevate efficient appliances and equipment within the global adaptation and resilience discourse.

It examines how appliance efficiency can reduce heat stress, strengthen food security, and support climate-resilient livelihoods. It also identifies barriers that are limiting uptake and offers actionable recommendations for governments, donors, civil society organizations, and the private sector on how to integrate appliances into adaptation strategies and frameworks under the Paris Agreement and national climate plans.

BOX 1: WHY EFFICIENCY MATTERS

Energy efficiency is necessary to meet global climate goals. The Paris Agreement has a dual mandate to decarbonize economies and help vulnerable communities adapt to climate change. Energy-efficient appliances sit at the nexus of these aims.

As temperatures rise, demand for adaptation-enabling appliances like air conditioners and refrigeration will soar. Without a focus on efficiency, this growth risks becoming a form or maladaptation: solutions meant to protect people from climate change that, in practice, exacerbate global warming. Inefficient appliances increase energy consumption, strain already fragile power systems, and drive up emissions. Efficient appliances break this cycle by delivering necessary services while constraining energy demand growth.

Efficiency is also a cornerstone of resilience, especially in resource- or energy-constrained settings. By delivering the same essential services with less power, efficient appliances lower operating costs for households and businesses. Lower energy bills free up income for other essential needs and allow businesses to keep more of their earnings. These savings help stabilize incomes and make communities more resilient to economic shocks and climate-related disruptions. Lower operating expenses also allow more households to be able to afford appliances, expanding access in lower-income households.

Finally, efficient appliances also provide more reliable performance in areas where electricity is expensive, unreliable, or unavailable. In areas with no or limited grid energy, efficient appliances can operate on smaller, decentralized power systems and extend the reach of critical services like refrigeration and cooling.

Reducing Heat Stress

Credit: CLASP

As temperatures increase, people will be exposed to more days of extreme heat and humidity.

These events will also become longer, more intense, and more frequent, posing significant threats to public health.[14] The Intergovernmental Panel on Climate Change (IPCC) estimates that as much as 76% of the world's population could be exposed to deadly heat stress by the end of the century, up from 30% today.[15] Vulnerable populations, including the elderly, people with pre-existing health conditions,[16] children,[17] low-income and informal urban communities,[18,19] and rural communities with limited access to modern energy are likely to be disproportionately impacted by rising temperatures due to systemic inequalities and limited adaptive capacity.

Space cooling is an increasingly critical service in climate change adaptation efforts. However, estimates of cooling access reveal a stark divide: Those who are most vulnerable to the dangers of extreme heat may find it more difficult to adapt. Globally, more than 1 billion people among the urban and rural poor are at high risk due to a lack of cooling access.[20] Expanding cooling access to these populations will be essential as the planet warms, but it creates a dilemma: *How can people find relief in extreme heat without worsening climate change?*

Current air-conditioning methods exacerbate climate change and put significant stress on electricity systems, and these challenges are growing as more people seek relief from heat. Cooling is already the fastest-growing use of energy in buildings,[21] and rising temperatures and incomes will continue to boost demand for cooling globally. In Southeast Asia alone, the stock of air conditioners is expected to increase ninefold between 2020 and 2040.[22]

To meet this demand, a diverse and inclusive approach to cooling is essential. These solutions must be tailored to and account for local climate conditions, energy access, and affordability to ensure they are effective, scalable, and accessible.

The answer lies in sustainable cooling, an approach that combines passive cooling (to reduce demand for mechanical cooling), low global warming potential refrigerants (to cut direct emissions), and energy-efficient cooling appliances (to lower indirect emissions and reduce grid pressure).

PASSIVE COOLING

Passive measures can lower indoor temperatures without mechanical cooling, using design strategies such as cool roofs, shading, and ventilation.[23,24] When passive cooling is unavailable or insufficient to achieve thermal comfort, space cooling appliances are needed.

FANS

Fans are an effective, low-cost cooling solution. Fans move air that can enhance the evaporation of sweat, helping to cool the body. Advances like super-efficient motors can further reduce operating costs and make fans more accessible to lower-income households.

However, fans are effective only within a limited temperature range (generally between 32°C to 40°C (90 to 104°F), depending on climate conditions).[25] When temperatures rise above these thresholds, additional cooling solutions are needed to keep people safe.

AIR CONDITIONERS

Air conditioners (ACs) are one of the most common cooling appliances in use,[26,27] and global ownership is expected to increase from 37% of the global population today to more than 45% in 2030.[28] However, these appliances are unaffordable to many low- and middle-income households around the world. According to a recent CLASP report, the purchase price of a 3.5 kW AC in some countries in Latin America and the Caribbean can exceed the median monthly income by up to 78%, with operational costs absorbing up to an additional 11% of income.[29]

As many as 4 billion people, especially those in poorer households in sub-Saharan Africa and South Asia, may still lack ACs in 2050.[30]

COOLING CENTERS

Cooling centers can help deliver equitable cooling access by offering temporary refuge from extreme heat to vulnerable individuals or those without reliable cooling access in their homes.[31,32] Cooling centers are typically located in air-conditioned public spaces such as libraries, schools, community centers, recreation facilities, senior centers, rural health centers, and shopping malls. They are a routine heat wave solution for governments in countries such as India,[33] Spain,[34] and South Korea.[35] By leveraging existing infrastructure, cooling centers can be a cost-effective and inclusive means of protecting public health (see Box 2).

DISTRICT COOLING

In urban areas, district cooling systems offer an efficient, climate-friendly solution for large-scale cooling needs. These systems, increasingly adopted in countries like the United Arab Emirates[36] and Qatar,[37] deliver chilled water from a central plant through insulated underground pipes to multiple buildings, where it is used to cool indoor air. District cooling reduces the peak power load associated with individual air-conditioning systems, making it a more sustainable option.[38] However, it requires substantial up-front investment and supporting infrastructure, which can be a barrier to widespread adoption.

BOX 2: DELIVERING EQUITABLE ACCESS TO COOLING CENTERS IN CITIES

Cooling centers are public facilities that provide refuge for those without home cooling.[39] They are particularly well suited for urban areas, which have denser populations, higher temperatures due to the urban heat island effect, and reduced access to nature-based cooling like trees and water features.[40]

Cooling centers are a common urban cooling solution in countries such as the US,[41] UK,[42] and South Korea.[43] In many developing countries, however, cooling centers are still emerging as a formal heat adaptation solution.

India, for example, has seen a growing number of heat wave days in recent years, and more than 44,000 suspected heatstroke cases were reported nationwide in 2024.[44] Against this backdrop, the City of Jodhpur introduced a first-of-its-kind net-zero cooling station in April 2024. This public cooling center is in a heat-vulnerable ward identified through a vulnerability assessment conducted as part of the city's heat action plan (HAP).[45] The center uses low-energy cooling strategies including solar power, passive ventilation, evaporative cooling, and shaded seating, while also providing drinking

View of a cooling center run by the Vienna Red Cross in a shopping center in the Vienna-Floridsdorf district on 9 August 2018. Credit: APA-PictureDesk / Alamy water and basic first aid. Early monitoring shows that indoor temperatures can remain 8 to 12°C (roughly 14–22° Fahrenheit) cooler than outdoors during peak heat, and community feedback affirms its importance for vulnerable people lacking access to other cooling options. Its success underscores how targeted siting, low-energy design, and community partnerships can make cooling centers a social safety net that improves climate resilience for the most at-risk populations.

India's National Disaster Management Authority (NDMA) published Guidelines for Cooling Centers in May 2025. The guidance emphasizes that cities should establish innovative, community-driven cooling centers in locations identified through heat vulnerability assessments. It outlines how existing buildings such as schools, community buildings, and transport hubs can be repurposed and how temporary structures can be deployed for outdoor workers.[46]

Location is one of central elements of equitable access for cooling centers. These facilities should ideally be reachable by public transit or located within a 15-minute walking distance for intended users and within a half-kilometer (approximately one-third of a mile) radius of heat hot spots.[47]

Identifying such locations requires data-driven heat risk and vulnerability mapping.[48] Mapping heat exposure, green space, income, health risks, and access barriers helps prioritize high-risk areas and avoid reinforcing existing inequalities.

New York City's Heat Vulnerability Index (HVI) illustrates how spatial analysis can reveal disparities. East Flatbush, a large neighborhood where Black New Yorkers comprise 85% of the population, is classified as having extremely high heat vulnerability (HVI 5).[49] This neighborhood had only two open cooling centers during a heat wave in 2022, leaving one of the city's most at-risk communities with limited resources for heat relief.[50]

Expanding efforts to map heat risk and vulnerabilities will be essential as the planet warms. However, many parts of the world struggle to establish these systems due to limited availability of high-resolution, open-source data.[51] These data provide critical information about where heat risks are high and where access to cooling centers may be lacking. Local collaborations are helping fill these gaps, but achieving equitable cooling at scale will require more resources and investment in mapping tools and community-led assessment processes. Building these systems is essential to ensuring that cooling centers are not just built, but built where they matter most, and that they actively reduce rather than reproduce climate inequities.

EFFICIENT COOLING

Energy efficiency is a cornerstone of a sustainable, multifaceted cooling approach. The global installed capacity of cooling equipment is expected to more than triple from 22 terawatts (TW) in 2022 to 68 TW in 2050 due to increases in extreme heat events and demand in low- and middle-income countries.[52] Residential space cooling will represent roughly half of that installed capacity.

By improving the efficiency of cooling equipment (and combining that with low-power cooling options, buildings that stay cooler naturally,[iv] and a reduction in global warming refrigerant gases[v]), electricity demand could be reduced by 8,500 TWh in 2050 and 110,000 TWh cumulatively between 2022 and 2050.[53] These measures would also reduce annual direct and indirect greenhouse gas emissions from cooling equipment to 2.6 Gt from 10.5 Gt in 2050 under a business-as-usual scenario (Figure 2).[54]

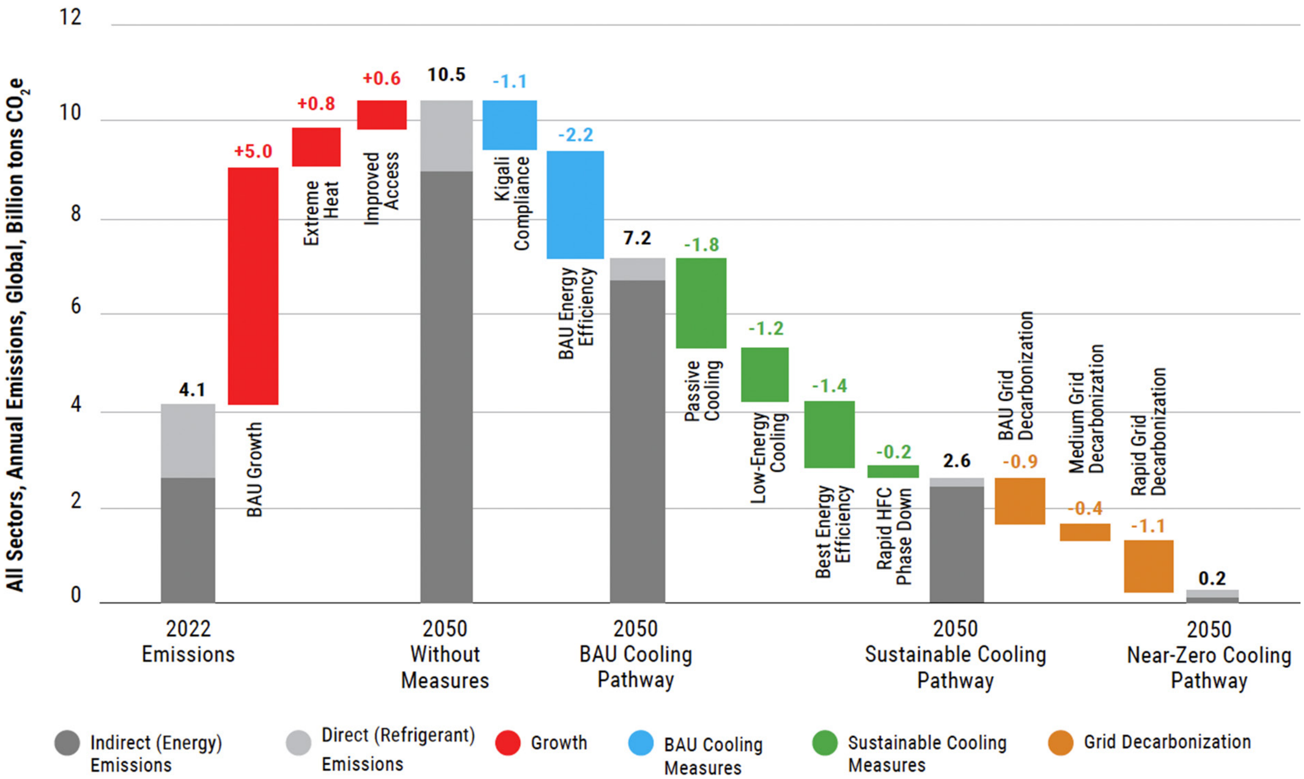
Efficient cooling appliances are not more expensive than conventional models. Evidence shows that AC units of average efficiency have similar prices to the best-available models.[55] For the same price, consumers can buy a unit with double the efficiency in Latin America and Southeast Asia.

Still, cooling appliances remain out of reach for many. Over 1 billion people are at high risk of a lack of access to cooling solutions, with much of this risk occurring in lower income brackets: 309 million people among the rural poor and another 695 million among the urban poor fall into this category.[56] Expanding access to cooling among these populations will be critical.

iv Passive cooling design principles.

v Reduce hydrofluorocarbon (HFC) emissions.

FIGURE 2 Modeled Pathway to Near-zero GHG Emissions from Cooling in 2050



Source: Figure 4-8 in UNEP, Global Cooling Watch 2025: The Free Degrees *(2025), https://wedocs.unep.org/xmlui/handle/20.500.11822/48926. Estimates generated from the Global Cooling Emissions Model. BAU: business as usual.*

Investments in energy efficiency can help expand access to cooling equipment in low- and middle-income households. In East Asia and the Pacific, 25% of low-income households own an air conditioner, compared to 75% of high-income households.[57] Efficient cooling appliances use less energy, making them less expensive to operate over their lifespan. These lower life-cycle costs (which include purchase and operational costs) can make air conditioners more affordable to lower-income communities.

Doubling the efficiency of residential cooling[vi] equipment globally would have a profound effect on cooling access and climate resilience. In India, Indonesia, and Nigeria alone, life-cycle costs could be reduced by 43% by 2050, unlocking $210 billion USD in consumer economic benefits, expanding access to an additional 13% of the population (mostly in lower- and middle-income households), and preventing more than 22,000 heat-related deaths each year.[58] By combining proven policies like efficiency standards with financial incentives and market transformation programs, the international community can dramatically narrow the access gap for low-income households (see Box 3).

vi Fans, room air conditioners, and refrigerators.

BOX 3: HIGH-EFFICIENCY FANS FOR HEAT RESILIENCE IN RURAL PAKISTAN

In rural Pakistan, sweltering heat, high humidity, and limited electricity access make staying cool a challenge. Air conditioners provide effective cooling, but their high up-front and operating costs put them out of reach for most households. For many households, fans represent the primary, and often only, line of defense against high temperatures, offering basic but essential cooling.

To effectively support heat resilience in low-income households and communities with limited grid energy access, fans must be affordable, energy efficient, and good quality. However, most options available in local Pakistani markets force consumers to compromise on one or more of these attributes.

Harness Energy, a Pakistan-based company, aims to address this gap. With support from the Efficiency for Access Research and Development (R&D) Fund, Harness Energy developed brushless direct current fans that are more durable and twice as efficient as their conventional counterparts.[vii] These fans can be bundled with smaller, lower-cost solar home systems and are rechargeable, allowing them to deliver sufficient airflow throughout the night or when the grid power is unreliable.

Through product R&D, Harness Energy was able to deliver these performance improvements at a price more accessible to low-income Pakistani consumers. The company's efficient fans retail for around $30 USD, about 18% cheaper than comparable imported models. To lower barriers to adoption even further, Harness Energy worked with microfinance partners to make the fans affordable via monthly payment plans. Efforts to localize 65% of fan production in Pakistan have also helped to reduce costs while strengthening local supply chains and expanding employment opportunities.

For small business owners like Ghulam Mustafa, who has operated a furniture repair shop in Pakistan since 2009, Harness Energy fans deliver both financial benefits and improved comfort and productivity during periods of high heat.

Harness Energy demonstrates its innovative fan technology to a local community in rural Pakistan, showcasing affordable and efficient cooling solutions for off-grid households. Credit: Harness Energy

"Summers are usually very tough on the body due to the heat and humidity. I was using a basic pedestal fan to keep cool in the extreme temperatures . . . Unfortunately, paying the bills for my workshop has become difficult due to the rising cost of electricity and business losses during COVID-19," he said.

> "I heard about this efficient solar fan from a nearby retailer, so I purchased it in installments from Harness Energy. The fan has turned out to be a blessing."
>
> *Ghulam Mustafa*

Since purchasing his efficient fan, Mustafa reported that his monthly electricity bill has fallen from the equivalent of $21 USD to $13 USD, allowing him to repay the full up-front cost of this appliance through savings alone.

vii Brushless direct current (BLDC) motors offer significant efficiency improvements in fans compared to traditional brushed motors due to their design and electronic control. They eliminate the friction between brushes and the commutator, resulting in lower power consumption, longer lifespan, and quieter operation.

Boosting Food Security

Climate change is disrupting food systems by altering weather patterns, shifting growing seasons, and increasing the frequency and severity of extreme events like droughts, floods, and heat waves.

These changes reduce crop yields, threaten livestock health, and degrade soil and water quality, undermining food production and security. We are witnessing these events unfold in real time: In 2022, more frequent heat waves and droughts caused 151 million more people to face moderate or severe food insecurity than the 1981–2010 average.[59] Over time, the annual cost of adapting to climate change and handling unavoidable damage for major crops is expected to rise sharply, from $63 billion USD at 1.5°C (2.7°F) of warming to $128 billion USD at 3°C (5.4°F).[60]

Smallholder farmers, who produce two-thirds of the world's food, are among the most vulnerable to climate change.[61] Globally, there are around 600 million smallholder farms, most of which consist of approximately 2 hectares of land, rely on rainfed agriculture, and have limited assets to buffer against climate shocks.[62,63] In sub-Saharan Africa, 95% of all agricultural land is rainfed and largely managed by smallholder farmers. These farmers account for 60% of the population, leaving millions of households economically vulnerable to drought, shifting rainfall patterns, and other negative climate change effects.[64,65] Crop failures in these communities translate directly to hunger and lost income and can even lock individuals into poverty, as households often have limited safety nets.

Strengthening food security under a changing climate will require building resilient value chains from production to storage and distribution. Off-grid agricultural appliances and equipment offer solutions for smallholder farms in regions where access to energy, mechanized equipment, and financial resources are scarce, boosting food security from field to market while reducing overall system costs and delivering high-quality services.[66] The following section examines how targeted investments in water pumping, food storage, and agricultural processing technologies can strengthen resilience at critical stages of the food value chain.

IRRIGATION PUMPS

Pumps with water storage can improve water access, helping farmers adapt to changing weather patterns and increasing drought conditions. By replacing or avoiding the use of expensive and polluting diesel pumps, solar water pumps (SWPs) can offer a pathway to reduce fossil fuel dependence, lower farmers' costs (both operational and total), and expand access to irrigation in areas with unavailable or unreliable grid power (see Box 4). In Kenya, for instance, adopting SWPs can halve the total cost of irrigation, with a typical farm spending around $3,000 USD over five years to irrigate one acre with SWPs compared to $6,000 USD with diesel.[67]

Beyond cost savings, SWPs have the potential to increase yield by two- to threefold, depending on crops and climate, compared to rainfed and manual irrigation techniques.[68] They are especially valuable for smallholder farmers when paired with improved agricultural practices in water-scarce regions like sub-Saharan Africa and South Asia, where 95% and 60% of farmland is rainfed, respectively.[69]

Credit: CLASP

BOX 4: BUILDING RESILIENT FARMS THROUGH AFFORDABLE SOLAR WATER PUMPS IN INDIA

Parvati, the village chief of Dungarpur in Rajasthan, India, manages farmland in a community where men have migrated to cities for work. Like many farmers, Parvati was forced to irrigate her crops late at night due to unreliable grid electricity. Even then, the power was available only intermittently. "We used to switch on the motors at night when the electricity came back, but the power would cut off again within five minutes," Parvati recalled. This practice exposed her to serious risks, including electrocution, snake bites, and sexual violence.

Everything changed when Parvati installed an energy-efficient solar water pump through an incentive program administered by CLASP that significantly reduced its price. Reliable daytime access to water immediately improved her productivity, safety, and quality of life. Parvati was able to expand irrigated land, diversify into higher-value crops, and complete farm and household responsibilities safely. "Now, with the help of solar pumps, we can finish our daily chores during the day and sleep comfortably at night," she said.

The resilience benefits of Parvati's solar water pump extend beyond daily farming. When a severe cyclone disrupted electricity and water supply across the region, her solar water pump continued to operate. Parvati was able to supply her household, livestock, and neighbors with water, maintaining essential services when conventional systems failed and building community resilience during a climate shock.

> "When a storm hit our village, I gave water to my neighbors and our animals with the help of my solar water pump."
>
> *Parvati, village chief of Dungarpur, India*

Parvati in her home in Dungarpur, India.
Credit: CLASP

COLD CHAIN EQUIPMENT

Globally, 526 million metric tons of food—enough to feed 1 billion people—were lost in 2017 due to a shortage of cold chain equipment.[70] Perishable products like vegetables, fruit, dairy, and fish can spoil within hours to days in high heat. Efficient cold chain equipment, from portable coolers and refrigerators to walk-in cold rooms, dramatically extend the shelf life of food. This has profound implications for food security as well as climate change. Less food waste means that more food reaches markets. Reducing spoilage also avoids the embedded emissions and land use associated with producing wasted food and avoiding the methane emissions from its decay.

Today, warm-climate nations in the Global South are particularly affected by food loss. In sub-Saharan Africa, as much as 40–50% of food is lost between production and consumption.[71] In South Asia, countries like India have large agriculture sectors but insufficient cold chain coverage in rural and peri-urban areas (see Box 5).[72]

Efficient off-grid cold storage technologies can bring food preservation to remote areas in the Global South. When powered by renewable energy or designed to optimize energy efficiency, cold storage equipment can avoid energy-related emissions and lower operating costs, making it more accessible and sustainable in climate-vulnerable regions. Solar-powered cold storage units, in particular, boost food resilience in areas where electricity is unreliable, unavailable, or disrupted by climate events.[73] Some existing products, such as solar direct-drive refrigerators, can provide an average of 133 hours of cooling without solar inputs.[74]

AGRICULTURAL PROCESSING EQUIPMENT

Agricultural processing equipment is critical in preparing grains for sale and consumption. Over the past century, mechanical milling equipment such as electric and diesel-powered mills has improved both the quality and quantity of end products while greatly reducing labor inputs compared to manual mills.

Beyond storage, many efficient appliances enable value-added processing of crops, reducing waste and improving livelihoods. Efficient agricultural processing equipment like grain mills ensure timely processing post-harvest. The World Bank estimates post-harvest losses of 10–20% for cereals in parts of sub-Saharan Africa, with processing bottlenecks and access as contributing factors.[75] Decentralized and efficient milling solutions allow grain to be processed soon after harvest, limiting exposure to pests, moisture, and mold. Likewise, efficient dryers (solar or hybrid) can preserve fruits, vegetables, and fish, allowing them to be stored or sold in the off-season.

Replacing diesel-powered equipment with electric alternatives also lowers operating costs. Solar-powered mills are the most energy-efficient milling option, producing more output per unit of energy than other methods.[76] Compared with diesel-powered mills, solar-powered mills are also more user-friendly and reliable, as well as less polluting and expensive to run.[77]

Rural diesel millers operate on slim margins, with over 40% of their revenue spent on fuel, oil, and maintenance.[78] In contrast, data from one commercially available solar mill finds that just 1% of the mill's revenue goes toward its power generating system, making it nearly 70% more profitable per unit of flour produced.[79] Reducing operating costs can help stabilize or reduce staple food prices, reducing the risk of price hikes during periods of shock.

Their portable design decentralizes milling locations and allows rural communities to have one or more locally based machines. This prevents spoilage, reduces transport needs, increases productivity, and lessens the time and energy that women and adolescents spend on drudgery. In doing so, solar mills build community-level autonomy in the face of climate shocks and strengthen rural livelihoods and food systems.[80]

Efficient agricultural technologies, like solar water pumps, cold storage equipment, and agro-processing equipment, are well aligned with the priorities countries are raising in international climate dialogues. Calls to action like the Emirates Declaration on Sustainable Agriculture, Resilient Food Systems, and Climate Action and the Belém Declaration on Hunger, Poverty, and People-Centered Climate Action ask nations to integrate food and agriculture into NAPs and provide a higher percentage of climate finance to agriculture and food security, with a special focus on smallholder farmers. While large-scale climate-smart agriculture projects like drought-resilient crops often get the most attention in this area, support for cold chains and agro-processing could also help achieve these goals.

For example, NAPs often include goals to reduce post-harvest losses and improve agricultural value chains. Efficient appliances are precisely the tools to achieve those goals, yet they are seldom mentioned. As of now, only a few NAPs (such as Bangladesh's) tangentially mention promoting solar irrigation. Countries could update their Nationally Determined Contributions (NDCs) and NAPs to include quantitative targets for these solutions, which would send clear signals to donors and the private sector.

Enhancing food security through appliances should not be a stand-alone intervention. Instead, efforts to increase the use of efficient agriculture technologies should integrate with other resilience measures. For example, climate-resilient crops like drought-tolerant varieties could be used in conjunction with efficient solar water pumps. Likewise, early warning systems for drought or heat could be used to notify communities to activate backup generators for cold rooms or harvest early and use mobile coolers to save produce. Complementary educational initiatives could also train farmers not just on new seeds but to use solar pumps efficiently to better time irrigation and conserve water. These approaches are well aligned to the concept of climate-smart agriculture, which combines mitigation, adaptation, and productivity. Efficient appliances tick all those boxes: They reduce emissions, enable adaptation, and increase crop yields and incomes.

BOX 5: REDUCING POST-HARVEST LOSSES IN INDIA WITH SOLAR COLD STORAGE

For Lokratnam, a farmer in Andhra Pradesh, India, harvest season once meant watching potential income slip away. Without a way to keep tamarind, cashew, and custard apple fresh, much of her crop spoiled before it could be sold. "All this produce would get damaged, and we would throw it away," Lokratnam said. "Whatever was left, we used to sell but sold at lower rates and earned very little profit."

Access to cold storage changed that experience. In 2025, a solar-powered cold storage unit was installed in her community as a collaborative pilot between Energy Efficiency Services Limited, a government-owned energy services company, and CLASP. With a place to keep her produce cool, Lokratnam no longer has to immediately sell and accept lower prices out of urgency. "After the cold storage was installed, we store custard apple and tamarind, and sell them later," she explained. She can now wait for better market conditions that allow her to earn more for the same crops.

Lokratnam's experience reflects a reality facing millions of farmers. Across India, only about 4% of produce has access to cold storage, leaving large volumes of nutritious food to spoil. Each year, post-harvest fruit and vegetable losses total almost 10 million metric tons, valued at more than 610 billion Indian rupees (approximately $7.4 billion USD).

The benefits of cold storage access are well understood in India. The challenge is how to make cooling equipment accessible to more farmers. To deliver lasting benefits, cold storage services must be able to operate reliably and sustainably year after year. Scaling delivery models that can stand on their own is critical. Identifying scalable business models like those tested in the pilot between Energy Efficiency Services Limited and CLASP, while continuing to share real-world farmer experiences like Lokratnam's, is essential to attracting investment, lowering costs, and expanding access.

Lokratnam (far right) with her produce at the solar cold storage facility in Andhra Pradesh, India. Credit: CLASP

Improving Livelihoods

Climate change poses a real threat to poverty reduction efforts.

The World Bank estimates it could push between 68 and 132 million people into poverty by 2030, many in the Global South.[81] This deepens a profound injustice: those least responsible for climate change are the most exposed to its impacts and the least resourced to adapt to it.[82,83]

For many households, particularly in rural and peri-urban regions of sub-Saharan Africa and South Asia, building resilience to climate change is closely tied to the ability to sustain and grow livelihoods under increasingly volatile environmental conditions. These regions are home to hundreds of millions of subsistence and smallholder farmers,[84] informal traders, and microentrepreneurs whose livelihoods directly depend on climate-sensitive sectors like agriculture, fisheries, and small-scale processing. Extreme heat, erratic rainfall patterns, drought, and floods can wipe out harvests,[85] spoil perishable goods,[86] damage equipment,[87] and disrupt local markets, pushing fragile households into poverty and reducing their adaptive capacity.[88]

A major barrier to resilient livelihoods in these communities is the reliance on costly and polluting diesel fuels. Many smallholder farmers and microenterprises depend on energy-intensive tasks such as irrigation, grain milling, cold storage, and small-scale food processing that are often powered by costly and polluting diesel fuels. The International Finance Corporation estimates that African farmers spend $2 billion USD annually on diesel-powered pumps, while in India's Gujarat desert, saltpan farmers spend as much as 40% of their annual income on diesel fuel for pumps due to volatile prices.[89] Similarly, small businesses, including shops and restaurants, rely on expensive fuels for backup diesel generators when grid power is unreliable, often operating them for hours each day to keep the lights on, equipment running, and perishable goods cold. This reliance locks enterprises into high and unpredictable operating costs, limiting profitability, and leads to harmful air pollution and greenhouse gas emissions.

At the same time, a significant share of smallholder farmers and businesses still completely lack access to modern energy services. Seventy-five percent of smallholder farmers in Africa depend on rainfed farming, leaving them vulnerable to climate variability and more extreme risks like crop failure.[90,91] For these households, providing first-time access to efficient appliances that can be powered by decentralized energy is transformative. Acquiring a refrigerator, water pump, or milling machine for the first time is not just a technological upgrade: It represents a step change in their ability to generate income, reduce losses, and avoid dependence on diesel.

Finally, efficient appliances can help support economic growth, development, and job creation. The most resilient communities are those with diverse and reliable incomes. Efficient appliances foster this by broadening the economic base, allowing new types of small businesses to emerge, and stabilizing existing livelihoods by reducing climate-induced losses and other costs. For example, a farming household that can irrigate during a drought, store produce in a refrigerator, and mill staple crops affordably and locally is less likely to experience income losses in a bad season. These benefits may also mean the household is better positioned to smooth consumption, preserve assets, or diversify income sources, making it more resilient to future climate and economic shocks.

Growing appliance markets also generate green jobs across the value chain, from manufacturing and assembly to sales, distribution, installation, and maintenance. The solar irrigation sector in India and Kenya alone has the potential to create more than 115,000 jobs by 2030.[92]

Development of local green jobs aligns with a national and international focus on just transitions, locally led adaptation, and climate-resilient development, as well as with the Global Goal on Adaptation's focus on strengthening adaptive capacity and reducing vulnerability. It also advances multiple Sustainable Development Goals, including SDG 1 (No Poverty), SDG 7 (Affordable and Clean Energy), SDG 8 (Decent Work and Economic Growth), SDG 9 (Industry, Innovation, and Infrastructure), and SDG 13 (Climate Action), and illustrates how investments in efficient appliances can deliver integrated climate, development, and employment benefits.

The remainder of this section focuses on a subset of small appliances and business appliances (many of which can be paired with decentralized energy sources) rather than large-scale industrial or mechanized agricultural equipment. This choice reflects the urgent need to target technologies that are most relevant to low-income and energy-poor populations, where energy and appliance access gaps are widest and the potential for direct, people-centered adaptation benefits is large.

AGRICULTURAL COLD STORAGE EQUIPMENT

Cold storage equipment allow farmers, fishers, and traders to store fresh produce, dairy, and fish longer, reducing post-harvest losses and enabling farmers to sell their products under better market conditions. For example, on Kenya's Lake Turkana, fisherfolk often incur high losses from fish spoilage, sometimes losing fish worth up to 30,000 Kenyan shillings ($230 USD) at once, due to the lack of buyers, poor market access, and lack of cold storage facilities.[93] To avoid these losses, they are forced to sell their catch to the first buyer at the landing site for much lower prices. Solar-powered cold storage hubs have helped reverse this pattern, enabling fishers to increase their incomes by up to five times.[94]

DOMESTIC REFRIGERATORS

Refrigerators can create new revenue streams for small businesses and vendors. In East Africa, a survey of refrigerator owners found that 89% of respondents used their appliance commercially, often to sell cold beverages in bars, kiosks, and restaurants (see Box 6).[95]

BOX 6: RELIABLE COOLING THAT PAYS OFF: SOLAR REFRIGERATION FOR SMALL BUSINESSES

Frequent power outages once threatened Doris Chuwa's ability to run her beverage shop in Lagos, Nigeria. Frequent electricity service interruptions meant disrupted refrigeration, melted ice, and fewer sales. To cope with these disruptions, Doris was forced to rely on daily ice purchases or costly diesel fuel to run her backup generator, eroding profits and exposing her business to ice supply interruptions and volatile fuel prices.

In 2024, Doris replaced her conventional freezer with a solar-powered model from Koolboks, a Nigerian refrigerator company receiving support from CLASP's Productive Use Financing Facility. With reliable access to cooling, Doris can now operate her freezer continuously through power disruptions, avoid expensive stopgap measures, and save money on her energy bills. She estimates that she saves an average of 2,500 Nigerian naira ($1.60 USD) each day on fuel alone. Reliable cooling has also strengthened customer trust and increased beverage sales, allowing Doris to hire two additional sales representatives.

> "Since I [bought a Koolboks fridge], I noticed the business has changed. When my customers come to me saying they have no power supply and ask how I have electricity, I tell them I am using Koolboks to chill my drinks. If you have this [fridge], your business will change."
>
> *Doris Chuwa*

Doris's experience demonstrates how efficient appliances can function as adaptation microinfrastructure by helping small businesses absorb shocks, protect livelihoods, and remain productive amid uncertainty.

Koolboks customer Doris Chuwa in Nigeria.
Credit: CLASP

IRRIGATION PUMPS

Pumps enable farmers to increase the amount of irrigated land on their farm, leading to better product yields. One randomized study of smallholder farmers in three counties in Kenya found that irrigation pumps increased net farm income by 13%.[96] Solar water pumps also can reduce or eliminate diesel fuel costs altogether.

SOLAR OR ELECTRIC GRAIN MILLS

Solar and electric mills significantly cut fuel expenses for operators. Traditional diesel millers spend over 40% of revenue on fuel. One mill manufacturer reports that this spending can be cut to under 1% with an energy-efficient mill, increasing profitability per unit of flour by nearly 70%.[97] These mills can also be located closer to rural communities and reduce the journey to milling centers from 30 to 60 minutes to much shorter distances, saving women and girls countless hours of walking and waiting time.[98]

E-COOKING APPLIANCES

Electric cooking can significantly reduce cooking expenses for the urban and rural poor, freeing up income for other household needs. According to surveys, households and businesses in informal settlements spend an average of 12% of their monthly income on fuel,[99] significantly higher than the 5% of monthly income the World Bank defines as affordable.[100] Transitioning to electric sources of cooking can drastically reduce energy expenditures.

The potential scale of these solutions is enormous. In Kampala, Uganda, where 62% of the population lives in informal settlements,[101] 92% of residents rely on charcoal as their primary cooking fuel, even though 95% of households in informal settlements are connected to the electricity grid.[102]

In a recent incentive program aimed at increasing access to efficient appliances, one female restaurant owner in Uganda reported saving 3,000 Ugandan shillings per day ($0.84 USD) by switching from a charcoal stove to an electric pressure cooker.[viii]

viii Based on internal consumer impact data from PowerUp, a Ugandan electric pressure cooker manufacturer, reported through CLASP's Productive Use Financing Facility (PUFF).

Barriers and Recommendations

Barriers

Unlocking efficient appliances' full potential for adaptation and resilience will require overcoming many barriers, particularly those related to awareness, information, planning, governance, policy, finance, and implementation.

AWARENESS AND INFORMATION BARRIERS

Appliances remain largely invisible to adaptation decision-makers. This occurs not because appliances are ineffective, but because their contributions to resilience are poorly documented, measured, and communicated.

Visibility and awareness

Many decision-makers are not aware of the advances in appliance technology and the success stories linking appliances to resilience. There are many successful case studies and pilot programs, but these stories often circulate in climate mitigation, energy access, or development circles rather than adaptation forums.

This lack of awareness about appliances' potential may bias the adaptation community toward large-scale adaptation projects or nature-based solutions.

Evidence and indicator gaps

Another major reason efficient appliances are undervalued in adaptation planning is the comparative lack of data and quantified evidence explicitly linking them to enhanced adaptive capacity and greater resilience.

Decision-makers rely on assessments of climate risk and option effectiveness. The benefits of appliance efficiency and access are multidimensional and dispersed, meaning traditional cost-benefit analyses or impact models may be unable to capture their true value. It is straightforward to model how a seawall reduces flood damage, but more complex to estimate how a suite of appliances improves a household, business, or community's climate resilience.

In practice, a government assessing agricultural drought vulnerability might consider options like conventional irrigation infrastructure or drought-resistant seeds but overlook solar water pumps due to a lack of quantitative evidence. The availability of trusted evidence and off-the-shelf indicators that answer questions such as "How do you measure the resilience gains from access to a refrigerator?" could help address this problem by enabling governments and adaptation planners to understand who benefits from efficient appliances and how.

Attribution challenges

Demonstrated adaptation benefits are often required of projects seeking financing. For appliances, drawing that direct line requires data. For example, for solar cold chain equipment, one must show that post-harvest losses are increasing with climate change and that solar cold rooms will specifically address the climate-exacerbated part of the problem. This often calls for localized climate impact data, which many countries do not systematically collect.

Overcoming this barrier will require continued effort in data collection and attribution, as well as making that knowledge accessible to those drafting and reviewing climate plans and funding proposals.

PLANNING AND GOVERNANCE BARRIERS

Outdated ideas about what constitutes adaptation, along with siloed governance structures, mean that cross-cutting adaptation interventions like efficient appliances that simultaneously deliver resilience, development, and mitigation benefits often fall outside the mandate of any single ministry or planning process.

Institutional silos and fragmentation

Within governments, adaptation is often coordinated by ministries of the environment or climate change while energy access and appliance programs fall under ministries of energy or agriculture. These ministries often operate in silos with limited collaboration and few frameworks for integrating interventions that span multiple sectors, such as the water–energy–food nexus or cooling for urban labor productivity.

For example, research on African policy shows significant misalignment between climate and development plans, indicating parallel policy tracks rather than integrated strategies for climate-resilient development.

The net effect is that cross-cutting solutions like efficient appliances get overlooked. Despite being critical climate solutions and fundamental inputs for economic transformation, efficient appliances can be neglected in both climate and development plans because they do not fall squarely into either camp. As a result, efficient appliances are counted only toward climate mitigation metrics rather than adaptation and economic development metrics despite delivering multiple benefits beyond avoided energy demand and emissions.

Past framing and financing of adaptation efforts

Climate adaptation's conceptual framing also contributes to appliances' lack of inclusion in adaptation and resilience efforts. Early adaptation discussions revolved around projects like flood control, drought-resistant crops, and disaster preparedness. These types of projects are tangible and important but tend to favor large-scale physical infrastructure like irrigation canals and seawalls or locally based natural resource management like habitat and watershed restoration. Small-scale appliances at the household or enterprise level often do not fit neatly into these framings.

Moreover, under the UNFCCC's historical financing paradigm, the incremental cost model used by funds like the Global Environment Facility or the Green Climate Fund required that adaptation and resilience finance be additional to existing official development assistance. Critics of this approach argue that it created an artificial distinction between adaptation and development priorities.

Lack of cross-sector coordination

Even when governments recognize the need to include priorities like appliance efficiency and access in adaptation, they face coordination hurdles. For example, NAP development processes may lack formal roles for interministerial coordination. Similar to the institutional silos that separate climate, energy, agriculture, water, and development planning, these gaps make it difficult to design and implement cross-cutting interventions that rely on collaboration across ministries.

Capacity constraints

Many countries across the Global South face overarching capacity challenges in adaptation planning and implementation, including a lack of technical expertise and planning tools. These constraints make it harder to incorporate innovative or cross-cutting solutions involving multiple actors. Likewise, governments may not be aware of successful case studies or may not know how to mainstream efficient appliances into adaptation planning. As a result, many find it simpler to stick with known or conventional solutions than to venture into a new territory that they may perceive as complex.

FINANCIAL AND POLICY BARRIERS

Financial and policy barriers are some of the most significant obstacles to scaling efficient appliances in adaptation and resilience efforts. While efficient appliances deliver clear benefits at the household and community levels, prevailing funding models, donor preferences, and policy environments are often poorly suited to decentralized, small-scale interventions. Additionally, high up-front costs for end users and limited access to consumer finance and subsidies prevent efficient appliances from being adopted at the household level. Moreover, weak or outdated policy frameworks can discourage market development and allow for the sale of inefficient products.

Donor priorities and project scales

Funding agencies' preferences can impede the use of efficient appliances as adaptation and resilience solutions. Donor countries and multilaterals often gravitate toward large-scale projects that require tens or hundreds of millions of dollars in financing. Appliance-focused adaptation will require deploying many small units to thousands of households and businesses, making these decentralized solutions appear comparatively small or complex to manage at scale. The transaction cost barrier means it can often be more difficult administratively to fund 100,000 solar water pumps for individual farmers than to fund a single dam, even if the aggregate benefits of the solar water pumps would be even greater.

Limited access to finance, credit, and subsidies for consumers and businesses

High up-front costs of efficient appliances are a primary constraint for households, small enterprises, and farmers, even where life-cycle savings are significant. Low-income (and even middle-income) households may struggle to afford efficient appliances without loans, grants, or subsidies. Innovative financing schemes such as pay-as-you-go (PAYGO) and energy as a service (EaaS) have improved access to efficient appliances but remain undercapitalized.

Without affordable financing and subsidies, households that clearly understand the adaptive value of appliances may still be unable to adopt them. This barrier creates a perverse outcome in which vulnerable households continue to incur climate-related losses that far exceed the one-time cost of an efficient appliance and neither market nor public finance is sufficiently mobilized to bridge up-front costs.

Lack of supportive policies

A lack of supportive policies can discourage the adoption of efficient appliances. Some nations lack strong standards, allowing cheap and inefficient models to flood the market, which can increase energy costs and lead to maladaptation. Policies like minimum efficiency performance standards not only ensure that the worst-performing products are kept out of the market but may also be crucial for adaptation to extreme heat. Updating minimum energy performance standards, along with building codes and mandating the use of efficient appliances in procurement guidelines, could build a supportive policy environment that would enable efficient appliances to diffuse into the market more easily.

IMPLEMENTATION AND MARKET BARRIERS

Even if a country decides to promote appliances for adaptation and can secure funding, practical, on-the-ground challenges can impede scaling. Weak supply chains, limited technical capacity, product quality concerns, and insufficient after-sales service can cause governments to raise questions about the feasibility and sustainability of appliance-focused interventions. In many countries, the enabling market and ecosystem conditions needed for appliances to thrive are underdeveloped. Adaptation institutions may lack experience working with private-sector and market-driven delivery models, and political timelines may not align with the longer horizon required to build viable appliance markets.

Supply chain and quality issues

Many appliances, like specialized solar agriculture technologies, are not readily available in many Global South countries, particularly in rural or peri-urban areas. For example, even if a NAP were to call for the mass deployment of solar cold storage, the local market may not have enough suppliers and technicians to successfully implement such an initiative. As a result, governments may worry that solutions are not well-established or proven locally.

Additionally, past experiences with poor-quality solar products or appliances that break without service support may lead to product quality concerns. Standards and testing are essential for ensuring product quality, as are after-sales service support networks. However, setting up these systems requires effort and coordination with the private sector.

Without confidence in the market's ability to deliver reliability, adaptation planners will continue to favor what they know.

Enabling conditions

Use of efficient appliances alone may not deliver the desired adaptation and resilience benefits. A strong enabling environment and complementary supports are equally necessary, especially in underserved rural areas that often lack infrastructure and human capital. For example, providing access to solar water pumps may not work unless users also have access to spare parts, repair services, and training on optimal irrigation. Similarly, providing a community with a walk-in cold storage room may yield poor results in the absence of strong market linkages and repair networks.

Partnerships for speed and scale

Scaling appliance use in developing nations can be slow and labor-intensive if governments lack the connections and distribution channels to reach the communities that most need efficient appliances. This is particularly true for solar agricultural technologies and other business appliances.

Partnerships with the private sector are essential, but governments might not have experience working with small enterprises or supporting nongovernmental organizations with delivery. At the same time, the adaptation and resilience sector has more experience in working with community-based organizations and large contractors than in stimulating consumer markets. As a result, it might leave out market-driven solutions for lack of a clear template to follow.

Additionally, near-term political cycles mean governments favor quick wins, while appliance markets take time to build. Subsidies, market priming, and capacity-building efforts may take several years to create a market tipping point. This timescale might seem too long and uncertain for five-year NAP implementation cycles.

Recommendations

1

REFRAME EFFICIENT APPLIANCES AS CRITICAL ADAPTATION AND RESILIENCE INFRASTRUCTURE TO UNLOCK NEW PARTNERSHIPS, PROGRAMS, AND FINANCE

Climate finance mechanisms and adaptation strategies often prioritize large-scale infrastructure and locally led initiatives, like wetland restoration and agricultural practices that draw on traditional practices, while overlooking appliances and equipment. As a result, solutions that directly support cooling access, climate-resilient livelihoods, and food and water security remain overlooked or undervalued in planning and finance.

Appliance efficiency advocates should reframe appliances as "microinfrastructure" for adaptation and resilience instead of optional consumer goods. This language should be integrated consistently into NAPs, NDCs, donor strategies, climate fund guidance, and climate and development roadmaps to position appliances alongside other widely recognized adaptation solutions. This shared framing helps individuals across the energy, agriculture, development, and finance communities see appliances as critical adaptation assets.

To reinforce this reframing, civil society organizations, research institutions, and governments should document and disseminate evidence and case studies that show how appliances contribute to adaptation and resilience outcomes like lower heat-related illness, reduced crop losses, and improved incomes. This evidence should be translated into accessible briefs and integrated into global dialogues and guidance materials for governments.

One critical aspect of this effort will be to address barriers that governments, private-sector actors, and other market stakeholders face in obtaining climate finance for appliance energy efficiency and access. Adaptation finance remains mostly focused on large-scale, supply-side infrastructure. Decentralized, demand-side solutions are often underutilized. Even when appliance-based interventions align with adaptation priorities (e.g., food security and water and cooling access), they struggle to secure funding under broad technology-neutral calls.

CLASP estimates that $38 billion USD in public investment is needed to close appliance ownership gaps.[103] These investments are essential to address market failures that limit access to appliances and equipment in off- and weak-grid areas. Public finance should support governments in developing credible policies, building consumer trust, and strengthening the market ecosystem to attract scale-up capital, new entrants, products, and innovation. Grants or very low-cost, high-risk capital will be required. Correcting these market failures can unlock further public and private investment, helping markets mature and scale. In turn, stronger appliance markets can boost electricity demand, improving returns on energy infrastructure investment.

Climate finance institutions like the Green Climate Fund and Adaptation Fund should work to ensure that processes to apply for and access funds are compatible with what is needed to correct appliance market failures and expand access. Climate finance institutions should work to ensure that definitions of adaptation-relevant infrastructure include solutions such as off-grid equipment (e.g., off-grid cold chain equipment and solar water pumps), household appliances (e.g., air conditioners), and devices that enable post-disaster energy service delivery (e.g., solar lighting and solar home systems). These institutions should also explicitly list demand-side energy efficiency and appliances as eligible investment areas for adaptation, not just mitigation. Establishing clear metrics for adaptation outcomes from appliance use, such as improved food security or reduced heat-related illness will further strengthen the investment case and help scale access to these vital technologies.

Donors and climate finance institutions may also consider expanding dedicated calls for appliances or expanding thematic funding calls (e.g., agriculture, health, and cooling) to help ensure that appliance interventions do not get sidelined. Doing so would increase visibility and competitiveness for projects and solutions that promote efficient appliances and help establish a stronger evidence base for appliances as adaptation solutions.

2

DEVELOP APPLIANCE-SPECIFIC ADAPTATION AND RESILIENCE METRICS

Appliances and equipment are largely invisible in adaptation metrics and reporting frameworks. Existing indicators tend to focus on large infrastructure or high-level policy changes, making it challenging to demonstrate, assess, and finance appliance-based interventions at scale.

To strengthen accountability, learning, and resource mobilization, a core set of appliance-specific adaptation indicators should be developed that:

- capture concrete resilience outcomes (e.g., improved food security, reduced heat stress, increased reliability of health and water services, enhanced livelihood stability);
- align with the Global Goal on Adaptation pillars of resilience, adaptive capacity, and vulnerability reduction;[104] and
- can be integrated into existing monitoring systems without excessive burden.

Where possible, indicators should build on tools already developed such as the Efficiency for Access Coalition's Impact Assessment Framework, which can help amalgamate evidence on the impact of solar-powered fans, refrigerators, water pumps, and TVs.

Governments should embed these indicators into NAP monitoring and evaluation frameworks, NDCs, and sectoral monitoring and evaluation systems. To enable data sharing, reduce duplication, and encourage cross-ministerial coordination, indicators should be designed to align with agriculture, water, development, and energy priorities.

Donors and climate finance institutions can catalyze uptake of indicators by supporting the use of appliance-specific indicators in concept notes, funding proposals, and project results frameworks. Civil society organizations and research institutions should develop practical guidance and tools to help governments and program implementers design projects around these metrics, establish baselines, and collect data efficiently. Over time, consistent indicator use will build a strong evidence base and allow appliance-based projects to compete more effectively.

3

EMBED APPLIANCES IN NAPs, NDCs, AND LT-LEDS AND INTEGRATE CROSS-SECTORAL PLANNING

Appliances remain largely absent from national climate plans like NAPs, NDCs, and LT-LEDS. This omission leads to missed opportunities for governments to align policies, attract finance, and accelerate implementation across multiple sectors (e.g., the water–energy–food nexus).

Governments should formally recognize efficient appliances and equipment as climate-resilient infrastructure in core climate policy documents. Appliances like solar water pumps, air conditioners, and refrigeration equipment should be explicitly named as infrastructure vital to achieving national goals.

In NAPs, countries could:

- identify appliances and equipment as key solutions in the agriculture, water, health, and development sectors;
- develop costed appliance implementation roadmaps that specify target populations and geographies, delivery models (e.g., public procurement, public–private partnerships, PAYGO), and indicative financing structures; and
- ground these roadmaps in regular cross-ministerial coordination between climate/environment ministries and line ministries, such as energy, agriculture, water, health, planning, and finance.

In NDCs, governments should present efficient appliances as dual-benefit mitigation and adaptation measures and set quantifiable targets. Examples could include:

- deploying a defined number of solar water pumps to farmers in drought-prone regions; or
- expanding access to efficient cooling for low-income households in heat-exposed cities.

These commitments should highlight co-benefits for energy access, development, and public health to broaden their political and financial appeal.

In LT-LEDS, appliances should be integrated into long-term climate-resilient development pathways, particularly for rural electrification, just energy transitions, and economic development. Governments should frame efficient, climate-appropriate appliances as low-carbon, climate-resilient infrastructure (see recommendation 1) that is critical to helping countries meet long-term development goals under a changing climate.

To make these climate policies operational, governments should strengthen cross-sectoral planning mechanisms, creating bodies such as interministerial task forces or NAP steering committees with formal representation from ministries such as climate, energy, agriculture, health, and planning. The bodies can ensure that appliance interventions are consistently reflected in policies and supporting frameworks, included in budget processes and public investment programs, and prepared as bankable projects for national budgets, multilateral development banks, and climate funds.

4

ENABLE SCALABLE, DURABLE DELIVERY OF APPLIANCES THROUGH STRONG MARKETS, STANDARDS, AND LOCAL IMPLEMENTATION

Even when efficient appliances are integrated into climate plans and fully financed, impacts may be limited due to a poor enabling environment and market conditions. Governments, donors, and implementing partners should focus on creating strong delivery models, efficiency standards, and local capacity to ensure appliances reach vulnerable populations and deliver resilience benefits over time.

Governments and climate finance institutions should use public–private partnerships, results-based financing, and service-based delivery models (e.g., irrigation-as-a-service, cooling-as-a-service) to reduce public implementation burdens and ensure maintenance, user training, and long-term functionality of programs. These models should be paired with targeted subsidies or voucher schemes to reach the poorest and most climate-exposed households.

To prevent maladaptation, governments should strengthen and enforce minimum energy performance standards (MEPS). Labeling programs can also be used and expanded to help consumers make more informed purchases.

Adaptation programs for appliances should also address supply chain, service, and repair challenges from the outset. This may include investing in local technician training, service contracts, maintenance funds, and repair and spare-parts networks to sustain performance beyond initial deployment. Investing in these services can help build government and consumer confidence and reduce failure rates.

Credit: CLASP

TABLE 1 Summary of barriers and recommendations

BARRIER CATEGORY	SPECIFIC BARRIER	IMPLICATIONS	RECOMMENDATION	IMPACT
Awareness and information	Limited visibility or awareness	Appliances are not recognized as adaptation solutions and are excluded from plans and finance	Reframe appliances as adaptation infrastructure; Develop appliance-specific metrics	Elevates appliances as legitimate adaptation assets and builds an evidence base for decision-making
	Evidence and indicator gaps	Lack of quantified outcomes limits inclusion in adaptation planning and finance	Develop appliance-specific metrics	Enables measurement of resilience outcomes such as reduced heat stress and food loss
	Attribution challenges	Difficulty linking appliance use to climate-driven risks weakens funding proposals	Develop appliance-specific metrics; Reframe appliances as adaptation infrastructure	Strengthens causal links between appliances and adaptation outcomes
Planning and governance	Institutional silos	Appliances fall between climate, energy, agriculture, and development mandates	Embed appliances in climate and development plans	Promotes cross-cutting solutions and clarifies ownership and responsibilities across ministries
	Lack of cross-sector coordination	No formal mechanisms exist to design cross-cutting appliance interventions	Embed appliances in climate plans	Establishes coordination structures and joint implementation pathways
	Capacity constraints	Governments lack tools and experience to design appliance-based adaptation programs	Develop appliance-specific metrics; Embed appliances in climate plans	Provides practical guidance and lowers technical barriers

BARRIER CATEGORY	SPECIFIC BARRIER	IMPLICATIONS	RECOMMENDATION	IMPACT
Financial and policy	Donor bias toward easier-to-fund projects	Decentralized solutions appear too small or too complex to finance	Reframe appliances as adaptation infrastructure; Develop appliance-specific metrics	Improves competitiveness of appliance-based projects in adaptation finance
	Limited consumer finance	Households and farmers cannot afford appliances despite life-cycle savings	Enable delivery through markets and standards	Reduces first-cost barriers through subsidies and innovative financing
	Lack of supportive policies	Inefficient products undermine confidence and risk maladaptation	Enable delivery through markets and standards	Strengthens MEPS, labeling, and procurement policies
Implementation and market	Weak supply chains, service networks, and quality concerns	Governments doubt feasibility and long-term performance	Enable delivery through markets and standards	Builds local delivery, maintenance, and repair ecosystems; Uses standards, testing, and after-sales support to reduce risk
	Weak market linkages and enabling conditions	Productivity gains from efficient appliances cannot translate into resilience or income without reliable access to markets, buyers, and value chains	Enable delivery through markets and standards	Builds market ecosystems so productivity gains deliver lasting resilience
	Limited delivery partnerships	Governments lack channels to reach vulnerable populations	Enable delivery through markets and standards; Embed appliances in climate plans	Aligns market delivery models with public planning and finance


Credit: CLASP

Definitions

There are many definitions for climate change adaptation and resilience. This brief uses the same terminology and definitions as the Intergovernmental Panel on Climate Change (IPCC). We have also included a definition for appliances that is broader in scope than many others.

ADAPTATION

In human systems, the process of adjustment to actual or expected climate and its effects in order to moderate harm or exploit beneficial opportunities. In natural systems, the process of adjustment to actual climate and its effects; human intervention may facilitate adjustment to expected climate and its effects.[105]

ADAPTIVE CAPACITY

The ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond effectively to consequences.[106]

APPLIANCE

A piece of equipment or machinery designed to perform a specific task using an externally supplied, nonhuman powered energy source, such as electricity or fossil fuels. CLASP's definition of appliances and equipment is broad in scope, spanning the residential buildings, commercial buildings, industrial, and agriculture sectors and encompassing small-scale, plug-and-play products that deliver everyday services like cooking and cleaning as well as customized products installed as part of systems that focus on delivering services at scale. Examples include home appliances (e.g., refrigerators and televisions), lighting equipment (e.g., light bulbs and tubular lighting), space cooling equipment (e.g., fans and air conditioners), space heating equipment (e.g., heat pumps and boilers), industrial equipment (e.g., electric motor systems and boilers), and agricultural equipment (e.g., solar water pumps and milling equipment).

RESILIENCE

The capacity of interconnected social, economic, and ecological systems to cope with a hazardous event, trend, or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure. Resilience is a positive attribute when it maintains capacity for adaptation, learning, and transformation.[107]

Acronyms and Abbreviations

AC	Air Conditioner
BLDC	Brushless Direct Current
COP	Conference of the Parties
EaaS	Energy as a Service
GGA	Global Goal on Adaptation
Gt	Gigaton
HAP	Heat Action Plan
HFC	Hydrofluorocarbon
HVI	Heat Vulnerability Index
IEA	International Energy Agency
IIED	International Institute for Environment and Development
IPCC	Intergovernmental Panel on Climate Change
kW	Kilowatt
LT-LEDS	Long-Term Low Emission Development Strategies
MEPS	Minimum Energy Performance Standards
NAP	National Adaptation Plan
NDC	Nationally Determined Contribution
NDMA	National Disaster Management Authority
PAYGO	Pay-As-You-Go
PUFF	Productive Use Financing Facility
R&D	Research and Development
SDG	Sustainable Development Goal
SEforALL	Sustainable Energy for All
SWP	Solar Water Pump
TW	Terawatt
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollar

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