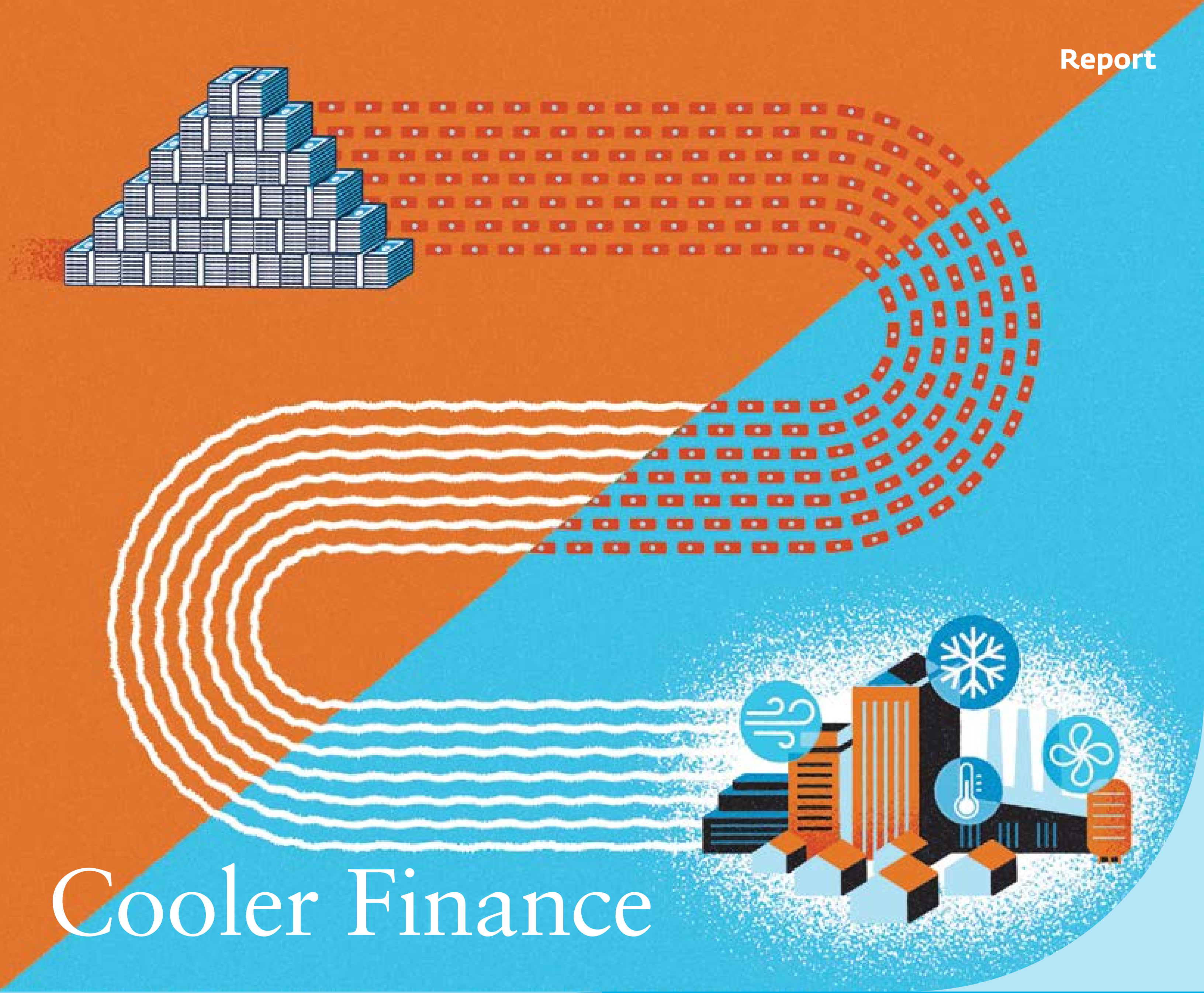
Report



Cooler Finance

Mobilizing Investment for the Developing World's Sustainable Cooling Needs

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Cool Coalition

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IFC International Finance Corporation WORLD BANK GROUP

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UK Government

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Abbreviations and Acronyms

ACES	Africa Centre of Excellence for Sustainable Cooling and Cold-Chains
AFAWA	Affirmative Finance Action for Women in Africa
ASF	Avaana Sustainability Fund
BAU	Business as Usual
BOO	Build-Own-Operate
BOOT	Build-Own-Operate-Transfer
B2C	Business to Consumer
B2B	Business to Business
CaaS	Cooling-as-a-Service
CCAC	Climate and Clean Air Coalition
CAPEX	Capital Expenditures
CDD	Cooling Degree Day
CDM	Clean Development Mechanism
CIF	Climate Investment Funds
COP	Conference of the Parties
CO2e	Carbon Dioxide Equivalent
EPC	Energy Performance Contract
ESCO	Energy Service Company
ESMAP	Energy Sector Management Assistance Program
GABC	Global Alliance for Buildings and Construction
GCCA	Global Cold Chain Alliance
GCF	Green Climate Fund
GDP	Gross Domestic Product
GEF	Global Environment Facility
GIZ	German Society for International Cooperation
GWP	Global Warming Potential
HFC	Hydrofluorocarbon
IEA	International Energy Agency
IFC	International Finance Corporation
ILO	International Labour Organization

IRENA	International Renewable Energy Agency
K-CEP	Kigali Cooling Efficiency Program
MEPS	Minimum Energy Performance Standards
MLF	Multilateral Fund for the Implementation of the Montreal Protocol
MP	Montreal Protocol
MSME	Micro-, Small, and Medium-sized Enterprises
NCAP	National Cooling Action Plan
NDC	Nationally Determined Contribution
NGO	Non-Governmental Organization
OBF	On-Bill Financing
OEM	Original Equipment Manufacturer
OWF	On-Wage Financing
PAYG	Pay-As-You-Go
PPP	Public-Private Partnership
R&D	Research and Development
SECO	Swiss Secretariat for Economic Affairs
SEforALL	Sustainable Energy for All
SDG	Sustainable Development Goals
SME	Small and Medium-Sized Enterprises
SWAC	Seawater Air Conditioning
TE-SCI	TechEmerge Sustainable Cooling Innovation
TES	Thermal energy storage
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNIDO	United Nations Industrial Development Organization
U4E	United for Efficiency
WBG	World Bank Group
WMO	World Meteorological Organization
WWR	Window-to-Wall Ratio

Foreword

As the world heats up, rapidly increasing access to sustainable cooling has become a global development priority. While 3.5 billion people, mostly from developing countries, live in hot climates, most do not have access to thermal comfort. Health-related impacts are increasing morbidity and mortality and generating substantial productivity losses. Insufficient vaccine cold chains are costing lives. About one-third of global food production is lost or wasted, in part due to inadequate cold storage and transportation.

However, increasing access to cooling must not come at the price of higher emissions, especially across developing economies that account for two-thirds of global cooling-related greenhouse gas emissions.

As highlighted in the earlier Global Cooling Watch report and the Global Cooling Pledge—signed by governments, businesses, and other organizations at COP28—increasing access while slashing emissions is feasible through joined-up sustainable cooling policies that integrate passive cooling, energy efficiency and a faster phase down of climate-warming refrigerants. This includes developing national cooling plans, establishing and enforcing standards, holistic building energy codes, smart urban planning, fiscal incentives, public funding, as well as financing and technical assistance from international organizations.

Perhaps the most important element, however, is a massive increase in investment from the private sector. Critical to this rapid scaling of investment will be greater global collaboration and ambitious policy changes. This report on scaling up private financing, from the International Finance Corporation (IFC) and the United Nations Environment Programme (UNEP)-led Cool Coalition, is a step towards achieving this goal.

The report quantifies sustainable cooling investment needs and financing gaps, highlighting many opportunities for private investors in a market that could grow to more than half a trillion dollars per year by 2050. Accelerating the adoption of passive cooling, energy efficiency and refrigerant phase down, would reduce electricity consumption, spending on equipment, and future power sector investments by more than $8 trillion in developing countries over the next 25 years.

The report lays out barriers to scaling up private finance, showcases financing solutions and innovations and provides recommendations to deliver on the Global Cooling Pledge. These include improving market data and evidence, promoting the business case for investable projects, prioritizing financing for passive cooling, expanding financial instruments for technological innovation, improving policy and regulatory frameworks and enforcement capacities, and increasing the use of concessional finance to support sustainable cooling solutions for those most in need.

IFC and UNEP are committed to working with governments and the private sector in these areas. Millions of lives are at stake, so we are pleased to launch this report to help jumpstart concrete commitments and actions to scale up private finance for sustainable cooling across developing countries.

INGER ANDERSEN

Executive Director, United Nations Environment Programme

MAKHTAR DIOP

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Executive Summary

With many of the world's poorest populations living in regions prone to episodes of extreme heat, it is clear that governments, multilateral institutions, and investors seeking to foster development should put sustainable cooling at the center of their plans. Indeed, with the global climate continuing to warm and dangerous weather events becoming increasingly frequent, that priority is becoming ever more urgent.

This analysis shows that meeting expanding needs for cooling solutions in developing economies presents a business opportunity to private investors and providers of cooling products and services, amounting to annual demand that will reach at least $600 billion by 2050.

Ensuring populations have access to cooling—for human comfort as well as preserving perishable goods—means workers are more productive, farmers can deliver produce to market before it spoils, and healthcare services can provide life-saving vaccines. These are desirable development outcomes and especially benefit the most vulnerable members of society such as women and children.

But meeting existing shortfalls in cooling is not enough. Demand for cooling is rising, not just because of economic and population growth, but also due to expected increases in global average temperatures. This presents a dilemma. More air conditioners and refrigeration systems mean higher demand for power, and generating more power threatens to trigger an increase in fossil fuel emissions that warms the climate further. To avoid this vicious cycle, therefore, cooling solutions must be sustainable, prioritizing energy-efficient technology and maximizing reliance on so-called passive strategies like using reflective materials to keep heat out or planting trees for shade.

This report builds on the United Nations Environment Programme's (UNEP)-led Global Cooling Watch, released in 2023, that highlighted the urgency of adopting "accessible, affordable, and scalable" cooling solutions that do not harm the planet.

This new analysis finds that the market for sustainable cooling in developing economies is set to double in size by 2050 from around $300 billion in annual demand currently. Much of this will be attributable to so-called active cooling solutions that use power sources such as fans, air conditioners, and refrigeration equipment. Passive measures currently account for about 10 percent of the market for cooling solutions in developing economies, according to this analysis. Uncertainties about future regulation and other trends make it difficult to forecast how the market for passive solutions will evolve. But while this report stops short of making such predictions, it acknowledges their role will be fundamental.

Currently, the biggest market segments are the provision of space cooling to both homes and commercial premises, and non-residential refrigeration. The fastest growth in cooling is expected in Africa, which will see the market multiply by a factor of seven, and South Asia, which will quadruple in size.

Meanwhile, scaling up the adoption of sustainable cooling across developing countries could cut consumers' electricity bills by as much as $5.6 trillion over the next 25 years, and reduce the amount of new investment needed in new power generation to meet peak electricity demand by $1.8 trillion. Greater reliance on passive measures and the use of more energy efficient refrigeration, fans, and air conditioning could also reduce cumulative spending on cooling equipment by around $800 billion.

Successful outcomes will depend on adequate access to finance, meanwhile. Indeed, simply closing existing shortfalls in access to cooling in developing economies will require between $400 billion and $800 billion, according to the estimates in this report, without accounting for future increases in demand.

But low awareness of the business case for investing in sustainable cooling as well as a lack of knowledge about the available financing solutions is limiting the amount of capital available for sustainable cooling in markets that need it most. This study aims to address some of these gaps.

Sustainable cooling needs to become as much of a fixture of development finance as other established climate-related areas such as carbon capture, renewable energy infrastructure, or battery technology which benefit from embedded institutional support from governments and multilateral institutions.

Governments and regulators have a critical role to play in creating an enabling environment to make sustainable cooling in developing economies more attractive to investors. The Global Cooling Pledge, agreed at the COP28 climate conference in 2023, amounted to a commitment by governments, businesses and other organizations to enhance energy efficiency while ensuring equitable access to cooling. This report recommends that governments should also, with support from multilateral agencies, focus on financing underlying infrastructure and address the cooling needs of challenging market segments affected by affordability constraints. Another step would be for national and sub-national governments to lead by example in prioritizing sustainable cooling in their own public procurement activities.

While developing country governments have limited spending power due to fiscal constraints, they can pursue public-private partnerships and encourage concessional funding, backstopping risk for private investors and attracting more capital to their economies.

This report aims to help investors and providers of cooling solutions, as well as private, public, and international financiers, identify the commercial potential in sustainable cooling, and respond with appropriate business models and financing mechanisms. It makes a business case for adopting or transitioning to sustainable cooling solutions and aims to help financiers better analyze the growth potential and market risks. In short, its purpose is to close the knowledge gaps that are stymying private investment flows into an area that is as vital for nurturing development as it is for supporting global efforts to confront and mitigate climate change.

Other key findings in the report include:

A variety of financing mechanisms are available to address the distinct requirements of the cooling market's diverse segments. The market landscape includes residential and non-residential space cooling, multiple uses of refrigeration, and transportation. So-called cold chains—supply chains for delivering perishable goods to market—are made up of multiple stages controlled by many different operators, each of which has its own distinct features and needs. Participants in cooling markets include equipment manufacturers, service providers, and designers of passive solutions in construction or urban design. They range from innovators and startups to multinational enterprises. Finance solutions must therefore be varied enough to reflect such disparities. While startups require seed capital and equity to fund innovation, more established equipment manufacturers, developers of green buildings, and suppliers of insulation materials are more likely to need debt financing to fund expansion plans and meet working capital needs. From the perspective of consumers, more efficient equipment promises lower long-term costs because it consumes less power but it is often more expensive to buy and install. Providing household and small firms with finance facilities to help them spread these high upfront costs will encourage wider adoption.

It is clear, therefore, that in terms of finding solutions for sustainable cooling needs in emerging markets, one size does not fit all. The report outlines a variety of financing mechanisms applicable to sustainable cooling, such as revolving funds, working capital loans, results-based finance, risk-sharing facilities, conventional equity, cooling bonds, and carbon offsets. It also highlights the role of concessional financing to demonstrate the feasibility of certain cooling markets and business models, and ways for development finance institutions to act as sources of leverage and private capital mobilization.

There are several response strategies already in place throughout developing countries that promote private and public investment in sustainable cooling and mitigate some of the barriers to widespread adoption. These include regulatory measures like enforcement of minimum energy performance standards and new building codes, systems approaches to supply chains, incentives to promote innovation, and the adoption of nature-based solutions for outdoor heat reduction.

Complementing these, different business models that encourage wider adoption of sustainable cooling are also becoming increasingly established. These include bulk procurement to reduce prices per unit, as well as initiatives to lower the burden of upfront costs such as the provision of cooling-as-a-service, on-bill financing, and pay-as-you-go programs.

But multiple challenges remain around affordability, poor access to electricity, skills shortages, and the inherent complexity of cold chain systems. Another major problem to overcome is the fact that cooling is not traditionally regarded as a standalone concept so much as a component within broader projects, much less the defining feature of a standalone financial asset class. Developing economies are also often burdened with weak institutions, making effective regulation, administration, and enforcement of standards difficult.

To address these challenges and ensure that adoption of sustainable cooling gains momentum in developing markets, the report offers a series of recommendations aimed at public and private sector stakeholders. They focus on financing and are complementary to the prescriptions outlined in the Global Cooling Watch report. The recommendations are:

Multilateral organizations, development finance institutions, and Cool Coalition members should work with local businesses and financial sector associations as well as national and subnational governments to:

Improve underlying data on cooling by building consensus around definitions, metrics, and methodological assumptions, differentiating sustainable cooling applications as well as providing information on capital costs and financing.

Develop and implement a comprehensive strategy, led by coordinated efforts in the public sector, which addresses issues identified in this report as hindering the mobilization of private finance for sustainable cooling.

Amplify dissemination strategies targeting key local cooling market stakeholders to improve awareness of business opportunities presented by the transition to sustainable cooling, including those related to financing.

Provide technical assistance to national and subnational governments as well as regulators, donors, investors, and financiers on:

- Prioritizing financing for the adoption of passive cooling strategies.

- Incorporating blended and concessional finance in the design of business models and funding mechanisms to address barriers to scaling-up tested technologies and affordability constraints.
- Adapting existing business models and financing instruments to support transitions to sustainable cooling.
- Promoting the development and financing of large cooling infrastructure services with development finance institutions also providing funding to financiers and co-financing opportunities to donors and investors in these areas.

Development finance institutions should work with entrepreneurs and mobilize local and international investors to:

> Increase seed and risk capital funding for pilot technologies and business models and disseminate results to relevant audiences.

Multilateral organizations, development finance institutions and Cool Coalition members should:

> Create a Sustainable Cooling Finance Partnership to foster international cooperation.

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The Urgent Need For Sustainable Cooling Solutions in Developing Countries

Global temperatures are rising. The year 2023 was the hottest ever, each decade since the 1980s was warmer than the previous one, while the average temperature over the past nine years was the highest on record.[1]

Rising temperatures are highlighting shortfalls in cooling that have fatal consequences, particularly in less-developed economies. Currently, around 3.5 billion people live in climates defined as "hot," the majority of these in developing countries.[2] However, only a small fraction of this population has access to cooling. Only 15 percent benefit from air conditioning[3] while even 'passive' low-tech solutions such as insulation or design that incorporates more efficient orientation or shading are out of reach for poorer groups.

Heat-related deaths are already running at an annual average close to 500,000 while the rate among over 65s is projected to increase almost four-fold by 2050 from around 300,000 per year in 2018.[4] At the same time, poor access to refrigeration makes it difficult to store perishable vaccines, resulting in thousands of preventable deaths from disease—particularly among children—while about one third of food produced is lost.[5]

There is an urgent need, therefore, to close cooling gaps in developing countries. However, air conditioning and refrigeration require energy and generating the power to meet that extra demand threatens to create more greenhouse gas emissions. Therefore, addressing shortfalls in developing world cooling access without undermining climate commitments must involve global adoption of sustainable cooling solutions.

This is why cooling is now widely recognized as a global challenge due to the vicious cycle that inadequately addressing rapidly increasing adaptation needs may imply for climate change. The 2023 Global Cooling Watch report[6] shows that without additional measures to improve existing solutions, annual emissions from cooling will double by 2050 and account for the equivalent of more than 10 percent of global greenhouse gas output (see Box 1.1). Furthermore, the problem is aggravated as rising cooling demand increases peak power requirements, which makes it more difficult to retire fossil fueled power plants.[7]

Therefore, it is imperative to accelerate the transition toward sustainable cooling solutions

1 WMO (2024).

2 Defined as locations with yearly Cooling Degree Days exceeding 2,000 (See Footnote 9).

3 For air conditioning penetration see IEA (2023); Basic passive cooling measures include shading, insulation and cool roofs, among others.

4 For global heat-related estimated deaths see Zhao et al. (2021); For estimates of heat-related deaths for those over 65, Watts et al. (2020) estimated 296,000 heat-related deaths by 2018. In addition, Romanello et al. (2023) estimated that heat-related mortality of people older than 65 years would increase 370 percent by 2041–2060, compared to 1991–2014.

5 See FAO (https://www.fao.org/nutrition/capacity-development/food-loss-and-waste/en/) and Shann and Steinhoff (1999).

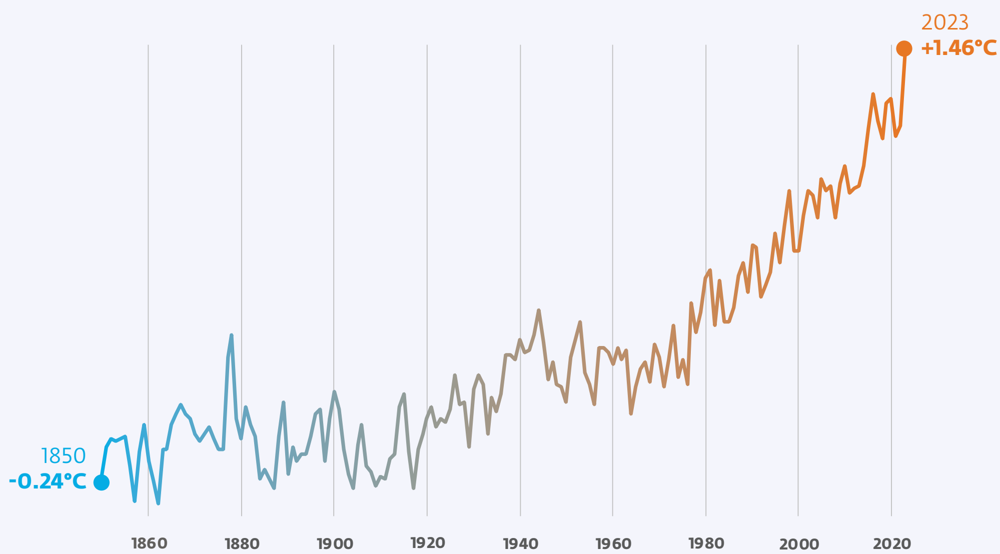
6 UNEP (2023a).

7 In early 2024, Mexico City and other states throughout the country experienced high temperatures leading to a surge in energy demand that triggered widespread blackouts. Cenace, the country's national energy authority, declared a state of emergency. This followed reported power plant shutdowns in the Philippines due to a heat wave that impacted the region.

FIGURE 1.1

The World Is Heating Up at an Accelerated Pace

Global mean temperature difference (compared to 1850-1900 average)



Source: World Meteorological Organization

Note: This graph uses data from Berkeley Earth, one of six datasets used by the WMO to monitor global temperatures, alongside HadCRUT5, NOAA, GISTEMP, JRA-55, and ERA5. All datasets show similar patterns.

using technologies that are accessible, affordable, and scalable, cause minimal impact on people and the environment, and reduce greenhouse gas emissions.[8] This includes passive design strategies for cooling to provide thermal comfort indoors—through insulation, coating, use of selected materials—and outdoors—using nature-based solutions like trees as well as cool surfaces. It also includes active cooling with energy-efficient equipment free of HFC refrigerants that contribute to global warming. When discussing the concept of the 'Cold Economy,' Peters and Sayin (2022) showed that the deployment of sustainable cooling contributes simultaneously to the United Nations' Sustainable Development Goals, the Kigali Amendment to the Montreal Protocol, and the Paris Agreement.

One of the key implications of the Global Cooling Watch (see Box 1.1), is that accelerating the transition toward sustainable cooling will require, not only policy action from governments alongside financing and expertise from

8 "Cooling technologies and approaches that are accessible, affordable and scalable but that minimize the impacts on people and the planet, including through large reductions in greenhouse gas emissions." Definition used in the 2023 Global Cooling Watch report, based on Khosla et al. (2021).

international organizations, but also massive private sector investment in both passive strategies and efficient equipment.

The majority of people exposed to extreme heat events are among the poorest populations in developing countries for whom affordable and sustainable cooling solutions are largely out of reach. Out of 21 countries in Africa (with an average of 2,900 Cooling Degree Days)[9] where data on ownership rates for air conditioning is available, only four exceed 10 percent and none are higher than 60 percent. In contrast, almost 90 percent of households in the United States used air conditioning in 2020.[10] Access to reliable power, a key feature of the UN's Sustainable Development Goals,[11] is an underlying structural factor affecting to the availability of cooling across emerging economies.[12] Data from the World Bank shows that in more than 80 percent of low-income countries and one-third of lower middle-income countries, less than 70 percent of the population has access to electricity.

The 2023 Global Cooling Watch report stresses that in a warming world, cooling is a fundamental necessity and there is increasing consensus about highlighting access to adequate cooling, especially for the most

9 Cooling Degree Days (CDDs) are defined as the cumulative number of degrees that the daily average temperature over a given period (here a year) is above a specified threshold (here 18 °C), adjusted for humidity.

10 U.S. Energy Information Administration (2022).

11 Sustainable Development Goal 7, to ensure access to affordable, reliable, sustainable, and modern energy for all, available at https://sdgs.un.org/goals/goal7.

12 Sustainable Energy for All (SEforALL) works across countries in this area to ensure universal access to affordable and reliable energy services, increase the share of renewable energy in the global mix, and double the rate of improvement in energy efficiency. For more details see https://www.seforall.org/.

BOX 1.1

Global Cooling Watch Report: Cooling-Related Emissions Projections

The 2023 Global Cooling Watch report, led by UNEP and prepared through the collaborative effort of Cool Coalition members, looks at three action areas to deliver sustainable cooling: deploying passive cooling measures to reduce cooling loads, higher efficiency standards, and a phase down of climate-warming hydrofluorocarbon (HFC) refrigerants at a faster rate than is required under the Kiga Amendment to the Montreal Protocol. The report undertakes, for the first time, modeling of the totality of emissions, both direct and indirect to provide a pathway to near-zero emissions from cooling. The underlying Global Cooling Emissions model is calibrated with data up to 2022, to generate cooling demand projections up to 2050. The emissions baseline is defined as "business as usual" (BAU) cooling demand growth and considers additional demand growth from improved access to cooling services.

In 2022, cooling-related emissions amounted to 4.1 billion tons of carbon dioxide equivalent (CO_2e), representing 7.1 percent of total global greenhouse gas emissions, which were approximately 57.4 billion tons.[1] Under the BAU "Without Measures" scenario, cooling emissions are estimated at 9 billion tons by 2050. This could constitute 16.3 percent of global emissions by 2050, assuming the median projection under current policies from the UNEP 2023 Emissions Gap report,

1 UNEP (2023c).

highlighting the urgent need for cooling-related mitigation efforts. The analysis presents a "BAU Cooling Measures" scenario steadily reducing emissions via existing cooling-related policy measures that slowly improve energy efficiency. It also showcases a pathway to near zero cooling-related emissions, defined as "Best Cooling Measures" plus a rapid power grid decarbonization. The Best Cooling Measures scenario is achieved through measures in the three key areas for sustainable cooling, an HFC phase down that goes faster than the Kigali Amendment, passive design strategies to reduce cooling loads, high efficiency active cooling equipment and improved operation of existing equipment.

The strategies outlined in the Global Cooling Watch report could decrease cooling loads (from active cooling equipment) by 24 percent (through the adoption of passive design strategies) and deliver near-zero carbon programs (through on-site renewables and grid decarbonization), while simultaneously increasing access to cooling for 3.5 billion additional people. On the policy side, the report also provides a comprehensive overview of national policy and regulatory actions across all cooling sectors for 192 UN member states.

Global Pathway and Key Steps to Achieve Near Zero Emissions from Cooling, 2022-2050

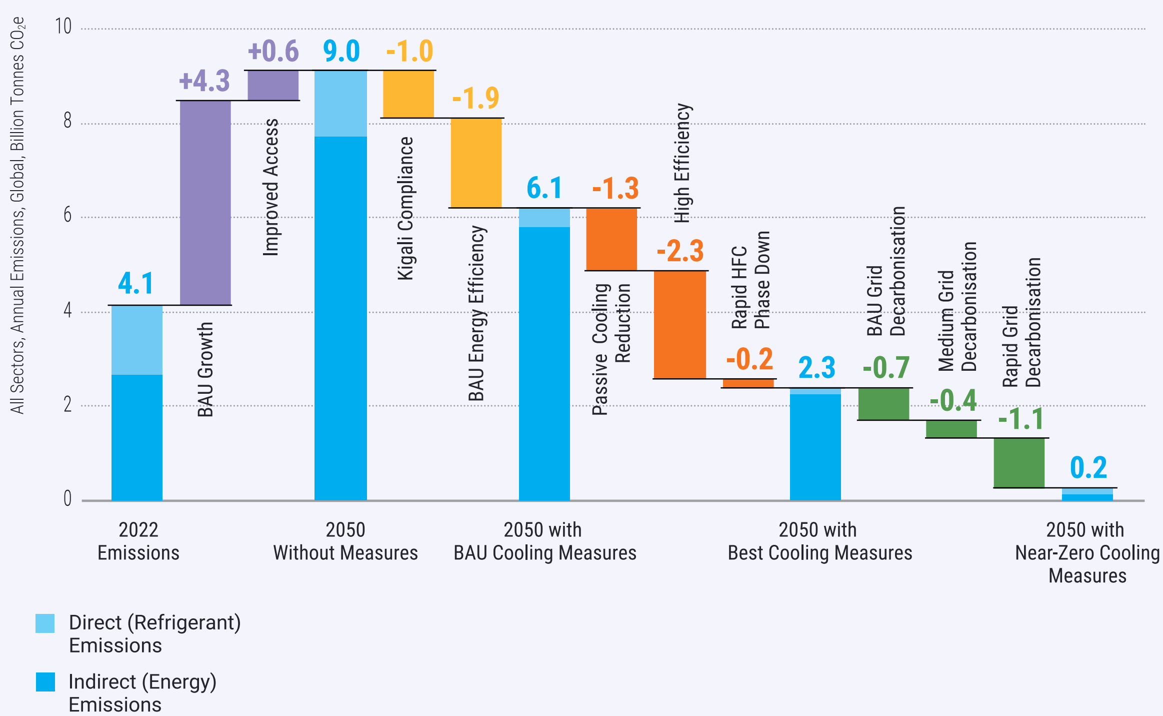
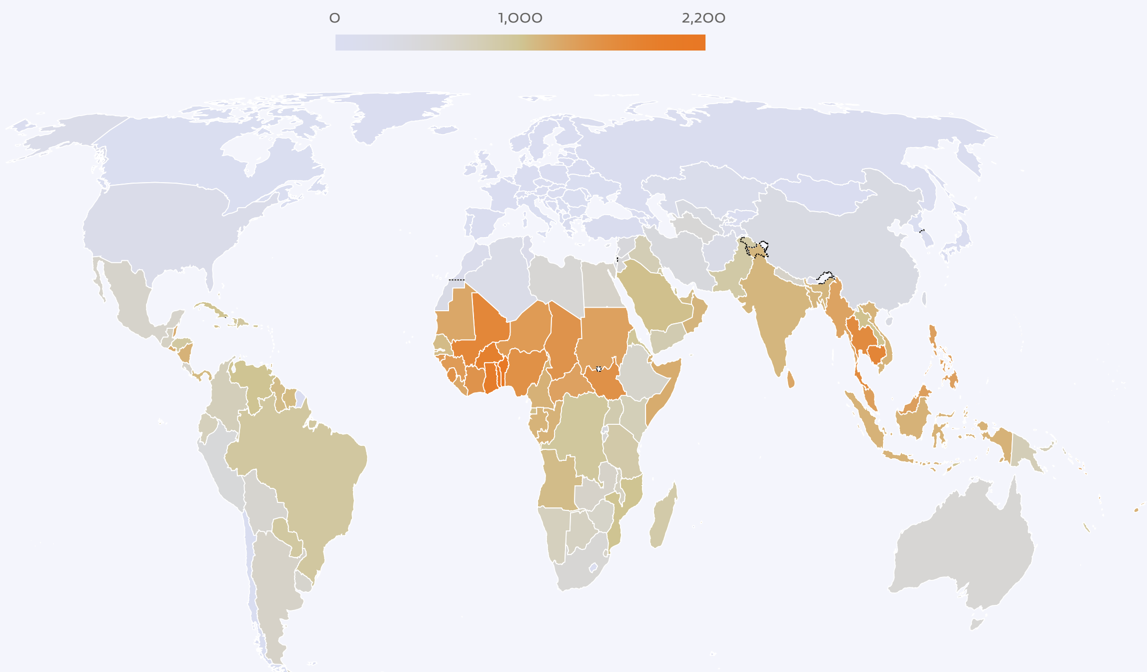


FIGURE 1.2

Developing Countries Are the Most Exposed to High Temperatures

Annual Cooling Degree Days (CDDs, 18.3 °C-day), 2021



Source: IEA (2024)

vulnerable, as a human right.[13] Sustainable cooling is not only a climate mitigation issue centered on emissions reduction through greater efficiencies, it is also critical to climate adaptation and the safeguarding of food safety and health for disadvantaged populations.

There is an interplay between urban areas, which face the challenge of heat island effects and large numbers of poor households with no access to cooling solutions, and rural areas, which must adapt to rising heat amid an absence of cooling for human health and food value chains. However, even the most efficient cooling technologies cannot entirely prevent public safety emergencies for vulnerable populations if they are plugged into an unreliable and collapse-prone power grid during episodes of extreme heat. In this regard, when featuring cooling as an infrastructure service—alongside electricity, water, or gas—the evidence of large cooling gaps across developing economies is

13 Mutiso et al., (2022).

FIGURE 1.3

Sustainable Cooling in Developing Countries is Critical for the Global Cooling Agenda

Greenhouse gas emissions from cooling by country groups

Source: UNEP (2023a)

Note: A2 and A5 regions are defined under the Kigali Amendment to the Montreal Protocol. Article 2 (A2) countries are mostly developed nations with immediate HFC reduction targets, while Article 5 (A5) countries are primarily developing nations with extended deadlines. A complete list of countries is available at https://ozone.unep.org/classification-parties.

clear in suggesting that infrastructure is insufficient where it is needed the most. There is a significant risk that climate adaptation and cooling gaps will be addressed with inefficient conventional cooling technologies, as opposed to sustainable alternatives over the coming decades. Therefore, it is crucial that access to cooling solutions follows a sustainable pathway. This is an enormous challenge. Many developing countries face significant shortages of the necessary technical skills to innovate, produce and implement sustainable cooling, and are often characterized by insufficient regulation and enforcement capacity.

Moreover, implementing sustainable cooling across developing countries is a key pillar of the global cooling agenda. Following the baseline analysis in the 2023 Global Cooling Watch report, about two thirds of emissions related to cooling in 2022 came from developing countries and this share could grow above 80 percent by 2050 (see Figure 1.3). The expected increase in the share of cooling-driven emissions is underlined by higher average temperatures in developing countries (see Figure 1.2) coupled with expectations of higher economic and population growth as well as urbanization in the coming decades, compared to developed economies.

1.1 Implementing Sustainable Cooling is Critical to Addressing Urgent Adaptation Needs and Meeting Sustainable Development Goals

The importance of addressing needs for cooling with sustainable solutions is critical to enabling developing countries to meet climate targets as well as development goals in areas such as health, food security, and productivity, as shown in Figure 1.4.[14]

With regard to health, access to cooling helps prevent deaths amid increasingly extreme and frequent heat waves. It enables the distribution and storage of vaccines in regions with hot climates, thereby preventing a variety of diseases, as well as improving provision of other healthcare services.[15] Analysis from the 2023 Lancet Countdown report shows that under a scenario where global temperatures rise to 2°C above pre-industrial levels, annual heat-related deaths among people older than 65 could increase 370 percent by 2050 if no substantial progress is made on adaptation, with populations across developing countries facing more days of exposure to life threatening temperatures.[16] Moreover, evidence from Falchetta et al. shows a significantly higher exposure to heat across the global south.[17] Meanwhile, according to the World Health Organization, vaccines—which are perishable and require effective cold storage—prevent 3.5–5 million deaths every year while data from UNICEF show that low and middle-income countries have the lowest vaccination coverage among children.[18]

With respect to food security, according to the Food and Agriculture Organization of the United Nations (FAO) most of the 702 to 828 million people that experienced hunger in 2021 lived in Asia, Africa, and Latin America and the Caribbean.[19] Yet paradoxically, developing economies in these regions see substantial food loss in part due to the lack of adequate and integrated cold chain[20] infrastructure and access to refrigeration by households. In addition, heat and animal stress in the dairy sector is causing lower productivity. According to another report from the FAO in 2019, global post-harvest food losses before distribution are about $400 billion per year, which corresponds to 14 percent of total food production.[21] Food loss across developing countries is as high as 20 percent in Central and Southern Asia, while the rate in Africa is in line with the global average. Latin America and the Caribbean as well as Western

14 For a detailed discussion about cooling and the Sustainable Development Goals see Khosla et al. (2021).

15 A group comprising some of the largest development banks formed the "Development Bank Working Group for Climate-Health Finance" and issued a "Joint Roadmap for Climate-Health Finance and Action" in June 2024.

16 See Romanello et al. (2023). Figure 2 in the report shows that Small Islands Developing States, Africa, Asia, and South and Central America are the regions with the highest rate of exposure to days in which temperatures exceed a threshold over which heat-related deaths are more likely.

17 Falchetta, et al. (2024).

18 See WHO at https://www.who.int/health-topics/vaccines-and-immunization#tab=tab_1, and UNICEF at https://data.unicef.org/topic/child-health/immunization/.

19 FAO et al. (2022).

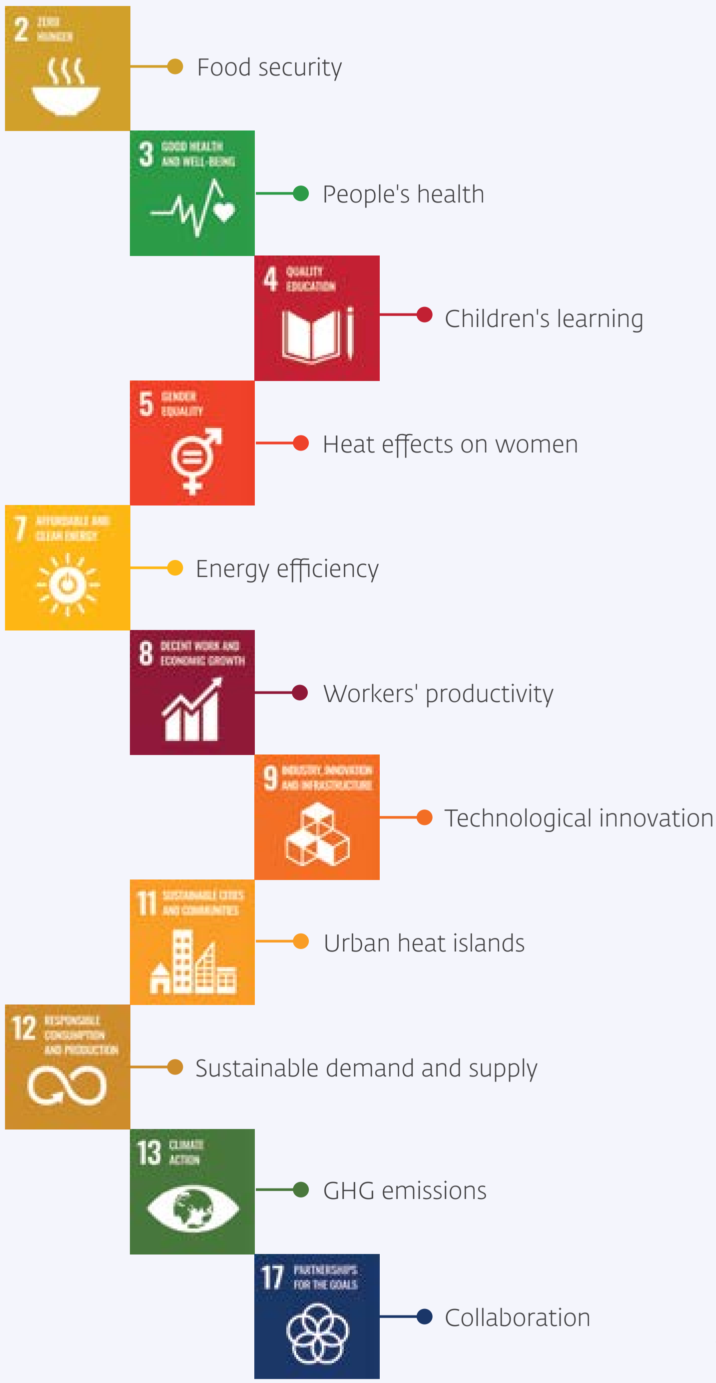
20 A cold chain is the set of procedures to coordinate temperature control across a supply chain for perishable goods such as food and medical supplies.

21 Following FAO (2019), food loss is all the food produced that completely exits the post-harvest/ slaughter/catch supply chain by being discarded, incinerated, or otherwise disposed of. On the other hand, food waste also occurs between the retail and final consumption stages. UNEP (2021a) estimated food waste to be equivalent to an additional 17 percent of global food production.

FIGURE 1.4

Sustainable Cooling is Fundamental to Countries' Development

Impact of sustainable cooling on the Sustainable Development Goals



Source: Authors

Note: For a full list of the UN's Sustainable Development Goals, see: https://sdgs.un.org/goals/

Asia and Northern Africa see food loss marginally above 10 percent.[22] Furthermore, UNEP estimates that annual household food waste in lower-middle income countries is 91 kilograms per capita, which is 15 percent higher than in high-income countries.[23] In addition, food losses at the farm gate to retail stage of distribution lead not only to income losses for farmers (and governments) but also to more organic waste at landfills, resulting in methane emissions.[24]

Adding to structurally low levels of productivity across developing economies, increasing temperatures in already warm countries pose additional challenges to workers' and students' productivity. According to the latest estimates from the International Labor Organization (ILO). over 70 percent of workers around the globe are exposed to excessive heat.[25] In its 2019 study, the ILO estimated that heat stress would imply a loss of working hours equivalent to 80–136 million full-time jobs and a loss in global gross domestic product (GDP) of $2.4 trillion in 2030, with "the impact of heat stress being most pronounced in lower-middle and low-income countries."[26] For instance, extreme heat, which tends to be more probable in developing economies, generates hazardous working conditions for agriculture workers who constitute more than 60 percent of labor in low-income, and close to 40 percent of workers in lower-middle income countries.[27]

Workers in other important industries for many developing economies like manufacturing and construction, are also exposed to hazardous conditions due to work being carried out in direct exposure to the sun or because of inadequate cooling.[28] In addition, heat stress also affects the well-being of children, implying lower school attendance in addition to physical and mental health effects. In this regard, UNICEF estimates that by 2050 "almost every child in the world—nearly 2.2 billion children—will be exposed to frequent heat waves."[29] Thus, resilience to these conditions will be highly dependent on schools' and children's access to adequate cooling. Unfortunately, education systems in developing economies are not yet well prepared to respond appropriately to extreme heat events.[30]

High temperatures have differentiated effects for women across developing economies, adding to existing inequalities. In line with one IFC

22 See Figure 3 in FAO (2019).

23 See Table 1 in UNEP (2021a).

24 It is worth noting that methane emissions are about eighty times more powerful than those from CO_2.

25 ILO (2024b).

26 ILO (2019).

27 Authors' calculations using ILO data.

28 For instance, Chinese provinces have issued guidance about workers' training on heat-related illness, provision of cooling measures, as well as "high temperature allowance standards". See (https://www.china-briefing.com/news/high-temperature-allowance-standards-in-chinas-major-cities-and-provinces/) and (https://www.gd.gov.cn/gkmlpt/content/0/140/post_140318.html#6).

29 https://www.unicef.org/stories/heat-waves-impact-children#:~:text=High%20temperatures%20are%20linked%20to,disorder%20more%20likely%20to%20occur.

30 See a recent blog published by Nagesh, Hares, and Leite for the Center of Global Development (2024).

study,[31] a key driver of women's vulnerability to climate change effects is the lack of resources to adapt. Munoz Boudet et al.[32] show that girls and women of reproductive age are more likely to live in poor households, which according to the evidence presented in this report are unsurprisingly those with the largest cooling access gaps (see Annex 2). Moreover, social structures, especially in poor countries, can also increase women's vulnerability to climate change.[33] Women's resilience to heat is not only affected by well-documented wage gaps, but also due to being over-represented in heat-exposed occupations such as primary agriculture and the garment industry where people often work in insufficiently cooled factories. Over-exposure to heat poses even higher risks for pregnant women.

The ILO in a 2019 study estimated that women in Sub-Saharan Africa accounted for about half of the agricultural workforce.[34] In addition, women and girls responsible for collecting water and wood, occupations that are typically unpaid, are not only heat exposed, but also increasingly vulnerable to gender-based violence.[35] Furthermore, a recent study by the Addrienne Arsht-Rockefeller Foundation Resilience Center provides evidence of a disproportionate effect of heat on unpaid domestic laborers, which not only substantially increases total heat-related productivity losses, but has important impacts on their families.[36] Along these lines, IFC, UNEP, and other organizations are fostering gender-responsive climate policies and actions.[37]

Improving access to sustainable cooling solutions will have important effects in cities and communities across developing countries,[38] for instance through integrated passive and active cooling solutions to address the challenges of urban heat island effects in rapidly growing urban centers.[39] Adopting sustainable cooling will also promote responsible production and use of cooling equipment through innovation, regulation, incentives and consumer education.[40] It will ultimately be an important element of the world's response to the need for greater energy efficiency and to the challenges of climate change,[41] as featured in the 2023 Global Cooling

31 IFC (2024).

32 Munoz Boudet et al. (2018).

33 IPCC (2022).

34 ILO (2019).

35 Romanello et al. (2023).

36 Adrienne Arsht-Rockefeller Foundation Resilience Center (2023).

37 See IFC (2024), ILO (2024a), IPCC (2022), Agoncillo and Woods (2024), and van Daalen et. al (2020).

38 See SDG 11: "Make cities and human settlements inclusive, safe, resilient, and sustainable."

39 A good specific example is the C40, which brings together large cities from developed and developing countries to share experience and technical assistance (for details see https://www.c40.org/). Additionally, the "Beating the Heat: A sustainable Cooling Handbook for Cities" report, by the Cool Coalition, UNEP, RMI, Global Covenant of Mayors for Climate & Energy (GCoM), Mission Innovation and Clean Cooling Collaborative provides 80 case studies and examples with strategies to help cool cities.

40 See SDG 9: "Build resilient infrastructure, promote inclusive and sustainable industrialization, and foster innovation," and SDG 12: "Ensure sustainable consumption and production patterns."

41 See SDG 13: "Take urgent action to combat climate change and its impacts."

Watch report. Collaboration through the Cool Coalition—a network of members assembled by UNEP from government, multilateral organizations, business, and academia[42]—to support the Global Cooling Pledge launched during COP28 will further all these efforts and contribute to achieving SDG17.[43]

1.2 The Importance of Financing Sustainable Cooling

Despite growing international recognition of the need for much greater financial support for climate adaptation, mitigation, and resilience, so far limited funding has been allocated to sustainable cooling. While it is encouraging to see tens of billions of dollars in private and public investment going toward improving battery technology, hydrogen fuels, carbon capture, and many other climate solutions, it is imperative to increase substantially the limited funding dedicated to supporting sustainable cooling technologies.[44] Furthermore, while promising sustainable cooling solutions have been demonstrated, there are no dedicated funding sources for their scaling and product development, investments that would typically range between $1 million to $10 million.

There are sizable cooling needs and high potential demand across many sectors and applications with important economic and social effects. For example, the Global Cooling Watch estimates that implementing sustainable cooling measures could generate $1 trillion in electricity savings for end users and reduce required investments in power systems by $5 trillion by 2050. Given the large underlying demand and associated monetary benefits for consumers across developing countries, it is crucial to understand what the investment requirements are. It is also important to identify the barriers to mobilizing enough private financing to support such investments and find effective approaches to overcoming them.

Fiscal challenges, inadequate infrastructure, perceived risks, high upfront costs, lack of awareness of the market potential, and inadequate regulation are key deterrents to financing sustainable cooling at scale across developing economies.

Many developing economies are facing fiscal constraints which are particularly acute for low-income countries. That means strategies that are predominantly dependent on public financing are not feasible. Therefore, it is imperative to mobilize private sector investments for sustainable cooling in these countries, at scale, to effectively address current and future challenges.[45]

Public and concessional funds should prioritize support for business models that close cooling access gaps that are predominantly caused by affordability constraints. Regarding commercial

42 The Cool Coalition includes more than 140 partner organizations (for further details see https://coolcoalition.org/).

43 See SDG 17: "Strengthen the means of implementation and revitalize the global partnership for sustainable development."

44 A stock take of disclosed funding and target financing of programs focused on cooling totals about $1.5 billion in financing, of which 85 percent comes from two specific programs.

45 World Bank (2023).

funding sources, the lack of financing for sustainable cooling is rarely caused by an absence of large pools of capital for investing, but rather a perception of high risk among investors. Risk aversion prompts lenders to raise borrowing costs while equity investors demand higher projected rates of return as a condition for extending new financing.[46]

A key driving factor of perceived risk is a lack of knowledge around potential levels of demand and market size for sustainable cooling across countries, sectors, and applications. Without clear evidence of sizable market opportunities offering attractive potential returns, it will remain difficult to attract innovators, entrepreneurs, and investors to sustainable cooling. Similarly, small- and medium-sized enterprises (SMEs) looking for funding to scale-up cooling solutions will need to be able to demonstrate to prospective financiers the commercial feasibility of their businesses. A fundamental challenge highlighted by many experts and reports in this area is a general scarcity of data on cooling. Meanwhile, such information that does exist is usually only available in selected market segments and countries. For instance, hard data on the stock of installed cooling equipment, the share of stock that would be considered sustainable, and how that stock is distributed across different markets has not been historically collected nor estimated systematically. Hence, this report seeks to improve the availability of underlying data and help establish a framework for generating cooling market investment estimates.

A lack of understanding of the business case for adopting sustainable cooling solutions deters potential consumers and the financiers who would back cooling providers. There is often a lack of knowledge about financing solutions that would help address challenges related to upfront costs. There is also a shortage of commercial incentives for making the transition to sustainable cooling, including by embedding cooling in the design of products and projects, even when doing so would be cost neutral. As will be discussed in this report, the range of cooling applications is matched by a correspondingly diverse set of sustainable cooling solutions, business models, and financing structures. While some sustainable cooling solutions have higher initial capital costs, they also bring potential monetary benefits. In addition, there are many passive solutions based on changes in building design, materials, and colors that may not require large upfront investments and could even reduce initial capital costs. There are also emerging business models to address affordability issues for low-income households, SMEs and agricultural smallholders, including the use of off-grid power. Furthermore, these groups, who often face difficulties accessing capital markets, are seeing increased availability of new financing structures that involve combining private and concessional funding.

46 The fact that cooling is usually a relatively small component of a larger investment often leads to it receiving less attention regarding the adoption or use of best technology. Additionally, the uncertainty surrounding new, relatively untested cooling technologies contributes to the perception that risks associated with cooling are higher than those in other areas like renewable energy.

The availability of appropriate financing for sustainable cooling is also shaped by local conditions in areas such as regulation, policy, and incentivization. For example, a growing number of developing countries are including cooling in their Nationally Determined Contributions (NDC)—commitments to reduce greenhouse gas emissions made to the United Nations Framework Convention on Climate Change. Other countries including, notably, India have made commitments to address cooling needs through a national cooling action plan.[47] In addition, more countries are now improving regulation around cooling and over 70 have already joined the Global Cooling Pledge, an initiative set up at the 2023 UN Climate Change Conference (COP28) involving a commitment to sustainable cooling.[48]

The Role of the Public Sector

As mentioned above, financing is one of several important elements of a broader strategy to scale up the adoption of sustainable cooling across countries. Governments and other public sector entities should be formulating as well as supporting the implementation of this broad strategy across different dimensions and sectors, in collaboration with the private sector.

The cooling action plans being adopted by various countries such as India outline national and subnational government strategies across sectors for understanding and quantifying the multi-faceted development impacts of sustainable cooling (discussed in Section 1.1). They also include cross-cutting and sector-specific policies to meet different demands for cooling, which should be embedded in government strategies for individual sectors. These national plans also amount to tools for addressing an important barrier pertaining to the public sector, namely the lack of inter-institutional coordination and capacity between different government agencies and departments. Since cooling is used in different sectors (as discussed in more detail in Chapter 2), if there is no active buy-in and coordination from government ministries, just having a national plan in place will not get very far in terms of effective implementation.

For instance, coordinated action is fundamental to the systemic approach required to develop end-to-end cold chains through a multi-sector and multi-modal infrastructure lens, as discussed in Chapter 3. For implementation, it is critical that public sector entities have the appropriate technical and enforcement capacities, and the funding, to effectively deliver on the actions and programs formulated in the plan. It is also essential that implementation is done in partnership with relevant private sector entities—firms and industry associations—that represent the main providers and users of cooling solutions, as well as investors and financiers. Multilateral development banks and other development finance institutions have the requisite knowledge and experience in many of these areas and can therefore help countries with technical assistance and funding.

47 World Bank and Global Facility for Disaster Reduction and Recovery (2022).

48 See UNEP (2023a) and the Global Cooling Pledge (https://coolcoalition.org/global-cooling-pledge/).

Along these lines, many of the dimensions required to support transitions to sustainable cooling—like policies, regulations and standards, underlying infrastructure, enforcement capacity, supply of intermediate goods and services for cooling—also impact the capacity to mobilize private financing as they determine potential sources of risk for a variety of cooling providers and users. This is why throughout this report, and especially in Chapter 3, issues around these areas are outlined as among the principal challenges to financing sustainable cooling in developing countries.

A key role for the public sector is setting conditions and supporting programs to make financing for sustainable cooling accessible, by fostering demand, supporting urban planning, and incentivizing procurement of sustainable solutions in public areas and buildings. The influence of public sector actions on private financing and mobilization for sustainable cooling is examined in more detail throughout this report.

1.3 How this Report Contributes to the Global Cooling Agenda

The 2023 Global Cooling Watch report made a significant contribution to reinforcing the case for sustainable cooling by providing a scenario analysis and outlining pathways toward achieving near zero cooling-related emissions. It highlighted key actions to achieve this goal, such as increasing the use of passive strategies for cooling, raising energy efficiency standards and rules for cooling equipment, and accelerating the phasing down of HFC refrigerants.

Regarding regulation and policy, it provided a comprehensive landscape of national cooling policies, analysis of market readiness, and regulatory instruments to improve access. The report also highlighted the importance of scaling up financing to support the transition to sustainable cooling, an overview of challenges, opportunities, financing instruments, and recommendations for moving forward.

This report builds on the discussion about financing sustainable cooling outlined in the Global Cooling Watch report, and provides a more in-depth analysis around the following three questions:

> What are the priority actions needed—and in which key cooling market segments—to accelerate private financing for sustainable cooling across developing economies?

> What are the main barriers holding back the scaling-up of private finance for sustainable cooling in developing economies?

> What existing business models, innovations, and financial instruments can be used to scale up the adoption of sustainable cooling across developing economies?

To address these questions, the report is structured around the following objectives:

> Provide credible estimates of the investment opportunities that cooling markets offer across developing economies;

> Highlight the key challenges and opportunities around financing sustainable

- cooling in the context of developing economies;
- Provide a blueprint for financing sustainable cooling across developing economies, covering business models, financing instruments as well as sector-specific and cross-sector interventions.

Cooling is not a traditional industry sector but rather comprises a set of applications across multiple sectors. Therefore, it is not straightforward for many entrepreneurs, investors, firms, and financiers to identify the potential of investing in or financing cooling. Thus, as discussed in other reports, the lack of systematic cooling data collection and market estimations poses a challenge to the effective scaling up of capital mobilization for cooling, especially across developing countries. To address this issue, Chapter 2 outlines different cooling segments and applications within a market landscape that incorporates a variety of firms providing cooling solutions and different types of consumers across segments. It also offers an overview of the different financing needs they have. The market segments include:

- Residential Space Cooling
- Residential Refrigeration
- Space Cooling for Small Vehicles
- Non-Residential Space Cooling
- Non-Residential Refrigeration[49]
- Refrigerated Transport Vehicles

Next, through an expanded and updated version of the Global Cooling Emissions Model used in the Global Cooling Watch—labeled the Global Cooling Emissions and Investment Model—this study estimates current and projected cooling market size based on expected satisfied demand in developing economies. In these estimates, passive strategies for cooling are the first layer of energy efficiency measures, determining the remaining cooling load that needs to be addressed through active cooling. Estimated investment opportunities in active cooling provision of up to $600 billion per year by 2050 (in constant US$) implied by different scenarios outlined in this report, amid growing populations and economies, highlight major opportunities for entrepreneurs, investors, and cooling provider firms across developing countries. Market size calculations along with the scenario analysis of monetary benefits also imply ample investment opportunities in passive cooling, which would be additional to, or in some cases replace, investments in active cooling. Targeted commercial financing is an effective channel to support the adoption of sustainable cooling solutions to address market needs and avoid persistent vicious cycles with negative climate effects.

In addition, the study provides estimates of the total costs required to close some of the existing cooling gaps. These shortfalls affect the most vulnerable groups and underline some of

49 Non-residential refrigeration includes cold chain logistics. However, the estimations in Chapter 2 mainly capture the most developed portion of cold chain systems across developing economies, from aggregation centers to retail storage and display. See the graphic in The Clean Cooling Network website: https://cleancooling.org/; and the ACES March 2024 report. Data collection and estimation of the potential growth of the cold chain portion going from farm and farm gate to aggregation are a critical area for future research.

the negative societal effects in areas such as health, heat-related mortality, education, worker productivity, and food waste. Cooling gaps are also barriers to achieving sustainable development goals. Estimated cooling investment gaps focus on space cooling and refrigeration for households and SMEs, and predominantly reflect affordability constraints. The estimated total costs required to close current cooling gaps across developing economies range between $400 billion and $800 billion.[50] It is important to note that there are additional cooling gaps related to cold chains in rural areas that were not estimated, as well as cooling gaps generated by other drivers, like access to electricity and regulation. Commercial business opportunities in closing cooling gaps driven by affordability issues would require not only innovations that bring down costs significantly, but also appropriate regulation that incentivizes providers and in many cases additional support in the form of concessional financing.

In addition to baseline market sizing, the analysis considers scenarios where the adoption of sustainable cooling is accelerated—through passive strategies and higher energy efficiency in active cooling—implying sizable positive gains for consumers, as well as for economies more broadly. These benefits signal that there is ample space to design commercially viable business models as well as economic justification for governments to support different strategies to accelerate passive and active cooling. Furthermore, this differentiates between adoption of sustainable cooling and the transition to near-zero emissions in different economic sectors, which may require additional support.[51]

While effective solutions to financing sustainable cooling are dependent on context, there are several experiences of investments and programs in cooling as well as in related areas like energy efficiency or off-grid distributive energy, that offer lessons to incorporate in the design of future strategies. Chapter 3 identifies the challenges of mobilizing private investment into sustainable cooling in developing economies based on existing initiatives and experiences. These include systemic issues like affordability across different households and firms as well as varying levels of electricity access and skills. Other challenges to consider include the complexity of cold chain systems, lack of consumer literacy in cooling and finance, as well as weak regulatory and administrative environments. The chapter offers examples of strategies to address some of these challenges as well as major gaps in some of the current approaches.

Following the discussion of key challenges, Chapter 4 provides a blueprint to design financing approaches for sustainable cooling. The proposed approach includes identification of the specific financing needs of cooling solution

50 This range was estimated under the assumption that existing cooling access gaps would be addressed with active cooling solutions only (either fans or air conditioning equipment). However, it can be expected that addressing these gaps will imply a combination of different kinds of active cooling solutions and passive cooling strategies. See Chapter 2 for details.

51 An analysis by BloombergNEF (Farhat and Rathi (2024)) shows that the level of sectors' emissions by 2050 when relying only on economically competitive technologies would bring global temperature increases to 2.6 °C above pre-industrial levels.

BOX 1.2

IFC Sustainable Cooling Initiative

To address some of the challenges outlined throughout this report and noting the important role of the private sector in transitioning toward more sustainable cooling, IFC launched the Sustainable Cooling Initiative with the support of the U.K. Government. IFC's sustainable cooling strategy addresses five cooling-intensive sectors through five areas of engagement: 1) district cooling; 2) cooling for green buildings; 3) consumer and SME finance; 4) innovation for agribusiness and manufacturing; and, 5) cold chain and temperature-controlled logistics, while paying particular attention to the growing field of cooling-as-a-service. This strategy will be executed through five modes of engagement: 1) providing thought leadership; 2) developing transformative cooling systems; 3) enhancing investment readiness of innovators and adopters of cooling solutions; 4) de-risking finance; and, 5) operationalizing and investment scale up. IFC is collaborating with several international organizations through the work of the Cool Coalition, not only setting the global agenda, but on implementation of practical solutions in countries of focus that effectively contribute to the objectives of the Global Cooling Pledge.

The "Five by Five" Plan

suppliers and consumers shaped by their varying characteristics. Practical examples that include existing business models and programs are featured to show how this approach applies to financing sustainable cooling applications and activities in different contexts. The discussion includes financing approaches for different stages of business maturity, including research and development, innovation, and the scale-up of new technologies, as well as how specific financing instruments can be used to finance sustainable cooling applications. These include revolving funds, working capital financing, results-based financing, risk sharing facilities, equity investments, grants, and concessional finance.

With these challenges in mind, addressing sustainable cooling is becoming more and more central to the mission of development finance institutions and multilateral development banks. These international institutions continue to play important roles in climate finance, and sustainable cooling is no exception. They bring important resources and institutional support for due diligence, the management of country and technology risk through concessional finance instruments, and resources for enabling activities like country climate diagnostics and national cooling action plans. Finally, they also offer expertise and experience in launching innovative financial instruments and could drive the establishment of so-called cooling bonds which would join the growing universe of labeled sustainable debt instruments alongside green, blue, and biodiversity bonds.

Finally, the report provides a series of recommendations, including ongoing initiatives at various stages of development, implementation, and evaluation. First, it outlines the need to increase capacity and dedicate funding to the improvement of systematic data collection across countries, build a centralized library of global cooling data, and establish a methodology for market projections. Second, it identifies ways to meet challenges to providing sustainable financing for sustainable cooling. These include raising awareness among investors and firms of the potential business opportunities, informing consumers about the benefits and avenues for financing sustainable cooling, and increasing the capacity of governments to improve regulation and enforcement. The third set of recommendations focuses on the roles that can be taken by governments, the private sector, and multilateral institutions.

Governments are pivotal in the design of effective programs to promote and partially finance sustainable cooling initiatives through participation in public-private partnerships while providing the right incentives for consumers, entrepreneurs, providers, and investors. The private sector leads in the provision, adoption, and funding of sustainable cooling solutions while multilateral financial institutions bring expertise to the design of programs and financing structures that help scale up private investment in sustainable cooling markets.

Together, these elements can steer the adoption of innovative business models, financing instruments, and mechanisms that have the potential to foster the growth of sustainable cooling in the coming decades.

Photo by Barbara Walton/EPA via Shutterstock

2

Diverse Sources and Sectors Imply Diverse Cooling Financing Needs

Boosting the supply of financing for sustainable cooling in developing economies requires an understanding of the magnitude of the potential demand for cooling in these countries. Market size estimates, as well as projections of demand growth, are critical for entrepreneurs, potential product providers, and financiers to assess potential returns. This chapter starts with a description of the cooling market landscape, outlining variations in the nature of supply and demand for broad types of cooling applications. It examines different market segments, the types of entities (firms and households) behind the demand and supply within each segment, as well as their broad financing needs.

This is followed by estimates of the current and future size of cooling markets across developing economies, focusing on segments across applications and regions. The business and investment opportunities around cooling markets include both 'passive' strategies—such as architectural design, nature-based solutions, and the use of new materials such as reflective coatings—and 'active' methods like space cooling with fans or air conditioning, and refrigeration.

Additional projections to quantify avoided costs and net monetary gains from accelerating the adoption of sustainable cooling—through increased use of passive strategies and penetration of high efficiency cooling equipment—make a clear economic case for the financing of sustainable cooling. Finally, there is a discussion of estimates of the total cost to close existing cooling gaps caused by affordability constraints. Closing cooling gaps and expanding access through the design and provision of affordable solutions to more households could emerge as a major business opportunity for innovators, private investors, and firms. In some cases, these activities will require additional support from concessional financing mechanisms.

2.1 Mapping the Investment and Financing Landscape for Cooling

Cooling Market Landscape

Cooling markets are complex, comprising multiple components to meet diverse needs. Each market segment incorporates suppliers of cooling solutions as well as the end consumers who buy their goods and services. The goods they provide include active cooling equipment as well as products used to implement passive cooling strategies. The services they offer include the design and implementation of passive strategies, cooling services for end-customers, as well as the provision of ongoing services related to active cooling equipment such as maintenance and training.

Suppliers and buyers require different kinds of financing mechanisms for their respective activities, to fund production and distribution, or to pay for the acquisition of cooling solutions.

The lower panel of Figure 2.1 describes broad cooling market segments. These include residential and non-residential space cooling with passive design strategies for buildings centered on architectural design or insulation materials, and active cooling with fans and air conditioning systems. They also incorporate refrigeration, using refrigerators and freezers, for households as well as non-residential functions ranging from large industrial operations to supermarkets, restaurants, or laboratories. The

FIGURE 2.1

Cooling Markets Landscape

Source: Authors

lower panel also highlights mobile applications, namely space cooling for small vehicles, buses, or trains, as well as refrigerated transport vehicles.

The supply side of these cooling markets, described in the top left panel of Figure 2.1, includes firms that contribute to cooling solutions with design, materials, equipment, cooling services, maintenance, or training. These firms can also be differentiated by their business development stage, from startups to well-established companies with mature operations. Cooling solution providers may cover more than one market segment whereby, for example, a refrigeration equipment manufacturer may supply both residential and non-residential customers.

The top right panel of Figure 2.1 describes demand for cooling solutions, comprising households, different kinds of businesses—from smallholder farmers and micro, small and medium-sized enterprises (MSME), to large corporations—and public sector entities. Households constitute the demand side of residential space cooling and refrigeration, and some of the market for space cooling of vehicles. Firms of varying sizes across sectors account for demand in areas such as non-residential property and buildings that require space cooling. This includes spaces that house the operations of micro, small and medium-sized enterprises, as well as larger firms like hotels, hospitals, data centers, and the offices of larger commercial and public entities. It also incorporates cold chains for agriculture and food processing—including solutions for smallholder farmers and large agribusinesses—as well as healthcare which requires temperature control for the storage of vaccines and other medical supplies. Finally, it covers refrigeration for industrial and commercial businesses such as small markets, restaurants, and supermarkets.[52]

Section 2.2 provides market sizing estimates and projections of investment opportunities for these cooling market segments across developing economies. Section 2.3 discusses the monetary benefits from accelerating the adoption of sustainable cooling, while Section 2.4 estimates the total costs to close existing and future cooling gaps for various types of consumers, including some of the households and small and medium-sized enterprises (SME) that cannot afford the cooling solutions they need.

Financing for Cooling Markets

As discussed throughout this report, different kinds of entities supplying or acquiring cooling solutions in these markets have different financing needs as well as gaps in terms of their access to financing. The type of financing required—seed financing, equity, or debt—varies according to the entity's characteristics. Therefore, a startup will have different needs to an established company with mature operations. A firm's finance requirements will also reflect the cooling-related activities it is engaged in, whether it is bringing new technologies to market, developing integrated passive cooling measures for construction projects, or producing cooling equipment.

52 Real estate developers, public sector programs, and energy service companies, among others, are cooling market intermediaries that acquire cooling solutions and incorporate them in a project or program directed at consumers in other markets.

In addition, the financing instruments available in specific markets are determined by the type of financing required, the business model underlying the transactions between suppliers and buyers, and the context in which such transactions take place. This section provides an overview of the varieties of financing required by different kinds of suppliers and buyers.

Supplying sustainable cooling solutions comprises several different phases of activity. The first of these, Research and Development (R&D), involves the carrying out of research, design, and testing of new products and technologies, as well as the conceptualization of business models. R&D is conducted by teams of academics or researchers working in small or large companies.

Next comes the Innovation Phase, which amounts to the initial testing in real-world conditions of a new design, technology or business model that has demonstrated its potential. The innovation phase can also include conducting feasibility studies for the new product, technology, or business model.

The third activity is Adoption, or Scale-Up, whereby sustainable cooling innovations are taken to market following a commercial strategy. At this stage, expanded private sector participation is critical if the new product or method is to successfully disrupt and compete in the market. It is also important to either leverage existing strategies to incentivize adoption from the demand side, or better, coordinate efforts to provide adoption incentives to both sides of the market (see Chapter 4 for specific business models and financing mechanisms).

Once sustainable cooling products or services reach a certain level of maturity and market adoption, a Growth phase gets underway as the market transforms with the relevant sustainable cooling products and services becoming accepted as the new standard.[53]

Figure 2.2 shows how the business development stage and specific activities being developed in the cooling space underline supplying firms' investment and financing needs.

Innovators providing disruptive cooling technologies require seed funding in the form of grants and risk capital. New manufacturers and providers of cooling as a service need equity and loans to finance expenditure and boost their working capital as they expand into new and uncertain markets. Meanwhile, established businesses producing or distributing cooling equipment will typically have more access to traditional debt financing from financial intermediaries and capital markets that they can use to maintain and grow their operations.

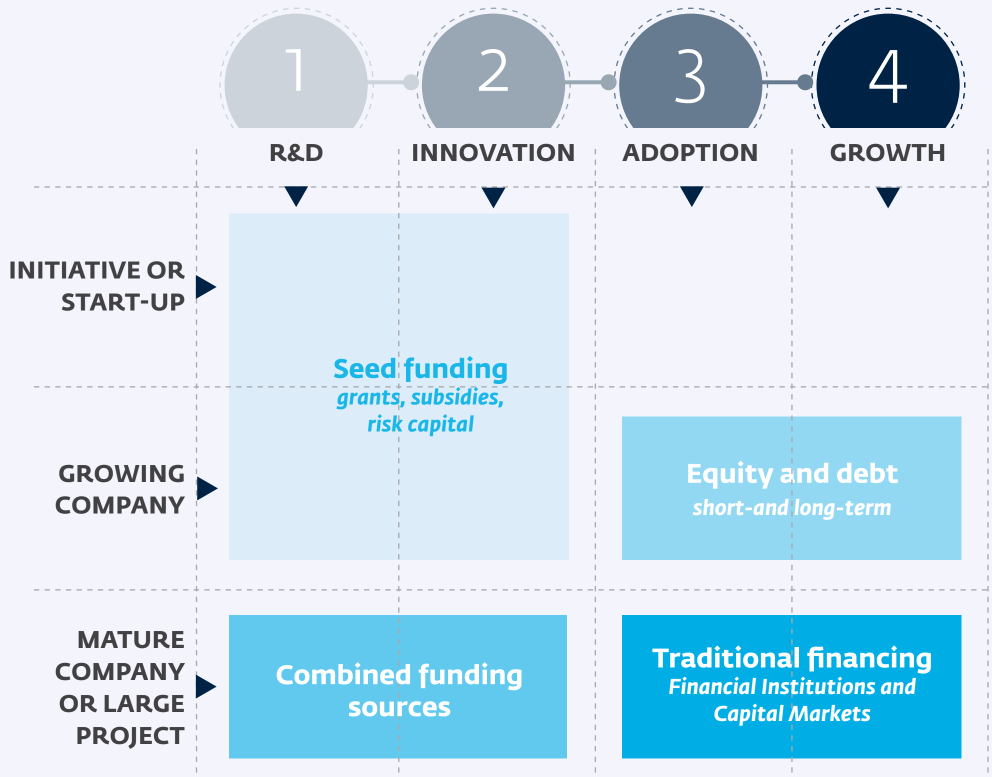
In active cooling markets, the manufacturing of air conditioning equipment and domestic refrigerators is dominated by a few very large companies, while production of refrigeration equipment for food retail and industrial process cooling, includes a significant number of medium-sized firms. A small number of large multinationals dominate the supply of refrigerants and mass-produced equipment

53 These include products for passive strategies (e.g., new insulation materials) as well as services related to the design and implementation of passive strategies for cooling (e.g., architectural design).

FIGURE 2.2

Diverse Cooling Provider Firms Require Diverse Financing Solutions

Examples of cooling supplying firms' financing needs by development stage and activity



Source: Authors

such as residential air-conditioning units, while approximately 80 percent of the world's room air conditioning units are made in China.[54] Furthermore, major companies also dominate production of key components like compressors and heat exchangers, leveraging significant R&D resources for product development and innovation. These mature companies engage in R&D and innovation and will combine internal and external seed funding with other sources of finance in the form of grants, concessional funding, or subsidies set up to support such activities.

Conversely, equipment installers and contractors are typically relatively small companies operating

54 ChinaIOL (2022).

within a single country or region, with a large proportion categorized as SMEs or MSMEs. These smaller firms have limited R&D capability and require extensive training and support to adopt and sell newer, innovative products. In addition, there are also differences across market segments. While residential refrigerators are mass produced and do not require specialized installation, residential air conditioning, though also manufactured on a large scale, does usually require specialized installation. Meanwhile, some non-residential refrigeration solutions need to be custom made and require extensive additional work on installation, mostly carried out by SMEs. Along these lines, a fraction of companies will have access to traditional financing sources depending on the stage of development of their business and that of the financial and capital markets where they operate. Chapter 4 provides specific examples of existing financing mechanisms for companies across different stages of development and engaged in different cooling activities.

On the other hand, companies offering passive cooling approaches range from small businesses providing architectural design and other kinds of technical consulting services, to large firms manufacturing special materials, with a correspondingly wide variance in financing requirements.

On the cooling market demand side, consumers' financing needs can be initially differentiated between those that cannot afford cooling and entities that can afford cooling but need the appropriate incentives and financing to upgrade to sustainable cooling solutions. The first consumer group is comprised of lower-income households, a fraction of MSMEs with limited or no access to financing, and smallholder farmers that lack access to cold chain infrastructure. Closing the cooling gaps for these kinds of consumers with sustainable cooling solutions can represent a sizable business and investment opportunity for cooling providers, as shown by the estimated costs associated with closing cooling gaps for households and SMEs presented in Section 2.4. Moreover, as will be discussed in subsequent chapters, closing the gaps for consumers with no access to cooling may require financing mechanisms that include concessional finance, subsidies, as well as public-private partnerships, all of which face significant challenges in many developing countries.

The second group of consumers, including higher-income households, established SMEs, and large firms, requires financing conditions that maintain the affordability of cooling solutions and provide the appropriate incentives to make the transition to sustainable solutions. In other words, the right financing mechanisms to foster the transition toward sustainable cooling are those that make a good business case for these entities. The types of financing for the demand side include mostly debt-based instruments, including revolving short-term facilities to support those that transition to cooling-as-a-service (CaaS) solutions, which may be combined with concessional finance that incentives adoption of sustainable cooling.

The next sections in this chapter use this landscape as a framework to estimate the current and future size of cooling markets across developing economies, and to assess the total cost to close existing and future access gaps.

Cooling market sizing is key to the identification of focus areas for firms, investors, and financiers, as well as governments, to increase access to cooling and foster the transition toward sustainability.

2.2 Estimating the Cooling Market Size in Developing Economies

Credible and consistent evidence on the state of cooling and cooling financing as well as up-to-date projections, are critical for effective policy design and mobilization of private investment. However, as identified by various reports and organizations in recent years, one of the critical challenges to scaling-up investment in sustainable cooling is the absence of systematic data collection and analytics to track and evaluate solutions in terms of place, market size, and financing gaps.[55] Recognizing the limitations on cooling data availability, the Global Cooling Pledge launched during COP28 in 2023, includes a commitment by governments "to review progress towards the target of the Global Cooling Pledge on an annual basis," which implies improving the availability of underlying data on the state of cooling in different countries.[56]

Therefore, it is critical to consolidate available cooling data through a systematic estimation effort that keeps track of market trends for both passive and active cooling.[57] An important step forward in this regard was taken in the Global Cooling Watch report launched at COP28. This introduced a Global Cooling Emissions Model[58] to estimate greenhouse gas emissions from global stocks of refrigeration and space cooling equipment, and project possible future trajectories until 2050.[59] The modeling results included estimated savings in electricity consumption and power sector investments from the accelerated adoption of passive strategies and new technologies that improve energy efficiency, both of which further reduce emissions from refrigerants.[60]

The Global Cooling Emissions Model is a bottom-up model for estimating the stock of refrigeration, air conditioning and heat pump cooling equipment across countries. It uses three main drivers—climate, economic growth, and population growth—to project the increase of equipment stock across 40 different technologies, spanning residential, commercial,

55 Research conducted in 2019 by the Economist Intelligence Unit remains the most up-to-date market size estimate available. See EIU (2019).

56 See the Global Cooling Pledge, led by UNEP in 2023 (https://www.unep.org/resources/report/global-cooling-pledge).

57 An initial effort in this direction is the GCI data dashboard (https://www.green-cooling-initiative.org/country-data#!total-emissions/all-sectors/absolute), which includes estimated unit sales and market value in addition to data on emissions, giving values for 2016 and projections thereafter based on a model.

58 See Gluckman Consulting's Global Cooling Emissions Model, a greenhouse gas modeling platform for refrigeration, air-conditioning and heat pumps, available at http://www.gluckmanconsulting.com/hfc-outlook-modelling/.

59 See Chapter 2 of UNEP (2023a).

60 The Economist Intelligence Unit implemented in 2020 a similar estimation of potential reductions in electricity demand from adoption of sustainable cooling solutions, focusing on space cooling. See EIU (2020).

industrial, and transport space cooling and cold chain sectors.[61] The approach considers passive strategies as a first layer of energy efficiency measures, which determine the cooling load that would need to be addressed through active cooling solutions based on electrically-powered equipment.

For this report, the approach was expanded to construct a Global Cooling Emissions and Investment Model that projects active cooling market size and total costs to close existing cooling gaps.

It uses three elements:

> Active cooling solutions capital costs which include cooling equipment costs, complementary component costs (e.g., pipes), as well as installation costs.

> Microdata on households, including their ownership of cooling equipment, and firms. This data establishes their capacity to finance the acquisition of cooling equipment, reflecting household income and firm size.

> Assumptions from the Global Cooling Watch report, underpinned by available data and studies, to incorporate the adoption of passive strategies through scenario analysis.

The baseline estimates of the current market size for active cooling are based on available historical data on cooling solutions traditionally used by different economic sectors and households, along with cross-country data on GDP, population and average temperatures.[62] While there is currently an uncertain underlying proportion of cooling provided through passive strategies in developing economies which affect the estimated levels of active cooling, this is difficult to quantify. Without such passive strategies, the active cooling load, electricity usage and greenhouse gas emissions would be much higher. Along these lines, data collection and further research to estimate the current usage of passive strategies worldwide should be a priority, given their importance for reaching near-zero cooling-related emissions.

Despite the uncertainties and data limitations, high-level estimates of current passive cooling activities for new builds and retrofits are quantified (see Annex 2 for details). Current passive cooling capital investments in new builds across developing economies are calculated to be between $15 billion and $25 billion per year.[63] An estimated 3.5 billion square meters of floor area are added every year in developing countries, but less than 20 percent of this is subject to effectively enforced building energy codes. As a result, low uptake and enforcement of passive cooling requirements is limiting this

61 Additional granularity, like estimates by industry sectors or urban-rural splits are not addressed by this model, as this would require additional data for calibration that is generally not available across countries. For instance, the urban heat island effect is captured at the country level as urban population and GDP are underlying drivers but is not modeled or estimated separately in this framework. A technical description of the model can be found in Annex 1.

62 See Annex 1 for details.

63 This is in line with IFC analysis showing that investment needs for green buildings in developing countries account for $1.5 trillion over the next decade (for further details, see https://www.ifc.org/en/insights-reports/2023/building-green-in-emerging-markets).

market in many geographies. As codes expand and enforcement improves, this annual market potential could increase substantially.[64] Along these lines, there is significant potential for local private sector development to deliver passive cooling as part of green building construction and developing countries can seize the opportunity to build a domestic industry as they expand application of building energy codes.

The current building stock in developing countries has an estimated floor area of 162 billion to 170 billion square meters, the vast majority of which requires retrofitting for passive cooling. This represents a significant potential market for entrepreneurs offering ways to enhance thermal comfort in buildings that will also lead to lower energy bills for their customers. Current investments in passive cooling retrofits are estimated at $10–$15 billion per year. However, due to limited data, uncertainty about the pace of regulation, and significant cost differences across markets, it is not possible to make meaningful projections for these investments up to 2050.[65] Going forward, delays in policy implementation will lead to increased retrofit costs as the stock of buildings with minimal passive cooling measures in place increases.

Given current levels of passive strategies adoption, the estimated market size for active cooling solutions across developing economies in 2023 totaled $272 billion,[66] which represents 43 percent of the worldwide active cooling market. Almost half of this market, or $129 billion, is for building space cooling. Stationary refrigeration followed at $96 billion or 35 percent of the cooling market, while mobile cooling solutions made up the remaining 17 percent at $47 billion. Within space cooling, commercial and industrial uses represented the largest market at $79 billion, while residential uses accounted for $50 billion. In refrigeration, non-residential uses also represent the largest market, at $64 billion, compared to $32 billion for residential use. The mobile cooling market was dominated by passenger vehicles, with a $44 billion market size.

Geographically, Asia represents the largest market, with-two thirds of the cooling market in developing economies, at $188 billion. Within Asia, China was the most significant contributor, representing 46 percent of the total developing economy cooling market. South Asia accounts for an additional 10 percent, 85 percent of which is attributed to India. This is influenced by warmer climates across Asia, combined with relatively high levels of income across several countries in the region. Emerging Europe, Latin America, and the Middle East each contributed

64 Considering an accelerated adoption of building energy codes by 2030 across developing economies, it is possible to reach an annual market size of $150 billion in 2050. This estimate is based on a 24 percent cooling demand reduction for all buildings.

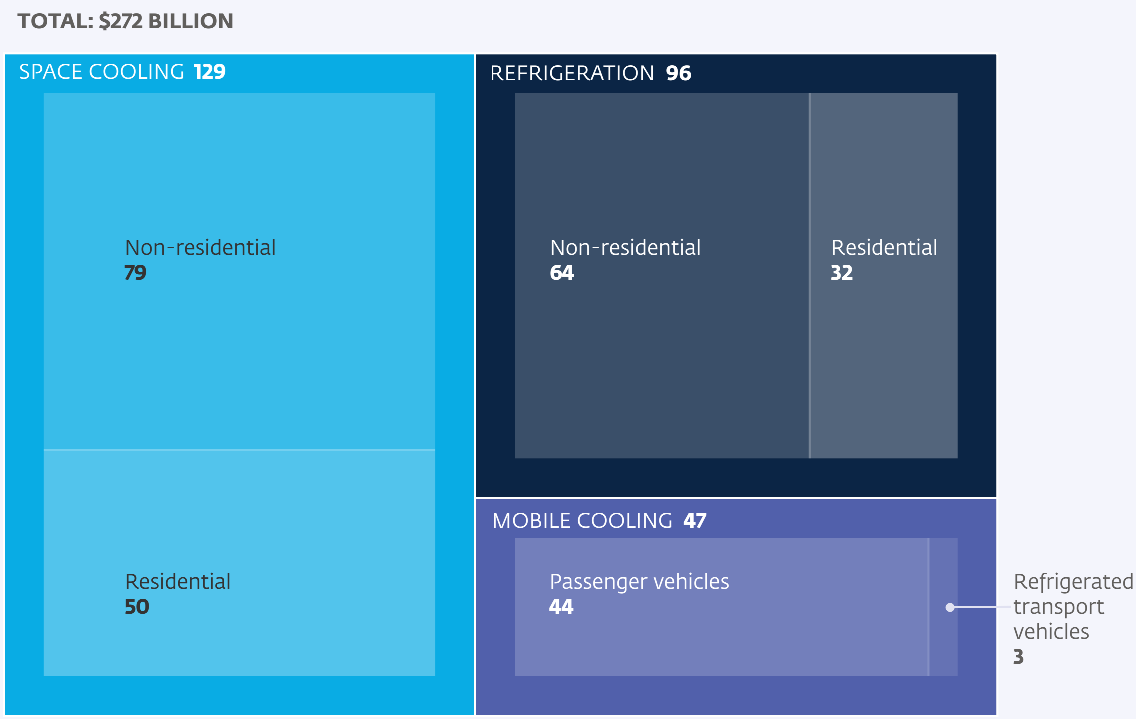
65 Similar to new builds, this estimate is in line with IFC analysis showing that the potential for green building retrofits amounts to a $1.1 trillion investment opportunity in developing economies in the next decade. Furthermore, the cumulative market potential for passive cooling retrofits in buildings can reach between $5–$15 trillion by 2050, if the policy environment is enabled for accelerated retrofit of existing building stock. This estimate considers adoption of passive cooling solutions which can reduce cooling demand in buildings up to 15 percent.

66 All estimates in this chapter are in constant 2024 US$.

FIGURE 2.3

Sustainable Cooling in Developing Countries Represents a Major Business Opportunity

Estimated active cooling market size for 2023 across emerging market economies ($ Billion)



Source: Global Cooling Emissions and Investment Model

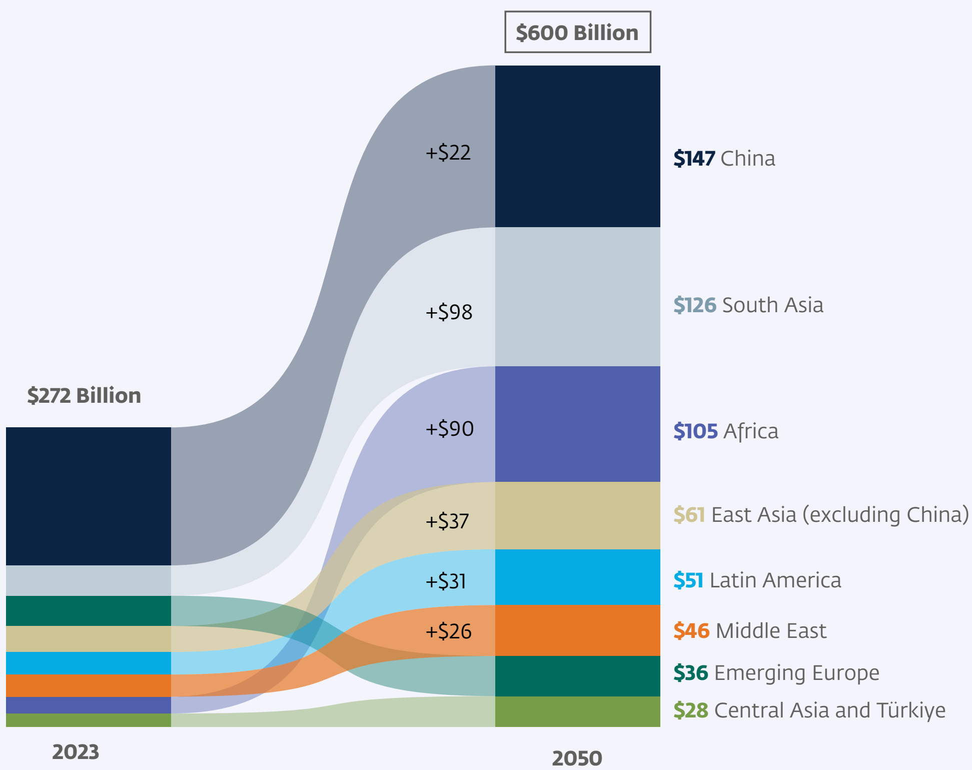
7–10 percent of the total.[67] These figures reflect a mix of warmer climates in the Middle East and the presence of higher-income economies with cooler climates in Europe and Latin America. Despite its warmer climate, Africa represents the smaller market, at $15 billion, contributing to 6 percent of the total. This is attributed to lower per capita income levels that limit affordability, but it also implies additional business and investment opportunities to close existing gaps (see Figure 2.4).

67 East Asia (excluding China) is primarily driven by Indonesia, Thailand, and Viet Nam. Central Asia's market is notably influenced by Turkey. In the Latin America and Caribbean region, Brazil and Mexico are the dominant markets. Given the nature of the model, we only highlight estimates at the regional level. Further work is needed at the country level.

FIGURE 2.4

The Cooling Market in Developing Countries Is Expected to More Than Double by 2050

Estimated active cooling market size across emerging market regions ($ Billion)



Source: Global Cooling Emissions and Investment Model

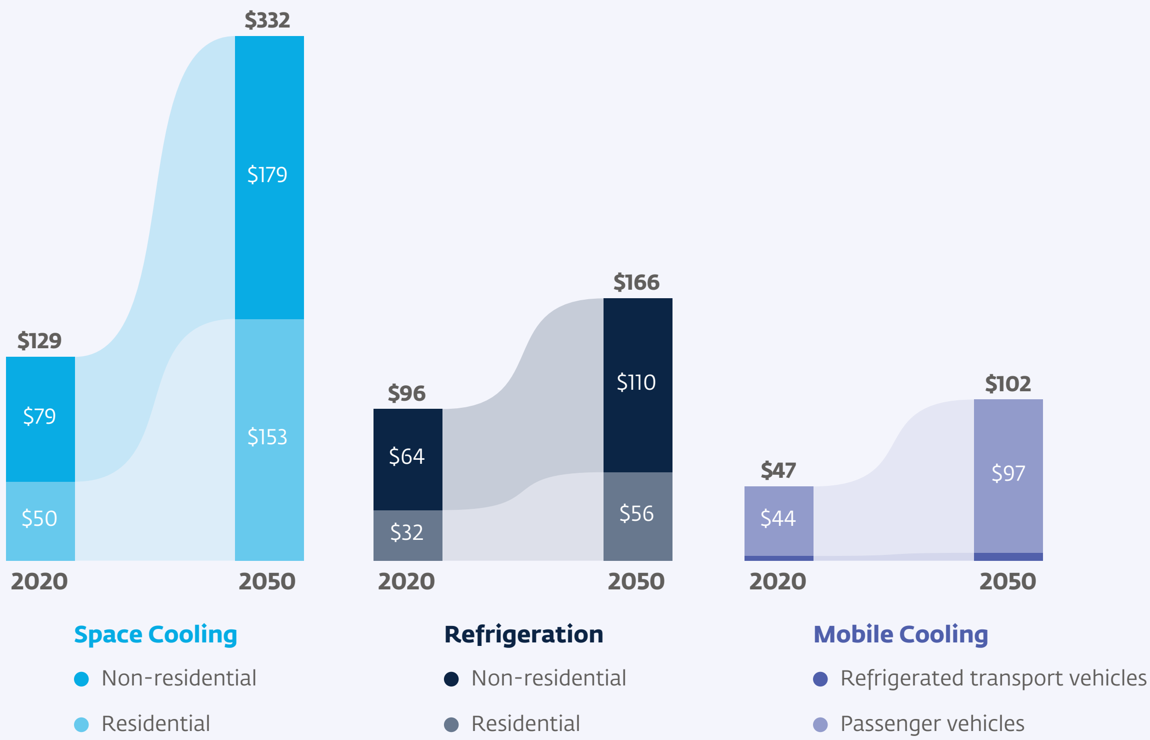
To build active cooling market size projections to 2050, we consider a business-as-usual baseline scenario that assumes continuing trends for the key underlying drivers of cooling demand—population, economic growth, and climate change. In terms of the evolution of cooling technologies, the baseline projection assumes a gradual improvement in active cooling technologies through a mid-efficiency scenario that reflects recent trends in cooling equipment efficiency.[68] This projection also assumes the continuation of limited reductions

68 The baseline case considered in the Global Cooling Watch report was a business-as-usual scenario with low efficiency gains, while in this report, we use as a baseline a middle-efficiency gains scenario that reflects the latest commitments and trends observed in the data. More details about the differences in the scenarios can be found in Annex 1.

FIGURE 2.5

Space Cooling Will Drive Cooling Demand, Underlined by Urbanization and Economic Growth

Estimated growth of active cooling market in developing countries by 2050 ($ Billion)



Source: Global Cooling Emissions and Investment Model

of the active cooling load from the use of passive strategies across developing economies. In terms of access and affordability, existing limitations for certain groups of firms and households to access cooling solutions are persistent over time and ease gradually with increasing incomes underlined by economic growth.[69] Therefore, the baseline projections combine limited use of passive strategies with active sustainable and conventional cooling technologies, where

69 The potential growth of market segments that are currently underdeveloped, like access to cold chains for farmers (through the portion of the cold chain going from farm gate to aggregation centers) is thus not fully captured.

the share of passive cooling remains at current low levels, while the share of active sustainable cooling solutions grows gradually over time as conventional cooling equipment is phased out due to replacement, improvements in technology, and regulation.[70] More details on underlying assumptions can be found in Annex 1.

Under the baseline scenario, active cooling markets can be expected to grow organically to $382 billion by 2030 and to $600 billion by 2050. The market in developing economies is expected to rise to 59 percent of the global active cooling market by 2050. Africa and South Asia will experience substantial growth driven by increases in population and GDP per capita. Africa's market is expected to grow sixfold, to $105 billion in 2050, raising its share from 6 percent to 18 percent. South Asia's market share will increase to 21 percent (or $126 billion) by 2050, from 10 percent in 2023. East Asia's market share is expected to decline from 55 percent to 35 percent by 2050, with China's market stabilizing at around $150 billion. Other regions are forecast to maintain their 5–10 percent market share.

Space cooling is projected to continue its dominance, growing its share to 55 percent of the developing economy cooling market by 2050, or $332 billion, given continued urbanization trends across developing economies. The residential space cooling market could triple in size to $153 billion by 2050, increasing its market share from 18 percent to 26 percent, mainly driven by urbanization mega-trends, while non-residential space cooling is expected to continue accounting for around 30 percent of the market, growing to $179 billion.[71] The refrigeration market is set to expand to $166 billion but decrease its market share to 28 percent.[72] The mobile cooling segment is projected to maintain its 17 percent share, growing from $47 billion to $102 billion.

2.3 The Economic and Business Case for Accelerating the Adoption of Sustainable Cooling

Sustainable cooling requires the use of technologies and approaches that minimize the impact on people and the planet. This requires navigating the trade-offs between rising cooling demand and the increase in electricity consumption. While cooling is essential for human comfort and health, industrial processes, and food preservation, higher electricity demand can boost greenhouse gas emissions. The challenge is to develop efficient cooling technologies that minimize the burden on electricity grids and promote energy conservation.

Approaches such as passive design strategies, the use of energy-efficient equipment, and renewable energy integration can help mitigate

70 Local regulation improves gradually, underlined by countries' compliance with international agreements.

71 Space cooling is expected to triple between 2023 and 2050, while non-residential space cooling will more than double. This compares to 70–75 percent growth in refrigeration. This is driven by the higher cost of space cooling equipment and installation costs compared with refrigeration, as well as the lower penetration of space cooling due to affordability constraints, which ease over time with economic growth.

72 Projections for the refrigeration market assume a business-as-usual scenario for cold chains. These projections do not consider potential developments in cold chain infrastructure, which could significantly impact the market, particularly in the agricultural sector.

these trade-offs and move toward sustainable cooling and a near-zero cooling pathway. For instance, under the baseline scenario, cooling energy consumption in emerging markets is projected to rise from 3,250 TWh[73] in 2023 to 6,530 TWh in 2050. By increasing the use of passive strategies and the penetration of higher efficiency equipment for active cooling, this could be reduced by 42 percent to 3,780 TWh.[74] This reduction would be about 10 percent of total global electricity consumption in 2022.[75] In terms of emissions, the baseline predicts total cooling emissions across emerging markets to decrease from 2,865 MtCO2e[76] in 2023 to 2,170 MtCO2e by 2050. This is driven by improved equipment efficiency over time, which reduces direct emissions from refrigerant gases despite increasing indirect emissions from associated electricity consumption.

In this regard, by increasing the use of passive strategies and accelerating the adoption of higher efficiency equipment, emissions in 2050 could be further reduced to 1,185 MtCO2e, encompassing reductions in both direct and indirect emissions. These are thus critical elements of the pathway toward near zero cooling.[77] Effective adoption of sustainable cooling requires an ample offer of passive cooling strategies and high efficiency cooling equipment, access to affordable cooling solutions and a clear business case for consumers. Along these lines, this section uses the Global Cooling Emissions and Investment Model to quantify the monetary benefits and costs of accelerating sustainable cooling adoption at the macro level. It is worth noting that, in addition to avoided costs in electricity consumption and reduced investments in power sector investments and in active cooling equipment, passive strategies bring a series of additional benefits that are not quantified in this report. These include climate resilience, affordability for low-income populations, and independence from electrical grid reliability issues.

The baseline scenario used for the cooling market sizing described in Section 2.2 is based on a business-as-usual growth projection that assumes some efficiency gains and limited use of passive strategies. In the estimations that follow, this report differentiates sustainable versus conventional cooling solutions by evaluating their environmental impact through energy and refrigerant use.

Along these lines, sustainable cooling solutions can include increasing the adoption of passive strategies, using low Global Warming Potential (GWP) refrigerants, improving energy efficiency,

73 Terawatt hours

74 The simulations assume an increase in the use of passive strategies for new buildings only. The effects of refurbishing existing buildings through passive strategies are not included in these estimates. Projecting these benefits and costs is complex and remains an area for future research.

75 In addition to directly lowering electricity consumption and emissions, shifting investments to energy-efficient and renewable sectors yields indirect benefits. These include job creation from moving investments from capital-intensive to labor-intensive sectors, enhanced economic resilience through local supply chain development, and improved industrial productivity with lower operational costs. See Laitner et al (2021)

76 Metric tons of carbon dioxide equivalent

77 An important additional element to this pathway is the decarbonization of the power grid. IEA and IFC (2023) discuss the challenges and opportunities for private investments in this area.

or raising reliance on renewables to minimize greenhouse gas emissions.

Conversely, conventional solutions depend on older, inefficient technologies, or high-GWP refrigerants, significantly contributing to environmental degradation.

As discussed before, there is uncertainty around current use of passive strategies and the stock of sustainable equipment.

In the baseline case, the former is expected to remain at current levels while the latter increases gradually as it is assumed that the availability of low efficiency equipment is phased out over time.[78]

To estimate the monetary benefits and costs of accelerating sustainable cooling, two scenarios are projected:

> **Mid efficiency and increased use of passive strategies**: this scenario assumes an increase in the use of passive strategies (e.g., improved building design), which reduces the required growth of active cooling, lowering the cooling load in 2050 by about 24 percent.[79] For space cooling, this reduction was estimated through an analysis of the potential load reduction for new buildings, the estimated proportion of new buildings over time, and an equivalent estimate for the effect of renovating existing buildings, based on existing evidence and studies. For refrigeration, the approach was similar but based on the estimation of new equipment as additions to, replacements for, or upgrades of existing stock.[80] In addition to lower growth in the amount of electricity consumed, the load reduction implies a lower peak demand for electricity and thus, reduced needs in terms of power infrastructure capacity.[81] Given the lack of data about the capital costs associated with the increased adoption of passive strategies, only monetary benefits in terms of avoided costs are estimated. As mentioned before, further research on the use as well as on the costs of passive strategies should be a priority going forward.

> **High efficiency and increased use of passive strategies**: this scenario combines the effects of the increased use of passive strategies with an acceleration in the adoption of higher efficiency active cooling equipment across countries. The underlying analysis to model this scenario considered that variations in efficiency

78 It is important to note that the baseline scenario projections and those reflecting the acceleration of sustainable cooling adoption assume that the financing required by the projected satisfied cooling demand will be available, for both cooling consumers and providers.

79 The total cooling load in the baseline scenario and the detailed underlying assumptions for building the load reduction, driven by passive design strategies for cooling, are consistent with the 2023 Global Cooling Watch report. This load reduction leads to a 21 percent reduction in electricity consumption in 2050.

80 For refrigeration, load reduction is achieved through improvements in insulation and other measures that reduce cooling needs. For non-residential applications, these include measures like the use of glass doors on supermarket display cabinets; better wall insulation and door airlocks for large cold stores; and better fan controls and defrost management for industrial refrigeration. For domestic refrigerators, the potential for load reduction is intertwined with system efficiency but can be achieved through improved operational use, hence the impact is small.

81 The effects of electricity load reduction through passive strategies are projected for different cooling market segments.

> differ across regions and technologies due to climate differences and the technical opportunities for each technology. In aggregate, electricity consumption in 2050 under this scenario declines by an additional 27 percent relative to the mid-efficiency baseline with passive strategies.[82] These additional efficiency gains could be driven by regulatory enhancements, implementation of national cooling plans, or effective actions to comply with government commitments like the NDCs or the Global Cooling Pledge. For this scenario, net savings from the adoption of higher efficiency equipment can be estimated, along with avoided costs from the increased use of passive strategies.

The projections show that increasing the use of passive strategies alone would generate cumulative avoided costs for consumers of $4.6 trillion in the period 2025–2050.[83] Almost half of this, $2.2 trillion, amounts to avoided costs from electricity consumption while the remaining $2.4 trillion corresponds to a reduction in spending on active cooling equipment. These sizable monetary benefits from increasing the use of passive strategies imply significant micro-level economic advantages for consumers in different cooling market segments across developing economies. As will be discussed in subsequent chapters, for effective adoption of these sustainable cooling technologies, it is critical that consumers have the information (including capital costs), knowledge and tools to make the best decisions in this regard. In addition to direct benefits to consumers, increasing the use of passive strategies also implies that developing economies would need to invest $940 billion less in electricity generation over the period 2025–2050.[84] These additional avoided costs are an incentive for governments to design and implement policies that foster the adoption of passive strategies in years to come, including fiscal benefits where appropriate.

Between 2025 and 2050, the adoption of higher efficiency cooling equipment is expected to result in cumulative net savings for consumers of approximately $1.8 trillion, relative to the mid-efficiency and increased use of passive strategies scenario.[85] In this case, $3.5 trillion in savings from reduced electricity consumption due to increased efficiency are partially offset by higher costs of more efficient cooling systems, of about $1.6 trillion.[86] Higher energy efficiency also implies about $930 billion in avoided costs on electricity generation investments over the period 2025–2050, opening further the window

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82 The underlying assumptions for the evolution of equipment efficiency in the high efficiency scenario follow those developed for the 2023 Global Cooling Watch report.

83 Avoided costs vary with local climate context across and within countries. There are no major differences in regional aggregates.

84 More details on the methodology for calculating power sector investment savings can be found in the 2023 Global Cooling Watch report.

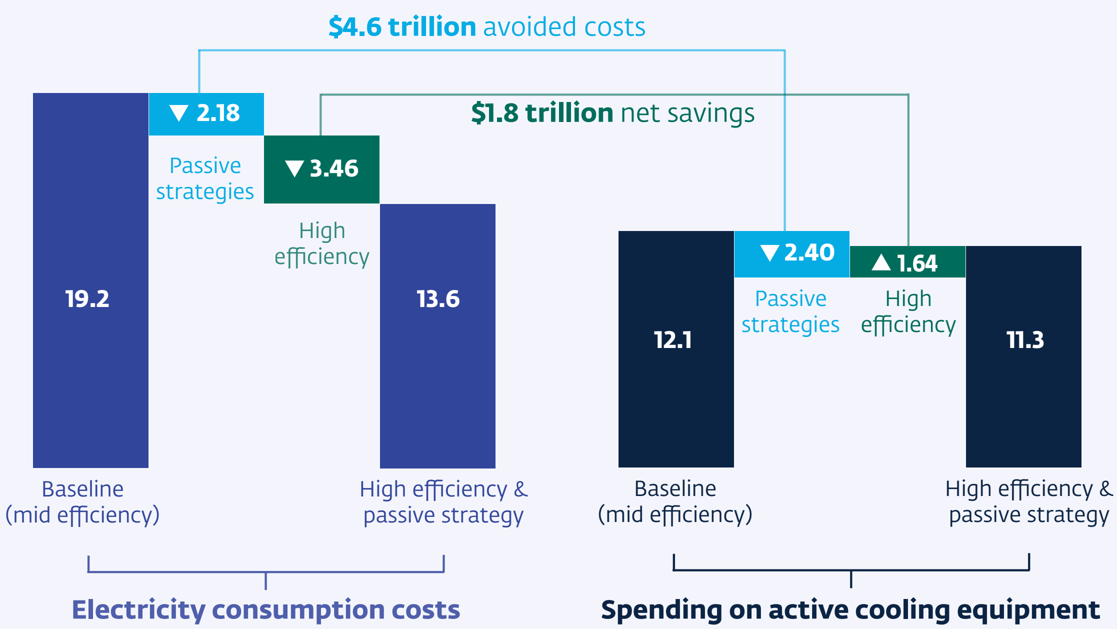
85 In this section, we first consider the benefits from load reduction as these should be viewed as the first line of defense against heat, followed by the accelerated adoption of higher efficiency active equipment. Monetary benefits are accrued over a 25-year period (2025–2050). It is worth noting that the actual lifetime of active cooling equipment is shorter than the projection period, and that the model assumes equipment is replaced at the end of its life.

86 This analysis does not account for the paid back period that electricity consumption savings implies. At the micro level, net present value benefits should be used to inform consumers making decisions between cooling equipment with different levels of efficiency.

FIGURE 2.6

Accelerating the Transition to Sustainable Cooling Will Help Developing Economy Consumers Spend $6.4 Trillion Less by 2050

Changes in cumulative electricity consumption costs and spending on cooling equipment for consumers from accelerating adoption of sustainable cooling 2025 to 2050 ($ Trillion)



Source: Global Cooling Emissions and Investment Model

for government policy and incentives for the adoption of more efficient equipment.

Overall, the case for expanding sustainable cooling rests on a combination of increasing the use of passive strategies and adopting higher efficiency equipment. Under this scenario, total electricity consumption costs over the period 2025–2050 will reduce by $5.6 trillion from $19.2 trillion to $13.6 trillion across developing countries, while cumulative spending on active cooling equipment will fall from $12.1 trillion to

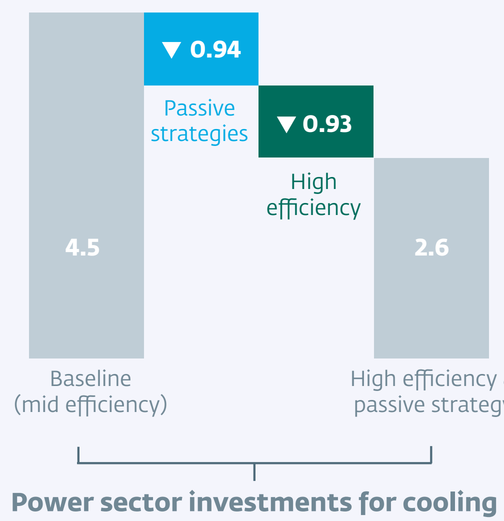
\$11.3 trillion.[87] In addition, total power sector investments to satisfy the electricity demand from cooling needs will drop from \$4.5 trillion to \$2.6 trillion from 2025–2050. This means that developing countries will require \$1.8 trillion less in power sector investments driven by the reduction in peak electricity demand.[88]

Similar monetary benefits from accelerating the adoption of sustainable cooling are observed across regions, with the magnitude of these benefits being commensurate with market size. For instance, the largest cumulative avoided costs from increasing the adoption of passive strategies until 2050 are expected to come from East and South Asia (at around \$2.6 trillion and \$1.2 trillion, respectively), followed by Africa, the Middle East and Latin America (between \$400 billion and \$500 billion). Furthermore, across all regions there is a positive net gain from accelerating the adoption of high efficiency equipment for active cooling.[89]

FIGURE 2.7

Accelerating the Transition to Sustainable Cooling Will Save Developing Countries $1.8 Trillion in Power System Investments by 2050

Changes in cumulative electricity generation investments from accelerating the adoption of sustainable cooling ($ Trillion)



Source: Global Cooling Emissions and Investment Model

87 Complementing this perspective, a forthcoming report "Bridging the Cooling Gap: Energy Efficiency as a Driver for Appliance Access" by Boucher et al. underscores the importance of energy efficiency improvements. By accelerating the energy efficiency gains of room air conditioners, fans, and refrigerators, the lifetime costs of these appliances can be significantly reduced.

88 These estimates include the effect of reduced demand on transmission and distribution of electricity.

89 In emerging Europe, despite the positive net gains for the economy, consumers do not directly benefit from higher efficiency equipment as the additional costs are higher than the savings from electricity consumption, though the difference is marginal. This is due to the combination of higher prices for high-efficiency equipment and lower benefits from reduced electricity consumption costs due to milder temperatures. Furthermore, technology adoption in European Union countries is heavily influenced by the rest of Europe, which is expected to have a faster adoption of higher efficiency equipment in the baseline case already. As a result, the difference between mid-efficiency and high-efficiency gain scenarios is not as significant as in other emerging markets.

In sum, this analysis shows that sustainable cooling not only generates important development impacts across different areas, including significant emissions reductions, but also provides tangible monetary benefits to consumers and economies in developing countries. Given the underlying economic case for the acceleration of sustainable cooling at the macro level, there is ample space to design business models and provide financing for sustainable cooling at scale on a commercial basis. In addition to the business and financing opportunities for active cooling equipment with high upfront costs, there are also important opportunities for users and providers of passive measures and low-cost active cooling solutions (such as fans), as well as for private sector participation in the disposal and recycling of cooling equipment.[90]

2.4 Estimating Cooling Financing Gaps Across Developing Economies

The level of demand for cooling solutions at any point in time is determined by end consumers' needs as well as willingness to pay. The cooling market size estimates presented in Section 2.2 reflect expected levels of satisfied demand, that is, investments in owned cooling solutions or payment for cooling services by households, firms and farmers that can access and afford the active cooling solutions they need. This implies that there can be an access gap determined by the unsatisfied demand of end consumers that cannot afford the cooling solutions they need at prevailing market conditions and prices.[91] For instance, while larger and more established firms have in general ample access to finance to maintain their operations and support business growth, including their cooling needs, there are financial constraints to accessing required cooling solutions for a sizable number of MSMEs, which vary across countries. Similarly, access to cooling and refrigeration for households is conditional on their level of income, which also determines access to credit, both of which are distributed differently across countries.[92] Smallholder farmers' access to cold chain solutions depends not only on the size of their operations, but also on the availability of cooling infrastructure by location, proximity to collection centers and linkages to distant domestic markets and export markets. Most of these cooling gaps can be expected to

90 Additionally, there are significant economic and fiscal benefits for countries to implement the required regulatory and policy changes to support sustainable cooling.

91 Unsatisfied cooling needs are valued using the same equipment prices used for cooling market sizing, when applicable. It is also worth noting that since GDP and population growth are underlying drivers of projected cooling market size, the estimates in Section 2.2 imply that part of current market gaps may decrease due to income growth. However, population growth puts upward pressure on market gaps as the scenarios projected do not consider policy changes or targeted financing to close market gaps over time. Cooling market gap estimates presented in this section take these dynamics into consideration. The gap estimates in this section do not include investment amounts required to provide universal electricity access.

92 In addition to constraints on electricity access and financial limitations, there are other restrictions that may prevent individual consumers from accessing the desired level of space cooling. For instance, sustainable cooling also encompasses efforts to reduce outdoor temperatures, which are beyond individual consumers' control. Additionally, many consumers are unable to implement passive cooling measures on buildings, even if they are willing to pay for them. Furthermore, decisions regarding the efficiency of active cooling systems are often out of consumers' hands, for example when renting or buying homes with pre-installed air conditioning units. These restrictions are not incorporated in the cooling gap calculations presented in this section. Furthermore, green buildings, which are designed to require less cooling, typically come at a higher price point, making them less accessible to many consumers. Retrofit measures to improve cooling efficiency face similar financial barriers as the purchase of new, more efficient equipment.

gradually close over time as income levels rise with economic growth. However, the negative effects on health, education, food security, and productivity discussed in Chapter 1, will continue affecting households and firms exposed to high temperatures and without access to appropriate cooling solutions. Along these lines, this section provides stylized facts and estimates of the current and future expected levels of cooling access gaps for households and firms.[93]

Ideally, cooling access gaps would be estimated from refrigeration and space cooling data, either through ownership or services, for different types of consumers. However, the available data is not comprehensive.[94] Increased efforts on data collection on cooling should include information about cooling needs and access to active and passive cooling solutions for different end consumers across countries.

The remainder of this section estimates cooling gaps for some of the largest cooling market segments, such as residential cooling and refrigeration, and for SMEs within the non-residential cooling and refrigeration markets. It also includes a description of the underlying data and estimation rationale.[95]

Residential Space Cooling

Access to space cooling improves the wellbeing of households across important dimensions, including health, productivity, and goods durability. Under extreme heat conditions, access to proper cooling can be a life saver. Cooling needs are driven by local temperatures and humidity levels, which vary across and within countries.[96]

Fans are an affordable cooling solution for many households which can be used as an alternative or complementary technology to air conditioning and passive strategies. Data from across emerging markets, as shown in Figure 2.8, suggest a positive relationship between fan ownership and country temperatures.[97]

Air conditioning, on the other hand, is highly effective in providing thermal comfort but it is not always required given varying temperatures and conditions in local contexts. Moreover, access to air conditioning is highly dependent on income levels and, therefore, subject to stronger affordability constraints than fans or many of the available passive design strategies. Consequently, there is significant variation in levels of air

93 Estimating costs related to cooling gaps for farmers requires additional levels of underlying data and complexity that is beyond the objectives of this report. The comprehensive work that the Africa Centre of Excellence for Sustainable Cooling and Cold-Chain (ACES) is conducting in this area will provide a solid basis for such an important effort in the future.

94 For instance, country-level data on access to cooling solutions is limited to households' ownership of refrigerators, fans, and air conditioning for selected countries. On cold chains, there is some data on the availability of refrigerated warehousing for selected countries as well as several localized case studies on cooling solutions for farmers, but no comprehensive country data is available in this regard. On the other hand, there is no firm-level data on access to cooling.

95 An important segment within non-residential space cooling markets which has sizable cooling gaps but is not covered by these estimates, is that related to inadequate cooling in public and institutional buildings across many developing economies (e.g., schools, public offices, and hospitals).

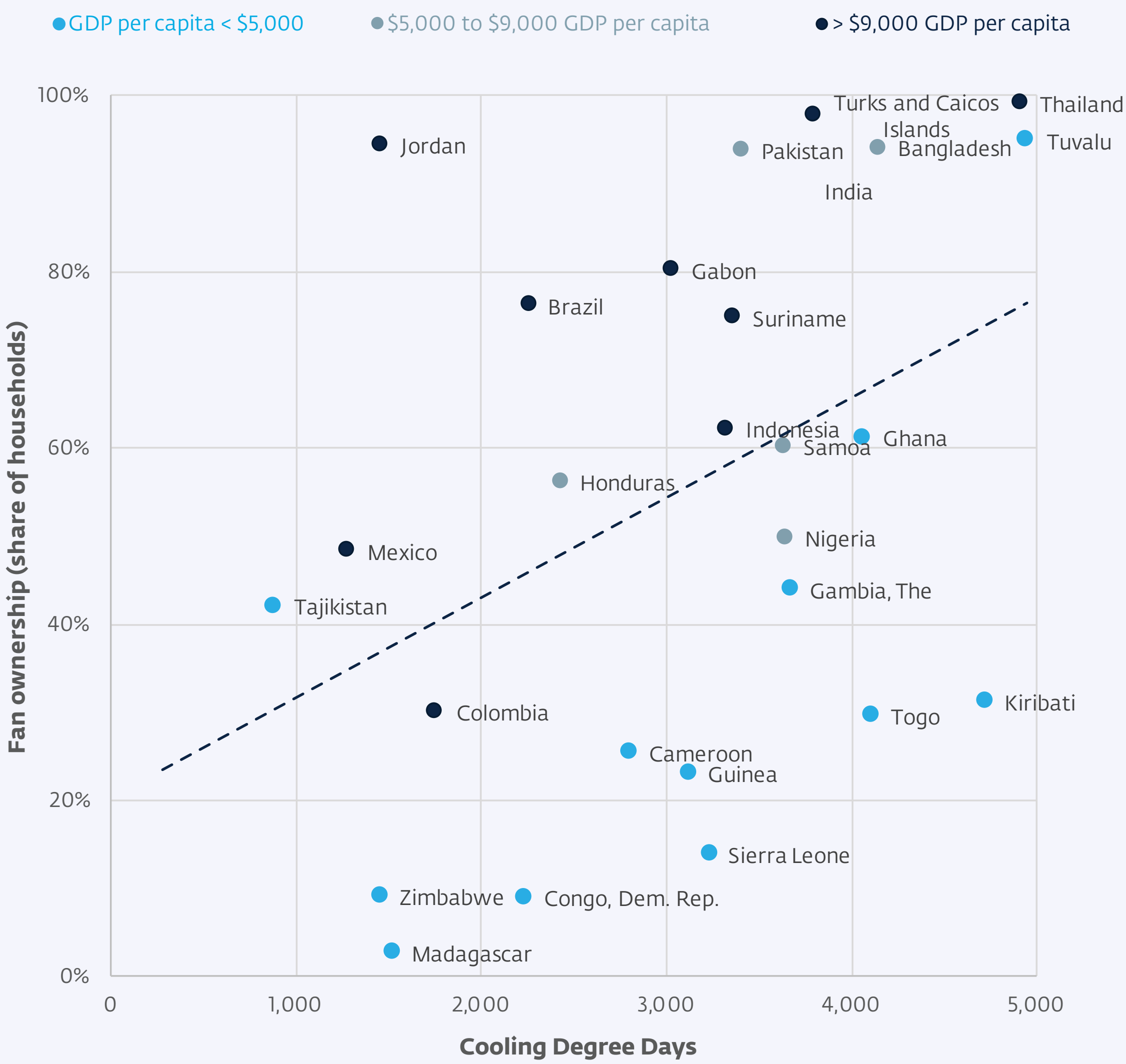
96 For instance, McNeil and Letschert (2008) show how air conditioner ownership varies across states in the United States, increasing in line with local temperatures.

97 The use of average Cooling Degree Days (CDD) has inherent limitations as it may not adequately reflect localized within-country climate variations. The positive relationship between fan ownership and temperature levels holds for groups of countries with similar income levels as well as for the total sample, although R-squared values are low.

FIGURE 2.8

Fan Ownership Is Greater in Warmer Climates, and Especially So Among Higher-Income Countries

Ownership of fans and cooling degree days across developing economies

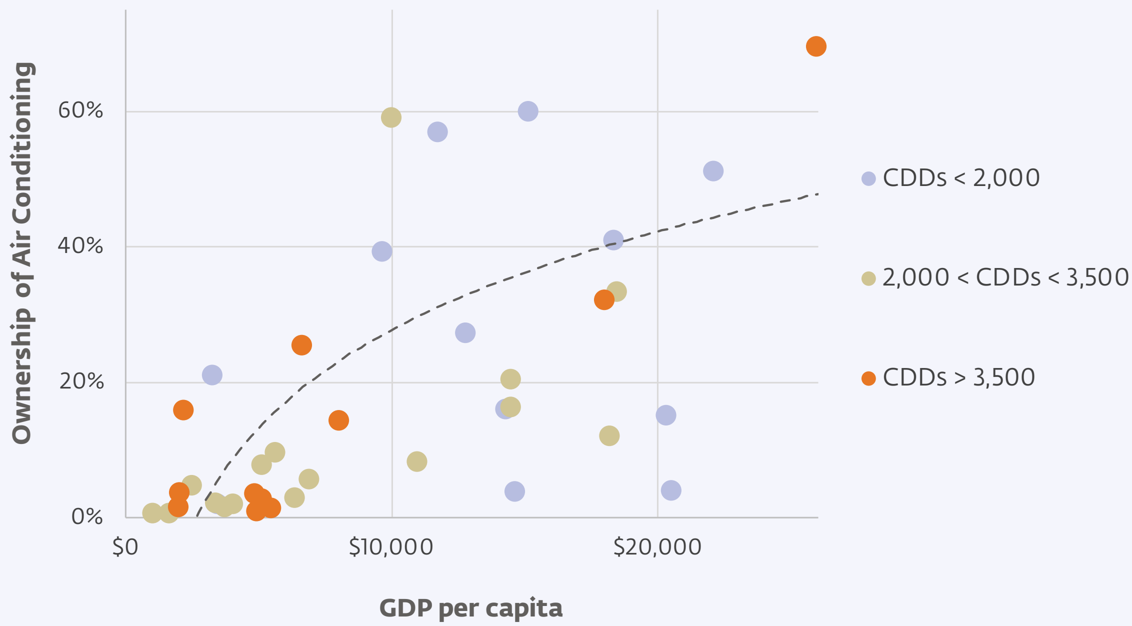


Source: Various surveys, International Energy Agency

FIGURE 2.9A

Air Conditioning Penetration is Driven by Country Income Levels

Air conditioning ownership, country income levels and cooling degree days across developing economies



Source: Various surveys, International Energy Agency, World Development Indicators

Note: GDP per capita is measured in constant 2017 International $ at PPP

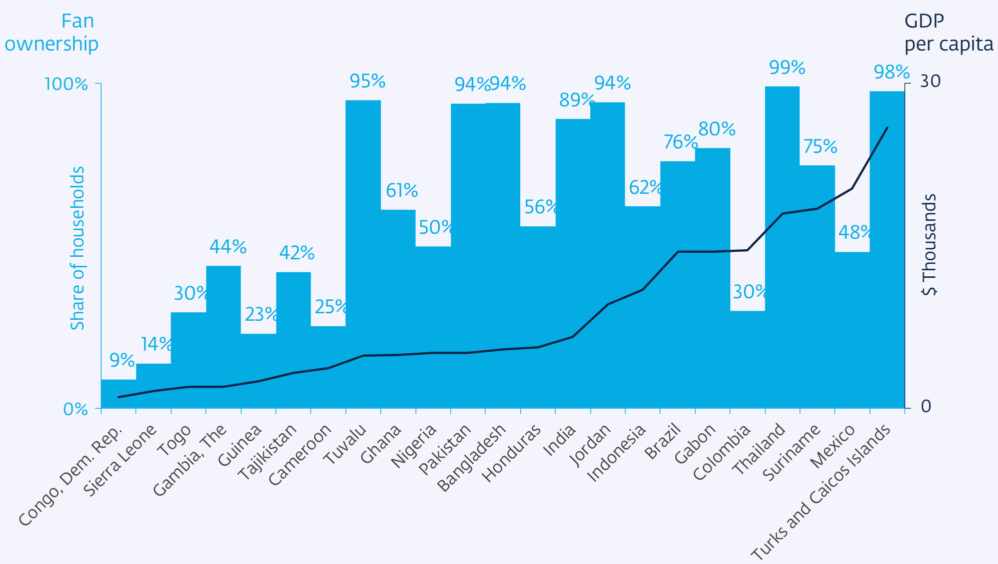
conditioner ownership both within and between emerging economies. Figure 2.9a shows rates of air conditioning ownership across countries.[98] Most countries in this sample with a GDP per capita below $9,000 have air conditioner ownership rates below 20 percent, while most countries with a GDP per capita beyond $15,000 have ownership rates above 30 percent.[99] Figure 2.9b shows this relationship between air conditioner and fan ownership rates and

98 GDP per capita in all the following charts is measured in constant 2017 International $ at PPP, and valued at the corresponding survey year for each country. Both panels of Figure 2.9 include countries with fans and air conditioner ownership data.

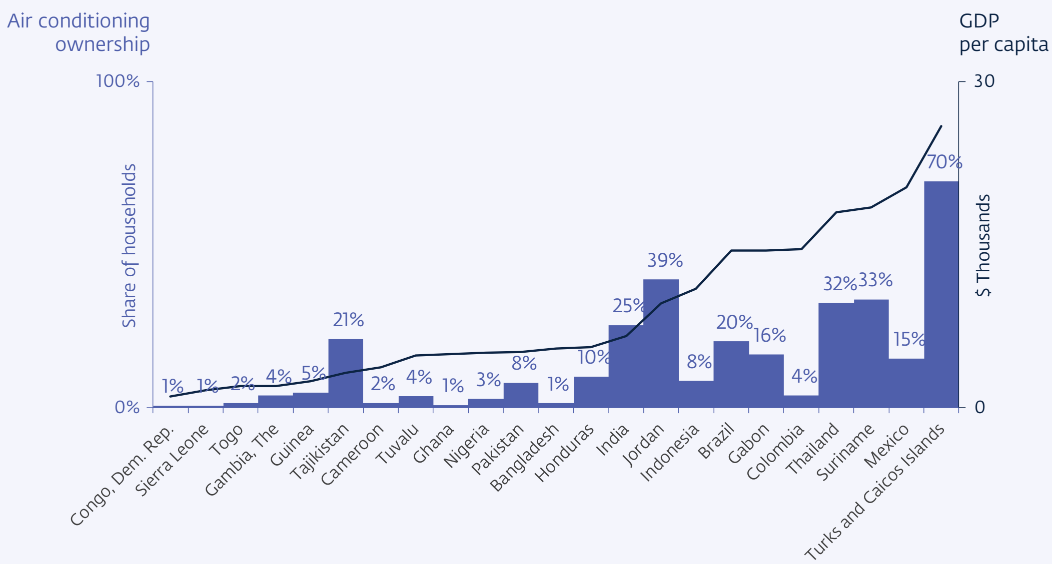
99 A notable exception are three outlier countries (Jordan, Iraq and Algeria) with income levels around $10,000 and air conditioner ownership rates between 40 percent and 60 percent. In addition, countries with lower incomes (GDP per capita below $9,000) and low ownership rates vary in terms of temperature levels. Similarly, countries at higher levels of income (with GDP per capita above $15,000) are also comprised of a mix of countries with different CDD levels, including several countries with lower temperatures (below 2,000 CDDs) and air conditioning ownership rates above 30 percent.

FIGURE 2.9B

Fans Provide the Base Load for Cooling Across Developing Economies



… While Deeper Air Conditioning Penetration Only Kicks In at Higher Income Levels



Source: Various surveys
Note: GDP per capita is measured in constant 2017 International $ at PPP

GDP per capita in the corresponding survey year. In lower-income countries, air conditioner ownership is nearly absent, while fan ownership is minimal. As income rises, fan ownership increases up to a certain point. Air conditioner ownership, however, starts low and only increases after reaching a higher income level. For most countries with higher income levels and relatively high air conditioner ownership, fan ownership remains above 90 percent.

In addition to energy-intensive cooling solutions like fans and air conditioning, there are alternative passive strategies for cooling, such as in building design, which combined with active cooling can provide more affordable and sustainable space cooling solutions. Further research on such holistic approaches should be pursued and evidence collected to serve as inputs that support the scaling up of these integrated solutions.

Fans and air conditioning ownership rates at the country level provide initial insights into the micro decisions made by households. For countries where household level data is available, it is possible to analyze in more detail the degree of access to cooling solutions by different types of households according to their income, consumption, or wealth levels.[100] The microdata shows that there are within-country differences in access and affordability of cooling driven by different dynamics across countries. The adoption of fans and the level of household incomes at which air conditioning becomes affordable vary greatly across countries, but similar patterns can be identified for economies with similar income levels. Annex 2 provides an analysis of fan and air conditioning ownership trends for households at different levels of income or wealth for selected countries in Africa, South and East Asia, and Latin America. Given the importance of these kinds of data for identifying cooling gaps and designing policies to address these, it is important to make efforts toward collecting this information in household surveys for more countries.

In the absence of data on access to passive cooling solutions and based on available fan and air conditioning ownership data across countries as well as data on the number of households per country, a range of the total cost required to close the residential cooling gap was estimated for all emerging market countries. This calculation does not assume a uniform need for space cooling; instead, it recognizes that the need for space cooling varies according to climate, which is detailed in Annex 2. The lower bound estimate of the total cost to close the residential cooling gap assumes that households with space cooling needs but without access to space cooling solutions fulfill their needs with fans only. The upper bound estimate assumes that air conditioning becomes available for all households seeking active cooling, even those that own fans.[101] These cases represent undesirable and incomplete scenarios as they

100 Fan ownership is obtained from several surveys, including national expenditure surveys, Demographic and Health Surveys and Multiple Indicator Cluster Surveys from UNICEF.

101 The residential space cooling gap is monetized by assuming that households with cooling needs require one fan or one split air conditioning unit, using the same data and assumptions on prices as for the cooling market sizing in Section 2.2. Under the upper bound scenario, households with space cooling needs that currently own fans only, are assumed to gain access to air conditioning.

do not include explicit assumptions about the use of passive strategies that would be part of the solution.[102] In the fan only scenario there will still be significant unmet cooling needs, particularly in climates with high humidity and very high temperatures. Conversely, in the air conditioning scenario, not all households in need of space cooling will require air conditioning and many could meet their requirements with a combination of passive strategies and fans.

However, these scenarios are useful to assess the order of magnitude associated with addressing these cooling access gaps. The air conditioning scenario sets the level of a maximum cost, which in reality will be lower when combined with passive strategies and fans. On the other hand, the fans only scenario sets a lower cost threshold, but as mentioned above, higher-cost air conditioning will still be the required solution in some areas. Therefore, the cost of closing these cooling gaps through different combinations of active and passive strategies across countries and regions is likely to be within this range. It is worth noting that in the actual combined solutions, passive strategies will play an important role as a first line of defense against heat as they can significantly reduce the need for active cooling and, as shown through the scenario analysis in Section 2.3, lead to additional benefits in terms of lower spending on active cooling equipment, lower electricity usage and lower emissions (see Annex 2 for further details on the estimation of the total cost to close residential cooling gaps).

Based on these scenarios, the total cost to close the residential space cooling gap across developing countries ranges from $7.8 billion to $372 billion in 2023, as using fans to close space cooling gaps for households costs around a fiftieth as much as using air conditioning.[103] This is driven by a higher ownership of fans relative to air conditioners, as well as the lower unit price of fans. Across regions, the total cost to close the space cooling gap when using fans as a possible solution is $3.9 billion in Africa, followed by $2.8 billion in South Asia. The total cost in the Middle East, East Asia and Latin America ranges between $100 and $500 million per year.[104] On the other hand, closing the gaps through access to air conditioning could imply costs of $117 billion in South Asia, $92 billion in Africa, and $85 billion in East Asia where China accounts for $30 billion. The total cost to close the space cooling gap with air conditioners in Latin America and the Middle East is between $25 billion and $35 billion, while remaining regions imply a cost of

102 Ultimately, how these gaps are addressed will be decided based on a global marginal cost curve of various existing cooling solutions: passive cooling, fans, air conditioners, variable flow systems, chillers, district cooling, among others.

103 These costs represent a gap of approximately 3.6 billion people without access to air conditioning and 900 million people without air conditioning or fans in 2023. According to a study from SEforAll (2023), 1.1 billion people face immediate risks due to a lack of access to cooling, including 815 million urban poor without electricity, unable to afford a fan—similar to the fan gap estimated in this report. An additional 2.9 billion people are at medium risk, primarily lower-middle-income groups, approaching their first purchase of affordable air conditioning or a refrigerator, which, when combined with the high-risk population, mirrors the air conditioning gap estimated in this report.

104 Aggarwal & Agrawal (2022) estimate an unfulfilled demand of 66 million ceiling fans in India. To satisfy this demand using super-efficient ceiling fans would cost $2.7 billion. Efficiency for Access Coalition (2019) analyses the global market for off-grid appliances. The estimated addressable market for off-grid fans, defined as the number of households which could acquire an off-grid fan if financing was available, was 232 million households in 2018, which is approximately 50 percent of off-grid and weak-grid households globally. The obtainable market, which is constrained by financing availability and accessibility to off-grid appliance distributors, was 39 million households in 2018, valued at $1.2 billion.

$15 billion or less. By 2050, increased incomes due to economic growth across most regions reduce the estimated costs to $20 billion or less, with the gap in China expected to close by 2040. The exception is Africa, where the cost will be $126 billion in 2050 as increased affordability driven by economic growth fails to keep pace with the expected increase in demand (see Figure 2.10).

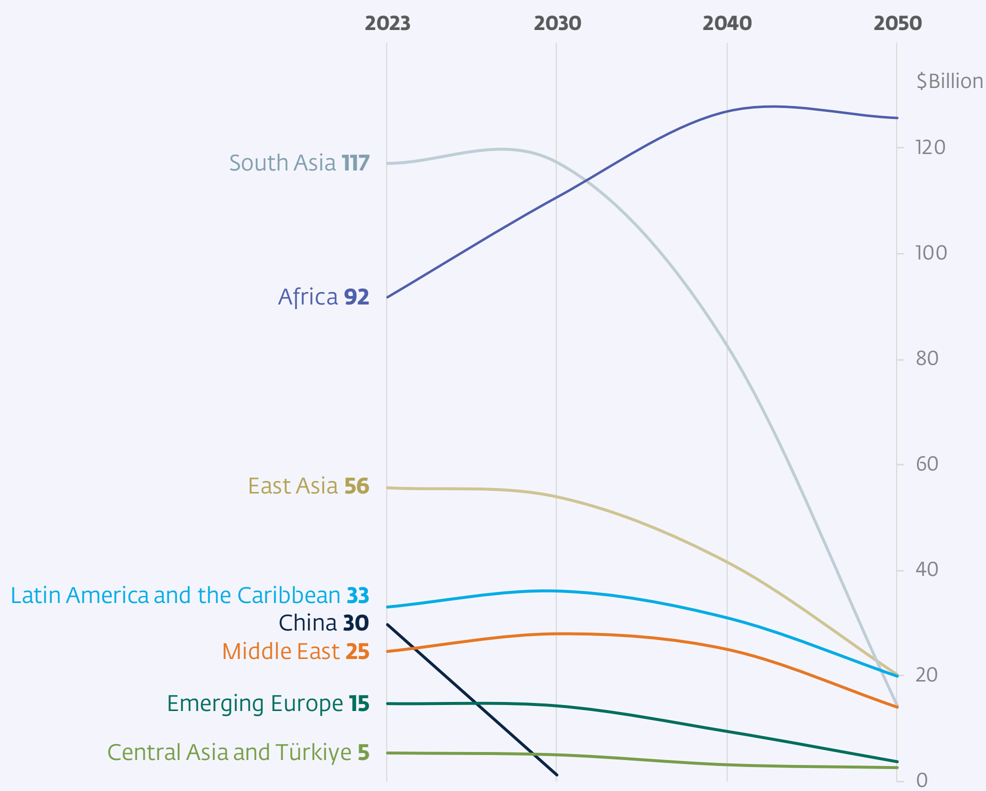
Residential Refrigeration

Refrigeration is critical for food and nutritional security around the world, with residential refrigeration an essential last-mile requirement

FIGURE 2.10

Space Cooling Gaps Will Close Gradually as Economies Grow Across the Developing World, Except in Africa Where They Will Widen

Estimated cost to close the gap in residential space cooling across emerging markets through air conditioning



Source: Estimates by authors (methodologies described in Annex 2)

of the entire food cold chain. Having a refrigerator at home allows households to store perishable goods and avoid dependence on local markets—which in many locations across developing economies don't have appropriate refrigeration to preserve such products. Access to refrigeration for households is dependent on income as well the availability of electricity. Figure 2.11 shows a positive relationship between refrigerator ownership and GDP per capita in developing economies, with ownership rates below 60 percent in countries with a GDP per capita under $8,000, and above 80 percent in most countries with a GDP per capita above $10,000.[105] Given the strong correlation between electricity access and GDP per capita, most countries with lower incomes and low electricity access also have the lowest refrigerator ownership rates.[106] There are also important regional differences in terms of access gaps. Africa and South Asia have the largest refrigeration gaps with average ownership rates below 40 percent for most countries. In East Asia, most countries have less than 60 percent ownership, while in Europe and in Latin America more than 80 percent of households own a refrigerator across most countries in the sample. Annex 2 highlights additional differences in ownership observed from survey data.

As in the case of fans and air conditioning, household-level ownership data provide further details underlying the aggregated ownership rates observed at the country level. As shown in Annex 2, there are important differences in access to residential refrigeration across the distribution of households (by income, expenditure, or wealth) for countries at different stages of development. Within countries with available microdata, those in Latin America and East Asia have higher rates of refrigerator penetration among households in the bottom deciles and show ownership rates close to or above 90 percent for households above the bottom 40 percent. In contrast, those in Africa and South Asia show significant access gaps, with at least 60 percent of households in the bottom 60 percent of the distribution not owning a refrigerator.

Given the essential need for refrigeration in food preservation within households, the target is for all homes to have access to residential refrigeration. Therefore, the total costs required to close residential refrigeration gaps are quantified based on the projected ownership rates underlying the market size estimates in Section 2.2, which already incorporate the growth in ownership driven by economic growth, vis-à-vis the universal ownership target for a growing population.[107] Along these lines, the cost of closing the residential refrigeration gap across developing economies is estimated to be $172 billion for 2023, and is expected to decline

105 Gabon, Indonesia, and Mongolia are notable exceptions, as they have a GDP per capita between $10,000 and $15,000, and refrigerator ownership rates between 48 percent and 67 percent.

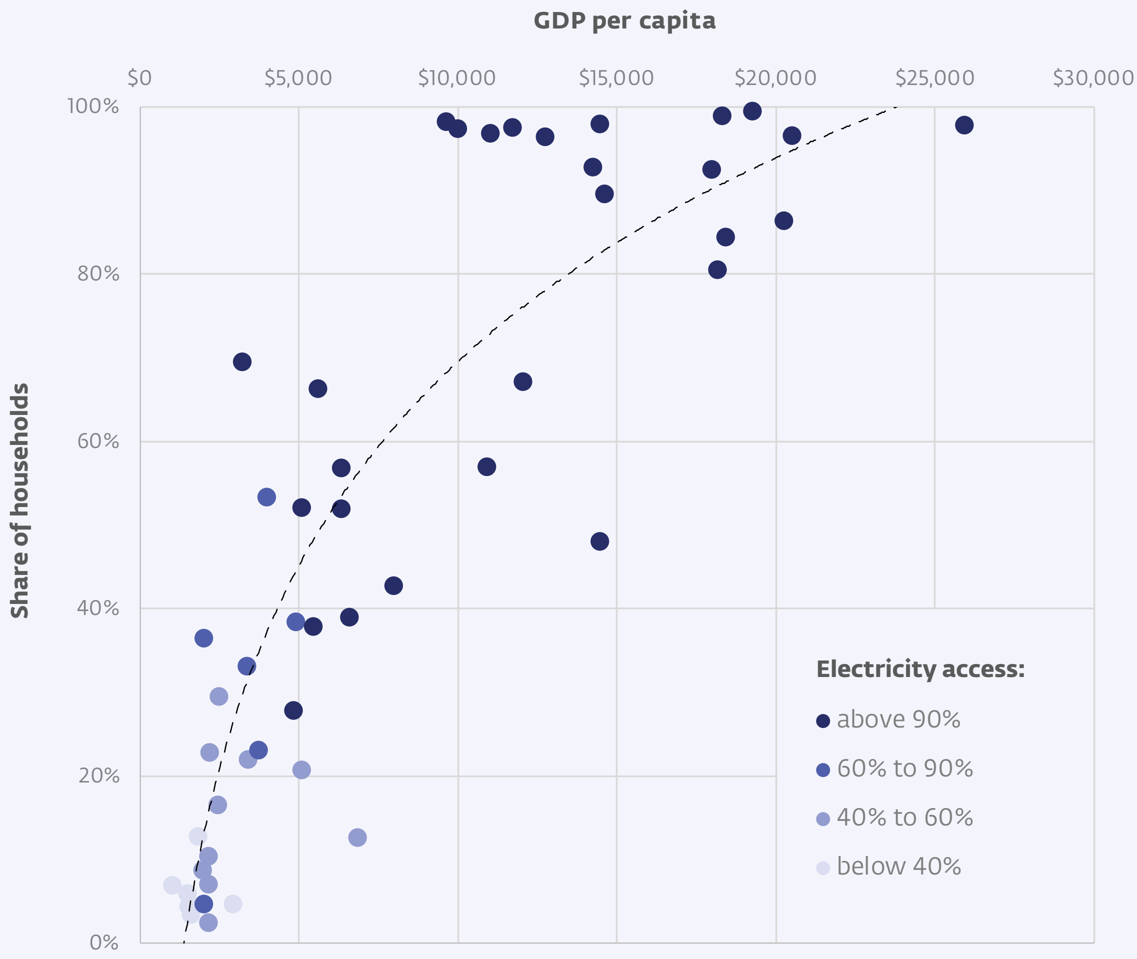
106 There are a few exceptions where higher electricity access explains relatively high refrigerator ownership, despite country income levels. For instance, refrigerator ownership in Gambia (at 36 percent) is above that observed for most countries at similar income levels. Other examples are Angola and Nigeria, where ownership rates in 2018 were 13 percent and 21 percent respectively, despite GDP per capita between $5,000 and $7,000, on account of electricity access below 60 percent of the population.

107 The residential refrigeration gap is quantified by assuming that households require at least one refrigerator and using the same data on ownership projections and assumptions on equipment prices as for the cooling market sizing in Section 2.2.

FIGURE 2.11A

Low Access to Electricity Hinders Access to Refrigeration (…and Other Cooling Solutions)

Ownership of refrigerators, country income levels, and access to electricity across developing economies



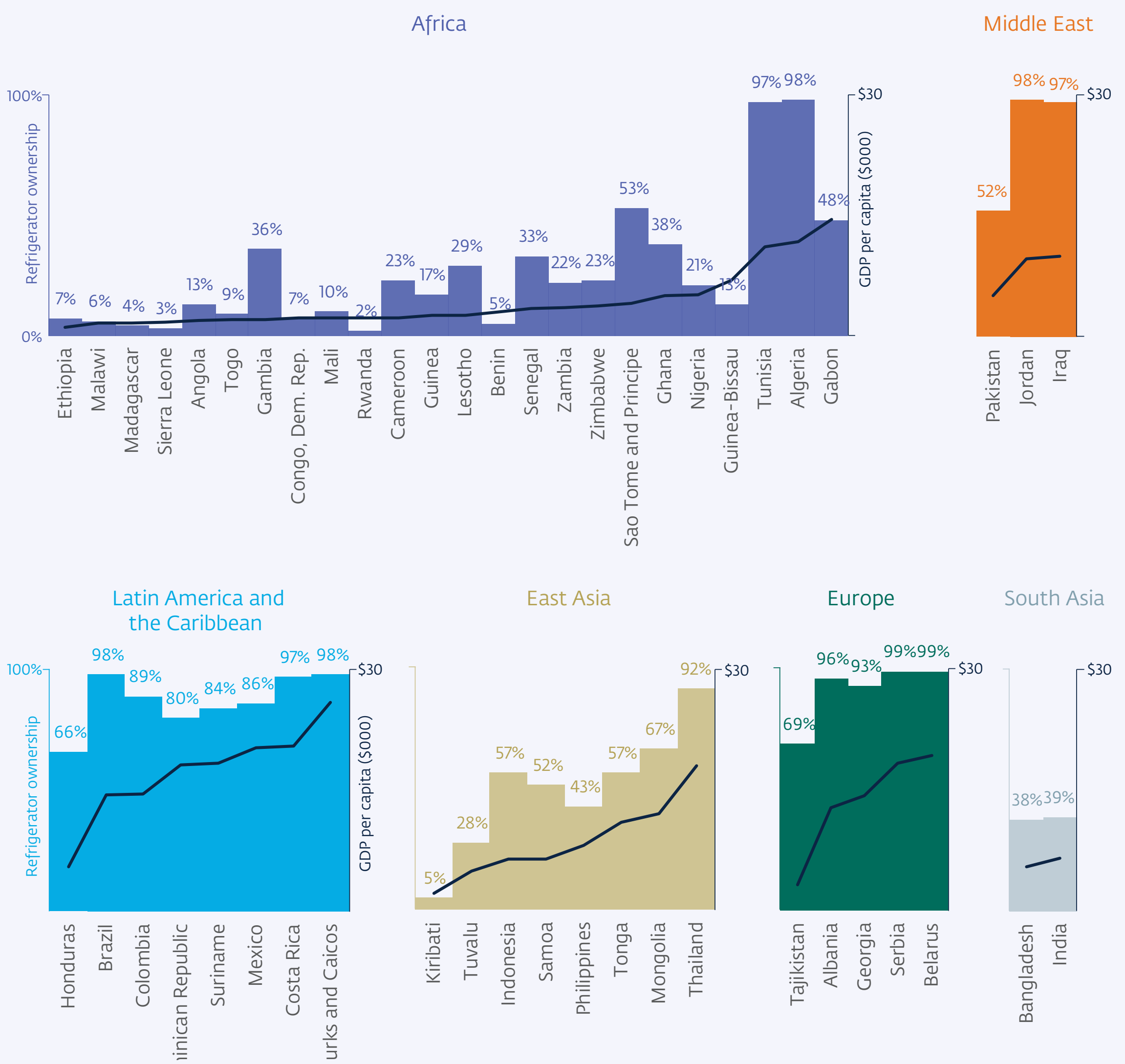
Source: Various surveys, World Development Indicators

Note: GDP per capita is measured in constant 2017 International $ at PPP

FIGURE 2.11B

Households in Africa, East and South Asia Have Lower Ownership Rates of Refrigerators

Ownership of refrigerators and country income levels across developing regions



Source: Various surveys
Note: GDP per capita is measured in constant 2017 International $ at PPP

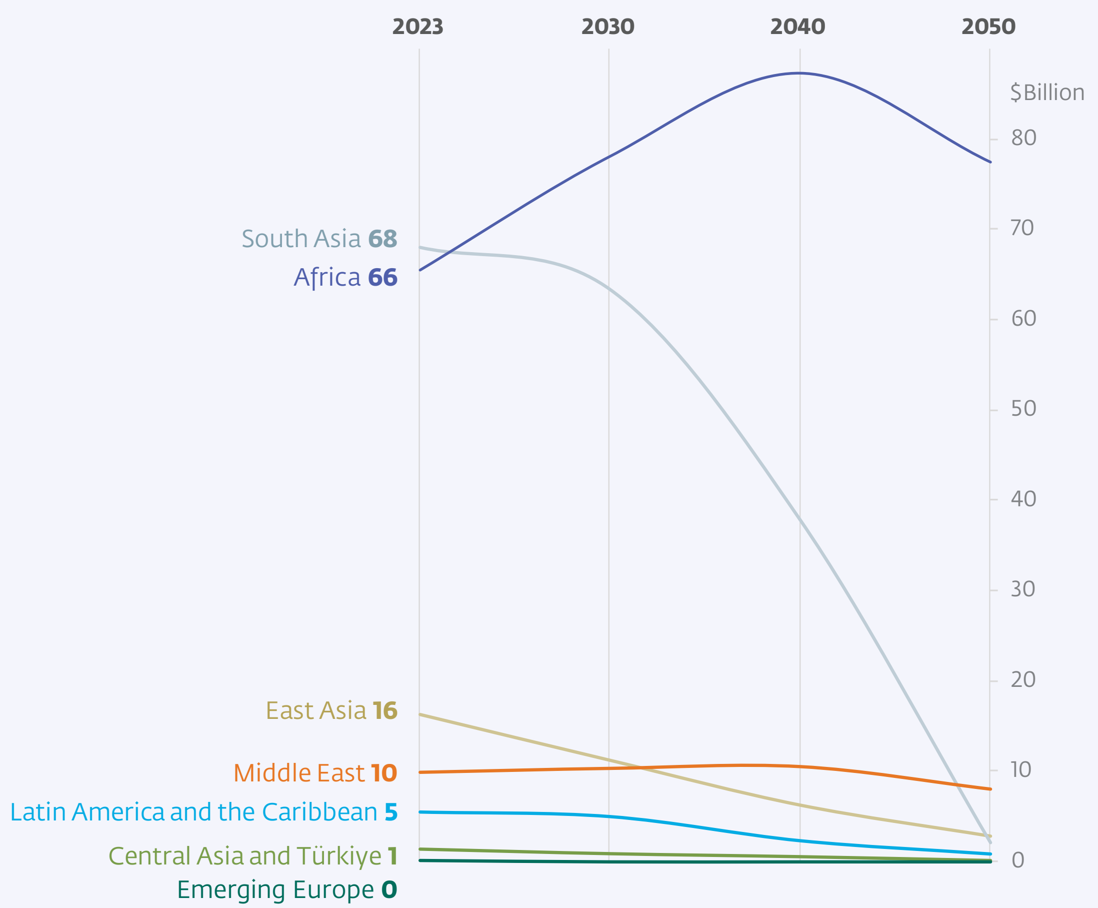
to $91 billion by 2050 due to increases in income per capita across countries.[108] For regions, the highest costs in 2023 are in South Asia and Africa, at around $65 billion each. East Asia, the Middle East and Latin America imply costs ranging from $5 billion to $15 billion. The residential

108 These costs represent a gap of approximately 2.5 billion people without access to refrigerators in 2023.

FIGURE 2.12

Refrigeration Gaps Will Almost Close by 2050 Across All Developing Regions, Except in Africa

Estimated costs of closing residential refrigeration gaps in developing economies



Source: Estimates by authors (methodologies described in Annex 2)

refrigeration gap in China and Emerging Europe is expected to close by 2025. In contrast, by 2050, the cost to close the residential refrigeration gap in Africa is projected to be $77 billion, while all other regions combined would require a total cost of $14 billion to close their residential refrigeration gaps.

Space Cooling and Refrigeration Gaps for SMEs

The cooling needs of SMEs are driven by the type of operations they run and vary across sectors. For instance, space cooling is critical for tourism and retail (to provide comfort to customers), while refrigeration is essential in food processing, retail food markets, and restaurants as well as in the retail pharmaceutical sector. In addition, firms across many sectors need space cooling to provide thermal comfort to their employees and maintain well-being and productivity.

Based on the cooling demand estimates from Section 2.2 and using available data on the contribution of SMEs to GDP and their access to finance, it is possible to estimate the total cost required to address cooling gaps for SMEs.[109] These firms contribute, on average, 35–40 percent of GDP across developing economies.[110] Since large businesses usually have the means to satisfy their cooling needs (including through financing), the unsatisfied non-residential cooling demand is mainly attributable to SMEs with insufficient financing resources to access the cooling solutions they require.[111] According to the SME Finance Forum, about one third of SMEs in developing economies are fully financially constrained and 12 percent are partially financially constrained.[112] For further details on the underlying rationale and assumptions for these estimations, please refer to Annex 2.

The total cost to close the SME space cooling and refrigeration gaps across emerging market economies is estimated to be $268 billion for 2023 and expected to be between $179 billion and $584 billion by 2050, depending on the evolution of access to financing.[113] China accounts for 69 percent of the total cost ($186 billion), followed by the rest of East Asia, South Asia and Emerging European countries with costs ranging between $15 billion and $25 billion. While the cost to close SME cooling gaps in both Africa and Latin America are $6 billion, the cost in other regions ranges between $2 billion and $4 billion.

SME cooling gaps can be expected to continue increasing over time across most regions, as

109 SMEs are expected to capture most private sector-driven gaps. However, due to data limitations, it is not possible to estimate cooling access gaps by industrial or commercial sectors. Additionally, given the underlying data, not all the SMEs in the agriculture sector are included in the estimation.

110 Authors' calculations from data gathered through multiple sources, including IFC MSME Economic Indicators Database 2019, OECD Structural and Demographic Business Statistics, Asian Development Bank Small and Medium-Sized Enterprise Monitor reports, reports from CEPAL and UNECE, and selected academic papers.

111 However, despite having the means to finance cooling solutions, there are large factories that do not provide adequate cooling for their workers.

112 For SME Finance Forum MSME finance gap data see: https://www.smefinanceforum.org/data-sites/msme-finance-gap. It is worth noting that a fraction of SMEs without access to finance may still have access to some cooling solutions if they are critical for their operation, such as in the case of small restaurants and grocery stores.

113 The lower bound of this range assumes SME access to finance improves according to current cross-country differential trends, while the upper bound assumes SME access to finance remains at current levels.

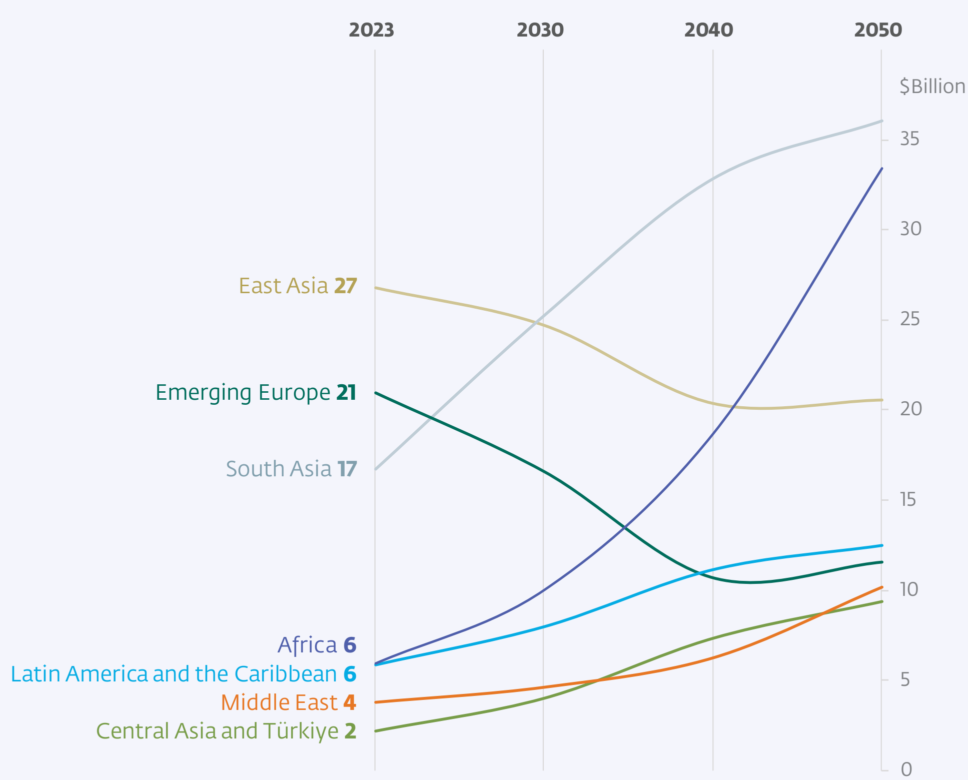
improvements in access to finance may not keep pace with increasing needs underlined by economic growth. Overall, these estimates show the relevance of SME access to finance for the cooling agenda going forward.

On the other hand, it is worth noting that this calculation is based on the levels of satisfied demand in the baseline projections, which are mainly driven by active cooling solutions. Therefore, the use of passive cooling solutions for SMEs—many of which could be more affordable—could reduce estimated future costs under a scenario with increased use of passive strategies.

FIGURE 2.13

Cooling Gaps for SMEs Will Grow Across Developing Regions, Except in Europe and East Asia

Estimated costs to close the SME cooling gaps in developing economies



Source: Estimates by authors (methodologies described in Annex 2)

Photo by Kazi Salahuddin Razu/NurPhoto via Shutterstock

3

Challenges and Response Strategies for Promoting Sustainable Cooling

This chapter examines some of the challenges to investment in sustainable cooling, including many that are specific to developing economies, before outlining ongoing efforts by IFC, UNEP, and other organizations to address them. The issues vary by sector, with sustainable residential space cooling presenting distinct challenges to those associated with cold storage. They also vary according to the type of project, their scale, and whether they are financed with private or public funding. Some cooling operations require multiple products and services, such as cold chains—supply chains that incorporate procedures for ensuring temperature control—for delivery of rural farm products to urban markets.

Providing sustainable cooling solutions, meanwhile, involves navigating trade policies, utility regulations, building codes, and electricity access. Firms and investors must also consider issues such as consumer awareness, the availability of finance for startups, and the willingness of banks to provide credit for purchasing more efficient appliances. Some of these challenges are being addressed through the financial support of the Montreal Protocol Multilateral Fund, though many remain persistent issues in many developing economies.

Scalability usually requires business models to be commercially viable. Therefore, projects in low-income or difficult-to-reach populations as well as some passive cooling strategies may require additional incentives to attract private capital. Some may need to be structured as public-private partnerships.[114] Indeed, cooling strategies that work in developed markets have not always proven as effective in developing countries.[115]

This chapter also discusses some of the significant gaps in existing initiatives promoting sustainable cooling. For example, IFC has identified multiple sustainable cooling solutions at early stages of implementation. However, many were developed by startup companies and available only on a very small scale. The time and resources required for these products to be fully proven and commercially ready is another challenge.

3.1 The Challenges to Private Investment in Sustainable Cooling in Developing Economies[116]

A key role for IFC and other development finance institutions is mobilizing private investment toward projects that will have a significant development impact for emerging economies. However, despite the evident benefits of sustainable cooling, investing in this area is often not immediately attractive for private investors. There may be a lack of awareness about the business case, a perception of excessive risks, high initial costs, differences in regulations, or complicated and time-consuming decision requirements. Indeed, not all applications can provide commercial returns using current technologies and business models. Some of these

114 Incentives may be provided in the form of grants, subsidies, tax breaks, reduced interest rates, or other enhancements to financing terms.

115 For a previous discussion on barriers to financing air conditioning and refrigeration, see GIZ Proklima - Cool Contributions Fighting Climate Change (2018).

116 Additional background and discussion of barriers and systemic challenges to cooling can be found in UNEP (2023a).

challenges that are stymying private investment flows into sustainable cooling are described in more detail below, while the remainder of this chapter reviews some of the initiatives underway to address them.

Systemic Issues on the Demand Side

Sustainable cooling faces significant hurdles stemming from socioeconomic disparities. These include income inequality, lack of access to reliable and affordable energy, limited infrastructure in developing regions, and other fundamental development issues.

High upfront costs, high risk, and lack of trust. Customers seeking active cooling equipment often focus on minimizing upfront capital expenditure without adequately considering future operating expenses. This approach often leads to selection of less efficient air conditioning units that ultimately cost more over their life cycles. In tropical regions, for example, the upfront cost of a new commercial air conditioning system may only account for 5 percent of the total expenditure over its entire lifespan, with the remaining 95 percent spent on energy and maintenance. This is causing some customers to buy units that are only one-third as efficient as some of the available alternatives.[117] Indeed, minimizing upfront capital expenditure is often mandated in public sector procurement rules. Furthermore, lack of trust in the veracity of promised savings from high-efficiency options is exacerbating the problem. To take the more efficient system, customers are required to invest a significant premium up front without guaranteed mechanisms to ensure future cost savings.

Affordability. Hundreds of millions of people in South Asia, Sub-Saharan Africa, and other regions with high exposure to extreme heat lack the financial resources to buy an efficient fan, much less an air conditioner. Business models are attempting to address this challenge as discussed below and in Chapter 4, but the need remains enormous, and in many areas the at-risk populations are growing.

Limited Infrastructure and electricity access. An estimated 760 million people lacked access to electricity in 2022[118] while millions who do benefit from power supplies are forced to restrict the operation of cooling equipment to afford their utility bills. Where access is provided, power is often unreliable during periods of extreme heat when demand is greatest. The absence of reliable electricity in many areas exposed to high temperatures is a major barrier to the operation of fans and cooling equipment. Figure 2.11B in the previous chapter shows differences in refrigerator ownership across low-income countries attributable in part due to differences in access to electricity. While the World Bank Group and other

117 IEA (2018).

118 IEA (2023c).

institutions have promoted electrification and off-grid power for many years, this remains a significant challenge in many developing countries.[119] This is especially acute in Sub-Saharan Africa where 600 million people lack access to electricity,[120] contributing to the sizable cooling gaps observed for African countries documented in Chapter 2. For this reason, the World Bank Group and the African Development Bank announced in April 2024 a partnership to provide 300 million people in Africa with electricity access by 2030.[121] Further background and case studies on affordability and energy access challenges can be found in reports from the Montreal Protocol Technology and Economic Assessment Panel.[122]

Other **non-financial barriers**. The introduction of products and services based on energy efficiency often faces issues such as the need for verification of performance and reliability (especially for business models linking payment to savings) and insurance coverage.

Systemic Issues on the Supply Side

Finance for small and medium-sized enterprises (SME) and innovative startups. While the potential for innovative cooling solutions is enormous and growing, the TechEmerge program (described in more detail in Chapter 4) identified a common quandary facing small firms and startups seeking new investment after the initial proof of concept. In order to obtain a commercial rate of return and minimize risk, private investors typically prefer firms with some scale and an established market. However, many promising TechEmerge recipients have found themselves struggling to secure capital following their initial support. Many discovered there are very few funding sources available to help small companies achieve the scale and revenue that would make them attractive for commercial investment. Furthermore, small businesses that are also subject to a lack of access to reliable power face major inhibitions to their operations and growth prospects.

Supply chain issues. Providing access to the most efficient cooling equipment and the support necessary for effective installation and maintenance as well as passive cooling measures is a frequent challenge in many developing countries. The challenge is greater still in markets that are smaller and poorer. This complicates the introduction of new refrigerants that became available in response to the Kigali Amendment to the Montreal Protocol (an ongoing process discussed in Chapter 4). These countries

119 Investments to strengthen the electricity grid's capacity and reliability with renewable energy are crucial in the electrification process.

120 IEA (2023c)

121 World Bank (2024).

122 UNEP (2021c).

may become the recipients of older "dumped" equipment (See Box 3.1) making them less likely recipients of the newest models. In addition, despite the introduction of energy performance standards in China, low efficiency units are still largely exported to countries in Africa and Southeast Asia as efficiency requirements do not apply to exported equipment.[123] Markets for used equipment, typically less efficient and often prone to leakage, exacerbate the problem. Box 3.3 outlines this challenge and a program supporting the adoption of more efficient refrigerators and air conditioners.[124]

Cooling is Not a Traditional Financial Sector or Asset Class

Cooling is generally not the primary focus of the industrial, public, or household activity, except in cases where refrigeration is a core function for a business. Typically, cooling serves as a supporting system essential for operational

123 ChinaIOL (2022); Moreover, most of the units imported into Southeast Asia do not meet the efficiency standards of the export country CLASP (2023).

124 BASE and U4E (2023).

BOX 3.1

Promoting Energy Efficiency Through Standards and Compliance

While adopting high-efficiency equipment offers long-term benefits for consumers, these advantages are in most cases obscured in the short term by higher upfront costs. Without minimum efficiency standards, which are still lacking in many developing countries,[1] uninformed and financially constrained consumers may continue to purchase less efficient units.

According to a 2023 report from CLASP,[2] energy efficiency policies in Southeast Asia are not keeping pace with technological improvements in high-efficiency appliances or with policies in surrounding countries. As a result, the market is at risk of becoming a dumping ground for outdated and inefficient appliances that are prohibited in the home jurisdictions of the multinational corporations that make them. By implementing minimum energy performance standards, Southeast Asia could reduce cumulative emissions from 2025 to 2050 by 20 percent and generate cumulative savings of $148 billion in electricity costs. In Africa, another region which risks becoming a dumping ground for inefficient equipment, implementing energy efficiency standards could reduce cumulative emissions by 14 percent.[3]

Nevertheless, the presence of regulations alone is often insufficient to ensure compliance, as informal cross-border trade and second-hand markets can undermine the enforcement of efficiency standards.[4] These issues underscore the need for regional and international measures to fully realize the benefits of high-efficiency equipment.

1 https://rise.esmap.org/pillar/energy-efficiency/subindicator/have-minimum-energy-performance-standards-been-adopted

2 CLASP (2023).

3 CLASP (2020).

4 A 2016 report by the World Bank (Khalfallah et al., 2016) shows that in Tunisia, despite the existence of energy performance standards for new units, there has been a decline in performance due to the smuggling of cheaper, less efficient products from neighboring countries.

efficiency and user comfort. For companies looking to procure goods and services for cooling systems, understanding the full spectrum of support available is crucial. These businesses require energy audits, technical assistance, grants for pilot testing, and blended finance for effective implementation (See Section 4.5). It is essential for them to recognize the business case that sustainable cooling can significantly reduce energy costs. However, investment decisions often relegate cooling to a secondary consideration.

Even when cooling is factored into project design, builders may choose to incorporate the lowest cost measures first. Investment identification, analysis, and decisions are often organized around sectors—buildings, infrastructure, agriculture, transport, manufacturing—and cooling is almost always a second order consideration in the design and financing of larger investments. Passive design strategies for cooling around orientation, insulation, and nature-based solutions such as shading with vegetation for buildings, can be very effective and may receive greater consideration insofar as they often require minimal additional investment.

In sectors like residential construction, developers often lack incentives to prioritize sustainable cooling unless driven by regulation or consumer demand for green certifications. Developers may benefit from the value that buyers attach to green certification in markets with some level of consumer awareness, but otherwise see little or no incentive to do better.[125]

Even in those markets where financial or regulatory incentives for green buildings do exist, companies focused on their short-term bottom line may lack motivation to develop sustainable cooling solutions. Many companies are not aware of additional benefits from sustainable cooling, such as access to international climate finance or government incentives like higher density permits for green residential buildings.

Furthermore, in most countries, the public sector must comply with national regulations on public finance and the procurement of goods and services. When there is a need to replace cooling systems, these investments are usually too small to justify the complex process of accessing public debt. Aggregating projects, such as upgrading all cooling systems in public hospitals and clinics nationwide, could make public financing feasible and encourage the adoption of sustainable cooling solutions. However, public entities often finance these replacements from their annual operating budgets due to the complexity of accessing public debt. This creates competition for funds between cooling system replacements and other public needs and operating costs.

Challenges to Innovative Cooling Solutions

> Beyond the systemic lack of financing for innovative SMEs working to scale up cooling, the limited capacity of the small firms involved in these activities and a

125 IFC has written extensively around the business case for green residential construction (which includes approaches for cooling), from the point of view of both developers and financial institutions. See, for example, Music (2023), Music (2021), and Cairncross and Naicker (2020).

lack of awareness among entrepreneurs and investors further constrain access to financing.

Consideration of innovative approaches requires time and expertise, amounting to unwelcome delays and upfront costs. Investors will also regard any uncertainty related to the innovation, particularly if it is untested in the specific market, as an added risk, prompting them to demand a higher return on their capital.

There are opportunities for accelerating the transfer of innovative cooling solutions from developed to developing countries. However, supply chain constraints for new products can present challenges in emerging markets, especially with new products such as refrigerants with low levels of global warming potential. The Kigali Amendment to the Montreal Protocol requires a phasedown in use of the most widely used refrigerants. The transition to alternatives is ongoing and yet to be fully incorporated in many developing countries where markets are dependent on imports, sometimes including older inefficient equipment. Initiatives to provide financing and technical assistance supporting Kigali Amendment implementation are described in Chapter 4. Some countries such as Brazil have requirements for locally sourced components in manufactured goods which can be a constraint to the import of more efficient cooling equipment. However, an interest in promoting more locally manufactured equipment may ultimately support innovative cooling solutions and development of supply chains.

The Lack of Consumer Awareness of Sustainable Cooling's Cost-Effectiveness

Efforts to raise awareness of cost-effective passive strategies, particularly among low-income consumers, are often lacking (See Box 3.2 for an example initiative to promote affordable cooling). Such measures can be as simple as painting roofs white or using natural ventilation.[126] Cooling with fans or air conditioners with the lowest upfront cost is, typically, the least efficient and more expensive solution over time, but is frequently the only option for low-income consumers.[127]

Promoting efficient cooling on grounds of lower operating costs requires consumer awareness validated by independent sources, such as the quality assurance programs developed in the IFC-World Bank Lighting Africa program. It also requires owners and renters to be willing to pay higher upfront prices in return for better energy performance later. This trade-off is complicated in some developing countries by the availability of subsidized electricity.

Socioeconomic factors have led the low-income residential sector to prioritize

126 See https://coolcoalition.org/side-event-passive-cooling-and-nature-based-solutions-for-building-comfort/ (summary of Cool Coalition side event on passive design strategies for cooling and nature-based solutions for building comfort, COP28, December 5, 2023).

127 As with air conditioners, the lowest cost fans are typically less energy efficient and often more expensive over time.

inefficient and environmentally harmful cooling systems. Africa has become a destination for 'zombie' refrigerators and air conditioners—cheap, obsolete units mostly discarded from European households and resold illegally. From 2004 to 2014, Ghana imported over 3.7 million refrigerators, around 75 percent of which were second hand. Despite a 2013 ban on importing second-hand refrigerators and air conditioners, illegal imports continue. While families benefit from the lower prices in the immediate term, these appliances consume at least twice the energy of more up-to-date equipment used in the United States or Europe, with significant environmental and health impacts.[128] There is a lack of competitive business models and financial strategies to counter these practices and address market needs.

Creating Effective Cold Supply Chains for Rural Farmers

Effective cold chains for rural farmers can improve the quality of agricultural products that reach markets, resulting in higher returns. Effective cooling solutions also enable longer holding and shelf lives for agricultural produce, further maximizing profits and minimizing losses.[129]

BOX 3.2

Ant Studio, India: Entrepreneurs Drive Passive Cooling for the Masses

Ant Studio is an architecture practice in India that combines passive cooling design, innovative low-tech cooling systems, and nature-based methods to help residential, government, commercial and industrial clients to lower cooling costs. It also works with leading Indian universities to lab test and showcase the cooling demand reductions their projects achieve. The firm was profiled by UNEP as a leading Indian innovator on sustainable cooling in 2019 and continues to engage with UNEP's passive cooling program in the country.

It is reporting a surge in demand with over 1,200 prospective projects involving schools, homes, government buildings and industries. As a company with strong environmental and social principles, it aims to help address the 99 percent of buildings in India it estimates lack access to expert architects that offer passive cooling solutions on account of affordability constraints. Ant Studio participates in a pro-bono program to provide support to those unable to afford expert architectural advice, though its availability is limited in the face of huge demand from clients. As such, Ant Studio is working with IT companies to establish an online platform that provides this architectural support through a combination of AI and technical expertise from Ant Studio architects. This free service will be financed by using the platform to connect building owners and developers with leading environmentally-friendly product providers that pay to profile services on the platform. This self-financing model both creates and connects demand to providers of passive cooling solutions with no obligation on users to pay for the advice.

128 Gyamfi et al. (2017); Agyarko, et al. (2021).

129 Holding life is the time spent by fresh produce in cold chain till it reaches wholesale. And shelf life by definition is the time spent by produce on the shelf of a retail store.

However, cold supply chains are by nature complex and involve multiple processes and applications, including packhouse processing, rural cold storage, transport, off-grid renewable energy, and cold storage at destination.[130] Integrating these services effectively can be a challenge and some processes may not offer prospects for generating returns that are obvious to potential investors.

Furthermore, cold storage systems can be unprofitable if only used for specific crops at limited times of the year. This means the economics of storage requires careful planning to ensure adequate occupancy throughout the year, an objective that can be difficult to align with crop cycles. IFC's Food Loss Climate Impact Tool (See Box 3.3) is one of the first attempts to understand the potential for food loss reduction in supply chains, including through better cooling.[131]

Other challenges and features of cold chains in developing economies include:

Limited access to financing. Firms in developing countries often struggle to access affordable financing options for cold chain development. Traditional financing sources may be limited, and financial institutions may have stringent requirements, making it difficult for small-scale farmers and businesses to secure capital for cold chain infrastructure.

High upfront investment costs. Establishing a comprehensive cold chain requires substantial investments in infrastructure, such as cold storage facilities, refrigerated transportation, and temperature monitoring systems. The Global Cold Chain Alliance estimates that building a basic cold storage facility can cost between $100 and $300 per cubic meter,[132] a significant barrier to entry for small-scale farmers and businesses in emerging markets. In India, where cold chain infrastructure is still developing, the Ministry of Food Processing Industries estimates that the investment required for cold storage facilities is around $100,000 to $150,000 for a capacity of 1,000 metric tons, approximately 4,300 cubic meters of storage space.[133]

Long-term operational costs. Beyond the initial investment, the operational costs of running a cold chain system can be significant, affected by energy consumption, maintenance, staff training, and quality control measures. Suppliers in emerging economies may struggle to allocate sufficient funds to cover these ongoing expenses, particularly in the absence of reliable electricity supply and

130 For a comprehensive overview and analysis of the critical links between sustainable cooling for agriculture and off-grid electricity provision, see: ESMAP (2024); See also UNEP (2023a), UNEP (2024), and FAO and UNEP, "Get Involved: International Day of Awareness of Food Loss and Waste" (Sept 29, 2023, PPT).

131 Available at https://www.gafspfund.org/ifcs-food-loss-climate-impact-tool.

132 GCCA (2019).

133 Ministry of Food Processing Industries, Government of India. (undated). Cold Chain. Retrieved from https://mofpi.nic.in/content/cold-chain. Conversion factor from GCCA (2020).

limited financial resources.[134]

Risk perception and uncertainty: Investors and financial institutions may perceive the cold chain sector in developing countries as high-risk due to factors such as weak regulatory frameworks, inadequate infrastructure, and volatile market conditions. The Asian Development Bank has implemented the Supply Chain Finance Program, which provides financing to small and medium-sized enterprises involved in the agricultural supply chain, including the cold chain. This aims to mitigate the perceived risks associated with lending to SMEs in developing countries.[135]

One of the main barriers to effective cold chains is that small farmers typically do not have the funds to cool their produce in the first few hours after it has been picked. Farmers need business models that let them invest in cooling to reap greater income through longer holding and shelf-life. Solutions are needed that allow for leasing of equipment or amortization of upfront costs over a longer time period.

Cold storage requires the aggregation of many small producers. The current demand for sustainable cooling products among farmers is typically low and so the potential product demand, which could be high, is not obvious to retailers. Community organizations of farmers can assist.

In addition to cooling needs in fresh produce, there is tremendous need for funding to introduce cooling in dairy and aquaculture where farmers do not have the financing needed for cooling technology. For example, chilling milk reduces food waste by up to 30 percent

BOX 3.3

The Food Loss Climate Impact Tool

With support from GAFSP and the Government of the Netherlands, IFC, in partnership with Carbon Trust, developed a tool to estimate the emissions and cost savings associated with reducing food losses. This reports greenhouse gas emissions broken down by value chain phase (production, transport, storage, processing, retail, and landfill) for 50 crops in 117 emerging countries.

Agribusiness is a priority because of its potential for broad development impact and especially strong role in poverty reduction. IFC combines investment and advisory services to help the sector address rising demand and escalating food prices in an environmentally sustainable and socially inclusive way. The institution thus invests across the agribusiness supply chain—from farm to retail—to help boost production, increase liquidity, improve logistics and distribution, and expand access to credit for small farmers.

134 Thermal Control Business Update (2024); International Forwarding Association (2023).

135 https://www.adb.org/what-we-do/trade-supply-chain-finance-program.

and minimizes food safety risks for consumers.

In some environments, providing cooling to cattle can increase milk production by as much as 40 percent, lowering overall greenhouse emissions per unit of output. However, the upfront cost of installing this type of cooling facility is beyond the means of most smallholders without financial assistance.

Weak Regulatory and Administrative Environments

Developing countries are characterized by less developed regulation and weaker enforcement capacity than more advanced economies in areas such as finance, as well as sustainability and environmental standards. While efforts to bolster regulatory regimes are accelerating in many jurisdictions, challenges remain in the supervision of minimum energy performance standards (MEPS), building codes and other areas such as promoting proper disposal of refrigerants that can be potent greenhouse gases. Box 3.4 provides an example of the challenges facing a government seeking to enforce a ban on imports of inefficient refrigerators.

BOX 3.4

Ghana’s Challenge Enforcing a Ban on Importing Inefficient Used Refrigerators

Ghana has banned the import of second-hand refrigerators, but enforcement remains a problem. Based on findings from ECOFRIDGES Ghana, a joint program by UNEP's U4E initiative and the Government of Ghana,[1] the absence of a functional e-waste management system in the country hindered implementation of proper disposal for old appliances. Despite an environmental levy on new purchases, the lack of a proper waste management system made it difficult to dispose of outdated and inefficient appliances responsibly. Exporting countries can help address enforcement challenges through regulations such as those adopted by the European Union. The Montreal Protocol Multilateral Fund also has a new requirement that cooling equipment manufacturers receiving international funding must meet their countries’ minimum energy performance standards whether the equipment is for domestic markets or exports.[2]

1 See Minguez et al. (2023).

2 CCAC (2023).

Other hindrances to the development of efficient standards and practices in developing economies include utilities not incentivizing consumers to operate more efficient cooling systems that would reduce peak demand and the need for additional generating capacity. Meanwhile, many developing countries lack effective building codes that prioritize energy efficiency or have overly complicated standards that are hard to enforce. Meanwhile, institutional weakness leaves many governments unable to deploy fiscal incentives to promote more sustainable outcomes.

The many challenges to sustainable cooling solutions reflect existing gaps in public policies and the incentives for private investment. The issues, which vary by sector and cooling application, are summarized in Table 3.1.

TABLE 3.1

Challenges to Sustainable Cooling Solutions by Sector and Market Segment

Sector	Key Public Policy Gaps	Key Private Market Gaps
District cooling	Multiple barriers including uncertainty of permit approvals and lack of public sector guarantees for long-term off-take contracts	High upfront costs create barriers to entry for new players and uncertain returns, resulting in few companies able to provide services and requiring long-term contractual payment risk mitigation
Cooling for buildings	Lack of up-to-date building codes and weak enforcement; a lack of awareness of non-fiscal incentives to go beyond the code	Complex market with information asymmetry leading to low awareness of the business case for more efficiency, including through utility savings, faster sales, and higher rents
Residential cooling	Absence of programs and incentives for product labeling, recycling, and disposal of refrigerants	Finance not accessible to lower income populations, requiring more innovative linkages of financial structures and utility bills or wage payments
Agribusiness value chain	Only governments are in a position to appreciate the full benefits from a fully functional agricultural cold chain	Cooling technology must be enabled by transformative systems, including off-grid renewable energy and battery storage, as well as payment structures that offset upfront costs. There is also a need for transformative cold chain systems
Manufacturing	Absence of local policies on MEPS and low-GWP refrigerants, combined with incentives for new manufacturing lines	High investment costs to retool manufacturing capacity can be offset through government bulk procurement; vendors require finance for more expensive systems; lack of commitment to more efficient product lines
Cold chain and logistics	Transformative cold chains should be seen as a form of infrastructure investment	Disaggregated market lacking modern temperature-controlled infrastructure also requires partnerships for first- and last-mile collection and delivery

3.2 Strategies for Addressing Challenges to Investment in Sustainable Cooling

There are multiple ongoing efforts to better understand and test possible responses to the challenges outlined above and in Table 3.1. However, as will become evident, in many cases potential solutions are currently being tested but for the most part still fall short of fully resolving the issue in question. Insofar as financial decisions largely revolve around sectors, these strategies are better understood in their relevant contexts.

Standards, Labeling, and Certification

Minimum energy performance standards for air conditioners, refrigerators, and other energy-intensive appliances have been widely used in developed countries and some emerging economies for decades. Standards are typically set based on economic benefits to consumers, for example when a higher initial cost is justified by energy savings over time. A widely used and frequently discussed strategy for promoting more sustainable cooling is the adoption of minimum energy performance standards (MEPS). These are primarily applicable to residential and small commercial cooling units, including fans, and can bring additional benefits such as reduced pollution[136] and a lower need for new power plants.[137] The Global Cooling Watch report included detailed analysis of the potential application of MEPS among strategies to achieve near zero greenhouse gas emissions by 2050. Currently, many developing countries lack such regulations or have minimum efficiency standards that, while periodically revised, fall short of the most efficient products that are currently available.

While challenges remain, MEPS can—and do—make a significant contribution to more efficient cooling. It is important that more progress is made toward their adoption within national building codes and that these standards evolve to incorporate advances in sustainable technologies. For example, while radiant cooling was successfully piloted in India,[138] the country's national codes do not include a minimum efficiency performance standard for this technology. As noted, many developing countries have shortages of the technical expertise and resources necessary to administer effective consumer awareness, testing, labeling, and standards.

CLASP, an international NGO, is among the organizations working to provide developing countries with support for standards and labeling. It supports the development,

136 "National appliance standards have led to significant reductions in PM2.5 and PM2.5 precursor emissions, avoiding hundreds of thousands of tons of pollutants in 2017. These standards prevented between 1,900 and 4,400 PM2.5-related deaths in 2017, translating to monetary benefits of $18 to $41 billion," CLASP (2024a).

137 In 2016, one study concluded appliance and building standards had avoided the need for over 300 power plants in the United States ACEEE, (2016). The benefit continues over time as standards become more stringent and older equipment is replaced; See also IEA (2021): "The programmes that have been operating the longest, such as those in the United States and the European Union, are estimated to deliver annual reductions of around 15 percent of their current total national electricity consumption. This percentage increases each year as more of the older, less-efficient stock is replaced with equipment that meets new higher efficiency standards."

138 Gombar (2019).

implementation, and enforcement of standards, testing, and labeling. It also promotes consumer awareness of energy efficient appliances and oversees award programs that promote best-in-class products and encourage innovation.[139]

UNEP-U4E also provides support through its model regulation guidelines.[140] A recent significant addition to the guidelines was the adoption of harmonized regional MEPS for East and southern African countries, formally approved and disseminated for implementation to the 16 Southern African Development Community member states.

Regulation aimed at utility companies can also promote sustainable cooling. This can be done through programs to raise awareness, incentives for consumers to purchase more efficient equipment, and charging structures that reward reduced energy use at peak times.[141] Utilities have also acted as agents for the removal and proper disposal of aging, inefficient refrigerators.[142] Development finance institutions have supported such efforts with loans to support the implementation of appliance efficiency standards, an example of which is an Asian Development Bank loan to Cambodia.[143]

Space Cooling for Green Buildings

According to the Global Cooling Watch report, under current trends space cooling will account for 70 percent of the energy attributable to cooling consumed in 2050, with the fastest growth in residential space cooling.

The growth in space cooling needs is arising from population growth often coupled with urbanization, rising incomes, and higher global temperatures. The benefits of green buildings, which typically must address space cooling, have been well documented. IFC has examined the business case for investing in green buildings in a number of publications.[144] The organization has also contributed to analyses focusing on specific sectors such as hotels and housing.[145] See Box 3.5 for an analysis of payback periods for passive cooling strategies within green buildings.

Despite this, sustainable space cooling and green buildings more broadly have not taken off, with some notable exceptions such as in Colombia where green buildings account for 25 percent of new construction. Real estate markets are complex and are characterized by asymmetries of information between architects, developers, builders, investors, and final tenants or buyers who may be reluctant to pass on benefits to counterparts elsewhere in the value chain.

139 https://www.clasp.ngo/about/.

140 CLASP (2024b).

141 UNECE (2015).

142 https://homeenergysavings.pepco.com/md/residential/appliance-recycling-program.

143 ADB (2021).

144 IFC (2023).

145 Sustainable Hospitality Alliance and IFC. 2020; Musić (2021).

BOX 3.5

Cost Analysis and Payback Periods of Passive Cooling Strategies in Green Buildings

Passive cooling strategies must be considered during the architectural design stage, which typically leads to incremental costs in the procurement phase. This, however, can be easily offset later by reduced utility costs, thus shortening payback periods and providing overall financial savings compared to traditional buildings. Citra Maja Raya, an affordable housing development project in Indonesia, was the first EDGE-certified building in the country. It incorporates an optimum window-to-wall ratio, external shading, insulation, and natural ventilation. Based on EDGE calculations, the upfront construction cost represented merely a 4.7 percent increase compared to typical houses in the country, and it achieved payback within 1.8 years, owing to a 30 percent reduction in annual utility costs. This benefit is equivalent to the energy consumption of 41 low-income houses in the country.[1] It is important to raise awareness of the benefits of passive cooling investment, especially among real estate developers and governments overseeing public procurement of buildings.

Although costs of passive cooling measures vary between countries, some initiatives are cost neutral or even generate savings. For instance, reducing the widow-to-wall ratio could be cost-negative since glazing is more expensive than building a wall. In India, a square meter of conventional glass, which is highly heat transmissive, costs around $75. For high-performance glass, the price rises to around $123, depending on the technology. Meanwhile, a thermally insulated brick wall costs less than $38, as of 2022.[2] Another example is a reflective surface. One case study in France shows that the upfront retrofit cost of a cool roof, including maintenance (typically 20 euros per square meter), could be recovered over an average of around 3.5 years.[3] It is important, therefore, that heat-stressed countries integrate these kinds of cost-negative or neutral passive cooling design strategies into their building codes to promote implementation.

While the magnitude of cost benefits varies according to building types, climate, or product quality, initial investments in passive cooling strategies for building projects are likely to yield benefits through reduced operating costs, with the added advantage of lowering emissions. It is important for developers and governments to understand the advantages of passive cooling strategies, especially in terms of return on investment, so as to accelerate sustainable cooling adoption.

UNEP and IFC analyses show that the payback periods for major passive cooling measures,[4] which achieve 24 percent cooling demand reduction in different developing economies, are 5–9 years. Some strategies like reflective surfaces, shading and reduced window areas, when combined have payback periods between 2–4 years. In India, for example the payback period for external reflective surfaces and shading systems is between 1 to 2 years. In Viet Nam, payback periods for solar reflective roofs and solar reflective walls are 3 and 4.5 years respectively.

1 Green Building Council Indonesia and IFC (2019).

2 Down to Earth (2024).

3 CoolRoof. What Internal Rate of Return Can Be Expected with CoolRoof? https://www.coolroof-france.com/en/faq/what-internal-rate-of-return-irr-can-be-expected-with-coolroof/.

4 Solar Reflective Roofs (SRI-0.8), Solar Reflective Walls (SRI-0.75), External shading (Shading Factor (AASF) - 0.4), Roof insulation (U-0.65), Wall Insulation (U-0.65), High Performance Glazing (SHGC-0.28 & U-1.9).

The EDGE Green Buildings Market Transformation Program,[146] an initiative developed by IFC, has developed analytical tools for identifying resource efficient measures and estimating cost. It also provides a certification system that enables the communication of benefits between investors, developers, and end-users. Buildings must meet a minimum 20 percent saving in energy, water, and embodied carbon in materials to qualify for the EDGE Standard, though projects are frequently achieving over 40 percent efficiency savings. In many climates, this reduction is achieved through sustainable cooling designs whereby passive measures focused on building orientation and shading reduce the extent and cost of the necessary cooling equipment (see Box 3.6).

Table 3.2 showcases some notable cases where efficient space cooling was utilized.

Holistic Integration: A Systems Approach for Rural Cold Chains

As briefly described above, providing rural farmers with cold chains to preserve food and enable transport to urban markets is a critical need for food security and development. Currently, a substantial proportion of harvested food, and landed fish, is lost due to the absence of a cold chain,[147] and producers are unable to sell at the higher prices possible in urban markets due to the inability to maintain freshness in transport. There is a need, therefore, for a combination of several distinct cooling services to achieve an effective end-

TABLE 3.2

Selected EDGE-Certified Projects

	Neo	Stallion Labs	Cosmos Yopougon	Rack Centre	Privadas del Parque
Building Type	Offices	Pharma	Shopping Center	Data Center	Homes
Country	Philippines	India	Côte d'Ivoire	Nigeria	Mexico
Energy savings	43% on-site savings, zero carbon certified through off-site RE purchase	Zero carbon certified through on-site EE and RE	29%	35%	40%

146 For more information, see www.edgebuildings.com.

147 United Nations (2023).

to-end cold chain, starting with the first mile packhouse or aggregation and pooling points for preconditioning and precooling; cold storage to preserve aggregated crops, fish, and dairy products; transport with effective cooling for long distances over bad roads; and further cold storage for rapid distribution in urban markets. Lack of access to electricity or an unreliable rural grid necessitates comprehensive cooling systems that include generation and storage of renewable energy. Addressing any of these needs without the others will undermine the effectiveness of the entire chain. There is also a need to ensure that export of products to higher-value markets does not result in food deprivation for local populations.

The challenges to financing cold chain systems vary considerably because of their multi-stage composition with different types of business operating in each, namely farmers, processors, distributors, and retailers among others. Providing funding for smallholders has been a focus among international institutions for several years with an emphasis on agricultural inputs. However, a holistic approach to agricultural cold chains is very recent. Financial products need to be tailored to meet the needs of farming communities and remain within their means so they can service the debt. Financing mechanisms must also be designed to ensure that smallholder farmers receive an equitable financial return.[148]

Implementing a comprehensive cold chain system requires significant investment in infrastructure, technology, training, and the raising of awareness and engagement. It also necessitates coordinating the multiple parties responsible for each stage. The Africa Centre of Excellence for Sustainable Cooling (ACES) is a major international initiative, launched in November 2020 and run from Kigali, Rwanda, with a mission to boost uptake of sustainable cold chain solutions in the agriculture and health sectors throughout Africa.[149] ACES was created with support from the UNEP United for Efficiency Initiative with diverse programs to address the many challenges to ensuring effective cold chains. Its activities include community outreach efforts, technical assistance, training, and industry partnerships, all framed by a holistic, whole systems approach (see Box 3.7).[150]

The ACES program is exploring the potential for governments to provide public financing for cold chain development, justified by the social and development benefits of creating a road or port facility. To secure public funding, the report notes, "it is essential that a clear, robust articulation of the real value and return on investment is developed. This will involve identifying, quantifying and, where possible, monetizing the multiple benefits that can be delivered by well-adapted clean cooling based infrastructure."

Other initiatives focused on financing cold chains for rural farmers are emerging in addition to ACES. For example, the African Development

148 SEforAll (2020).

149 https://ur.ac.rw/?The-Africa-Centre-of-Excellence-for-Sustainable-Cooling-and-Cold-chain-ACES (University of Rwanda website).

150 ACES (2024).

BOX 3.6

Using the EDGE Tool for Project Assessment, Market Sizing, or Policy Analysis

The EDGE Tool can be used to assess individual buildings in order to find efficiency enhancing measures that are best suited for the local climate and context. EDGE can also be used for a market sizing exercise to understand both projected energy needs and investment potential.

In the below graphic taken from the EDGE Tool, we can see that a typical middle-income household in Karachi, Pakistan spends 28 percent of its energy needs on cooling, with the rest divided between cooking, hot water, lighting, and other appliances. EDGE can provide similar analysis for different types of buildings as well as for income levels within the building category, such as low income versus high income households or a city hotel versus a luxury resort. EDGE first suggests passive efficiency measures in a color-coded approach where blue corresponds to cooling. The system then offers more technology-oriented solutions. In this example, passive strategies brought the energy needs down almost 17 percent. The EDGE app provides an estimate of the upfront costs for each intervention and a packet of interventions, as well as the utility savings and the payback period.

This type of comparison of costs and benefits can be used by policy makers to understand which measures would be most effective in their respective environments and can be included in revised building codes. Instead of trying to include a number of measures, IFC recommends focusing on a few places where there the potential saving is greatest.[1]

The computational power of EDGE can also be used for market sizing or other data analysis. Knowing energy usage per building type multiplied by floor space enables calculation of the total market. EDGE makes it possible to explore adaptation to rising heat by overriding current climatic data with predicted temperatures. For example, increased temperatures in Karachi in the summer will increase the cooling load by almost 6 percent from 18.38 kWh/m2/year to 19.47 kWh/m2/year but will also raise overall savings from passive strategies. The model from the EDGE tool thus tells policy makers how much they can reduce electricity generation demand by incentivizing passive strategies or other demand-side standards.

While beyond the scope of the EDGE tool which focuses on energy efficiency, the program that produced it has issued guidance on choosing refrigerants that comply with the Montreal Protocol.[2]

For builders, certification is a mark of quality and enhances the market value of the building. Helped by IFC's marketing co-partnerships, this allows them to sell faster or lease their space for a higher rate. For financiers, the certification is a strong indicator that expected lower energy costs, which can be substantial, are valid and can support a client's ability to repay a loan.

1 For a paper on the lessons learned and how to design and implement building codes, see: IFC. (2020).

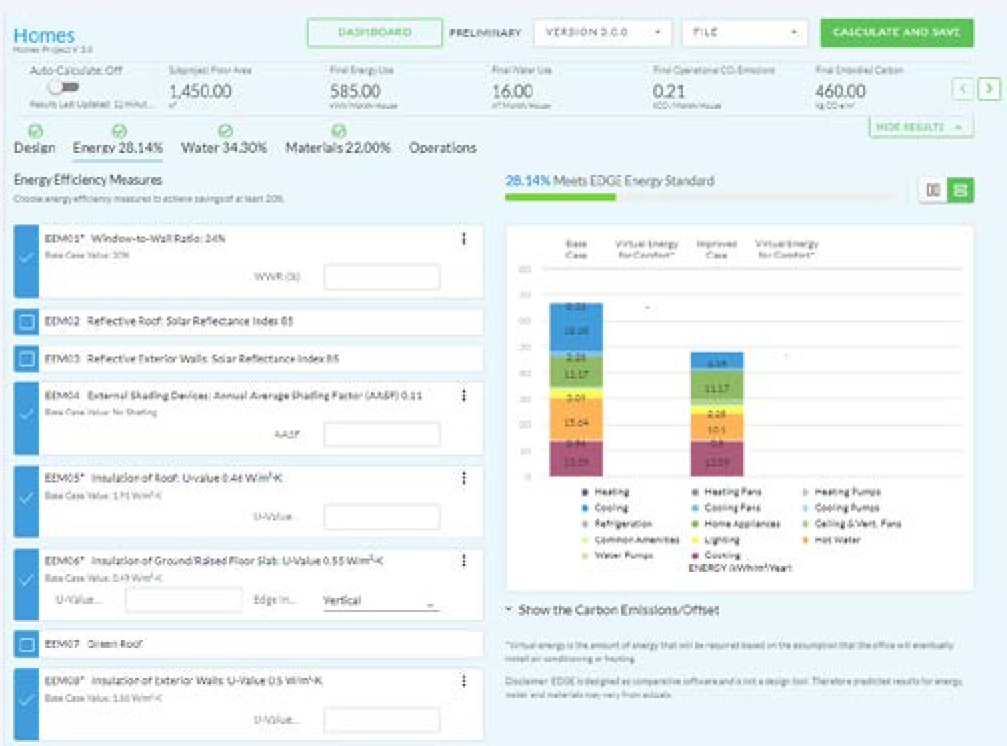
2 EDGE, (2017).

This has enabled a proliferation of instruments like green mortgages or green bonds funding new construction and retrofits. In contrast with other certification systems, the process is streamlined, location-specific and quantifies impact.

EDGE is equally effective with the building retrofit process, helping the building owner understand impactful technical measures and the business rationale. IFC partners like Sintali have launched guides and training programs on decarbonizing existing buildings and IFC has developed an integrated advisory and financial program called GRIP: Greening Real Estate Investment Portfolios. Many IFC partners are now able to achieve Net Zero Certification through retrofits. After NEO company offices in the Philippines led with the world's first zero carbon office portfolio, Ayala Land, one of the country's largest real estate companies, pledged to certify 1.5 million m2 of their portfolio by 2025.

Certified green buildings are helping increase revenues and attract clients. In Colombia, for example, over 27 percent of new buildings are being certified with EDGE, due to a confluence of banking and government incentives and a powerful lobbying effort from CAMACOL, the national chamber of construction and local provider for EDGE certification. In Viet Nam, about 8 percent of the addressable market for building growth is certified with EDGE without any incentives in place, as developers recognize the value of product differentiation, particularly in the housing sector.

A snapshot of the EDGE tool with efficiency measures and payback calculations



Source: EDGE website - https://edgebuildings.com/

Bank launched the Affirmative Finance Action for Women in Africa (AFAWA) program, which aims to provide $3 billion in financing to female entrepreneurs, including those involved in agriculture who have use for cold chains.[151]

Addressing the challenges to financing cold chains in developing countries thus requires a range of approaches including public-private partnerships, financing mechanisms such as risk-sharing facilities, blended finance, and grants, or fiscal incentives such as tax breaks and subsidies, and the provision of technical assistance. International organizations, development banks, and governments can play a crucial role in facilitating access to finance and providing support to developing countries in implementing and expanding their cold chain systems.

Demand Aggregation to Lower Prices

One proven way to lower the price of efficient appliances is through bulk procurements, a strategy that can be implemented by public agencies, private entities, or public-private partnerships. This approach was used effectively by the World Bank-IFC Lighting Africa program to accelerate the introduction of efficient light bulbs and can be accomplished by public and private partners through a variety of instruments. Box 3.9 highlights the potential and challenges of demand aggregation in different contexts. These programs demonstrate significant cost reductions but also underscore the need for comprehensive strategies to address awareness, participation, and investment challenges.

Promoting Innovation

There is broad consensus about the need for more innovative cooling technologies, which require support for innovation—research and development, and acceleration—as well as growth capital for innovators. Notable examples of initiatives addressing innovation are the IFC TechEmerge sustainable cooling program, the Mission Innovation heating-cooling working group, the Ashden Foundation Fund Fair Cooling Fund, the Global Cooling Prize (launched by RMI, the Government of India's Department of Science and Technology, and Mission Innovation in 2018), and the Million Cool Roofs Challenge (launched by the Clean Cooling Collaborative in 2019).[152] In March 2024, CLASP was announced as the head of a new $25 million Energy Access Institutions Facility to support organizations across sub-Saharan Africa and South Asia and increase the delivery of innovative off-grid clean energy solutions, including efficient appliances.[153]

TechEmerge is an IFC program that provides funding and technical support to early stage, companies offering products and services with significant potential to benefit developing countries. Participants are also connected with leading manufacturers and industrial companies in emerging markets to conduct pilot projects, build commercial relationships, and reduce risk on investments.[154]

151 African Development Bank (2021).

152 IFC https://techemerge.org/; Ashden https://ashden.org/fair-cooling-fund/; Global Cooling Prize https://globalcoolingprize.org/.

153 CLASP (2024b).

154 https://www.techemerge.org/our-focus/sustainable-cooling/.

BOX 3.7

The ACES Program Approach to Enhancing Rural Cold Chains

"Taking a whole systems view will be vital to ensuring the successful use of cooling as an adaptation strategy, particularly in the context of transitioning to the widespread use of renewable energy. In this holistic approach both the physical and non-physical components within the infrastructure system are considered, as well as the physical and non-physical interdependencies and feedback loops at the whole systems level. In essence, the entire eco-system within which the cooling infrastructure sits and operates must be considered in-line with the core social goals cooling needs to deliver (i.e. safe environments in which to live, work and move; the provision of universal healthcare and affordable and nutritious food year-round; protection against future pandemics). . . . Equally by taking a holistic view, the cooling service needs can be integrated more effectively, efficiently, and optimally into the infrastructure system. This allows not only the harnessing and leveraging of synergies between processes, energy resources and other subsystems, but also the identification of, planning for, and mitigation of, possible negative unintended consequences, as well as the realization of potential indirect benefits that are often overlooked."

Excerpt from "The Hot Reality: Living in a +50C World", p. 7.[1]

1 Fox, Peters, and Sayin (2024).

With financial support from the U.K. government, IFC's TechEmerge implemented a program supporting early-stage, sustainable cooling solutions during 2019–2024. The design and results of this program are discussed in Chapter 4. Through its Disruptive Technologies and Funds department IFC is also seeking to support early-stage climate technology companies through investments in thematic climate funds. A recent example is $15 million in the Southeast Asia Clean Energy Fund II, an investment platform and pilot program that will provide equity for early- and growth-stage investments in energy projects in Southeast Asia. The fund will invest equity in utility-scale solar, wind and energy storage, in addition to helping businesses go to scale in areas ranging from rooftop solar, energy efficiency, electric mobility and grid management.

Additional initiatives to support early-stage innovative cooling have been announced in recent months consistent with the increasing attention being given to its importance for climate and development. In 2024, the Green Climate Fund approved a $24.5 million equity investment in the Avaana Sustainability Fund, a venture capital fund that aims to invest in early-stage climate technology companies in India. Also in 2024, the CPI Finance Lab, a multi-donor program that provides technical backing for innovative climate startups, announced support for a venture fund focused on sustainable cooling. In yet another 2024 announcement, the Climate and Clean Air Coalition issued a call for proposals from nonprofit organizations for ways to promote climate mitigation in cooling applications.

Programs Supporting Urban Measures to Respond to Extreme Temperatures

Cities and other subnational authorities are increasingly engaged in responding to extreme heat events as urban areas are typically much hotter than surrounding areas. These so-called urban heat islands are partly caused by the presence of heat absorbing paving and buildings, made worse by the limited presence of trees and vegetation to provide cooling. City governments have a range of potential powers and strategies for reducing heat through zoning measures, building codes, and requirements for lighter colored paving. Yet most cities, especially in low-income developing countries, lack the technical capacity and resources to identify and implement such measures. Multiple initiatives and bodies have formed in an effort to provide cities with the support needed for climate programs (See Box 3.10 for some examples), including C40,[155] the Arsht-Rock Resilience Center,[156] and the Institute for Market Transformation.[157]

Local and national governments as well as firms and banks can now benefit from solutions like Medellin's green corridor (see Box 3.10) by accessing new sources of climate finance. IFC's Biodiversity Finance Reference Guide[158] provides a structured approach for investors and financiers to identify eligible uses of proceeds that constitute biodiversity finance and nature-based solutions. Building on the Green Bond Principles and the Green Loan Principles, the guide provides an indicative list of investment projects, activities, and components that help protect, maintain, or enhance biodiversity and

BOX 3.8

Potential for Sustainability-Linked Financing

Most of the major cooling equipment manufacturers have announced sustainability targets, aiming, for example, to be carbon neutral by 2030 and achieve net zero emissions by 2050. Some companies have goals that are beyond their current operations. For example, in support of reducing food waste, a Trane target is to "innovate and commercialize low-cost sustainable products for developing markets." The company also worked with street vendors to create a cooling cart using reflective materials from other suppliers. Godrej has a goal to generate a third of its revenue from "good and/or green" products. Daikin supports its commitment to sustainability goals with a Sustainability and Innovation Center in Washington, D.C. These commitments create opportunities for trade and supply chain financing from large equipment manufacturers to support partners, suppliers, and customers in achieving more sustainable cooling solutions.

155 https://www.c40.org/.

156 Ajitsaria (2023).

157 https://imt.org/resource-collections/city-energy-project/.

158 IFC (2023b).

BOX 3.9

Examples of Demand Aggregation Initiatives

The Super-Efficient Air Conditioning Programme (India)

This was created by Energy Efficiency Services Limited (EESL) to provide affordable, efficient air conditioning in India. The program involved a tender for 100,000 super-efficient room air conditioners for residential and non-residential use. Manufacturers (including Daikin, Godrej and Panasonic) developed high-efficiency air conditioners for sale at half their original cost, transforming the market. A significant feature of this program was that 40 percent of the units used lower GWP refrigerants. While the program made more efficient products available at reduced cost, consumer awareness and acceptance reportedly remained a challenge as distributors and vendors were not participants and the uptake fell short of targets.

Efficient Fans Program (India)

Demand aggregation has been more successful for efficient fans. The Clean Cooling Collaborative and its partners have been working to transform India's ceiling fan market, with a goal of deploying 10 million super-efficient fans—roughly 25 percent of national annual sales—across the country by the end of 2024. To date, implementing partner EESL has completed a bid for 2 million units, achieving a high level of manufacturer interest and a price reduction of nearly 40 percent, which brings the cost of the fans in line with much less efficient alternatives.

Public-Private Partnership in Morocco

A program in Morocco illustrates the potential for public-private partnerships to aggregate demand and negotiate lower prices. A buyers' club was created with participation from government agencies, commercial banks, and farmer cooperatives.[1] One government aim was to promote local manufacturing as well as encouraging energy efficiency, lower emissions, and savings to consumers.

IFC EDGE Program

There are also opportunities for aggregating purchases to lower the cost of some passive cooling measures in the context of financing multiple housing and commercial building projects. This is a feature of the EDGE program for certification of green buildings.

Potential Integration with Montreal Protocol Multilateral Fund

Another opportunity for promoting energy efficiency and lower GWP refrigerants may be to integrate bulk procurement and other demand aggregation initiatives with funding from the Montreal Protocol Multilateral Fund. The fund has approved $100 million for energy efficiency improvements as part of enterprise manufacturing conversion projects, but the technical issues and scale of the efforts require much more investment.[2]

1 Andersen, et al., (2020).

2 UNEP. (2023b).

ecosystem services, as well as promote the sustainable management of natural resources. It also maps the investment activities' contribution to the targets of the Kunming-Montreal Global Biodiversity Framework to halt and reverse biodiversity loss by 2030.

IFC's APEX program provides support for cities to improve sustainability by identifying steps to reduce carbon emissions from buildings, transport, waste, and water. This includes a combination of public policy measures that incentivizes the private sector along with public procurement. Cooling is addressed for both public and private buildings and via nature-based solutions to the urban heat island effect. The APEX process shows cities how to achieve ambitious climate and resource goals with complementary policies and investment action, and maps out needs and sources of funds, as shown in Figure 3.1. Participants have included Ekurhuleni, South Africa; Ho Chi Minh City, Viet Nam; and Almaty, Kazakhstan.[159]

District Cooling and Other Large-Scale Infrastructure Projects

Urban areas typically offer the most promising opportunities for large-scale cooling infrastructure projects, such as district cooling, centralized cooling systems, and large thermal storage facilities. Industrial zones represent another significant opportunity.

District cooling involves the centralized production and distribution of cooling to multiple users or buildings within a defined area. These systems typically produce chilled water at a central plant and distribute it via an insulated pipe network to various end-users, including residential, commercial, and industrial buildings. District cooling offers a significant opportunity to efficiently meet the demand from large, concentrated, and mixed-use sites such as office buildings, entertainment venues, shopping centers, and high-rise residential and hospitality buildings.

Aggregating demand lowers installed cooling capacity requirements and limits peak demand surges. These systems often feature thermal energy storage which ensures that the chillers operate in a baseload mode for a higher percentage of the time and reduces operating costs. District cooling benefits all stakeholders and lowers emissions, refrigerant leaks, heat islanding effects, noise pollution, electricity demand, and lifetime costs, while raising financial returns for district cooling companies. Overall, a chiller-based district cooling system results in lifecycle cost savings of 40–50 percent, depending on baseline technology, which is shared between the cooling service provider, real estate developer, and the tenant. Greenhouse gas emissions can be up to 50 percent lower over the project lifetime. Another major advantage of district cooling systems is that they can utilize renewable thermal sources such as geothermal, biomass, solar, or natural bodies of water, which will further increase energy savings and reduce emissions significantly.

159 For more information, see www.apexcities.com.

However, district cooling typically involves high upfront costs as constructing a central plant and piping network requires significant investments. Meanwhile, a lack of supportive legislation and building codes, low awareness among public stakeholders, sluggish real estate growth, and subsidized electricity in certain markets also present challenges to the future growth of district cooling. There is also a widespread lack of experience in structuring appropriate cooling tariffs, alongside low levels of expertise in public sector administrations and among real estate developers and cooling consultants.

One challenge to the greater adoption of district cooling is the difficulty of undertaking the analysis necessary to identify locations most suitable for the large investments and complex procedures such projects require. These systems can be poorly designed, resulting in overcapacity or sub-optimal thermal efficiency. IFC is seeking to address this by developing a toolkit that helps real estate developers, building owners, and municipalities estimate the technical requirements of proposed district cooling systems and better understand the business case for installing them. A number of development institutions offer advisory support for initial assessments of district cooling. For example, SECO, the Swiss Secretariat for Economic Affairs, and UNDP have supported feasibility studies in countries like Colombia while UNEP has backed district cooling assessments in India, Egypt, and beyond.

BOX 3.10

Examples of Initiatives and Programs

The C40 has a Cool Cities Network to promote climate action plans that includes multiple cities in emerging markets: Accra, Cape Town, Dar es Salaam, Durban, Freetown, Guadalajara, Mexico City, Quito, Rio de Janeiro, Salvador, and Sao Paulo. Cities share policies and strategies such as heat mapping, heatwave emergency management, and heat mitigation solutions.[1] With the support of such organizations, a growing number of cities now have heat officers responsible for leading responses to extreme heat events.

Medellín, Colombia offers an example of a large city with traffic clogged roads that has been able to reduce urban temperatures by 2.5°C since 2016 using green corridors that mimic natural forests. Large heat trapping buildings like the city hall have been greened with thousands of carefully chosen trees and plants. Officials expect a further 4°C to 5°C decrease in temperatures in coming decades.[2]

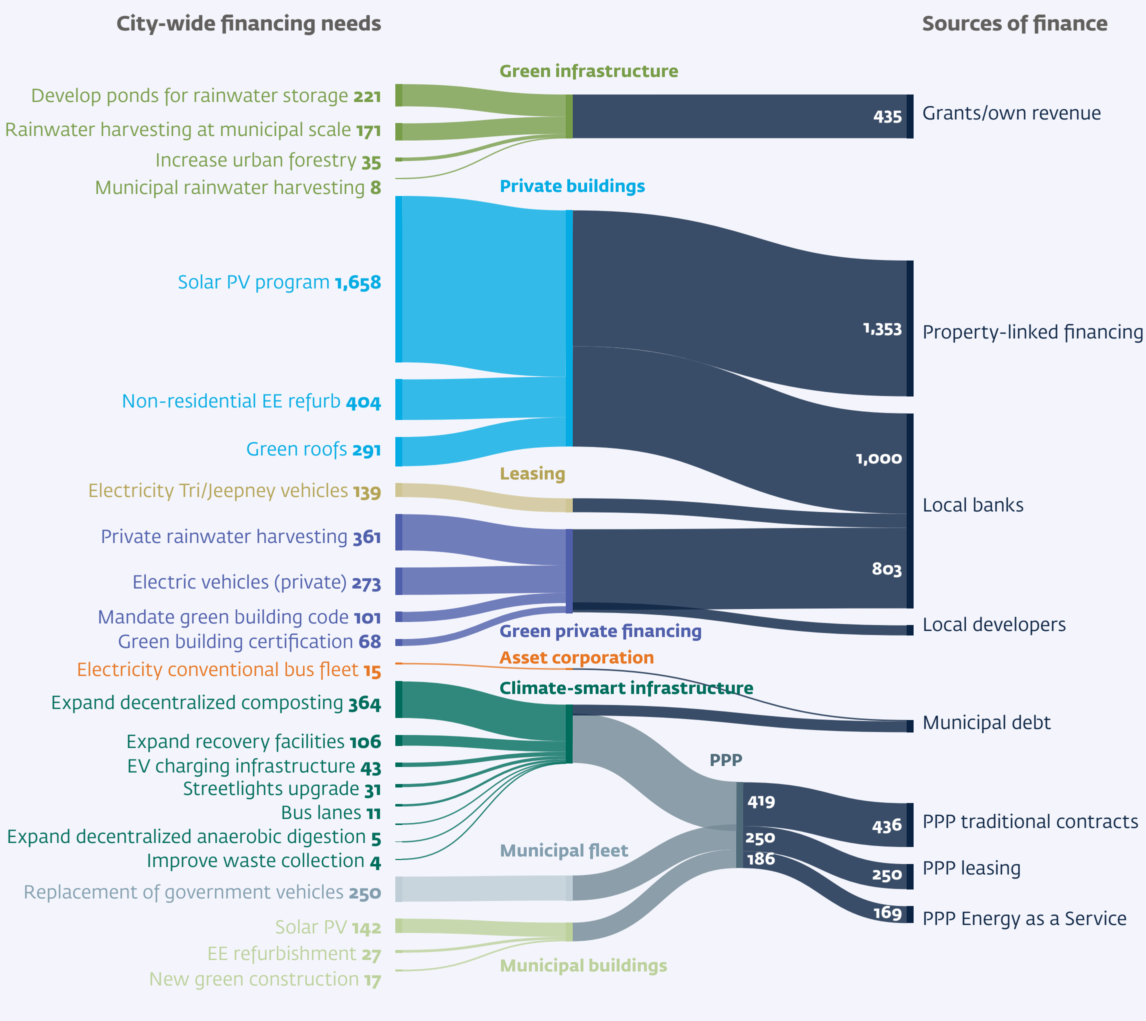
1 https://www.c40.org/networks/cool-cities-network/. More details on the many specific measures adopted are available from the C40 Knowledge Hub, https://www.c40knowledgehub.org/s/?language=en_US.

2 World Economic Forum (2024).

FIGURE 3.1

IFC's APEX Tool Connects City-Wide Climate Outcomes With Sources of Finance

Example from a city in the Asia-Pacific region



Source: https://www.apexcities.com/

Note: EE refers to energy efficiancy, EV to electric vehicle, PPP to public-private partnership, and PV refers to photovoltaic.

BOX 3.11

IFC Initiatives Promoting Green Building Codes

Through the Global Alliance for Buildings and Construction (GABC), IFC is a global leader in disseminating information on best practices in setting up green building codes which address cooling, in part through passive strategies. Governments can adopt both fiscal and non-fiscal policy measures, but there is little awareness that non-fiscal levers can be beneficial for both the public and the private sectors. Interventions such as allowing higher density or extra floor area for green certified buildings do not cost more in public funds but can be advantageous to developers. This is because it allows them to sell more apartments on the same plot of land, thereby offsetting any additional upfront costs related to greener construction. IFC has mapped out incentives already offered by governments in emerging markets,[1] and together with the GABC has shared case studies from industrialized countries.[2] IFC has also developed a Public Policy Pathways Guide that communicates with emerging market governments how to design building codes that generate the most impact in a given climate, how to generate buy-in from the private sector, and how to ensure eventual enforcement.[3] This guide is further supplemented by a step-by-step process based on IFC's experience in Latin American cities.[4]

1 https://edgebuildings.com/marketplace/governments/

2 https://globalabc.org/resources/publications/stimulus-programmes-green-buildings-best-practice-examples

3 IFC (2020).

4 https://edgebuildings.com/toolkit/guia-practica-para-el-funcionario-publico/

One prominent example of a successful project is the Pearl Qatar District Cooling Project in Doha. This is one of the largest district cooling plants in the world and was constructed on a man-made island. The plant provides cooling to residential, commercial, and mixed-use developments, and can service over 45,000 residents and several commercial entities. A broader selection of best-practice district energy projects, recognized for their innovation and sustainability, is detailed in UNEP's "District Energy in Cities" report.[160] Additionally, the Global District Energy Climate Awards, organized by the IEA, Euroheat & Power, and the International District Energy Association, provide further insights into district energy systems worldwide, showcasing projects that have effectively addressed key challenges in the sector.

District cooling was first established in the 19th Century with the installation of pipeline refrigeration systems, evolving to the most up-to-date renewable-based smart systems which combine cooling with other energy considerations.[161]

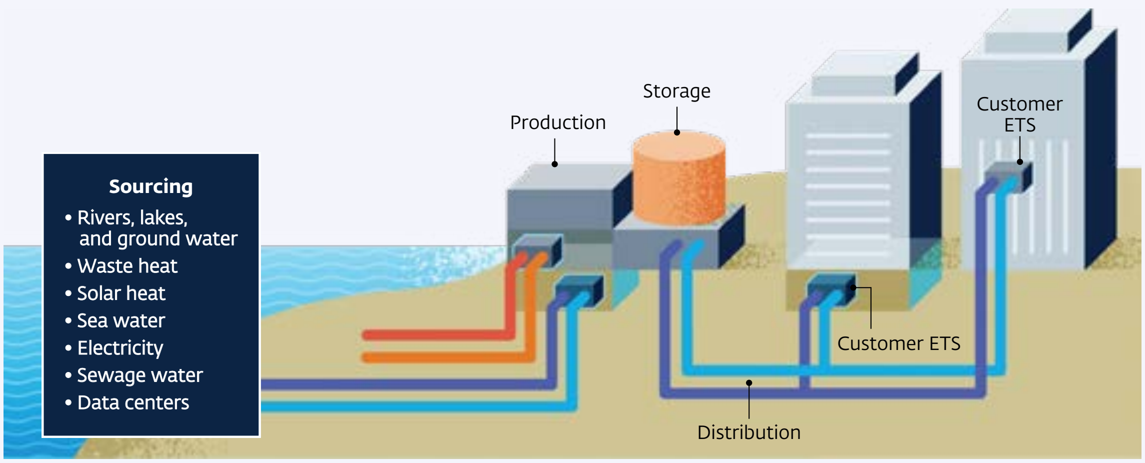
It relies on new technologies in areas such as geothermal energy and so-called Seawater Air Conditioning (SWAC) that utilizes the colder temperatures found at ocean depths for heat exchange. Figure 3.3 outlines how such systems work. According to the World Bank, SWAC can reduce electricity use by more than 85 percent compared

160 UNEP (2015).

161 Østergaard et al. (2022).

FIGURE 3.2

District Cooling Connects Many Buildings to a Central Source of Cooling Production



Source: Adopted from Devcco - District Energy Venture, https://www.devcco.se/

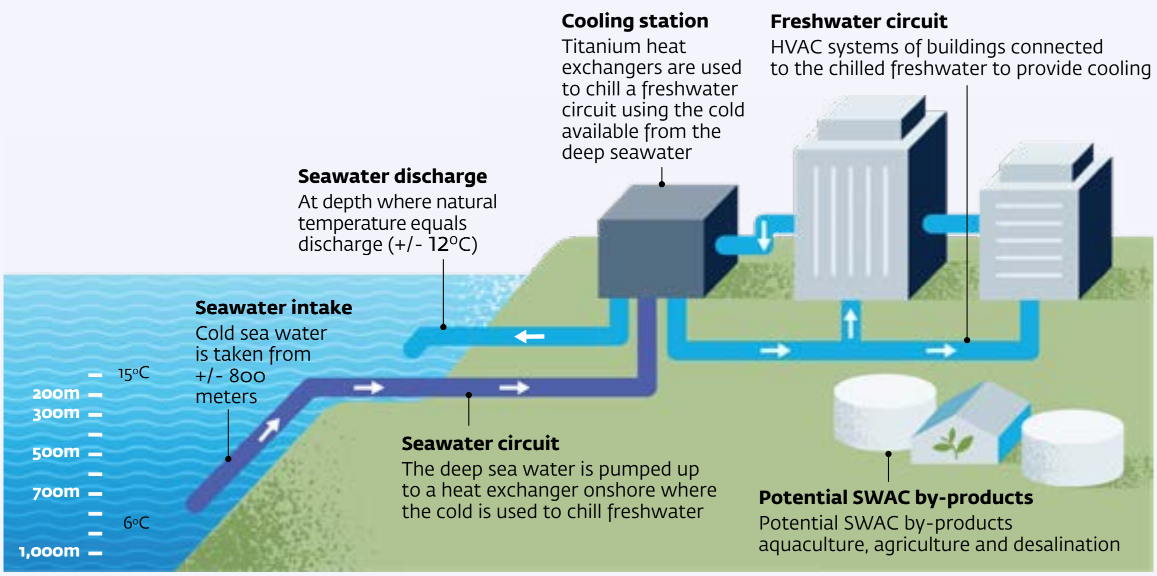
to conventional systems, with high reliability and less environmental impact because it avoids dependence on fresh water or synthetic refrigerants. Box 3.12 highlights examples of recent technologies.

Other cooling technologies such as absorption chiller units are essential for improving efficiency and reducing operational costs. These systems often utilize waste heat from sources such as combined cycle power plants, waste-to-energy facilities, and industrial ovens, or they harness the temperature differences from seawater, lakes, or geothermal sources. Key components include energy-efficient cooling production technologies such as variable speed drives, high-efficiency compressors, and advanced control systems.

Cold thermal storage plays a crucial role in district and industrial cooling by storing excess cooling energy during off-peak periods and releasing it during peak demand times. This not only reduces energy costs but also enhances grid stability. In general terms, these systems work by producing ice or chilled water during times of low energy demand and using the stored cold energy to cool buildings during the day.

FIGURE 3.3

Seawater Cooling Utilizes Cold Sea Water for Heat Exchange



Source: World Bank

New Business Models That Address First Cost Barriers

As already discussed, for many consumers and cooling applications, the greatest barrier to the purchase of more efficient and sustainable cooling solutions is the high initial cost, even though savings will accumulate over time because of lower operating costs.

A range of new business models have been developed in an effort to eliminate or minimize the first cost barrier including ways to separate cooling services from equipment ownership.

As discussed in more detail in Chapter 4, these include pay-as-you-go systems which allow users to pay for cooling in small amounts, and subscription models in which consumers pay nothing upfront and are instead charged a monthly fee that covers both installation and maintenance. Some of these approaches have been used with varying degrees of success to promote efficient lighting, clean cookstoves,[162] and other energy saving measures. Several organizations are actively working to develop, implement, and evaluate alternative business models for sustainable cooling including BASE,

162 UNIDO (2023).

BOX 3.12

Examples of District Cooling Technologies

Seawater Air Conditioning (SWAC)

A SWAC system under consideration in Montego Bay, Jamaica will provide efficient air conditioning for buildings and district cooling systems. It will work by pumping cold seawater through a pipeline to a heat exchanger where it will cool a secondary freshwater loop. This chilled water will then be circulated through a district cooling network, significantly reducing energy consumption compared to conventional air conditioning systems.[1]

The Deep Ocean Water Applications project in Mauritius is supported by the Sustainable Energy Fund for Africa. The system is expected to use only 4MW of electricity compared to the 30MW currently needed to power conventional systems, resulting in significant energy savings and a reduction of 40,000 tons of CO_2 emissions annually.[2]

Absorption Chiller Units

The Keppel Seghers Tuas Waste-to-Energy Plant in Singapore converts municipal solid waste into energy and uses the waste heat for district cooling. Singapore's success with waste-to-energy technology provides a model for developing countries seeking to manage waste and energy needs efficiently.[3]

Cold Thermal Storage

Viking Cold Solutions[4] provides thermal energy storage for refrigeration, optimizing energy use in supermarkets, cold storage warehouses, and distribution centers, across the United States.

DN Tanks[5] specializes in thermal energy storage tanks for district cooling systems, large commercial facilities, and industrial applications. These tanks store chilled water or ice and are used in projects like the Enwave Deep Lake Water Cooling system in Toronto, Canada, a massive district cooling project demonstrating the utility-scale application of this technology.

1 UNEP. (2023b).

2 ACR Journal (2016).

3 Keppel Corporation (2020).

4 https://www.vikingcold.com/.

5 https://www.dntanks.com/what-we-do/thermal-energy-storage/.

an NGO based in Switzerland, and CLASP. Many of these business model innovations have been demonstrated primarily in well-established, higher-income markets rather than poorer, rural areas where gaps in cooling access are acute. However, efforts to learn from experience and design and implement such approaches more effectively are ongoing.[163] Chapter 4 includes a detailed discussion of new business models and financial instruments for promoting sustainable cooling solutions in difficult-to-reach market segments.

Business models for financing and operation of district cooling also include a number of different company structures and agreements:

> **Private or public concessions**: A private company or a government entity procures cooling through a long-term concession agreement. In this model, a district cooling system is financed and operated by a utility. The contract includes terms such as exclusivity of service, performance standards, take or pay (for the whole project or partially until a certain level of demand builds up), or the right to suspend or terminate service for non-payment. This arrangement is common in markets like France, the United Arab Emirates, Malaysia, and Singapore.

> **Joint Venture or Special Purpose Vehicle model**: A joint venture is formed between a real estate developer and a district cooling company. The venture is co-financed by the parties while a district cooling utility operates the assets. This model can be found in countries like Malaysia and Thailand. Other business models are emerging in India and Egypt where district cooling companies are working with office buildings and malls under build-own-operate or build-own-operate-transfer structures. They are usually equity financed by the district cooling companies. Once the project is established, the infrastructure is in place and regular payments are coming in, it may take on debt to pay back the equity capital. The role of blended finance through instruments such as subordinated debt or performance-based grants can encourage adoption by covering the risk around upfront costs with long-term payment partially offset through first loss guarantees.

> **In-house model**, where a real estate developer or a municipality (or a municipally-owned company) develop district cooling solutions, handling their design, financing, construction, and operation.

Government Cooling Action Plans and Other Initiatives Promoting Greater Consumer Awareness

National Cooling Action Plans (NCAPs) are emerging as a vehicle for countries to develop, engage communities, and communicate their actions to reduce emissions and improve access to cooling. The UNEP-led Cool Coalition

163 Perros et al. (2024).

BOX 3.13

Gas Utility Business Model for District Cooling, for Social Housing in Colombia

The tropical city of Cartagena in Colombia was one of the first cities in South America to operate district cooling. The Gran Manzana district system is a private project operated by Celsia, the third largest utility in Colombia.

Celsia, in collaboration with the Energy District Project, is launching a pilot to connect around 50 low-income families from a nearby social housing development. This effort involves support from the Colombian ministries of Environment and Energy, the United Nations Industrial Development Organization (UNIDO), and the Swiss government, which has provided grant funding. Celsia's expansion into district cooling, along with similar moves by other Colombian utilities helped boost the credibility of district cooling in the country and advance the maturity of the local utility industry. The project in Gran Manzana uses waste heat from Celsia's gas power operations, resulting in significant environmental benefits from the simultaneous generation of energy and cooling.

The Energy District Project with a grant injection of $400,000 will contribute to this Gran Manzana project to cover connection costs and finance the internal fan coil systems in each home that link to the chilled water supply providing the cooling. Challenges faced by the project include the need for Celsia to compete against heavily subsidized power tariffs for residential users while much still needs to be done to build customer confidence.

This initiative to connect social housing to a district cooling system is the first of its kind in South America but is similar to efforts being made in locations elsewhere including in Paris. The same model has been employed globally for district heating for decades. While connecting social housing may require high levels of public finance, the developmental benefits are significant, making it possible to protect vulnerable populations from extreme heat.[1]

1 For more information of the Colombian District Energy Project please visit: https://www.distritoenergetico.com/.

includes a working group on NCAPs, with a methodology to assist countries and cities creating regulatory plans. For example, multiple cities in India have adopted cooling action plans that include measures like community cooling centers to promote the use of passive strategies and protect the most vulnerable residents from extreme heat.[164] The Government of India has developed a framework for heatwave mitigation[165] and is working with the World Bank to develop and fund a substantial program to support sustainable cooling efforts.

Initiatives that promote the availability of more sustainable cooling solutions can only succeed if consumers come to understand and desire such products. A bulk procurement program, for example, may lower prices to competitive levels but if vendors do not promote them, consumer acceptance may continue to lag. This challenge is the focus of ongoing work by the Government of India and CLASP. One approach would be for banks or micro-finance institutions together with manufacturers to jointly devise consumer awareness programs and financial products that would enable low-income consumers to switch to more efficient products or access new cooling solutions.

IFC and other development finance institutions have collaborated for many years on related issues in the context of initiatives to promote off-grid solar systems. Initially focused on the benefits of efficient lighting, the organization GOGLA has shared its experience with a range of productive applications, including cooling, dependent on distributed energy solutions for areas not served by a reliable grid connection.[166]

In sum, there are many challenges to increasing private sector investment in sustainable cooling products and services in emerging markets. Fortunately, there are increasing efforts to develop innovative strategies and solutions.

164 NRDC (2023).

165 NRDC (2023).

166 Global Off-Grid Lighting Association (GOGLA) website, www.gogla.org.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Financing Solutions and Innovations

Chapter 3 discussed challenges to the adoption of sustainable cooling technologies and efforts being made to address them through policies, regulations, and consumer awareness campaigns. But even when non-financial measures such as these are successful, people and firms still need a broad set of financing mechanisms to access cooling technology or adopt passive strategies.

While many sustainable cooling solutions have high initial purchase and installation costs offset by lower operating costs over time, the former is still perceived as a significant disincentive for households and firms. In response, new business models are emerging to cover these initial costs and spread them over a longer period through novel consumer finance structures or service-based mechanisms.

Ultimately, these need to be commercially viable and financially sustainable, and some already are. This chapter describes some of the new business models and the financing options that can enable them. It also outlines facilities that leverage concessional finance to break down market barriers and create new funding streams.

The chapter begins with an overview of business models for financing demand for cooling among consumers facing affordability constraints on account of the upfront capital costs of implementing certain passive strategies or of installing active cooling equipment. This is followed by an overview of the financing requirements and challenges faced by sustainable cooling providers at various stages of their maturity. Next, it provides a blueprint for financing facilities to fund sustainable cooling that meet the needs of distinct markets and business models. This includes a discussion of different financing mechanisms and instruments, from revolving funds to risk-sharing facilities and equity, giving examples of their application.

Finally, the chapter discusses the role of concessional funding and how development finance institutions can help mobilize private capital into sustainable cooling.

4.1 From Cooling and Financing Needs to Business Models and Financial Instruments

This chapter builds on the premise that scalable private commercial financing for sustainable cooling requires a diverse set of instruments to address the many challenges, needs, and gaps described in Chapters 2 and 3. This is necessary to meet the varying needs of the many different firms providing cooling solutions as well as the end customers, including both firms and households.

As Figure 4.1 depicts, the design of financial instruments for cooling begins with a very basic formulation: an understanding of both consumer needs and the characteristics of firms that offer products that meet those needs. Financial instruments must take each into account while remaining responsive to the risk appetite of financiers. At each stage it is important to consider the following critical questions:

- Who needs the finance and why do they need it?
- Who is providing the finance, why are they doing it, and what is their risk appetite?

Consider the example of homeowners thinking about purchasing a high-efficiency air conditioner. To make this decision, consumers need first to understand the financial benefits of purchasing the new equipment that may be more expensive to buy than some alternative products but uses less electricity, making it cheaper to operate and less costly in the long run. Consumers can be made more aware of the better long-term financial outcome from buying the more expensive unit through campaigns by government agencies, power companies, vendors, or local financial institutions. For those homeowners that do not have access to sufficient capital to buy the desired unit outright, an alternative payment system or business model can spread the cost over time.

The retailer, for example, may offer terms that spread the cost of the appliance over a longer period, helping address consumer resistance to the higher upfront cost of more efficient equipment. Rather than provide the financing from its own capital reserves, the retailer may seek a line of credit from a bank that lets it offer similar payment plans to multiple customers. A bank providing this service will want to understand, at least at a basic level, the risk associated with the latest high-efficiency air conditioning technology. Having assessed and priced the risk, the bank may decide it needs additional liquidity in anticipation of high demand for this type of loan. It would then need to raise additional funds or seek a risk-sharing agreement with a public entity or international financial institution. The multilateral organization or public body may in turn want to offer preferential terms to encourage adoption of a more sustainable technology. Uncertainty about the level of risk this puts on its own balance sheet may then prompt it to seek a third party—such as a bilateral donor or philanthropic fund—willing to extend credit at preferential rates to be blended with the multilateral institution's funds, or to serve as a first loss guarantee in the event of loan defaults.

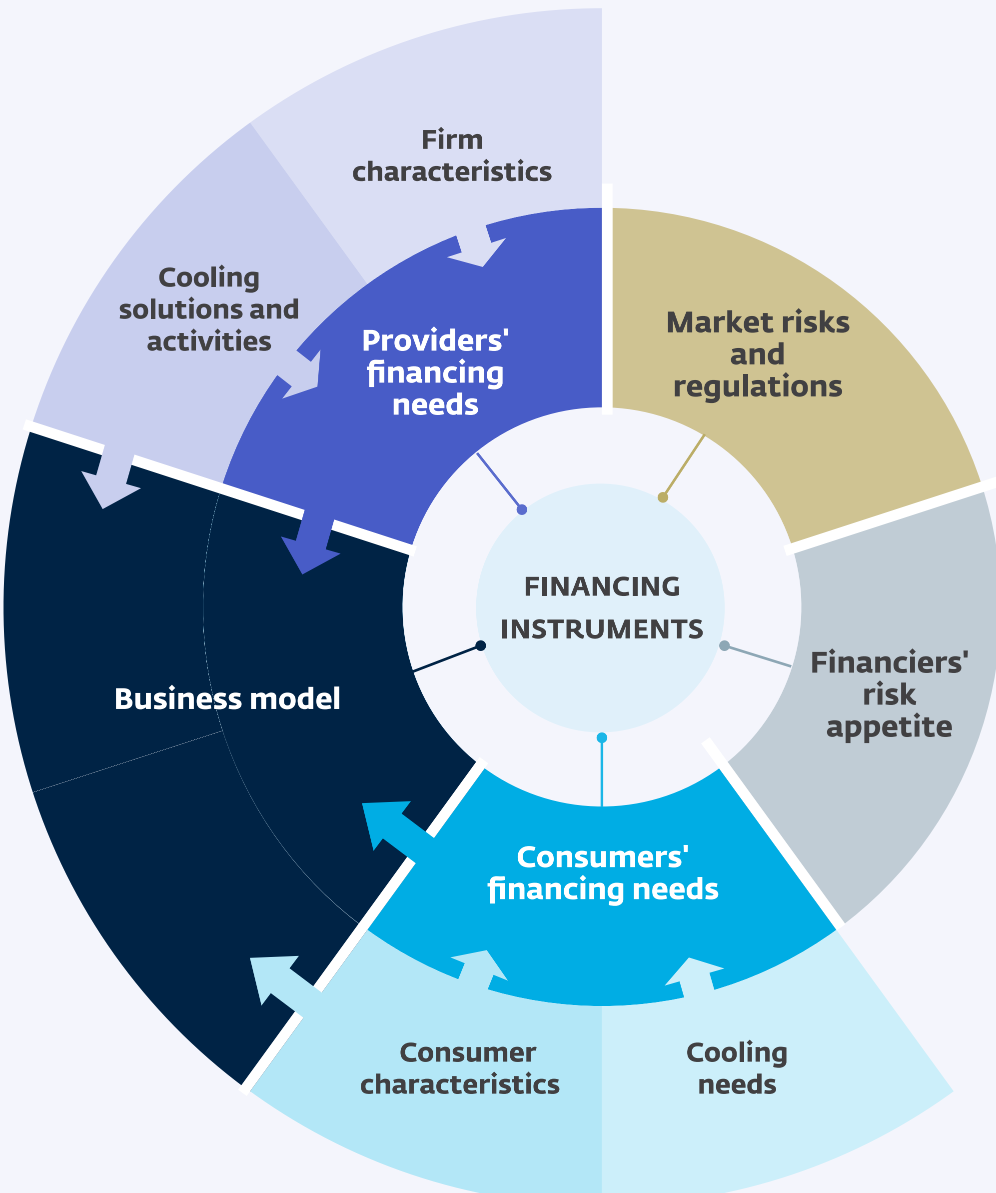
Understanding these financial supply chains for different cooling markets is critical to providing the right business model, and then the appropriate financial structure to cater for the requirements of the cooling provider firm, the consumer, and the relevant financial sector. Building awareness around the financial and business case for each stakeholder in the value chain is the key to success.

4.2 Business Models Addressing Affordability and Financial Constraints

Business Models are shaped by how a company creates, delivers, and captures value to satisfy customer needs. This includes the nature of the relationship between the provider of a product or service, and the consumer. Affordability is a particularly significant constraint and central to any business model. The private sector has shown considerable innovation and initiative in creating business models to address key challenges around affordability related to high upfront costs, reducing risks, and ensuring market growth and sustainability. These include pay-as-you-go (PAYG) programs, cooling-as-a-service (CaaS), on-bill financing (OBF), dealer financing, leasing, energy service companies (ESCO), and bulk procurement. The principal financing constraints of these different

FIGURE 4.1

The Design of Financing Instruments for Cooling Is Driven by Consumers' and Providers' Needs and Characteristics as Well as the Local Market Context



Source: Authors

models can be summarized as follows:

Cooling Consumers' Affordability Constraints

In developed economies, financial markets are typically more sophisticated, offering a broader array of financing options to private consumers. This contrasts with many developing economies, where, despite the presence of high-income individuals who may have access to savings and credit, these resources may not be available to the majority of consumers. This is particularly true for low-income urban and rural populations who are the most vulnerable to heat-related climate impacts.

Micro, small and medium-sized enterprises comprise the majority of businesses in most developing countries and represent a diverse group of firms. Many face liquidity challenges, which may hinder their access to finance and ability to address their cooling needs or adopt sustainable cooling solutions.

On-bill financing (OBF) has proven to be an effective business model for promoting and financing the widespread replacement of inefficient appliances, such as refrigerators and air conditioning systems. This model primarily targets residential customers and SMEs, facilitating the purchase of energy-efficient appliances. The cost of these new appliances is added to the customer's regular utility bill, allowing them to pay for the equipment over time. This integration is proving successful because customers prioritize paying bills for utilities, which are essential services, thereby reducing the likelihood of payment defaults. Furthermore, utilities can enforce payment through disconnection policies for non-payment, providing a strong incentive for customers to stay current on their bills. Additionally, utilities have access to customers' payment histories, enabling them to assess creditworthiness and reduce the risk of granting financing to unreliable payers.

However, utilities typically do not want to divert their own funds to finance these mechanisms. Third-party financing can provide the necessary capital without straining utilities' resources, allowing financial institutions to manage the loans. Loan guarantees and insurance policies can protect against potential losses, while reserve funds offer a financial buffer. Robust credit risk assessment tools help identify reliable payers, and structuring payments to align with energy savings to make financing more affordable, reducing default risks. Additionally, partnerships with government programs can provide extra financial support and incentives.

On-wage financing (OWF) enables employees to acquire energy-efficient appliances and systems through a financing mechanism that is repaid via deductions from their monthly salaries. This model makes cooling accessible for low-income individuals in formal employment as it capitalizes on the stability of their income and the employer's commitment as a guarantor to secure the financing. Under the OWF model, a bank or financial institution provides the necessary upfront capital for the purchase of energy-efficient appliances. The repayment is structured as a deduction from the employee's monthly salary, facilitated by an agreement between the bank and the employer, which guarantees the credit repayment. The OWF model provides the potential to engage a wider consumer base through employers who are committed to sustainability and employee welfare.

Cooling Providers' Financial Constraints

Businesses operating leasing type models including Pay-as-you-go (PAYG) need access to sufficient capital and financing to build inventory as well as to train and pay staff. In off-grid settings, the technology may need to be bundled with additional equipment, such as solar home systems, increasing cost and financial risk due to higher debt-to-equity ratios.

The emergent business models for larger and smaller appliances are still in their infancy and viewed as high-risk transactions by financial institutions. PAYG and regular asset financing are the two business and financing models that have gained prominence in bringing cold storage equipment and cooling appliances such as fans within reach of rural users. The equipment is often sold in these contexts by a distributed energy service company alongside a solar power supply that enables the stand-alone powering of the appliances.

In a structure widely used for the sale of off-grid solar systems, the customer agrees to make regular payments through mobile payment systems. In cases of non-payment, the service provider can remotely disconnect the service. Detailed descriptions of such

BOX 4.1

Cooling as a Service Initiative

BASE launched the global "Cooling as a Service Initiative,"[1] now part of the SET Alliance,[2] to showcase the CaaS model across various countries. This effort engaged leading manufacturers like Johnson Controls, Daikin, Trane, and Carrier, as well as project developers such as Singapore's Kaer, South Africa's Energy Partners Refrigeration, India's Smart Joules, and Indonesia's Synergy Efficiency Solutions. Specialized funds such as MGM Innova Capital (focused on Latin America) and Sustainable Development Capital (focused on Asia, Europe, and the United States) also participated. Despite financial benefits such as stable yields and attractive returns on investment, CaaS providers face several potential financial constraints. They may be accustomed to a rapid turnover of capital leaving them reluctant to immobilize funds for extended periods. The shift from traditional sales to a service model can impact revenue recognition and financial statements. Additionally, holding a large number of assets on balance sheets can affect financial ratios and perceived health. High initial capital requirements may lead to increased debt, raising concerns about leveraging and the cost of capital.

Cooling-as-a-service has been effectively implemented to strengthen agricultural cold chains in developing countries. This approach enables entities to invest in and manage distributed cold rooms, often solar-powered due to their off-grid locations, providing essential refrigeration services that reduce food waste and help small crop producers maximize yields. BASE has supported operators and investors in India, Nigeria, and Guinea-Bissau to scale up this model by incorporating CaaS, allowing farmers to pay per use

1 www.caas-initiative.org.

2 www.set-alliance.org.

rather than invest in cold storage infrastructure. Additionally, digitization and machine learning tools[3] are helping operators and investors in cold storage manage payments, maintenance, and other functions more efficiently. Digitization also enables farmers to use their phone cameras to analyze and track their crops in the cold storage facility. They receive technical and market information on the optimal timing and duration for cooling, helping to maximize shelf life and product quality. This tool ultimately aids farmers in optimizing their profits.

Scaling this model is investment-intensive and requires patient capital due to the long-term recovery periods. Moreover, risk mitigation instruments are essential. Partial credit guarantees are necessary to facilitate access to credit for operators, who are typically small and medium-sized enterprises. Additionally, insurance coverage is crucial to protect against liabilities arising from potential technical failures in the refrigeration process.

Some cold-chain project examples include:

- **Koel Fresh**, in partnership with Rourkela Municipal Corporation, is implementing solar-powered cold rooms at farm-gates and market-yards operated by local women's federations in Rourkela, India. This initiative, supported by BASE and Empa's Your Virtual Cold-Chain Assistant, leverages the Coldtivate mobile app for inventory management, post-harvest processes, and market intelligence within a CaaS business model. Strategically placing smaller cold rooms across major areas in Rourkela rather than a single large facility enhances accessibility and efficiency. The pilot cold room has already benefited over 300 farmers, and the entire project aims to impact more than 2,500, significantly improving their incomes and reducing post-harvest losses.

- **SokoFresh**, a supporting partner of the CaaS initiative by BASE, is actively exploring and implementing the model in Kenya. By disseminating success stories and strengthening the CaaS network, SokoFresh has made significant strides in energy-efficient cold storage. As of 2020, SokoFresh operated nine units and planned to increase this number to 190 by 2023, aiming to offset 7.7 million kilograms of CO_2 emissions annually through solar power use and reductions in post-harvest losses.

- **ColdHubs** employs a pay-as-you-store model in Nigeria, charging 100 Nigerian Naira ($0.50) per day for storing a 20kg crate. Operated by female hub operators, this model ensures efficient management and monitoring of the storage process. By owning the equipment, ColdHubs eliminates the capital expenditure barrier for small-scale operators. Serving 3,517 farmers, retailers, and wholesalers, ColdHubs has 24 operational cold rooms, with plans to expand to 54 by the end of 2020. The social and economic impacts are profound, doubling household income for small farmers, retailers, and wholesalers to add an extra $60 per month; creating 48 new jobs for women; and improving the quality of 20,400 tons of fresh produce to help ensure food safety and reduce waste. Additionally, ColdHubs has saved approximately 462,528 kg of CO_2 emissions and reduced annual energy consumption by 547 kWh in these facilities.

3 BASE program - Your Virtual coldchain Assistant - Coldtivate App. https://yourvcca.org/.

systems and experience to date is available from project reports.[167]

Bulk procurement has been used for the sale, service and maintenance of stand-alone cold storage appliances and cooling devices such as fans, mainly in the public sector. Organizations engaging in bulk procurement need to have sufficient financial resources from loans, grants, or public finances, as well as access to the organizational capability to run such tenders and distribute the appliances. While they help to lower prices, it is important to design these programs in a way that does not create market distortions. The Energy Efficient Services organization in India, a state-owned venture, is in the early stages of a program to distribute efficient fans and cookstoves, building on earlier experience promoting energy efficient lighting.[168]

Under the **cooling-as-a-service (CaaS)** model, the provider owns infrastructure such as the HVAC systems that cool commercial buildings or the solar powered cold rooms used by farmers. The end user pays a fee for using the system, eventually covering the CaaS provider's investment, maintenance and operation costs while providing them with a margin of profit. CaaS has been championed by BASE[169] and adopted in hospitals, commercial buildings, and cold chains in crop production. It is important to note, however, that CaaS is still an emerging business model. It has high potential to be an effective stimulant for the cooling market but experience, both positive and negative, needs to be accumulated, evaluated, and disseminated.

Under the **energy service company (ESCO)** model, the financier makes direct investments into an energy service company which enters into a performance contract with its clients. These contracts can include commitments to guaranteed savings, shared savings, and contract energy management. The ESCO guarantees energy and monetary savings, carries the performance risk of the technology, and is also responsible for making payments to the financier. IFC has financed projects based on this business model for more than a decade with mixed results.[170] This type of model is best suited to standardized technology packages with predictable levels of energy and cost savings. However, there are associated issues to consider, including high upfront investment and energy audit requirements, risks to lenders amid uncertain energy efficiency savings, and potentially complex energy performance contracts.

Another business model boosting energy efficiency is known as Contract Energy Management, where the energy assets remain in the hands of the host company, but a third party operates the infrastructure. This approach can be appropriate for small and medium-sized enterprises (SME) where they do not have the in-house expertise to manage their energy services.

167 IRENA (2020); see also Pay-as-you-go Approaches (Energypedia), https://energypedia.info/wiki/Pay-as-you-go_Approaches_(PAYGO).

168 Kumar (2023).

169 BASE (2019).

170 IFC (2017b).

Box 4.2 presents various examples of the business models discussed in this section, some of which were drawn from a 2024 report by ESMAP and SEforALL.[171] These examples illustrate different strategies for financing and delivering cooling solutions, highlighting a focus on energy efficiency and sustainability.

4.3 Program Design to Address Market Barriers to Sustainable Cooling Finance

To show how different financing mechanisms can be designed to address the financing needs of cooling providers and consumers interacting through a variety of business models, we use a generic framework that combines technical assistance and financial instruments for a range of partners including commercial transactions between private parties (e.g., consumers, banks, retailers), as well as governments, development finance institutions, and concessional finance.[172]

This approach may be highly applicable to sustainable cooling markets. But significant nuances arise from the appropriate business models in each sector and whether the stakeholder relationships are 'business to consumer' or 'business to business.' Food transport has a very different value chain than real estate construction, and even within real estate residential construction has a distinct model to commercial property. Another issue to consider which is particularly relevant for equipment replacement programs, is how to sustainably dispose of old equipment so that it does not re-appear as inefficient second-hand equipment in a target or third country. Old appliances may contain hazardous materials, including refrigerants, which need careful handling and disposal. But they may also contain valuable materials such as metals. Incorporating partnerships with waste management companies can significantly enhance the benefits of a program and help to avoid issues around hazardous waste and dumping of outdated equipment. Figure 4.2 shows some of the many ways such arrangements can operate through a generic program design featuring alternative methods to structure finance and payment arrangements for sustainable cooling equipment and services.

4.4 Financing for Different Stages of Business Maturity

For all companies, research and development (R&D) activities may be highly dependent on grants and fiscal incentives from philanthropic organizations, governments, or development agencies. However, mature businesses would have more access to equity financing to fund their R&D than smaller or younger companies. For smaller, earlier-stage firms involved in innovation and scale-up activities, venture capital and private equity can be sources of funding. This may be combined with financing from multilateral funds or development finance institutions, complemented by grants and fiscal incentives. To date, there has been very

171 ESMAP (2024).

172 Nonbanking financial institution partners include insurance companies and specialized funds, among others.

BOX 4.2

Examples of Additional Business Models for Cooling

On-Bill Financing

- An OBF Program in Mexico aimed to replace 1 million fridges. The program included energy-efficient lighting, refrigeration, and air conditioning, supported by financial instruments and backed by a $251 million World Bank loan, a $50 million CTF loan, and a $7 million GEF grant.
- The ECOFRIDGES on-bill financing program in Senegal facilitates the purchase of energy-efficient appliances by allowing consumers to finance them through manageable monthly payments added directly to their electric utility bills.

On-Wage Financing

- Green On Wage in Ghana offers credit to employees for sustainable air conditioners and refrigerators, with repayment deducted from their wages.[1]

Pay-as-you-go

- Koolboks offers a cooling service funded by small payments in Nigeria and supplies distributors in East and West Africa.
- Oorja in India offers solar-powered cooling services to smallholder farmers on a pay-per-use basis.

1 https://united4efficiency.org/country-regional-activities/ghana-senegal/.

limited funding for sustainable cooling from private equity and venture capital which have focused on other climate technologies, including many at very early stages of development such as direct air capture and green hydrogen. One exception is the Catalyst Fund, a recipient of support from the CPI Lab, an accelerator with international funding from over 100 institutions in government, development finance, philanthropy, and the private sector.[173] The Catalyst Fund has made several investments in early-stage companies with cooling and cold storage solutions for Africa.[174]

Grant financing can be particularly important for project preparation, market research, development of new financial products, investment strategies and new technologies. It is also key to channeling technical assistance to governments developing enabling policies. Grants have also targeted Africa and challenging sectors. One example is the World Bank ESMAP cooling facility approved by the Green Climate Fund with $32 million in grants out of a total commitment

173 https://www.climatepolicyinitiative.org/the-programs/the-global-innovation-lab-for-climate-finance/.

174 Catalyst Fund (2023).

of $157 million.[175] Grant funding for distributed renewable energy also sometimes includes powering efficient appliances in its objectives, such as the $25 million Energy Access Institutions Facility launched in March 2024.[176]

Concessional finance—provided by multilateral funds and development finance institutions in the form of concessional loans, risk capital for guarantee facilities, capital buy downs, or results-based instruments—is especially helpful for pilot projects and higher risk, lower return markets. On the other hand, impact investment or traditional financing from financial intermediaries are available to fund more established firms engaged in scaling-up their sustainable cooling products and services. Public-private partnerships can be used to finance scale-up and growth, although the private side of these partnerships will usually seek financing through financial intermediaries, multilateral funds, and development finance institutions.

Financing Needs for R&D and Innovation

Surging demand for active cooling for comfort, agriculture, healthcare, and industry implies greater energy use. In order to stop that translating into soaring emissions, new and more efficient technologies are needed, which will require more financing for research.

Many of the new initiatives under development are achieving promising results. But they will not be sufficient to meet current and plausible estimates of future demand needs. Some of the initiatives to support R&D for sustainable cooling fall in the alternative instruments of the framework proposed by Cirera and Maloney,[177] which includes market-based and nonmarket incentives, as well as provision of goods and services to innovators, collaboration policies and regulation. Box 4.3 highlights several such initiatives supporting early-stage development.

While grants provided by the programs in Box 4.3 have been successful in identifying technically feasible solutions to challenges in specific sectors, larger scale funding with the involvement of venture capital financing is required to attract new firms and entrepreneurs. The Avaana Sustainability Fund is an example of what is needed. Greater seed financing will incentivize broader innovation across the different areas of cooling covered in this report.

There is an increasing awareness and demand for sustainable cooling technology, but the challenge is to find technologies that justify the upgrade of equipment and that can be produced at costs consistent with affordability. The absence of (i) market incentives, (ii) support to innovation (R&D and acceleration), and (iii) growth capital to innovators hinder industry efforts to invest in research and development. Without significant market pull, manufacturers may be reluctant to invest in new technologies and may continue to produce and sell conventional cooling systems that are less

175 https://www.greenclimate.fund/project/fp177.

176 https://www.clasp.ngo/updates/clasp-chosen-to-lead-initiative/.

177 Cirera and Maloney (2017).

FIGURE 4.2

There Are Different Financing Mechanisms to Support a Variety of Business Models Defined by the Interactions Between Cooling Providers and Consumers

Transaction participants:

Cooling consumers

- Firms
- Households

Cooling providers and market partners

- Cooling provider firms
- Associations
- Energy service companies
- Utilities

Financial institution partners

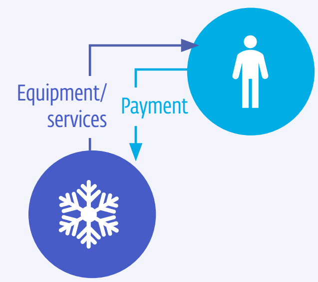
- Banks
- Non-bank financial institutions
- Public finance institutions
- Leasing companies

Government / International Finance Institutions / Implementing Agency

Private commercial transactions:

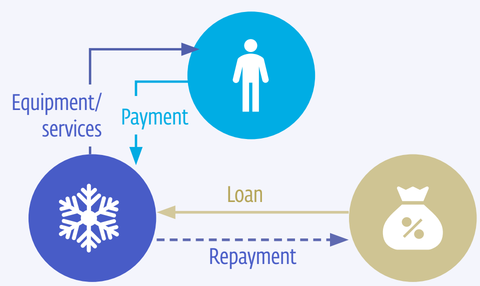
SCENARIO A

This is the simplest scenario whereby a consumer uses their own funds to purchase or lease an appliance.



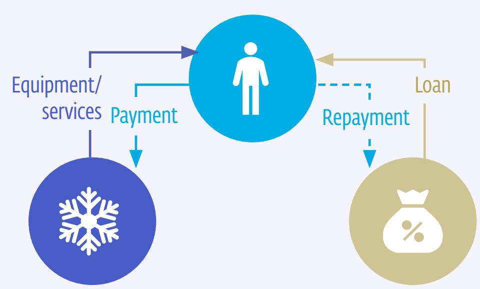
SCENARIO B

An extension of scenario A but where commercial borrowers take loans from banks to manage their capital structure.



SCENARIO C

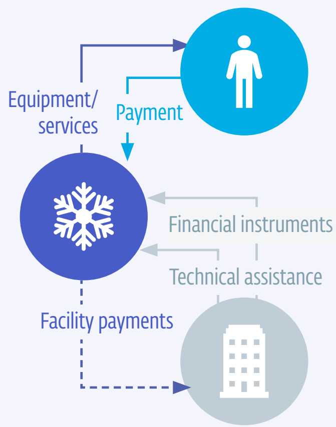
An extension of scenario A but where a consumer takes a credit from a bank to purchase an appliance.



Transactions supported by concessional finance:

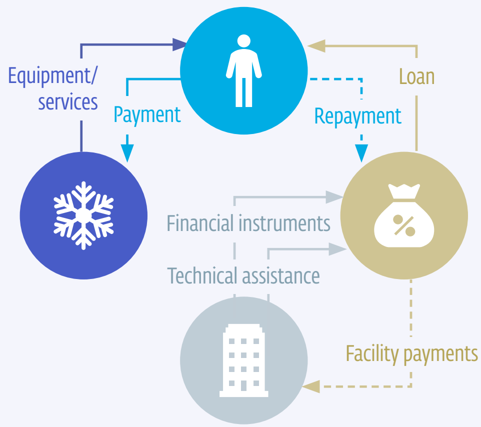
SCENARIO D

An Implementing Agency provides a blend of technical assistance as well as a financial instrument (either 'funded' or 'unfunded' and possibly on preferential terms) to an intermediary such as a utility or retailer, who then provides financing to consumers.



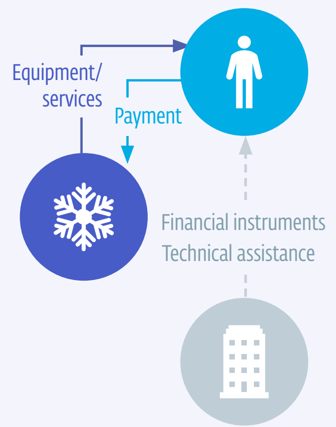
SCENARIO E

An Implementing Agency provides a blend of technical assistance as well as a financial instrument (either 'funded' or 'unfunded' and possibly on preferential terms) to a financial intermediary such as a local bank or leasing company, who then provides financing to consumers.



SCENARIO F

An Implementing Agency, including the government, provides incentives and technical assistance and information to consumers to encourage their adoption of sustainable cooling solutions.



Note: Additional scenarios can be created by combining those outlines here, for example, a scenario where commercial borrowers (Scenario B) and private consumers (Scenario C) take loans from banks, or an alternative scenario where implementing agencies incentivize sustainable cooling both from the cooling market supply (Scenario D) and demand (Scenario F) sides.

BOX 4.3

Initiatives to Support R&D and Innovation

The Global Cooling Prize (launched by the Rocky Mountain Institute in 2018) and the Million Cool Roofs Challenge (launched by the Clean Cooling Collaborative in 2019) are two global competitions that provided up to $1 million awards to scalable cooling innovations (and in the former case, under certain minimum efficiency and sustainability standards).[1]

In April 2024, UNEP and ASHRAE, the professional association of heating and cooling engineers, announced a competition to promote innovative design, research, and practice in developing countries to minimize the global warming potential of refrigeration and air conditioning applications.[2]

In 2024, the Green Climate Fund approved a $24.5 million equity investment in Avaana Sustainability Fund, a venture capital fund that aims to invest in early-stage climate technology companies in India, including some with a focus on sustainable cooling.[3]

Also in 2024, the CPI Finance Lab, a multi-donor program that provides technical support to innovative climate startups, announced support for a venture fund focused on sustainable cooling.

In yet another 2024 announcement, the Climate and Clean Air Coalition released a call for nonprofit organizations to propose ways to promote climate mitigation in cooling applications.

1 For further details on the Global Cooling Prize see https://globalcoolingprize.org/ and on the Million Cool Roofs Challenge see https://www.cleancoolingcollaborative.org/blog/million-cool-roofs-challenge-local-champions-for-a-global-movement/#:~:text=With%20the%20ultimate%20goal%20of,access%20to%20cooling%20is%20low. Two of the prize winners came from established air conditioner manufacturers. To further incentivize disruptive innovations, existing or new firms and entrepreneurs need to be attracted into the cooling space through a combination of greater funding for seed capital and venture capital funding to scale and implement successful innovations. These can be provided through larger targeted funds in the cooling innovation space combining different funding sources from currently involved donors and multilaterals with private investors.

2 https://www.unep.org/ozonaction/news/news/ashrae-and-unep-launch-2024-lower-gwp-innovation-award.

3 For additional details on the Avaana Sustainability Fund see https://www.greenclimate.fund/project/sap037.

environmentally friendly. Much more needs to be done to make investors aware of the sizable business opportunities available in a market growing to $600 billion per year, or more, across developing economies in the coming two decades (see Chapter 2). This market is likely to become even larger in response to the increasing climate and cooling commitments made by countries, evidenced by the Global Cooling Pledge and evolving regulations documented in the 2023 Global Cooling Watch report. Even more support is required to close an $813 billion gap across developing economies through affordable and sustainable cooling technologies.

Scaling Up Adoption of New Technology

There are additional challenges moving beyond R&D and initial testing during the innovation phase to scale up the adoption of new technologies. The focus shifts to funding for innovative business models, greater incentives for design changes and the use of passive strategies, as well as exploring instruments that reduce risk in order to attract more private investment. Development of

BOX 4.4

IFC TechEmerge Cooling Program

In 2019, IFC launched the TechEmerge Sustainable Cooling Innovation (TE-SCI) program to connect innovators across the world with leading emerging market companies to pilot sustainable cooling technologies and business models. The aim was to reduce risk on investments and provide a demonstration effect to accelerate the adoption of new cooling solutions. In partnership with the U.K. Government, TechEmerge carefully matched 40 high-potential cooling innovators with 52 corporates in Bangladesh, Colombia, Ecuador, India, Kenya, Mexico, Nigeria, Rwanda, Turkey, and Viet Nam. Together, they field-tested a total of 79 cooling solutions in real world conditions, focusing on the key themes of cooling in cities, cold chains, temperature-controlled logistics, space cooling, and CaaS business models.

Along with providing expert technical advice, TechEmerge leveraged $5.2 million in grants, combined with matching cash and in-kind contributions from participating innovators and corporates to demonstrate and validate climate-smart cooling solutions. This approach stimulated more than $75 million of investment in innovators and proved to be an effective model to address the biggest barriers. For example, most investment opportunities in cooling innovators do not conform with the typical return profile in the venture capital asset class as they are usually asset- and CAPEX-heavy businesses with relatively long gestation periods. This tends to extend the duration between funding rounds for cooling innovators and stunt their growth prospects, while also delaying the launch of mass market-ready cooling innovations that are critical to meet climate commitments at all levels. However, through the calibrated blending of commercial and non-commercial capital, TechEmerge was able to balance risk and reward and provide corporates and innovators with confidence to pilot innovative cooling technologies. Similar approaches could be replicated to determine the right amount of blended capital to support and sustain the growth of new cooling technologies and business models to scale over time and help bridge the growing gap between climate commitments and realities.[1]

1 Supporting follow-on financing was beyond the scope of TE-SCI, which focused on establishing techno-commercial feasibility under pilot conditions. TE-SCI encouraged direct negotiations between adopters and innovators rather than participating in the actual financing mechanisms. The new cooling trust fund will build on the learnings from TE-SCI with a broader mandate, allowing for potential investments following initial interventions. This fund aims to support larger, more integrated, and longer-duration projects across various sectors such as built environments and cold chains.

BOX 4.5

Cooling-as-a-Service as a Model to Scale Up New Technology

Cooling-as-a-service is an effective business model for scaling up the adoption of new technology, in part because it frees consumers from the need to pay high upfront costs for purchasing and installing new equipment. It is important to promote acceptance of this structure and support its adoption with public and private finance, as well as development aid and technical assistance.

Key support areas for implementing the CaaS model include:

Standardizing Contractual Arrangements: These should involve long-term relationships between providers and customers, with a focus on managing risks. The emphasis is on the cooling system's performance rather than its characteristics. Contracts need to address aspects such as early termination, default on service fee payments, and system failure or underperformance.

Pricing Structure: Estimating the service outcome price differs from traditional supply and installation contracts. It must incorporate usage or outcome-based pricing, asset amortization, financing, maintenance, operational costs (sometimes including energy costs), and monitoring.

Financing Strategy: Providers need a robust financial structure to manage asset ownership, secure financial support, and incorporate risk mitigation mechanisms. CaaS is typically offered as an off-balance-sheet agreement, meaning the customer benefits from the asset's performance without owning it. This adds complexity to liabilities and risks. Financial structures such as Special Purpose Vehicles or refinancing mechanisms like securitization or sale-leaseback are important considerations. Additionally, finding the right equity-to-debt ratio is crucial to meet the capital intensity of these deals and maximize returns.

Behavioral Change Strategy: A significant challenge for providers seeking to convince customers to adopt the 'as a service' model is a widespread emotional attachment to owning assets. Providers need support to change customer behavior and build market trust. Key arguments include avoiding the need to invest in non-core business opportunities and not impacting their credit capacity.

financial initiatives and new instruments to mobilize public and private sector finance for scaling sustainable cooling requires time to implement, evaluate, and expand.[178] For instance, energy-efficient cooling technologies face challenges in gaining market share due to higher upfront costs and limited awareness among consumers. Therefore, policymakers and market actors need to incentivize the adoption of sustainable cooling solutions through some of the measures described in Chapter 3, such as labeling programs, and public procurement of high-efficiency products.[179]

The process of scaling sustainable cooling technology can be accelerated in several ways. One is harmonized regulations and

178 World Bank (2021).

179 For examples of public procurement of energy efficiency products see ESMAP (2012).

market incentives, another is collaboration between governments, research institutions, manufacturers, international organizations, and venture capital funds. Public funding can help bridge the financing gap and encourage private sector investment in sustainable cooling solutions.[180] Development finance institutions can also contribute to closing the financing gap by promoting high risk capital—private equity and venture capital—investments, sustainability-linked instruments, as well as instruments that backstop risk, and concessional finance, thereby mobilizing further private capital.

Public-private partnerships can also be structured to scale-up tested innovations involving SMEs and firms with limited resources when combined with government incentives on the demand side. This is the concept behind the approach being promoted by the ACES initiative, which seeks to convince governments to evaluate rural cooling improvements as equivalent to a form of infrastructure investment. This will be of particular importance to increasing access to sustainable cooling for households, access to cold chains by farmers, cooling as a service to support firms, as well as district cooling.

Different financing bodies have distinct preferences for the type of instrument they engage depending on their history, mandate, relative competitive advantage, and experience. For example, among development finance institutions and multilateral funds, the World Bank focuses on large loans to sovereign governments, IFC uses blended finance instruments to promote private sector engagement, and UN agencies tend to focus on grant-based instruments. It is important to understand this landscape and approach those institutions that have the best strategic and operational match for the activities and sustainable cooling suppliers in question.

Financing for Supply Side Projects

Most of the discussion so far has revolved around increasing demand for sustainable cooling products while boosting accessibility. Many developing countries are entirely dependent on imported equipment, much of it comprising lower cost, lower efficiency models that cannot be sold in the country of origin.[181] Working with large so-called Original Equipment Manufacturers (OEM) may therefore be an important avenue for increasing the supply and availability of efficient equipment.

In countries with some domestic manufacture of cooling equipment, it is also important to help those producers increase the supply of more sustainable cooling products. Figure 4.3 illustrates points of aggregation and financing opportunities in the manufacture, assembly, and distribution of efficient appliances using better components. For both the production of OEM units as well as assembly of a bespoke system where different components need to be brought together, the emphasis is on using technology that utilizes refrigerants or parts with low or no global warming potential and that are more

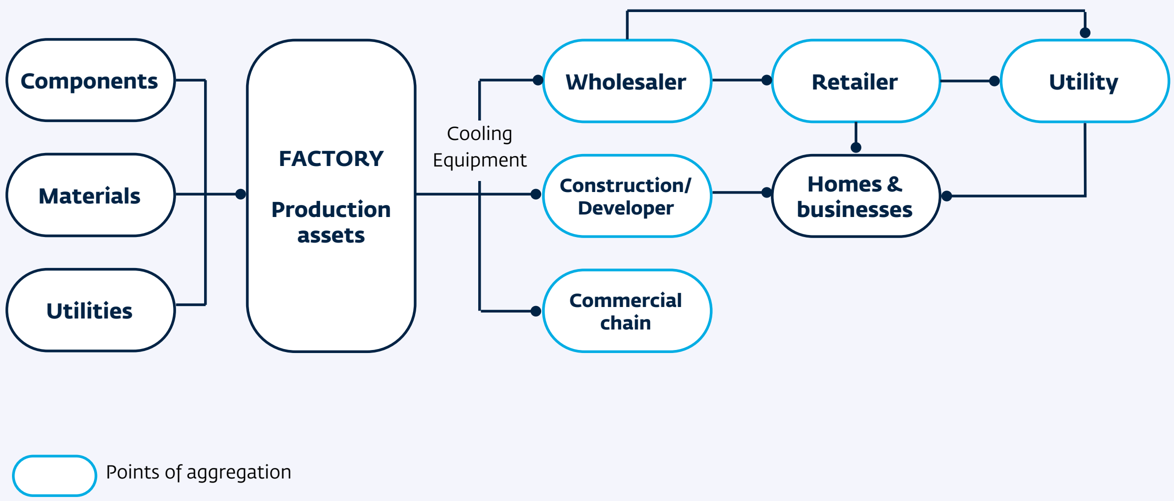
180 IEA. (2020).

181 CLASP (2023).

FIGURE 4.3

Financing Needs and Opportunities Vary Throughout Cooling Supply Chains

Cooling equipment supply chain



Source: Authors

energy efficient than those previously used. Financial needs here could include the funding of fixed assets such as new plant and equipment to manufacture new technologies, enhanced working capital to pay for more expensive higher efficiency components, or even additional equity to support the growth of new ventures. Financing the development of supply chains linked to locally manufactured sustainable cooling equipment is critical to transforming markets.

One institution that has focused on improving the supply of sustainable cooling devices is the Multilateral Fund of the Montreal Protocol. This has made significant investments in supporting the phase out of different refrigerants and is now turning its attention to the phase down of HFCs and improving the energy efficiency of appliances. This includes expanding the availability of proven technologies in new markets.

Financing Large-Scale Cooling Projects

Large-scale cooling infrastructure projects, such as district cooling as described in Chapter 3, have diverse financial needs across different phases of their development. Understanding the capital intensity and associated risks at each stage, namely planning, construction and operation, is key to securing optimal financing solutions.

Planning Phase: During planning—which encompasses engineering and permitting among other activities—capital intensity is low, but risks are high. This stage relies heavily on equity to finance feasibility studies, engineering designs, and securing regulatory approvals.

Construction Phase: Capital intensity is high and this stage requires significant upfront investment. However, the financial risks moderate as the project develops. This phase typically seeks debt financing through competitive construction loans or project finance. Additional instruments like credit guarantees, concessional finance—loans with favorable terms and grace periods—and syndicated loans can further ease the financial burden.

Operational Phase: Once operational, the investors would look for recapitalization instruments. These mechanisms allow investors to recoup their initial investment, invest in other projects and potentially generate returns. Common options include securitization (converting project cash flows into tradable securities), sale-leaseback (selling the project asset with a leaseback agreement for continued operation), and debt refinancing (replacing existing debt with new arrangements offering potentially more favorable terms).

These projects can be linked to public-private partnerships, green bonds and thematic financial products from banks or specialized funds.

BOX 4.6

Dedicated City Cooling Funds to Drive Multi-Level Financing on Cooling in Viet Nam

Viet Nam offers an example of multi-level action, incorporating measures on cooling and extreme heat into its strategy for delivering net-zero emissions by 2050 and pushing forward with efforts to link refrigerant and cooling emissions into its domestic carbon market design. These measures recognize the increasing importance of subnational and city governments in driving action on sustainable cooling. The country's government set up the National Green Cooling Action Plan to promote adoption of energy efficient technologies in the cooling sector. UNEP and the Global Green Growth Institute with support from the Clean Cooling Collaborative are supporting the country's Ministry of Natural Resources and Environment (MoNRE) to implement a three-year program, initially focused on three cities, that incorporates plans for cooling investment pipelines and planning and policy changes based on new research and analysis. The aim is to address limited availability of public funds and a lack of expertise in leveraging private investment for sustainable cooling. The project is exploring integrating cooling under MoNRE's existing Environmental Protection Fund to provide finance for cooling projects such as retrofitting buildings as well as nature-based solutions and district cooling structures.

4.5 The Role of Concessional Funding to Support Sustainable Cooling

The size of the cooling industry suggests that there is finance available to pay for conventional cooling technologies. This chapter focuses primarily on financing instruments and business models consistent with private commercial funding of cooling transactions. However, affordability of new sustainable cooling technologies due to higher upfront costs is one of the key barriers that hinder mass adoption.[182] Finding risk capital for establishing and scaling startups and SMEs and reducing loan tenors to commercial standards can also present challenges. Therefore, to meet the growing needs for cooling described in Chapters 1 and 2, certain populations and market segments will require concessional financing instruments to accelerate deployment and reduce the access costs of new technologies.

Some of these financing mechanisms, like funding for research into new cooling technologies, will be seed funds for a limited period which, complemented by risk-reducing measures, may attract further private investment. Others, like support for poor populations in rural areas, may require more substantial backing through incentives and concessional financing over longer time periods to address affordability limits. Even in the latter case, innovative approaches around scaling to reduce costs or other strategies can reduce the need for concessional funding over time. The many variables associated with cooling across different markets make estimation of fiscal incentive costs and concessional funding difficult, if not impossible.

Concessional finance is characterized by several features that distinguish it from standard financing products. These include below-market funding costs, longer loan durations, and higher risk tolerance. Major organizations such as development finance institutions and multilateral funds, provide concessional finance to support investments in developing countries, aiming to accelerate development objectives. The most common financial products used to deliver concessional finance come in the form of loans, technical assistance, incentives and guarantees. How these products are delivered must remain flexible to the unique needs of each development challenge. The focus of concessional finance is not on a specific method or solution so much as bridging the gap between limited pools of philanthropic and public sector funding and the private sector funding opportunities that enable such projects to scale. Recent research has also found that publicly funded startups achieve a significantly greater rate of financial success compared with purely private investment.[183]

It is also important to note that the pool of funds available for concessional finance is not infinite. There is increasing awareness of cooling as an imperative, however, and providers of wholesale donor funds through bilateral

182 Nain and Bhasin (2022).

183 Kennedy et al. (2024).

BOX 4.7

Accelerating Private Investment in Cold Chain Through India's Credit-Linked and Back-Ended Capital Subsidy for Cold-Chain Development

In 2012–13, India's National Centre for Cold-chain Development (NCCD) reviewed ongoing cold-chain programs and proposed certain changes. Observing that the weakest performance was in the fresh produce segment, it prioritized revisions to the program including a requirement that public financial support be credit-linked and its disbursal back-ended into banks. The idea was to change the earlier perception that a subsidy was upfront capital, to where the subsidy receiver understood it was an incentive in support of projects. Since the subsidy was not assessed in advance, banks had to evaluate the commercial viability independent of the subsidy component. Thereafter, only fully financed projects were eligible to apply for a subsidy. This enhanced the viability and effectiveness of projects being proposed and financed by the private sector and allowed the government to effectively target support for missing cold chain links.

Besides this, other mechanisms and rules were introduced to rationalize the capital outlay and instill some minimum system standards. The newly structured subsidy is released in two tranches, only after completion and commissioning, and directly into a credit-linked account and not into the hands of promoters. The changes allowed India to reshape the subsidy system into an incentive designed to offset the interest burden over the full term of the credit availed. As a result, the incidence of viable projects increased and hastened development of cold chains. Later, to foster a service orientation, key cold-chain services were exempted from service tax on the recommendation of the NCCD. The aim was to encourage higher throughput and earnings in the cold-chain and eventually reduce reliance on infrastructure-based subsidies. Under the advice of the NCCD, India's support for cold chain has components of capital subsidy, fiscal and tax benefits, upgrading, training, and minimum sustainability standards.

The cost norms for subsidy were also rationalized in 2013 and weighted to encourage investment in less developed and more critical areas of the cold chain. This promptly began to drive specific investments and efficient operations. The revised cost norms reduced the subsidy outlay in traditional and unnecessary components, allowing the addition of 13 new components. These included modern packhouses with pre-coolers, inter-modal reefer containers, packaging lines and automation systems, as well as alternate energy options.

In 2014, the government approved the launch of a new rationalized horticulture mission under the Ministry of Agriculture, which included holistic support for cold chain. The government linked cold chain development to cluster-based production of horticulture and in the fisheries sector. Given the prevalence of small land holdings in India, cold chain support is prioritized for farmers groups, especially professionally run farmer-producer companies and cooperatives. While the priority remains modernizing the supply chain for horticultural produce, the support continues to extend to upgrading the cold chain for the fisheries, meat, and dairy sectors.

national contributions or philanthropy, as well as international funds such as the GCF and GEF, are increasingly receptive to proposals for innovative cooling programs. But any request to mobilize donor funds for concessional use is competing with other programs also aimed at addressing climate change. The onus, therefore, is on implementing agencies and partners to be innovative and have clear objectives and anticipated results in mind if they want to be successful in securing funds.

Public and Blended Finance Mechanisms

Blended finance,[184] defined as the "use of catalytic capital from public or philanthropic sources to increase private sector investment in sustainable development," is critical for creating an enabling environment for the cooling sector to develop at scale. Blended finance through multilateral development banks has helped launch high-risk initiatives with the potential to produce beneficial, quantifiable social and environmental outcomes in regions of severe need.[185] Multiple climate projects supporting energy efficient appliances with commercial technologies and cost savings over time have proven attractive for blended finance.[186] But achieving similar leverage for access to cooling measures remains elusive.

Any public finance mechanisms must be strategic in design and execution. Suitable solutions could include public procurement of appliances, concessionary loans and grants, subsidies, and other fiscal incentives contingent on scale and risk preference or viability of the economic model.

The nascent nature of the cooling market means that technical support, market research and development activities, along with grants to enable project development, are needed to enable the scale up of new technology adoption. This has been demonstrated by the Lighting Africa programs and the proliferation and success of energy efficiency and renewable energy finance projects. Providing these concessional funds in this formative period for the cooling sector has the potential to help these markets take off and proliferate. A number of initiatives are now providing this type of support, such as Cool Up, the ESMAP Efficient and Clean Cooling Program, and the Clean Cooling Collaborative commitment of $1.5 million for projects and programs supporting passive strategies in Southeast Asia.[187]

One of the issues raised in recent reports on energy efficiency and sustainable cooling, especially the 2023 Global Cooling Watch report, is that there is little experience with the financing of sustainable cooling technologies. However, there is very significant experience in financing demand side energy efficiency in industry and residential sectors through a variety

184 https://www.convergence.finance/blended-finance.

185 Hatashima and Demberel (2020).

186 See, for example, a GCF project promoting energy efficient equipment in El Salvador through an insurance scheme developed by the IDB, https://www.greenclimate.fund/projects/fp009.

187 https://www.cleancoolingcollaborative.org/rfp-passive-cooling-in-southeast-asia-2024/.

of partners including local banks and leasing companies, equipment vendors, energy utilities, and ESCOs. Hence, financing energy efficiency plus HFC phase-down may in some respects be a less difficult business proposition since the efficiency aspects generate real cost savings and there are models developed with a wide variety of stakeholders that successfully demonstrate the effectiveness of energy efficiency finance.

4.6 Financing Instruments for Sustainable Cooling

The cooling markets landscape described at the beginning of this chapter and in previous reports illustrates how cooling needs vary between market segments, providers, and end users. It also highlights the importance of the policy environment and available business models as factors that can hinder or enable adoption as well as financing.

Financing sustainable cooling requires an understanding of the existing financial infrastructure and where public and private funds are being allocated to meet current needs and enable transitions to more sustainable practices. For example, venture capital focused on innovative cooling technologies, business models, and services can generate positive disruptions in the market beyond the efforts of large incumbent firms. In rural areas in low- and middle-income countries, as noted above, public private partnerships may play a significant role in support of access to cold chains.[188]

As highlighted in Figure 4.2, there are many different financial instruments available to help increase the uptake of sustainable cooling technologies depending on the characteristics of the manufacturer, vendor, and consumer. Some of these work at the consumer level (a homeowner, small firm, or corporate entity) and some work at the aggregator level (bank, leasing company, or retailer) enabling these to enter into a financial arrangement with the consumer.

Figure 4.4 shows a number of different instruments and the type of entities where they may be most applicable. However, specific market conditions, such as the level of liquidity and the regulatory environment, must be thoroughly understood in order to pick an appropriate financial instrument. It is also important to match the instrument with the capabilities of the implementing agency to maximize their comparative advantages. Some of these instruments have already been tested or programs are being developed specifically for cooling applications. All of the others are applicable to cooling applications given the underlying benefits they try to harness such as lower energy costs, reductions in food loss, and carbon finance benefits.

Some of these financial instruments are described in more detail below. These financing structures could incorporate concessional finance elements. In such cases, given the limited availability of public and donor funds for cooling, it will be critical to ensure that funding is deployed in the most efficient, effective,

188 This is in line with the Clean Cool Collaborative's blog "Show me the money: Financing the transition to efficient, climate-friendly cooling for all", March 2022 (https://www.cleancoolingcollaborative.org/blog/financing-the-transition-to-efficient-climate-friendly-cooling-for-all/).

FIGURE 4.4

Some Financing Instruments Are Better Suited for Certain Cooling Market Entities

Applicability of different financing instruments for different entities involved in cooling transactions or financing

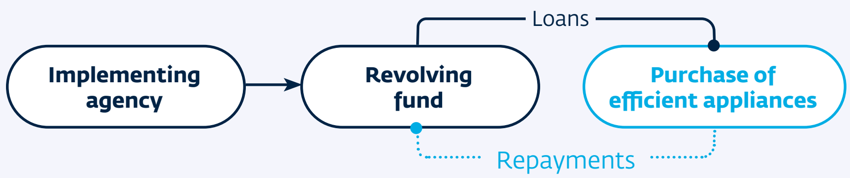
	Banks	Manufacturer	Wholesaler	Developer	Commercial chain	Utility	Retailer	Homes & businesses
Revolving Fund	■	■			■	■	■	
Results-based finance	■	■	■	■	■	■	■	
Conventional equity	■	■	■	■	■	■		
Conventional loan	■	■	■	■	■	■	■	■
Risk sharing	■		■			■	■	
Performance guarantees		■		■		■	■	
Blended Finance	■	■		■	■	■	■	
Public Finance						■		■
Working capital loan		■	■	■		■	■	

Source: Authors

and strategic way to achieve the desired market transformation, including maximizing the potential to mobilize private capital.

FIGURE 4.5

Illustrative Structure for a Revolving Fund



Source: Authors

Revolving Funds

A revolving loan fund leverages an initial amount of money to fund multiple rounds of energy efficiency projects. Energy cost savings that accrue from the initial round of projects replenish the fund, which can be subsequently used to fund additional projects. As long as the projects remain cost-effective—that is, total energy cost savings exceed upfront investment costs—a revolving loan fund can be used to repeatedly fund programs. This may be suitable for a smaller country or sector within a country, and for smaller projects. This is so that funds can be disbursed and reflows collected quickly, improving the fund's performance. Revolving funds are often implemented by NGOs or government partners and do not necessarily have to be based around an accredited financial institution such as a bank or leasing company. However, the implementing agency has to demonstrate that it has appropriate systems for financial management. These requirements make such funds less relevant for development finance institutions but may be more suitable in cases where there are a limited number of clients, the project values are relatively small, and there is a good simple payback return on investment. Revolving loan funds for energy efficiency have been widely used in U.S. states and cities, offering models and lessons for use in

BOX 4.8

Thailand's Energy Efficiency Revolving Fund

Thailand implemented a highly successful revolving fund for energy efficiency from 2003 to 2011. Loans were made for 294 projects and the involvement of public funds resulted in greater investments by commercial banks producing substantial savings in electricity, oil imports, and emissions. A significant outcome was the creation of a network of private financiers and ESCOs.[1]

1 See Frankfurt School and UNEP (2012).

other countries.[189]

In a simple structure such as that shown in Figure 4.5 a donor may make a grant available to an implementing agency to capitalize a revolving fund, managed by the agency directly or through an outsourced contract. The manager of the revolving fund allocates funds to projects through a selection procedure which can be a bidding process. As those projects deliver energy savings, the loan from the revolving fund is repaid and the funds can then be re-allocated to a different set of programs. The MLF[190] is currently developing a revolving fund to address projects with an energy efficiency component alongside a phase-down of HFCs.[191]

To assess whether a revolving fund is appropriate for a particular product and market, it would be important to know the estimated payback periods for the investments, the tenor of the loans, and the time that funds will be available. For example, if the duration of funding is only three years, it may be difficult for the fund to revolve. A five-year fund may be a better alternative as there will also be a ramp-up period as the fund needs to be established, project ideas solicited, and funds disbursed. IFC has consequently found that the concept is generally not suitable for mobilizing private investment in debt finance.

Such a program may be most appropriate for smaller countries where the project size is modest and there is an institution, such as an NGO, able to act as the fund manager.

Working Capital Loans

Working capital loans, which cover a company's operating costs, could be focused—in the case of a manufacturer of sustainable cooling equipment or provider of cooling services—on financing the incremental costs of purchasing more efficient and more expensive components. This instrument would be an option to supplement or replace grant-based structures that address the higher incremental costs of manufacturing more sustainable and efficient equipment. It is applicable to supply side manufacturers and CaaS companies to support the expansion of their business operations, including purchases of components by manufacturers or CaaS providers.

Working capital loans support businesses' general operating costs. In the case of a small manufacturer or project developer, the development of sustainable cooling products would come with an increase in operating costs. Providing a working capital loan to such an entity might be a valid alternative to offering grant funding for incremental costs.

In this case, a donor would make funds available, usually a grant, to an implementing agency, that then uses funds to backstop loans that local banks make to eligible borrowers. The local banks, who would have an existing banking relationship with the cooling manufacturers or

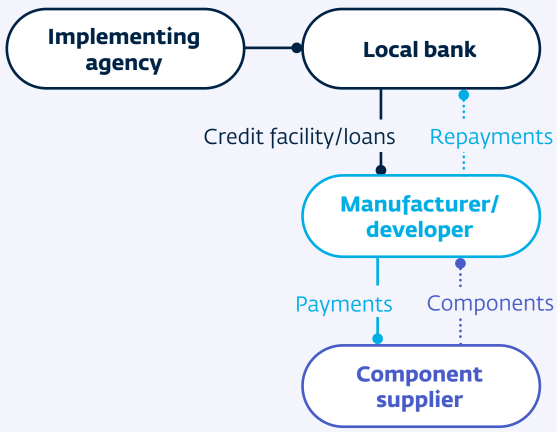
189 https://neep.org/blog/how-states-can-grow-equitable-efficiency-programs-revolving-loan-fund; https://www.naseo.org/issues/energy-financing/revolving-loan-funds; https://www.epa.gov/statelocalenergy/revolving-loan-funds.

190 Multilateral Fund for the Implementation of the Montreal Protocol. See Box 4.11.

191 UNEP (2023b.).

FIGURE 4.6

Illustrative Structure for Working Capital Loans



Source: Authors

assemblers, could use these funds to enhance existing working capital loans so that these companies could afford to buy more expensive, efficient components without negatively impacting their cashflow. Because there may be a limited number of clients, especially in small countries, this might be a more efficient mechanism than setting up large facilities or banking relationships.

Results-Based Finance

Results-based financing revolves around the provision of funding to a project or portfolio of projects where the facility is subject to pre-agreed outputs and outcomes and independently verifiable performance in areas such as reduced energy usage. While this instrument has proven to achieve development outcomes and accelerate innovations across sectors, it is yet to be deployed at any scale for cooling applications.

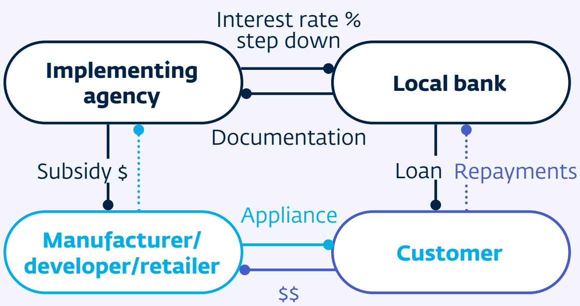
Figure 4.7 illustrates a results-based financing structure with two potential pathways for payments. The first involves incentivizing the distribution of products through manufacturers, wholesalers, retailers and potentially utilities, who would receive a performance bonus for meeting sales targets for sustainable equipment or for, say, commercial refrigeration projects. In the second pathway, if the aim of the program is to encourage local banks to finance the purchase of sustainable technology, then the reward could be either grant payments or interest rate step downs for meeting targets based on the number and value of loans.

In each case the implementing agency would need to carefully verify each of the reward payments based on project documentation and use of proceeds. Technical assistance may be required to provide the monitoring agency with the ability to verify the performance. There would, therefore, be a likely increase in transaction costs for banks, manufacturers, and retailers but this could also be offset by the results-based payments.

Working out the correct results-based payment program requires additional thought and information. But some approaches can consider applying existing methodologies for calculating incremental costs, such as using a shadow price of carbon per ton of CO_2 avoided or using a

FIGURE 4.7

Illustrative Structure for Results-Based Finance



Source: Authors

BOX 4.9

SEforALL Universal Energy Facility

The SEforALL Universal Energy Facility is an example of results-based financing applied to sustainable energy projects. The facility is eligible for cooling and already has two firms proposing support for off-grid refrigerators.

The fund offers a fixed subsidy of $592 per mini grid installation and covers 40 percent of the costs of standalone solar installations for productive uses. Both of these can provide energy for sustainable cooling technologies in commercial activities such as refrigeration for food retailers, or other applications such as air conditioning in healthcare facilities.

percentage of project costs. In the case of banks, there could be a step down in interest rates, calculated based on the prevailing base interest rates and risk premiums on a country-by-country basis.

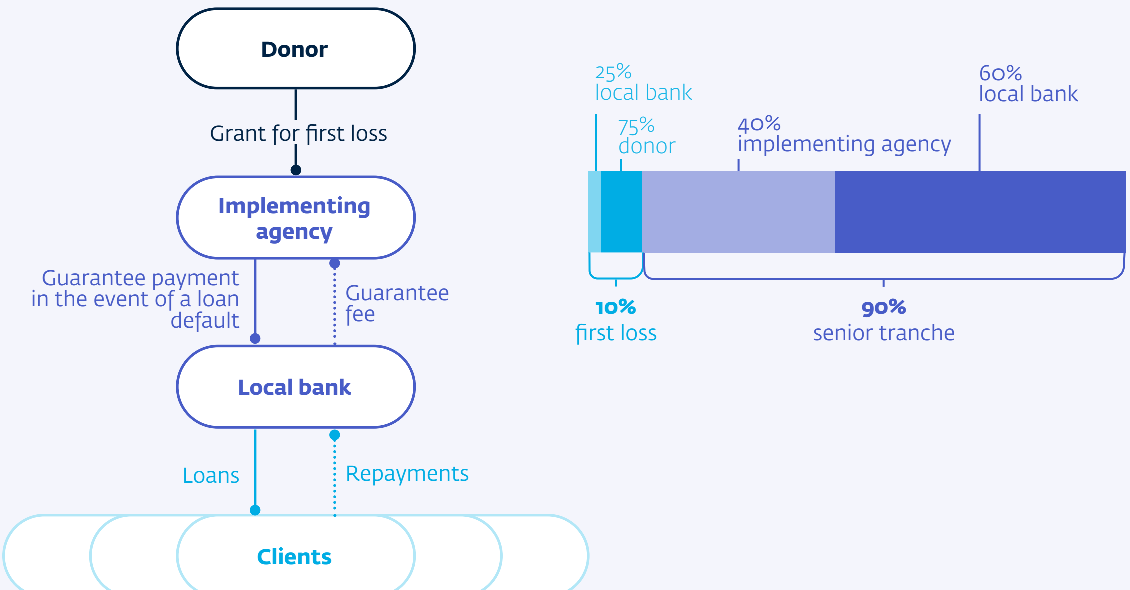
Risk Sharing Facility

Risk sharing is a mechanism where an institution, usually a development finance institution or a bilateral entity, agrees to share the risk on a portfolio of projects meeting agreed criteria with a local bank or leasing company. Funds extended to such a mechanism may or may not be grant-based. A major advantage of risk sharing facilities is that for modest applications of donor funding there could be major leverage of funds by multilateral development banks, local lenders, and project sponsors.

Figure 4.8 shows an illustration of a risk sharing facility. This model is of interest insofar as a relatively modest investment from a donor can achieve high investment leverage backed by an international development institution and local banks. Risk sharing facilities address markets with excess liquidity where banks have more money to lend than there are clients to borrow, and where there is a lack of understanding of the risk profile in new markets. Risk sharing facilities have been very successful in catalyzing new investment in energy efficiency. For example, one of IFC's earliest energy efficiency finance projects was a risk sharing facility for commercial banks in China. IFC provided technical assistance to help bank staff better understand the economics

FIGURE 4.8

Illustrative Structure for Risk Sharing Facility



Source: Authors

and risks associated with energy efficiency loans and a partial risk guarantee for any losses greater than the bank's established performance. The energy efficiency loans were offered to existing customers whereby the banks were already familiar with clients' operations and risk profiles.[192] Properly evaluated, energy efficiency loans should pay for themselves through energy savings.

The core of a risk sharing facility is an agreement that any loan defaults will be repaid by the facility manager according to an agreed formula. Using the outline, in the case of a $50 million guarantee facility agreed with a local bank, the first loss tranche is 10 percent and losses would be shared between the local bank and the multilateral institution on a ratio of 25 percent to 75 percent. Any losses above 10 percent would be split between the local bank and the implementing agency. So, if the portfolio is $50 million, the first loss value would be $5 million, of which the international financial institution's share is $3.75 million. So potentially, a multilateral development bank's commitment of up to $3.75 million would leverage $50 million of loans.

192 https://documents1.worldbank.org/curated/en/823071500891138274/pdf/116595-WP-Terminal-Evaluation-of-CHUEE-PUBLIC.pdf.

The amount of first losses would need to be determined on a country basis and be dependent on the typical loan default ratios. It is important that a bank is encouraged to enter the market on the basis that some of its defaults would be covered. However, that risk coverage should be set at a level low enough to avoid incentivizing the booking of bad loans. IFC and the World Bank have used this type of instrument to encourage commercial banks to offer energy efficiency loans to existing clients as typically such facilities lack traditional security and require lending officers to become familiar with new types of investments.[193]

Conventional Equity

Although concessional finance mechanisms have a significant role to play in accelerating the uptake of new technology, there are still many projects that can be financed through conventional financing instruments.

Post-harvest food loss has been discussed elsewhere in this report and is the focus of some commercial finance for transport control logistics. Box 4.10 gives some examples of IFC's equity investments for projects.

BOX 4.10

IFC Equity Investments for Cooling Projects

In 2007, IFC began talks with Snowman Logistics Limited, a Bangalore-based transport service provider. The company was seeking funding for ambitious expansion plans and IFC made an equity investment of $5.4 million. This made it Snowman's first private financial investor, highlighting confidence in a small company operating in a nascent but rapidly growing market and bringing significant development benefits. IFC subsequently invested a further $8.5 million helping Snowman increase its capacity from 900 pallets and 100 trucks to over 107,000 pallets and over 300 trucks. Thanks to the improved handling efficiency and temperature-controlled facilities, food wastage is dramatically reduced.

Another example is the facility that IFC and the company Tabreed created by together investing $100 million ($25 million from IFC and $75 million from Tabreed) in an equity facility to support up to $400 million of investment in district cooling projects.

193 In 2015, the World Bank and the Government of India signed an agreement for the Partial Risk Sharing Facility for Energy Efficiency (PRSF) project, aimed at mobilizing commercial finance for energy efficiency initiatives by providing partial credit guarantees to cover default risks, thereby facilitating easier access to finance for such projects. See: https://www.worldbank.org/en/news/press-release/2015/03/31/partial-risk-sharing-facility-energy-efficiency-singing.

Other Instruments

Cooling Bonds

The World Bank Group has for some time used its triple-A credit rating to raise funds from the international bond market for sustainability objectives. This has included green bonds, blue bonds (financing for marine environment), and bonds for the protection of forests and biodiversity. Eligibility criteria for green bonds include some sustainable cooling measures, such as projects that reduce net energy consumption in buildings, reduce food losses or waste, and improve energy efficiency in data centers. The World Bank is exploring the possibility of more narrowly defined cooling bonds to attract more private capital to cooling projects. The concept is based on World Bank experience with CO2L bonds designed to cut risk on investments in financing carbon credits by linking returns to project success in reducing emissions.

Carbon offsets

Incentives for energy efficiency improvements that would not be expected from existing practices may qualify for payments through carbon credits. In the past, substantial credits were generated from financing the reduction of greenhouse gas emissions from the production of refrigerants.[194] Recently, multiple cooling projects have been registered as carbon credit projects under VERRA, Gold Standard, the Clean Development Mechanism, and the Joint Crediting Mechanism. These projects include initiatives such as installing high-efficiency air conditioning systems and chillers in a semiconductor factory in Thailand,[195] introducing high-efficiency air-conditioning in a hotel in Viet Nam,[196] and upgrading the cooling system in an industrial complex in Singapore to enhance overall energy efficiency.[197] These initiatives registered significant reductions in greenhouse gas emissions through the adoption of more efficient cooling technologies and highlight the potential for generating carbon credits through improvements in energy efficiency within cooling systems. In addition, carbon markets could play a significant role in promoting a switch to lower Global Warming Potential refrigerants or to natural refrigerants, where the additionality criteria is met. Programs targeting emissions reduction from a large number of cooling units, including fans and air conditioners, could be well suited for carbon credits, including to promote business models such as cooling-as-a-service and performance contracting.

194 A. Michaelowa et al (2021).

195 https://www.jcm.go.jp/projects/44.

196 https://www.jcm.go.jp/projects/23.

197 https://registry.verra.org/app/projectDetail/VCS/1084.

BOX 4.11

The Multilateral Fund for the Implementation of the Montreal Protocol

The Kigali Amendment to the Montreal Protocol, adopted in 2016, aims to phase down the production and use of HFCs, powerful greenhouse gases commonly used as refrigerants.[1] The Multilateral Fund for the Implementation of the Montreal Protocol (MLF) has historically focused on phasing down ozone-depleting substances, including polluting refrigerants used in cooling. The MLF has supported projects through financial and technical assistance in the form of grants or concessional loans, primarily delivered through four implementing agencies: UNEP, the United Nations Development Programme (UNDP), the United Nations Industrial Development Organization (UNIDO), and the World Bank.

While the HFC phasedown is crucial for mitigating climate change, there is some risk that less energy-efficient alternatives could be introduced resulting in increased greenhouse gas emissions from increased power consumption. If, on the other hand, the transition in refrigerants is accompanied by measures to enhance the energy efficiency of cooling equipment, the mitigation benefits could be doubled.[2] This was the focus of a decision by the parties to the Montreal Protocol fund in 2022, when the MLF initiated discussions on energy efficiency, to recognize the need to integrate it into the existing framework. A pilot program was launched to better understand the institutional arrangements, technical feasibility, and financial issues associated with this integration into existing operations.[3]

In December 2023, the MLF Executive Committee expanded its focus to include energy efficiency and has committed $100 million to supporting the development of more energy efficient appliances.[4] The Executive Committee is developing an operational framework to guide this new direction and is engaging with various institutions to design effective strategies. This includes exploring a revolving fund approach to facilitate investment in both HFC phasedown and energy efficiency. The MLF expansion to focus on energy efficient appliances is encouraging, especially as it includes consideration of alternative financing structures to support private sector adoption.

1 See Della Cava (2022) and Khosla et al. (2022).

2 Shah et al. (2015).

3 The parties agreed to the creation of a $20 million pilot program. The MLF is also exploring opportunities for greater coordination with the GCF and GEF, both sources of finance for energy efficiency projects. See MLF (2023), which cites total grant funding of $4 billion for 9,321 approved projects with assistance to 144 developing countries.

4 http://www.multilateralfund.org/93/default.aspx.

4.7 Development Finance Institutions as Key Mobilizers

Cooling has only recently been considered a standalone asset class worthy of attracting dedicated finance. Traditionally, it was viewed as a component of other financing efforts that were often focused on cities such as the GCF Green Cities Facility and the GEF Sustainable Cities Impact Program. Concerted action started in 2017 with the launch of the Kigali Cooling Efficiency Program (K-CEP) with initial financing of $51 million. In August 2021 K-CEP became the Clean Cooling Collaborative embracing partnerships and strategic collaborations. The assessment of market opportunities for sustainable cooling solutions in Chapter 2 is an effort to give further momentum to this development as the larger the market, the more opportunities for IFC and other development institutions to mobilizize private financing.

Development finance institutions have several characteristics that make them central players in the evolution of finance for sustainable cooling in emerging markets. First and foremost is their mandate to devote increasing resources to climate mitigation and adaptation. Second is their expertise in understanding relationships between different types of investments and sustainable development goals. Third is their access to concessional resources from climate funds, creating a buffer for greater risk taking and resources for blended finance instruments. Fourth is an emphasis on using their resources to mobilize greater volumes of private investment.

Lastly, and very importantly, development finance institutions can lead by example. They have the capacity to invest in new technologies and innovative business models, and they possess a significant convening power to engage both private and public actors. This allows them to act as anchor investors, playing a crucial role in demonstration effect. By investing in these projects, development finance institutions can show the viability of new cooling technologies and business models, encouraging local private and public financing organization to participate in subsequent investment rounds. IFC has played this crucial role in several countries across the climate finance space, making initial investments that prompted local institutions to eventually take the lead.

Funding of cooling infrastructure requires a mix of public and private finance. Growing awareness that access to sustainable cooling contributes to climate change mitigation and adaptation, particularly in rural settings, also opens broader opportunities to access climate finance. One of the first examples of major climate financing that supports access to cooling was a commitment from the Green Climate Fund to provide $157 million to a new Cooling Facility managed by the ESMAP Sustainable Cooling Program, with an additional $722 million in leveraged co-financing from World Bank projects.

The fact that sustainable cooling solutions address both climate mitigation—reducing emissions—and adaptation—reducing the impacts of climate change—is also relevant for accessing the multiple sources of climate funds. The Green Climate Fund, for example, aims to deliver a 50:50 balance between adaptation and mitigation in its portfolio and ensure that at least 50 per cent of adaptation funding goes to categories of particularly vulnerable countries, including Least Developed Countries, Small Island Developing States, and certain African states. A grant of up to $3 million is in place for the formulation of National Adaptation Plans and other planning processes.[198] The World Bank Group has similarly made a commitment to put adaptation and resilience on an equal footing with mitigation.[199]

Recognition of cooling as an adaptation solution also opens opportunities for access to additional sources of concessional funds, such as the Global Environment Facility's (CIF) Least Developed Countries Fund and Special Climate Change Fund, as well as the Climate Investment Fund's $1.2 billion Pilot Program for Climate Resilience. Synergies between the funds can also produce greater leverage, and the Cooling Facility aims to identify such opportunities with the CIF to improve its impact. For example, where the CIF could address barriers to standalone solar technologies in rural settings, the Cooling Facility would focus on cooling solutions for productive uses. The Montreal Protocol Multilateral Fund is also exploring ways to coordinate funding for refrigerant replacement with other sources of funding for improving energy efficiency. (See Box 4.11)

Climate finance to support mitigation and adaptation in rural settings can also seek to leverage the nexus between electricity access and cooling. The CIF Scaling Up Renewable Energy Program in Low Income Countries is one example of climate finance being utilized to boost renewable energy for the purpose of expanding electricity access and facilitating access to fans and refrigerators.

The types of instruments engaged in meeting cooling needs will change over time as technologies and business models evolve and achieve widespread adoption. Overall, significant financing gaps remain, notably in the agricultural and health sectors and in finance for passive strategies and building design. There is also a risk that finance continues to favor higher income, urban markets whereas cooling challenges in rural areas are more diverse and the ability to pay is typically lower.

To summarize, there are many instruments for financing sustainable cooling in emerging markets, but significant challenges remain, particularly around provision of solutions for poor populations and the large number of households still without access to reliable power. These challenges are the focus of increasing efforts, many still at an early stage, to find business models that meet the needs of both vendors and low-income consumers. Two additional challenges in need of much greater attention are the multiple, complex issues associated with the creation of effective cold chains for small scale rural farmers and support for innovative, early-stage cooling technologies. The diversity of cooling needs, populations, and regulatory environments means there is no one-size-fits-all solution.

198 Green Climate Fund (2022).

199 https://thedocs.worldbank.org/en/doc/189851543772751358-0020022018/original/AdaptationandResilienceActionPlanKeyMessages.pdf.

As was noted at the outset of this chapter, the absence of private sources of finance is rarely primarily about an insufficient availability of capital. It is almost always a reflection of investor perceptions that the balance between risk and return is unappealing. This chapter also highlighted the diverse range of financial instruments available to address this challenge with public sector assumption of some risks. As discussions of climate finance increasingly focus on the need to leverage greater private investment from limited public resources, these instruments are likely to become increasingly important.

As private sector lending institutions with an emerging market focus, IFC and other development finance organizations are in a unique position to help create greater awareness of the importance of cooling for development and the potential for creative financial solutions. This is a goal that will require collaboration with UNEP, other multilateral bodies such as the World Bank, government entities, and civil society organizations.

Photo by Dominic Chavez/International Finance Corporation

5

Conclusions and Recommendations

Achieving successful transitions to sustainable cooling across developing economies is fundamental to addressing climate change, boosting health, safeguarding food security, and fulfilling many of the UN's Sustainable Development Goals. This report highlights the mechanisms available for financing such a transition, as well as the challenges and opportunities they present.

Building on the Global Cooling Watch report and Global Cooling Pledge—both released at COP28 in Dubai in December 2023—it brings important new analysis based on estimates of market size and projections that leverage existing data about cooling applications. It incorporates both passive design strategies and the adoption of more efficient equipment across sectors in developing countries and shows business opportunities in these areas are much larger than the estimates presented in previous studies.

In addition, the report describes barriers and opportunities to financing sustainable cooling based on lessons learned from the past as well as ongoing initiatives. Finally, the study provides an overview of existing business models and financing mechanisms that can be adapted to finance sustainable cooling, harnessing the knowledge and expertise of IFC, UNEP and other Cool Coalition members.

5.1 Conclusions

The following are the main conclusions of the analysis, assessing barriers and opportunities for financing sustainable cooling in developing economies, the available business models and potential funding structures.

Sustainable cooling is critical to address the urgent adaptation needs and development pathways of developing countries. These economies are particularly vulnerable to global warming because they host most of the people exposed to the highest temperatures and the negative impact on health, food security, and productivity that extreme heat episodes entail. They also face greater challenges in areas such as regulation, enforcement of rules, and infrastructure that are central to creating business environments that attract private investment. In addition to curbing the negative effects of heat, the adoption of sustainable cooling would provide opportunities for innovation, generation of new value chains, and job creation in the economy.

Supporting the transition to sustainable cooling in developing countries is a fundamental element of the global climate agenda, which could cut cooling-related emissions by almost half. With global temperatures set to rise over the coming decades, all countries, and especially developing economies, face a choice about the strategies they will implement to address increasingly urgent cooling needs. Helping developing countries move toward a comprehensive approach to sustainable cooling that avoids a vicious cycle of meeting cooling demands with solutions that emit more greenhouse gases, is vital for the global climate agenda. Many developing economies are among the most vulnerable to higher temperatures. Yet they also have low penetration of passive cooling strategies and household space cooling appliances, and lack effective cold chains for rural farmers or for the distribution of food and vaccines. Emerging economies currently generate two thirds of global cooling-related emissions, a share that could grow to as much as 80 percent without a significant change of course. The estimates in this report show that increasing the use of passive strategies and accelerating the adoption of high-efficiency equipment could reduce cooling-related emissions from 2,170 MtCO2e to 1,185 MtCO2e in 2050.

The adequate supply of finance, and particularly private finance, is essential to support the transition to sustainable cooling across developing economies. Cooling needs are diverse and span most sectors of the economy, including buildings, agriculture, health, and industry. Therefore, cooling provider firms as well as commercial and household users have a wide range of financing needs. For those with adequate resources, private commercial financing may be available, but the relatively high upfront cost of more efficient equipment is often a disincentive. Households and firms with severe affordability constraints or with low access to finance will require additional support in the form of grants and fiscal incentives such as tax breaks and subsidies. Financing structures and instruments can be designed to incentivize the transition to sustainable cooling solutions on both the supply and demand side.

There is a scarcity of systematic data on cooling markets and financing across countries and market segments, especially for developing economies, as well as on passive strategies and rural cold chains. Access to comprehensive underlying evidence is key to policy design, tracking progress, constructing finance strategies, and identifying market potential. There have been a number of initiatives by different organizations in recent years to measure cooling market activity, which varied in scope in terms of segments and geographies. However, these remain fragmented, highlighting the need for a comprehensive and systematic gathering of data.

Sustainable cooling represents a major business opportunity in developing economies. This report estimates that the value of the cooling market in developing countries will more than double to at least $600 billion per year by 2050 from around $300 billion currently. This estimate, based primarily on active cooling solutions, incorporates standard expectations of economic and population growth as well as responses to climate change. Space cooling accounts for about half of the total market, while non-residential refrigeration (such as cold storage for farm products and transport) accounts for 25 percent. While China is currently the largest market, accounting for 46 percent of the total, it is expected to grow less than other developing regions including Africa and South Asia where the markets are projected to at least double in size by 2050. High-level estimates imply that passive cooling for new builds and retrofits could be currently between $15 billion to $25 billion and $10 billion to $15 billion, respectively. These markets could see substantial growth in the coming decades if the application of building energy codes is expanded across developing economies.

There is a clear business and economic case for accelerating the adoption of sustainable cooling in developing economies, with passive cooling strategies and more energy efficient cooling equipment together reducing electricity demand and lowering the need for additional power generation. Projected scenarios that consider increased adoption of passive cooling strategies and an acceleration in the use and adequate operation of high efficiency cooling equipment show that consumers would avoid $5.6 trillion in electricity consumption costs by 2050. They would also save $800 billion in new equipment needs and $1.8 trillion in additional power infrastructure investments that would be required to satisfy peak demand. Countries would also benefit substantially from improved outcomes in health, education, the wellbeing of women, and productivity by mitigating the impact of extreme heat events.

A focus of this report is on the creation of conditions for attracting private investment toward the creation of sustainable commercial markets. However, closing existing cooling gaps for households and SMEs across developing economies facing constraints on affordability and access to finance would also require substantial public support to achieve investment of up to $800 billion. Technological and business model innovations could provide additional opportunities for private investments to deepen cooling markets, and in many cases will also require additional support from concessional financing mechanisms.

Despite the business case, there are many challenges to mobilizing sufficient private sector investment in sustainable cooling products and services in emerging markets. Effective solutions will require comprehensive government strategies. While there are several dimensions in addition to financing to bring developing economies to a sustainable cooling pathway, a number of these have significant influence on the availability of financing and the capacity to mobilize private financing for sustainable cooling. These include systemic issues like affordability, electricity access, technical skills, availability of finance, and cooling supply chain development. In addition, despite its importance at the aggregate level, cooling is usually a broader project component across sectors which does not necessarily receive the attention it deserves. There are also barriers in many developing countries to the emergence of innovative solutions, including low awareness, regulatory or legislative complexity, and the absence of adequate supply chains. Solutions for low-income consumers are challenging given the outsized weight of initial costs, low awareness of affordable solutions such as passive measures, and ignorance of the long-term benefits of sustainable cooling. Effective cold chains for rural farmers imply a complex systemic end-to-end approach at scale that needs to combine private and public sector efforts. Weak regulatory and administrative environments with poor enforcement capacity, long off-take agreements, and unsuitable building codes, among other issues, also present challenges to financing sustainable cooling in these countries.

Regulation and policy play a critical role in creating an enabling environment for private investment. There are increasing efforts to develop strategies to address the challenges in developing economies that are hindering the provision of financing for sustainable cooling.

Robust regulation around building codes, energy efficiency labeling and certification as well as regulatory approaches that include minimum energy performance standards across a growing number of countries all contribute to creating market conditions that attract private investors. Other government initiatives to promote more sustainable cooling include bulk procurement to lower prices and utility rate structures that reward efficiency. However, many developing countries lack the capacity to effectively implement such measures, a challenge addressed through donor-funded initiatives from bodies such as BASE, CLASP, and other international organizations and NGOs.

There are also many innovative strategies, most still early stage, for promoting sustainable cooling solutions. One example are holistic systemic approaches to cold chains such the ACES program in Africa. Others include innovation promotion through various prizes and grants, urban programs using passive strategies and nature-based solutions, and new business models addressing first-cost barriers. On the other hand, many technologies and business models successfully tested through some of these programs remain fragmented and cannot scale up due to lack of appropriate financing. In recent years, a growing number of cities, including many in developing countries, have created heat action plans and positions for heat officers, often with the support of donors and NGOs.

There is a diverse range of financing mechanisms and instruments available to address existing challenges. However, there is no one-size-fits-all approach. The design of financing mechanisms for sustainable cooling must reflect the needs of provider firms and consumers—both households and firms—, the business models that define the terms of the transaction between providers and consumers, and the operational context.

One significant focus has been the adoption of business models addressing challenges related to affordability constraints and the higher upfront costs of more efficient equipment. These include, for instance, pay-as-you-go programs that smooth out payments for consumers and cooling-as-a-service that addresses consumers' needs without requiring them to acquire equipment. On-bill financing, leasing and energy service company models are also bringing energy and monetary savings to clients—mostly SMEs—while bulk procurement strategies for equipment help lower costs per unit.

Adequate financing mechanisms and instruments also differ according to the stage of business maturity. Research and development activities are highly dependent on fiscal and financial incentives as well as other forms of government or donor support. Innovations can be supported by grants, and venture capital financing from a mix of public and private sources while early-stage commercialization requires working capital and longer-term CAPEX financing. Instruments that mitigate risk are important for scaling up the adoption of new technology, including sustainability-linked guarantees and public private partnerships to mobilize private financing. These can be combined with energy labeling, standards and other regulations.

Financing sustainable cooling requires an understanding of existing financial infrastructure and capacity. Market studies are necessary to identify where public and private funds are currently being allocated to address unmet needs for cooling and to enable a transition from conventional to sustainable cooling. Depending on the characteristics of cooling providers and consumers, the appropriate financial instrument may be revolving funds, working capital loans, results-based finance, risk-sharing facilities, conventional equity, or cooling bonds.

There are many instruments for financing sustainable cooling in emerging markets, but significant challenges remain which will require a combination of private investment and financing with public and concessional investment in addition to comprehensive government strategies. These include providing sustainable cooling solutions for poor populations across developing countries, many of which are still without access to reliable power. These challenges are the focus of increasing efforts, many still at an early stage, to find business models that meet the needs of both vendors and low-income consumers. Two additional challenges in need of much greater attention are the creation of effective cold chains for small scale rural farmers, and supporting early-stage cooling technologies, including the provision of follow-on financing to fund expansion. Meeting these challenges will enable positive market disruption that nurtures broader adoption of sustainable cooling.

Development finance institutions have a key role to play in mobilizing private investments at scale for sustainable cooling. Given their mandate for mobilizing private capital to support interventions that generate development impact, measures that include sustainable cooling merit significant attention. As these organizations have also made commitments to increase funding for climate adaptation, sustainable cooling solutions are also a good fit as they typically provide both climate mitigation and adaptation. Development finance institutions benefit from wide private sector networks with both cooling providers and user firms, as well as finance providers from venture capital and private equity funds to commercial banks. This means they are better able to participate in the design and roll out of financing mechanisms to support innovation, fund expansion, and encourage adoption of sustainable cooling. They also have access to donor support and experience in implementing concessional finance mechanisms that maximize capital mobilization through appropriately designed incentives. Furthermore, they are in a unique position to help create greater awareness of the importance of sustainable cooling for development and the potential for creative financial solutions.

5.2 Recommendations

This report provides further support to the recommendations outlined in the Global Cooling Watch report which are summarized in Table 5.1.

It also provides additional recommendations for scaling up finance as part of a broader strategy to support the adoption of sustainable cooling in developing countries. These prescriptions, which amount to a call to action to different stakeholders, should be shaped according to the different conditions in the countries where they are applied.

TABLE 5.1

Global Cooling Watch Recommendations to Scale Up Financing for Sustainable Cooling

Market Data	Systematically track cooling finance and its impacts as the market grows
Regulation & Safeguards	Strengthen the role of Minimum Energy Performance Standards, efficiency, and sustainability standards in cooling financing decisions
	Incorporate sustainable cooling into the environmental, social, and governance safeguards for multilateral development banks
Financing	Expand public funding, mobilize private capital, and develop needs-based funding models to support implementation of energy efficiency improvements alongside the refrigerant transition.
	Direct wholesale finance for sustainable cooling in large real estate projects and in district cooling
	Provide retail finance for cooling for households and small and medium enterprises
	Support innovative business models and financing to make sustainable cold chains affordable, distribute risks and costs fairly, and overcome investor concerns. This includes financing the cold chain through public-private partnerships and protecting smallholder farmers in developing countries with seed financing
	Validate consumer-financing interventions through pilots

Source: UNEP

Multilateral organizations, development finance institutions and Cool Coalition members should work with local business and financial sector associations as well as national and subnational governments to:

> Improve underlying data and evidence on cooling by building consensus around definitions, metrics and methodological assumptions, including differentiating sustainable cooling applications and gathering information on capital costs and financing. Measuring cooling activity is fundamental to moving the cooling and financial markets to accelerate the transition to sustainable cooling. Initiatives in this regard lack consistency in terms of basic definitions, metrics, assumptions, and methodologies. Thus, knowledge and expertise should be leveraged to continue building a systematic and consistent body of evidence and data on cooling markets. Incorporating this into the objectives of the newly created Cool Coalition working group on data will be an important first step. Special attention should be given to underlying data for assessing market size and gaps in passive cooling strategies and rural cold chain infrastructure.

> Develop and implement a comprehensive strategy led by the public sector that addresses the dimensions identified in this report as challenges to fostering private finance mobilization for sustainable cooling. This should start with improving understanding of the development and economic impacts of sustainable cooling throughout public sector agencies. This would aid the design of appropriate policies and regulations across sectors and should be followed by effective implementation through improved public sector capacity, funding and infrastructure. To foster public sector action and necessary reforms, agencies must understand the interrelated development and economic impacts of sustainable cooling. This includes improvements to health and education, empowering women, reducing food loss, averting productivity losses, and creating new jobs and value chains. Adoption of more sustainable cooling will also reduce the need to divert investment toward power infrastructure. In addition to strengthening standards, the design of cross-cutting and sector-specific policies embedded in broader strategies is important for facilitating the transition to sustainable cooling. These can include adoption and effective enforcement of building energy codes to untap the large market potential for passive strategies, as well as utility policies that reward consumers for purchasing efficient equipment. Coordinated inter-institutional action and effective enforcement of regulations are critical for the adoption of sustainable cooling approaches. The work that the Montreal Protocol community, along with UNEP, Cool Coalition members, multilateral development banks and other institutions are doing with governments across different countries should be expanded and funded appropriately, especially to support Global Cooling Pledge signatory

countries. The inclusion of targets related to adoption and enforcement of regulation in the conditions of technical assistance programs and development financing can nurture better market environments for investments. Furthermore, there are important synergies and potential for multi-country regional approaches in this regard.

- In low-income or less developed markets, there should be an increased focus on underlying infrastructure, minimum regulation required, and basic enforcement capacity; as well as on the critical role of the public sector to jumpstart markets and to foster the expansion of basic credit.
- In middle-income or more developed markets, efforts should emphasize improving existing infrastructure and adapting regulation to encourage innovation and increase standards, boosting enforcement, and incentivizing market growth with appropriate policies. This should include regulation that fosters innovation around financial instruments.

Amplify dissemination efforts targeting key cooling market stakeholders to increase awareness of business opportunities and financing alternatives across developing countries. These should include innovators, cooling provider firms, consumer firms and households, financiers, governments, and regulators. Given the nature of cooling applications as components of broader projects and investments, there is a lack of awareness of the importance and benefits of transitioning to sustainable cooling and embedding cooling as a design dimension of products and projects. Developing country-specific granular market assessments and micro case studies of such benefits across different sectors would be instrumental in delivering clear messages to these stakeholders. Targeted campaigns would be more effective when done in partnerships with business associations and the financial sector, as well as with national and local governments. Increasing inter-institutional coordination on targeted dissemination by international organizations, including those in the Cool Coalition, would increase the impact of individual initiatives in this regard. One focus for such efforts may be the development of national cooling action plans to support the implementation of a broader strategy following a multi-stakeholder consultative process.

- In low-income or less developed markets, dissemination should prioritize policymakers, financiers, and cooling consumer industries.
- In middle-income economies or countries with more developed markets, dissemination efforts should cover all cooling providers of goods and services including intermediaries, consumer industries, policymakers, investors and financiers.

Cool Coalition members, development finance institutions, and multilateral organizations should provide technical assistance to governments, regulators, donors, investors, and financiers on:

Prioritizing finance for the adoption of passive cooling strategies. The Global Cooling Watch report makes a compelling case for the importance of promoting passive cooling to reduce cooling loads and limit the need for electricity-powered cooling equipment. This is complemented by high-level estimates in this report implying substantial potential growth of passive cooling markets in the coming decades. Given the possibility that projected growth in cooling markets could prompt higher energy demand as well as the sizable savings inherent in adopting passive cooling, there is ample justification to embed incentives to back passive cooling in the design of financing instruments. Combined with conducive regulation, these could center on certifications like IFC's EDGE and use results-based and sustainability-linked financing mechanisms.

Using blended and concessional finance in the design of business models and financing mechanisms to address persistent gaps related to scaling-up tested technologies and help users facing affordability constraints. This includes financing that reduces risk around firms developing innovative cooling technologies and extending funding to companies that provide or adopt tested sustainable cooling technologies ready to be scaled-up. This is in addition to bringing capital resources, including through demand aggregation, to poorer consumers such as lower-income households and smallholder farmers. The design of such financing mechanisms should be informed by a comprehensive understanding of the perceived risks and the limits of commercial approaches to deepening markets. This will help to leverage as much as possible public, philanthropic or donor funds in blended and concessional financing approaches.

- In low-income countries or less developed markets, this could be led by donor-funded grant programs.
- In middle-income or more developed markets, alternative blended or concessional financing structures should be considered, in addition to donor-funded programs.

Leveraging existing business models and financing instruments, adapting them to support the transition to sustainable cooling. Financing mechanisms already used for cooling applications should be redesigned as necessary to foster the transition to sustainable cooling and incorporate lessons learned from previous utilization. Existing business models and financing instruments applied in other industries to promote specific priorities (e.g., inclusion, gender, green and blue bonds) or adoption of innovative technologies should be considered and adapted to sustainable cooling. For instance, certain trade and supply chain financing instruments—especially climate-linked products and sustainability-linked pricing—can be adapted to meet the needs of sustainable cooling.

- In low-income countries or less developed markets, standard financing instruments should be prioritized such as trade finance or working capital loans, with longer tenors for CAPEX loans.
- In more developed markets, innovative financing instruments should be fostered to complement traditional financing structures.

Promoting the development and financing of large cooling infrastructure services. For certain large-scale and systemic applications, cooling business models could be designed and integrated as infrastructure services, like those for providing access to other essential services such as electricity, water, or waste collection. These include integrated district cooling systems for cities and large urban areas as well as cold chain end-to-end infrastructure linking farmers to retail food markets. These applications should leverage the capacities and roles of the public, private, and financial sectors, leveraging knowledge and experience from financing basic infrastructure in developing economies. The public sector's capacity to support the delivery and unlocking of private investment needed for the scale of expansion of such infrastructure needs to be financed too.

Development finance institutions should work with local entrepreneurs as well as mobilize local and international investors to:

Increase seed and risk capital funding to pilot technologies and business models and communicate results to relevant audiences. Given the sizable business opportunity that cooling represents in the coming decades, it is critical to continue supporting new technologies and business models that can underpin the growth of sustainable cooling. Promoting continued financial support in the form of grants, prizes and even equity or quasi-equity instruments will be crucial to building an entrepreneurial ecosystem that supports the transition to sustainable cooling. International organizations and other development finance bodies are well positioned to mobilize investors and financiers to support these business initiatives.

- In low-income countries or less developed markets, funding should be directed toward adapting existing solutions to local needs and emphasize technology diffusion.
- In middle-income countries, a greater portion of funding could be dedicated to domestic research and development while continuing to emphasize adaptation and diffusion.

Multilateral organizations, development finance institutions and Cool Coalition members should:

> Create a Sustainable Cooling Finance Partnership to foster international cooperation and promote the development of sustainable cooling financing solutions. This partnership could promote financing programs and the use of financial instruments appropriate for supporting different sustainable cooling solutions in specific countries. It could grow and lead a network of international as well as local investors and financiers to share knowledge and support pilot programs, encouraging further cooperation. This partnership could be comparable to the World Bank Group's Energy Storage Partnership.

Annexes

Photo by Africanstar via Shutterstock

Annex 1:
Technical Description of the Global Cooling Emissions and Investment Model

Stock Estimates

The Global Cooling Emissions and Investment Model is a bottom-up model to estimate the stock of air conditioning and refrigeration equipment across countries. The model projects cooling equipment stock for 40 different technologies based on climate, economic growth, and population growth. For each year, the model requires data for each technology type to quantify (i) the total number of equipment in stock, (ii) the number of new equipment units, and (iii) the number of units reaching end-of-life status. Cooling capacity and stock estimates are based on available primary data points from various sources, combined with a series of assumptions and secondary data. The primary data includes, for example, reported gas consumption from Montreal Protocol reports, import and export data for RACHP equipment, market reports, national cooling plans, national or regional MEPS studies (incl. EU EcoDesign) and national surveys and statistics (such as the American Housing Survey for the United States and China Statistical Yearbooks). The secondary set is comprised of country data from different sources, population statistics and forecasts from the UN World Population Prospects, GDP history and forecasts from the World Bank, climate data, access to electricity, electricity consumption, as well as number of households, vehicles, supermarkets, residential and commercial floor area, among others. Functions based on key drivers are calibrated against available primary data for selected countries and extrapolated for others based on similar levels of economic development and technology availability. Additional calibration is done for reported data on refrigerant gas consumption and emissions, and energy consumption and associated CO_2 emissions, to further improve the model's estimates.

While the model's methodology may vary across different technologies, it generally follows this structured approach:

1. **Macro-economic and climate data**: The algorithm leverages historical and forecasted data on population, GDP, and Cooling Degree Days (CDD).
2. **Demand drivers**: Various additional factors influencing demand, such as number of dwellings, building floor area, and number of vehicles, are incorporated from external sources. In cases where specific data is unavailable, estimates are derived based on population and GDP per capita.
3. **Market penetration rate**: Penetration rates, such as proportion of households equipped with refrigerators or air-conditioning available for certain countries and years; and estimated for the others.

4. **Cooling demand intensity**: Metrics such as air-conditioning cooling load (kW) per m2 or per household are based on industry guides and extrapolated based on wealth and climate.
5. **Technology splits**: Distribution of technology types is estimated based on GDP and technology availability.

Macroeconomic and climate historical data and projections are based on the following sources:

TABLE A.1

Primary Variables for the Stock Model

VARIABLE	SOURCE
Population	• UN World Population Prospects. • The model uses the UN "Medium" population growth forecast to 2050.
GDP	• "GDP per capita, purchasing power parity (constant 2017 international $)" from the World Development Indicators. • Future estimates of GDP per capita growth are based on the UNFCC's "Shared Socioeconomic Pathways (SSPs)", using the "Middle of the Road, SSP2" pathway.
CDD	• The model uses humidity adjusted Cooling Degree Days at the national level, with a base temperature of 18 degrees C, based on data published by the IEA

TABLE A.2

Intermediate Variables for the Stock Model

VARIABLE	SOURCE
Number of households	• "Database on Household Size and Composition 2019", UN, Department of Economic and Social Affairs, Population Division (2019)
Grocery retail floor area per capita	• "Retail in London: Working Paper C – Grocery Retailing", GLA Economics, 2005. • "Have grocery stores reached the saturation point?", Grocery Dive, 2017
Residential floor area per capita	• "How Big is a House? Average House Size by Country." Shrink That Footprint, www.shrinkthatfootprint.com/how-big-is-a-house/
Rate of household ownership of air conditioners	• "Future of Cooling", IEA 2018; • Household surveys from the World Bank Microdata Library and authors' calculations.
Cooling load per floor area (residential sector)	• ASHRAE Handbook; • Industry "rule of thumb" guides
Proportion of population employed in commercial sector	• International Labor Organization
Commercial floor area per employee	• "Modelling China's Building Floor-Area Growth and the Implications for Building Materials and Energy Demand", LBNL (aceee.org)
Cooling load per floor area (commercial sector)	• ASHRAE Handbook
Number of vehicles per capita	• International Organization of Motor Vehicle Manufacturers (OICA)
Access to electricity	• World Development Indicators
Proportion of new vehicles with air conditioning	• "The evolution of automotive air conditioning", ASHRAE Journal (reprinted in HVAC&R Nation), 2008; • Anfavea (Brazilian Association of Automotive Vehicle Manufacturers), February 2020, https://anfavea.com.br/docs/apresentacoes/apresentacao_fevereiro_2020.pdf

In addition, the algorithm uses a series of intermediate variables (i.e., demand drivers). These may be available from reliable data sources or are estimated based on relationships with macroeconomic and climate data. Table A.2 displays the set of intermediate variables used along with the data sources.

These variables are combined with additional factors such as access to electricity, technology availability and cultural factors to estimate stock level for each of the technologies modeled. These factors are important to differentiate demand for specific markets or technologies between otherwise similar countries.

From macroeconomic and climate data, intermediate variables and additional factors, the model estimates stock level for each technology type following the algorithm discussed previously. The model predictions are calibrated against real-world data up to the year 2022, and use the resulting parametrization to forecast the equipment stock levels in the future.

The estimated stock data is used to estimate refrigerant gas consumption, emissions, and energy usage, which are validated against external references. This "feedback loop" is used to further improve the model's calibration.

Overview of the Baseline Scenario's Underlying Assumptions

Population growth is projected according to the UN World Population Prospects Medium scenario, which considers the median trajectory across several projections of fertility and mortality. GDP growth is projected according to the Shared Socio-Economic Pathway SSP2. The Shared Socio-Economic Pathways SSP1 to SSP5 describe a set of plausible trends in socio-economic developments over the 21st Century.[200] They consist of storylines regarding GDP, population, urbanization, economic collaboration, and human and technological development projections that describe different future scenarios. Each pathway future scenario does not account for the effects of climate change or additional climate policies. The five SSPs differ in terms of the socioeconomic challenges for climate change mitigation and adaptation. The SSP2 scenario, or "Middle of the Road Scenario," assumes intermediate challenges both in terms of mitigation and adaptation. Regarding climate change, the baseline scenario assumes a further 1°C of global warming by 2050.[201]

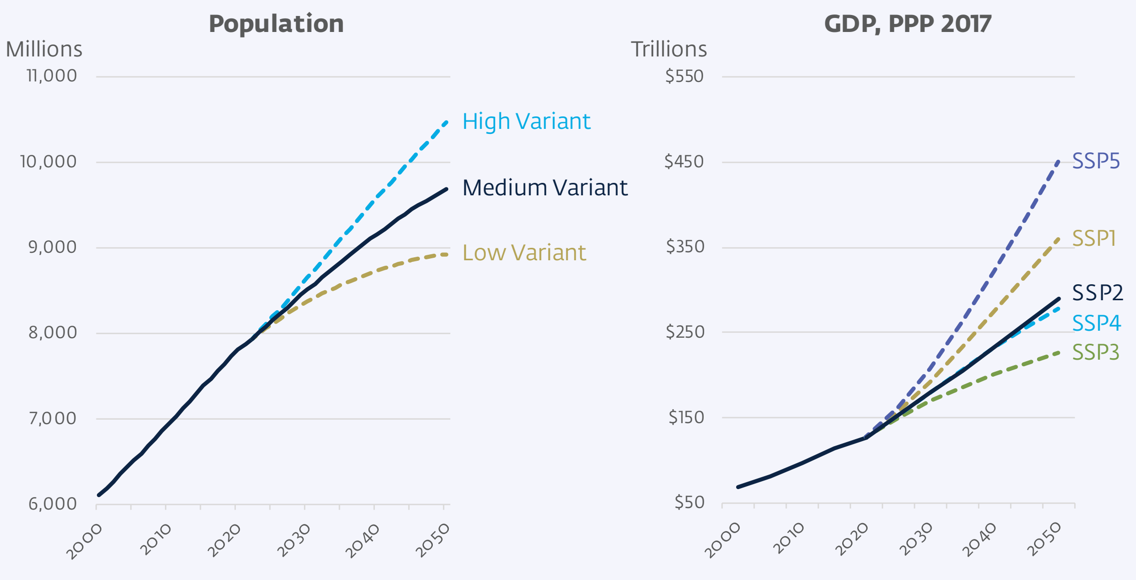
Following the Medium Variant population projection and the SSP2 scenario, world population is expected to grow by 20 percent from 2023 to 2050, and GDP per capita to grow by 70 percent. Africa should see the largest growth in population, by 70 percent, while in

200 For details, see United Nations World Population Prospects (https://population.un.org/wpp/) and United Nations Intergovernmental Panel on Climate Change (IPCC) Climate Change 2021 (https://report.ipcc.ch/ar6/wg1/IPCC_AR6_WGI_FullReport.pdf) and Climate Change 2023 (https://www.ipcc.ch/report/ar6/syr/downloads/report/IPCC_AR6_SYR_LongerReport.pdf) reports.

201 The model does not produce projections beyond 2050, but it could be expected that the influence of climate change would be larger than that of population and economic growth in the second part of the century.

FIGURE A.1

Population and GDP Projections



Source: World Development Indicators, United Nations World Population Prospects, Riahi et al. (2017), Dellink et al. (2017)

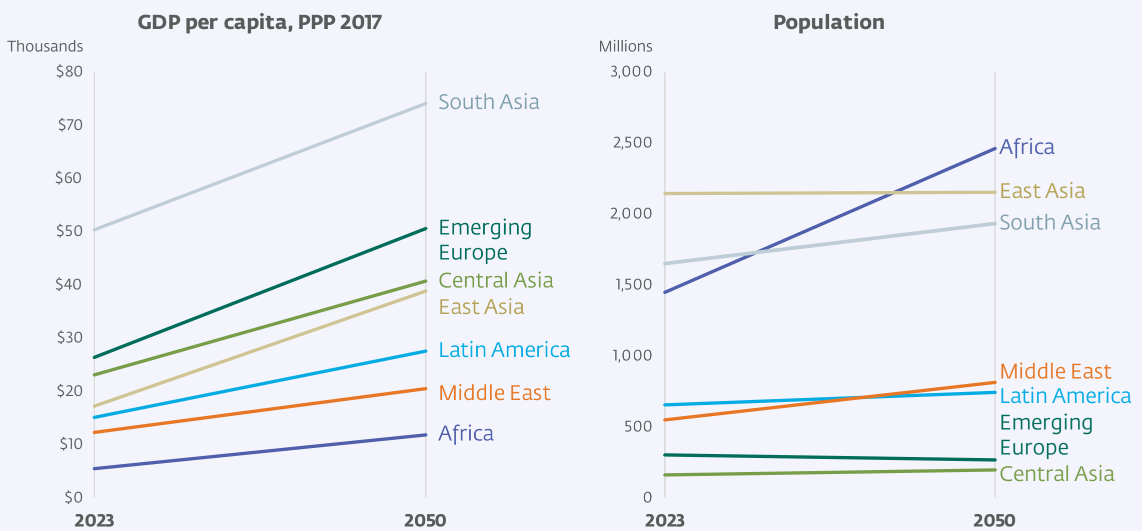
East Asia the population is expected to be stable. GDP per capita is predicted to more than double in Africa, East Asia and South Asia.

Regarding equipment efficiency, the baseline scenario assumes a business-as-usual trajectory with moderate improvements in efficiency. Under this scenario, the market is composed of a mix of equipment with different efficiency levels. The share of low-efficiency units will gradually decline as they are phased out and replaced. New units with medium energy efficiency are introduced more rapidly, while high-efficiency solutions are adopted at a slower pace. Notably, these baseline projections depart from the assumptions of low efficiency gains in the 2023 Global Cooling Watch report. Under that more conservative scenario, no high-efficiency units are introduced by 2050, and medium efficiency units are introduced slowly. The accelerated efficiency gains considered in our baseline scenario reflect recent trends and assume national efforts toward more sustainable cooling practices going beyond commitments under the Kigali amendment.

In the baseline scenario, passive cooling strategies are assumed to remain at current low levels. This assumption is intrinsically captured through the historical relationship between cooling needs and active cooling loads, which already incorporates any reductions due to

FIGURE A.2

Population and GDP Projections Across Regions



Source: World Development Indicators, United Nations World Population Prospects, Riahi et al. (2017), Dellink et al. (2017)

existing passive strategies. These assumptions are consistent with those considered in the 2023 Global Cooling Watch report for passive strategies in the baseline scenario.

Active Cooling Market Size Estimates

Market size estimates for active cooling are calculated based on the capital cost of new items projected by the stock model. The expanded model considers equipment prices and efficiency levels, with different scenarios regarding equipment efficiency. The Low, Mid and High Efficiency Gain scenarios assume improvements in efficiency over time, varying the degree with which new units become more efficient. The Low Efficiency Gain scenario was the baseline for the 2023 Global Cooling Watch report, while the Mid-Efficiency Gain scenario is our baseline. Additional scenarios assuming load reduction from passive strategies are considered. To calculate specific capital costs for different efficiency levels across years, we rely on research from online retailers in countries like Brazil, Colombia, Ethiopia, India, Nigeria, Pakistan, and Thailand. We also reference reports like the Oeko Research Report for the EU Commission, along with data from HVAC.com (U.S.), EIA (U.S.), and BSRIA (China). In addition to estimating the unit cost, the capital cost also includes estimates for other ancillary equipment and materials as well as labor costs (based on SPON's 2024 price guides and international labor rates) but does not include maintenance costs.

FIGURE A.3

Capital Costs Across Emerging Markets for Different Efficiency Scenarios

Source: Global Cooling Emissions and Investment Model

Figure A.3 displays the total estimated capital costs across developing economies for the scenarios outlined.

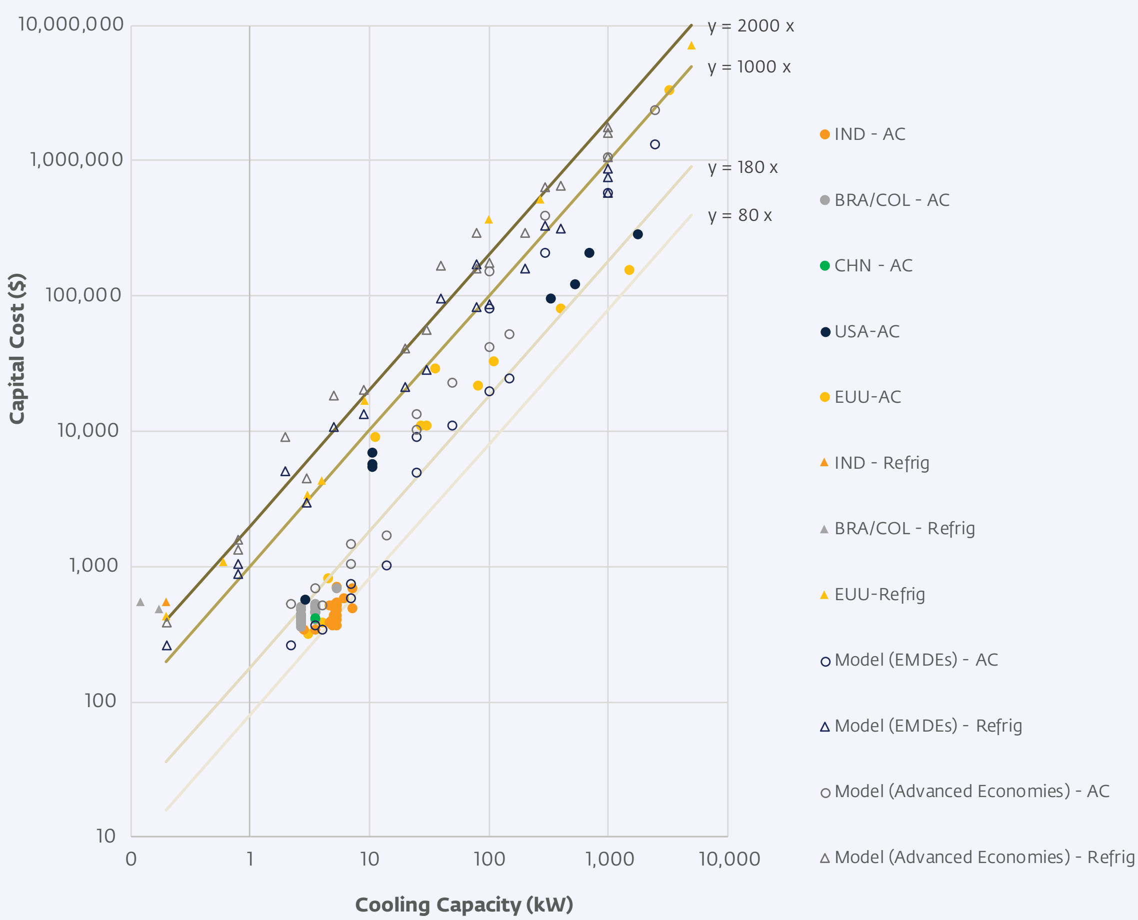
Assumptions on Capital Costs

The capital cost assumptions considered in this study are derived from industry reports on equipment costs and efficiencies, as well as desk research on equipment prices from online retailers of residential equipment in various emerging markets (including Albania, Brazil, Colombia, Nigeria, Pakistan and Thailand). Figure A.4 illustrates the relationship between capital costs and cooling capacity from different sources against the assumptions considered in the model. The dashed lines in Figure A.4 represent contours of equal capital cost per unit cooling capacity ($/kW). The data indicates that costs vary from around $80/kW to $2,000/kW. Most air conditioning costs in emerging markets range between $80/kW and $180/kW and are greater than $180/kW in advanced economies. Refrigeration costs are even higher, ranging between $1,000/kW and $2,000/kW. The capital costs assumed in the model fall within these ranges.

The wide range in costs reflects significant differences between the very different

FIGURE A.4

Capital Costs and Cooling Capacity



IND	India: desk research, using Amazon India
BRA/COL	Brazil & Colombia: desk research
CHN	China: BSRIA, 2019. "China's residential air conditioning prices set to increase"
USA	USA: EIA, 2023. "Updated Buildings Sector Appliance and Equipment Costs and Efficiencies"
EUU	EU: Oeko Recherche report for EU Commission (Schwarz et al., 2011)
Model - EMDEs	Model estimates for developing economies (e.g. Africa, South Asia)
Model - Advanced Economies	Model estimates for advanced economies (e.g. N. America, Europe, Japan, Australia)

technologies in the chart, from small room air conditioners and domestic refrigerators to very large office air conditioning systems and commercial or industrial refrigeration systems. The cost range reflects both inherent differences in the technologies and the effects of large-scale manufacturing efficiencies for some high-volume sectors.

In addition, there is a wide range of installation costs associated with different technologies. For example, domestic refrigerators require almost no additional installation costs. They come supplied with a mains power lead and can be plugged in to the home by the owner. At the other extreme, the installation of an air-conditioning system in a large office building involves not only the main cooling plant items (e.g. chillers), but also very significant ancillary equipment (e.g. condensers, chilled water pumps and pipework, air-handling units, ductwork, and packaged terminal units) as well as skilled installation technicians incurring significant labor costs. It is not always clear from the sources whether their estimates are based on the costs of the main cooling plant alone, or total installed costs (i.e. with ancillary equipment and labor costs). Equipment costs for split air conditioning systems and residential refrigerators, sourced from online retail platforms, are generally inclusive of all applicable taxes. In contrast, costs for non-residential air conditioning and refrigeration systems, as derived from the Oeko Recherche study for the EU F-Gas Review and various U.S. studies, likely exclude VAT.

For transport cooling, the cost estimates focus solely on the cooling systems rather than the entire vehicle. The analysis centers on refrigerated road transport and ISO containers. International shipping costs are not specifically included in the calculations. Although refrigeration and air conditioning are utilized in rail transport, their contribution is minimal and has not been separately modeled.

Based on the baseline estimates for each technology, we include multipliers according to efficiency and regions, which evolve over time. Initially, higher efficiency models are often accompanied by a significant cost premium, reflecting the advanced technologies and manufacturing processes involved, and include a higher multiplier. Over time, the cost associated with higher efficiency equipment is assumed to decrease as manufacturing efficiencies improve and technologies become more common.[202]

Differences in Active Cooling Market Size Estimates Compared to Recent Market Sizing

The current active cooling market size estimates presented in this report significantly surpass recent market sizing conducted by both the Economist Intelligence Unit (2019) and the University of Birmingham (2020).

The Economist Intelligence Unit's (EIU) 2019 cooling market size and demand forecasting focuses on eight sub-sectors (space cooling and refrigeration for residential, commercial, industrial, and transport/mobility uses) and

202 For instance, in Japan, the efficiency of room air conditioners has improved nearly threefold since 1970, while prices, adjusted for the consumer price index, have dropped by 65 percent from 1997 to 2010. Phadke et al., (2017).

six countries (China, India, Indonesia, Japan, Mexico and the United States). The EIU uses panel regressions to establish correlations between underlying demand drivers (like urbanization, income, temperature and electricity access, among others) and unit sales of cooling equipment across sub-sectors and countries of interest. It uses aggregates of air conditioning equipment sold by leading producers and recognizes the limitations on refrigeration equipment due to broader market fragmentation.

TABLE A.3

Variations in Market Size Estimates

PARAMETER	GLOBAL MARKET VALUE	
Reference Year		2030
Sector	All sectors	All sectors
Estimates from previous studies[203]	$135bn[204] - $143bn[205] (2018)	$170 bn[206]
Global estimate (equipment only)	$380bn (2020)	$585bn

Previous estimates sized the global cooling market at approximately $140 billion in 2018, whereas the model used for this report estimated a global market size of $530 billion by 2020. A significant portion of the disparity in estimates arises from the inclusion of installation costs and ancillary equipment in the current analysis—factors that are not believed to be accounted for in earlier studies. When we exclude these additional expenses, the global market estimate for all sectors stands at $380 billion in 2020, projected to grow to $585 billion by 2030 under a mid-efficiency gain scenario. Additionally, previous market estimates, last revised in 2016, would see an approximate 40 percent increase when adjusted for global inflation rates. Lastly, the data utilized in these estimates, from the Global Cooling Initiative,[207] may be reflective of manufacturers' sales of equipment. In contrast, the estimates in this report are based on prices to end consumers, which include markups above factory prices.

Estimation of market for passive cooling measures

UNEP and IFC have undertaken an analysis of the potential current market for building-level passive cooling measures, including reduction in window area, shading of windows, use of reflective roof and wall surfaces, wall and

203 World Bank (2022) projects India's cooling market by 2038 at $29 billion for refrigeration, $8 billion for mobile air conditioning, and $1.5 trillion for green buildings (based on IFC, 2017). Our estimates for 2040 are $23 billion for refrigeration and $8 billion for passenger vehicles. The green buildings market estimate is not comparable as it goes beyond cooling solutions; our estimate for space cooling in India for 2040 is $50 billion.

204 EIU (2019).

205 University of Birmingham, 2018. "The Clean Cooling Landscape Assessment".

206 EIU (2019).

207 https://www.green-cooling-initiative.org/country-data.

roof insulation and high-performance glazing. Integration of these measures into building energy codes and the timeline of their adoption and enforcement follows the same global assumptions as the Global Cooling Watch report. UNEP and IFC used a building stock model for developing economies to estimate the market potential and current size including cost estimates for passive cooling in new builds and retrofits for different markets.

The modelling of the impact and market for passive cooling measures is highly complicated for the following reasons:

- Lack of validated data on current quality of building stock and divergent ranges for future building stock growth;
- Poor understanding of application of building energy codes in countries;
- Significant variation in the resource and installation costs between countries within regions and across developing economies;
- Climate variation within countries that affects motivation to implement passive cooling. Nevertheless, the vast majority of emerging market populations and countries have high potential to benefit from passive cooling measures;
- The scope and rate of building energy code adoption and enforcement is highly uncertain.
- A lack of data on informal settlements in developing economies and the transition into formal housing. Such dwellings could benefit significantly from passive cooling and their inhabitants are most at risk amid poor access to active cooling;
- Limited data on retrofit markets and on measures such as shading or cool roofs, the cost of which can be spread over several years and do not require large scale building refurbishment.

The current built-up area of residential and commercial buildings in developing economies was adopted from various national and global sources and then weighted and set to match IEA estimates in 2022.[208] Growth rates for floor space are highly uncertain and a range of sources were used including the IEA growth rate for developing economies up to 2030.[209] Beyond 2030, increases in floor areas for buildings is estimated using the incremental floor areas by 2050 mentioned in the UNEP-IEA Global ABC regional roadmaps[210] for Africa, Asia and Latin America.

The penetration of building energy codes across emerging markets is sourced from the Global Cooling Watch data survey. Rates of building energy code adoption and enforcement up to 2050 are highly uncertain and, given the significantly higher cost of retrofitting with passive cooling measures as opposed to regulating their requirement during new

208 IEA (2023b).

209 IEA (2023b).

210 IEA (2020b); IEA (2020c); GlobalABC, IEA and UNEP (2020).

construction, this has a huge impact on the potential market for passive cooling in 2050. Rates of building energy code adoption have been previously modeled by the IEA.[211] Furthermore, the IEA's Net-Zero Energy Scenario in 2050 requires global coverage of building energy codes and fast retrofit of buildings at 2 percent a year through to 2050 for developing economies.

Based on the cost analysis across several countries, assumed cost ranges for a combination of passive cooling strategies were developed for different new building types in different climate zones that deliver energy reduction of 16 percent to 27 percent from cooling. On average across these regions, additional incremental costs lie in the range of 3 percent to 5 percent over the new construction costs,[212] which shows a positive impact on integrating passive cooling measures at the design stage itself. Cost estimates vary significantly by country, as do construction costs in general.

Given the significant uncertainties around costs, the pace of retrofits and building energy code adoption, and other variables mentioned above, UNEP and IFC have not estimated the cumulative cost for passive cooling up to 2050 nor the market size in 2050. Further analysis at the country or sub-regional level should be undertaken.

An example of cost estimates[213] for passive cooling measures that can deliver 24 percent reduction in cooling demand in terms of additional capital costs for new builds is provided in the table for India.

211 IEA (2021b).

212 CBRE Global Office Fit-out Cost Guide 2024, https://www.cbre.com/insights/books/global-office-fit-out-cost-guide-2024.

213 Costs include material and labor and exclude transport, taxes.

TABLE A.4:

Example of Cost Estimates for India

PASSIVE MEASURES	COST ($/M2)	SOURCE
Cool Paint	0.32	Multiple cool surface service providers
Roof insulation	7.75	Multiple insulation contractors
Glazing	36.29	India Schedule of Rates and local contractors
Wall insulation	7.75	India Schedule of Rates and local contractors
Shading	1.3	Average of cost of concrete for 500 mm overhang and plastic overhang with fixtures in India

Note: There is significant variation for costs even within one country and these cost figures should not be used in actual projects nor should they be used as a benchmark.

Annex 2: Methodology for Estimating the Total Cost to Close Cooling Gaps

Residential Cooling

Residential cooling gaps are estimated according to the following equation:

$$Gap = (target\ level - penetration\ rate),$$

where:

- **target level** denotes the target share of households that are expected to need a cooling appliance. For example, while it is reasonable to assume all households need a refrigerator, not all households need active space cooling equipment, and the target level will depend on climate.
- **penetration rate** denotes the share of households that own a cooling appliance.

The gap represents the share of households that do not own a cooling appliance. To calculate the costs to close these gaps, the gap is multiplied by the projected number of households in the country, the assumed number of units per household, and the average cost of the cooling appliance.

In the following subsections we provide a detailed analysis of each of these elements for the residential refrigeration and residential space cooling sectors, as well as the data sources used for the estimation.

Residential Refrigeration

The methodology employed to estimate the cost to close residential refrigeration gaps is outlined below:

Data Sources

The estimation process relies on data generated from the global stock model, specifically the output concerning residential refrigeration, coupled with projections regarding the number of households. Survey data on penetration of refrigerators is also used.

Target Level

Given the critical importance of refrigeration for household food preservation, our target level for residential refrigeration is set at 100 percent of households.

Penetration Rate Calculation

Penetration rates are calculated by dividing the projected number of refrigerators in each country by the projected number of households, with the assumption that each household owns one refrigerator. The estimated numbers are validated against penetration rates of refrigerators obtained from household surveys.

Residential Refrigeration Gap

The residential refrigeration gap is determined by calculating the difference between the target level of 100 percent and the projected penetration rate. This calculation enables the identification of households lacking adequate refrigeration access.

Estimating the Costs to Close the Gap

The total cost to close the residential refrigeration gap is quantified by multiplying the number of households with access gaps by the equipment prices, assuming one refrigerator per household. These prices are determined based on the assumptions outlined in section Annex 1.

Residential Space Cooling

There are two bounds for the cost to close the space cooling gaps. The lower bound estimate assumes that households without access to space cooling solutions fulfill their needs with fans only, while the upper bound estimate assumes that air conditioning becomes universally available for all households seeking active cooling needs.

Data Sources

The estimation process relies on data generated from the global stock model, specifically the output concerning residential space cooling, coupled with projections regarding the number of households. Additional survey data on penetration of air conditioners and fans is used. Box A.3 illustrates the available survey data and the differences in access to air conditioners and fans across the distribution of households (by income, expenditure, or wealth).

Target Level

Household survey data indicate that not all households require cooling in some countries, as shown in Mexico and Colombia, where even households at the top income deciles do not universally own fans or air conditioners. Therefore, the target level of space cooling varies by country, according to climate. The target level for space cooling needs is estimated based on fan ownership in different climates, obtained from surveys. For countries with available household level data, cooling needs are determined by the ownership rate of fans or air conditioners by households in the top deciles of the income (or wealth) distribution.

For countries where this kind of data is not available, a saturation curve representing a maximum space cooling penetration rate for different levels of CDDs is estimated based on cross-country fan and aggregate air conditioner ownership data. The underlying rationale in estimating this saturation curve is that households with higher levels of income (or other features that make cooling solutions more accessible) will, in general, face lower constraints to access the cooling solutions they need. Therefore, the observed largest ownership rates of space cooling solutions (fans or air conditioners) reflect closer the space cooling needs of households in countries facing similar temperature levels. Figure A.5 shows the data and estimated saturation curve. As expected, most countries with higher income levels are the main drivers of the saturation curve. In addition, fan or air conditioner ownership among households in the top deciles of the income (or wealth or expenditure) distribution observed in countries with available microdata, are broadly

BOX A.2

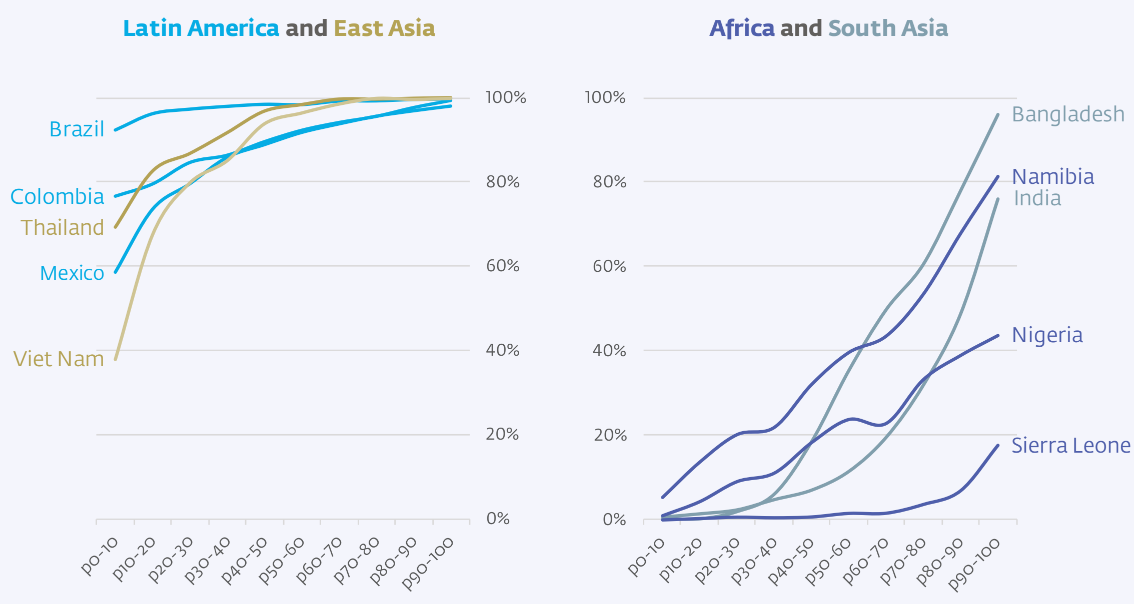
Detailed Analysis of Refrigerator Ownership by Household Distribution

There are notable differences in access to residential refrigeration across the household distribution (by income, expenditure, or wealth) for countries at various stages of development.

Countries with available data for Latin America (Brazil, Colombia, and Mexico) and East Asia (Thailand and Viet Nam) have relatively high rates of refrigerator penetration for households in the bottom deciles of the distribution, with between 40 percent and 80 percent of households in the bottom 20 percent of the distribution owning a refrigerator. These countries also show ownership rates close to or above 90 percent for all households above the bottom 40 percent.

In contrast, countries with available ownership microdata in Africa (Namibia, Nigeria, and Sierra Leone) and South Asia (Bangladesh and India[1]) show significant access gaps for refrigeration. At least 60 percent of households in the bottom 60 percent of the distribution across all these countries do not own a refrigerator. This is followed by steep increases toward 80 percent ownership by the households in the top decile for Bangladesh, India, and Namibia. Nigeria and Sierra Leone show the largest access gaps, with less than 50 percent and 20 percent of households, respectively, in the top decile of the distribution owning a refrigerator.

Household ownership of refrigerators (average within income, expenditure or wealth deciles)



Source: NBS and UNICEF (2019, 2019b, 2021), IBGE (2018), DANE (2018), INEGI (2018), NSSO (2012), Namibia Statistics Agency (2016), NBS (2018), SSL (2018).

1 Household survey data from India is from 2012 (NSSO, 2012) and is useful for highlighting within-country patterns. However, it is important to note that refrigerator ownership has increased from close to 20 percent in 2012 to almost 40 percent by 2019 (according to the 2019-2021 India DHS Survey).The 2019 data was not used in this analysis as this survey does not provide data on income or expenditure.

in line with the saturation curve. This approach ensures the target level for space cooling is estimated based on both direct survey data and the modeled saturation curve for different climates.

Penetration Rate Calculation

Air conditioner penetration rates are calculated by dividing the projected number of air conditioners in each country by the expected number of households, adding an adjustment factor to account for the fact that households that own air conditioners often own more than one unit. The adjustment factor is calibrated to follow penetration predictions for China from IEA (2019).[214] Figure A.6 illustrates the ownership rate from the model, the penetration suggested in the report, and the adjusted penetration curve.

To calculate the total cost to close the gaps using fans, we estimate the penetration rates of space cooling (fans or air conditioners). Space cooling penetration rates are estimated based on GDP per capita, using penetration rates collected from surveys, filtered for countries with warmer climates. For countries where the data source enables distinction between ownership of only fans, only air conditioners or fans and air conditioners, space cooling penetration is calculated as the share of households that own fans or air conditioners (the share which only own fans is added to the share which own air conditioners). For the remaining countries, the fan penetration rate is used as a proxy for space cooling penetration. From the first set of countries, this was identified as a better proxy than adding fan penetration to air conditioning penetration (Figure A.7, right panel). The left panel of Figure A.7 illustrates the relationship between GDP per capita and space cooling penetration.

Residential Space Cooling Gap

The residential space cooling gap is determined by assessing the difference between the target level of space cooling estimated for each climate and the estimated space cooling penetration rate (for the lower bound) or the air conditioner penetration rate (for the upper bound).

Estimating the Costs to Close the Gap

The total cost to close the residential space cooling gap is quantified by multiplying the number of households with access gaps by the equipment prices. Air conditioner prices are determined based on the assumptions outlined in Annex 1, assuming the gap will be filled with one 3.5 kW unit per household. For the lower bound, we assume an average price of $40 per fan to calculate the current gap, assuming one super-efficient fan per household.[215]

214 IEA (2019), The Future of Cooling in China, IEA.

215 Although there might be cheaper fans available, this assumption considers the use of super-efficient ceiling fans. The unit price is similar to the one used in Aggarwal & Agrawal (2022).

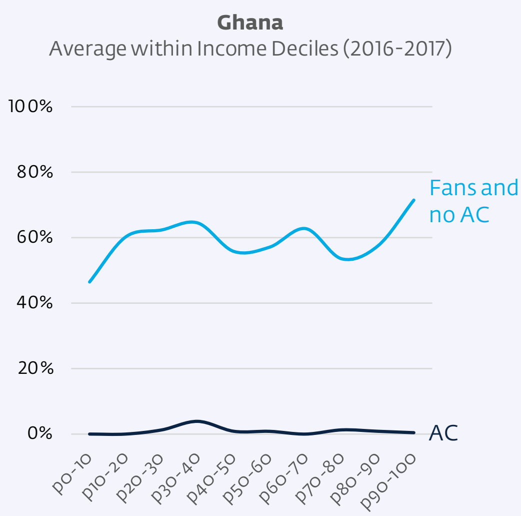
BOX A.3

Fans and Air Conditioner Ownership Across Households for Selected Emerging Markets

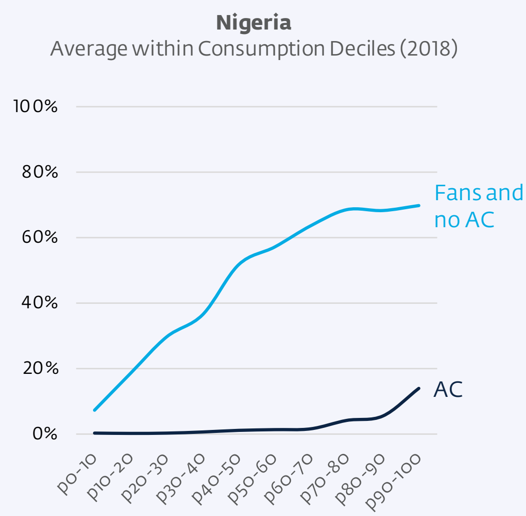
This analysis was done for eight countries across four regions, where household-level data on ownership of fans and refrigerators was available. These countries are Ghana and Nigeria in Africa, Bangladesh and India in South Asia, Colombia and Mexico in Latin America, and Thailand and Viet Nam in East Asia. For each of these countries, the graphs below show fans and air conditioner ownership rates across deciles of the household distribution. The distribution metrics vary by country according to what is available in each survey, with some using income, others using expenditures, consumption, or wealth levels, as indicated in each graph's heading.

Each of the graphs below compares the share of households that have air conditioning with households that have fans only—but not air conditioning.*

Household ownership of fans and air conditioners



CDDs	3,883 (2022)
GDP per capita ($)	2,204 (2022)

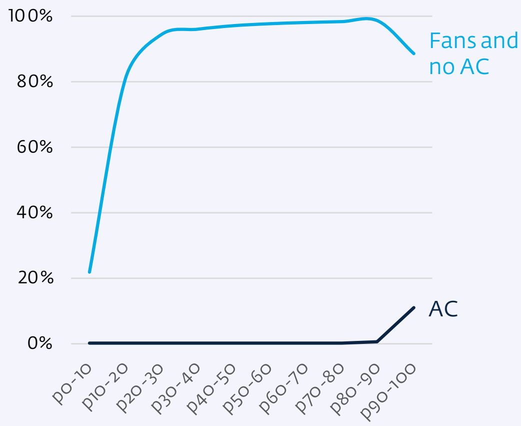


CDDs	3,830 (2021)
GDP per capita ($)	2,163 (2022)

Ghana and Nigeria, the countries with the lower income levels in the sample, show the largest gaps as air conditioning ownership is very low for most households, even those in the top income deciles.

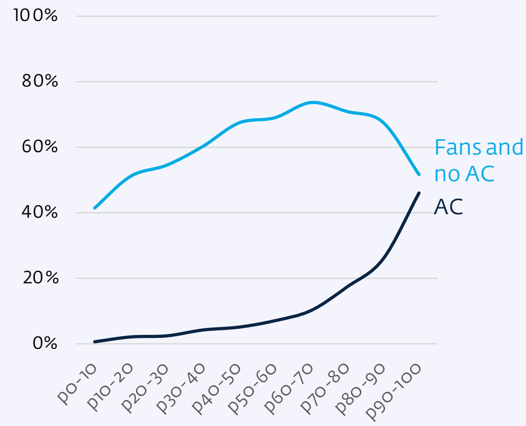
While about 60 percent (or more) of households in Ghana own fans across all deciles of the income distribution, ownership of fans in Nigeria grows between 40 percent for the lowest expenditure decile to about 70 percent for top deciles. This may be driven by access to electricity which is close to 60 percent (of the population) for Nigeria, compared to 86 percent for Ghana.

Bangladesh
Average within Wealth Index Deciles (2019)



CDDs	4,142 (2019)
GDP per capita ($)	2,688 (2022)

India
Average within Expenditure Deciles (2011-12)

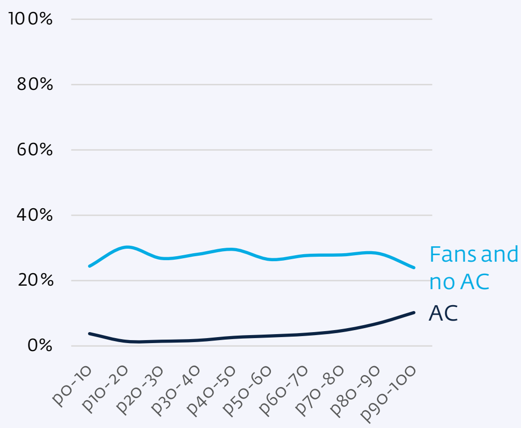


CDDs	3,751 (2019)
GDP per capita ($)	2,411 (2022)

In Bangladesh and India, countries with relatively low income levels within the sample, there is also a large air conditioning access gap across households. In Bangladesh, fan ownership is above 80 percent while air conditioning ownership is close to zero for most households and less than 20 percent for those in the highest wealth decile.

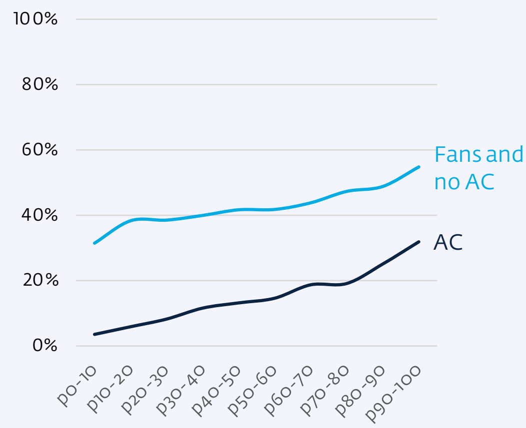
On the other hand, in India, the air conditioning access cooling gap is large and increasing up to the sixth (expenditure) decile, where it starts closing gradually up to the top (expenditure) decile where half of households own air conditioners and half own fans.

Colombia
Average within Income Deciles (2019)



CDDs	1,756 (2019)
GDP per capita ($)	6,624 (2022)

Mexico
Average within Income Deciles (2018)



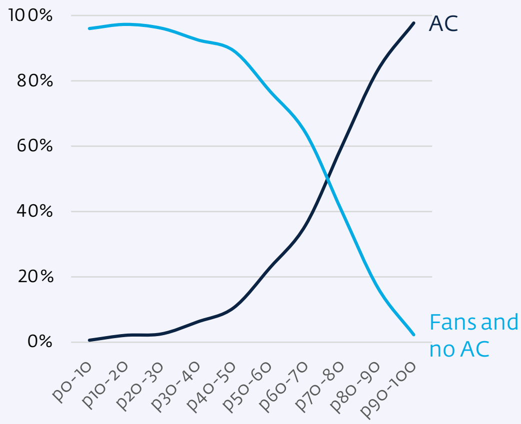
CDDs	1,279 (2018)
GDP per capita ($)	11,497 (2022)

Colombia and Mexico have higher income levels but colder temperatures (measured by CDDs), which imply less cooling need as evidenced by the rate of fan ownership throughout the income distribution.

However, there is still an air conditioning access gap, which remains relatively constant in Colombia across the income distribution, while it closes slightly for Mexico in the highest three income deciles.

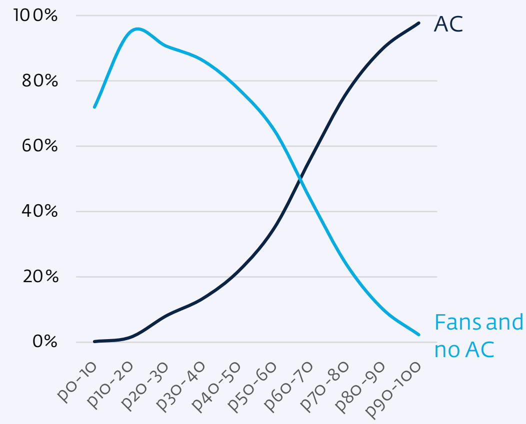
While Colombia is warmer than Mexico, air conditioner ownership in Mexico is higher (and grows across income deciles) given higher economy-wide income levels.

Thailand
Average within Wealth Index Deciles (2019)



CDDs	4,522 (2022)
GDP per capita ($)	6,910 (2022)

Viet Nam
Average within Wealth Index Deciles (2020-2021)



CDDs	3,758 (2018)
GDP per capita ($)	4,164 (2022)

Thailand and Viet Nam have similar temperatures to sampled countries in Africa and South Asia, but significantly higher income levels. This implies an increase in air conditioner ownership that starts at lower deciles (around the fifth wealth decile).

It is worth noting that air conditioner ownership increases from zero for the poorer households to a level above the (decreasing) fan ownership for households in the top three wealth deciles; and reaching close to 100 percent for households in the top wealth decile.

Source: NBS and UNICEF (2019, 2019b, 2021), DANE (2018), INEGI (2018), NSSO (2012), NBS (2018), GSS (2017).

Note: It is important to note that households in the top income levels tend to be underrepresented in household surveys, and therefore some of the shares for the top deciles may be underestimated.

Non-Residential Space Cooling and Refrigeration

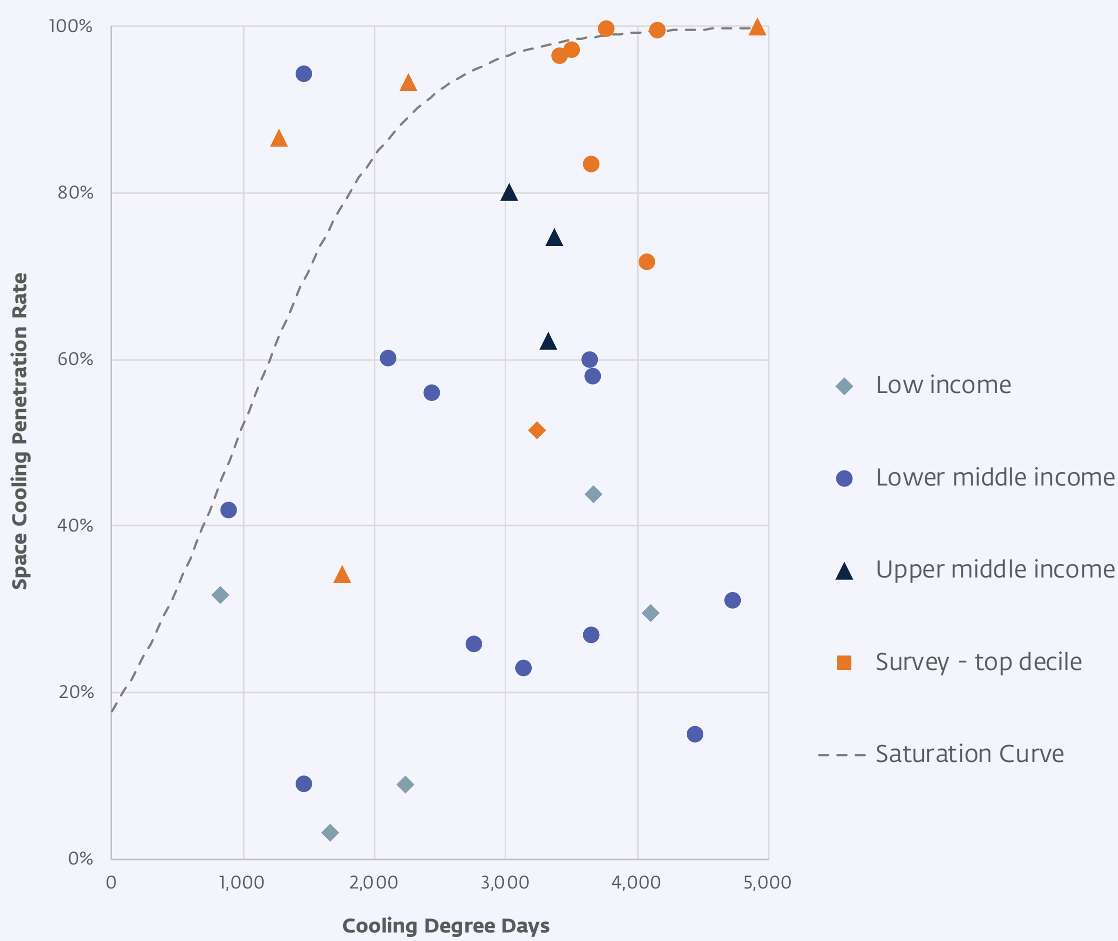
While it may be possible to identify key sectors underlying the bulk of the total non-residential cooling market estimated at the country level in Section 2.2 (based in part on total GDP), using information about the sectoral composition of the economy, there is in general no data available on access to cooling solutions for firms across different sectors, and not enough sectoral granularity on other types of economic data. Therefore, it is not possible to estimate non-residential cooling access gaps by sector.

However, based on the cooling demand estimates from Section 2.2 we can estimate the total cost required to address non-residential cooling gaps for small and medium enterprises (SMEs). The analysis divides firms into two categories: large firms and SMEs. Large firms have no financial constraints and can fully satisfy their cooling demands. SMEs are further classified as either fully financially constrained or partially constrained (or unconstrained). It is assumed that partially constrained and unconstrained SMEs satisfy all their cooling needs, while fully financially constrained SMEs cannot satisfy any of their cooling needs.[216]

216 Further evidence and research are required to establish a more robust relationship between access to finance for firms and their ability to satisfy their cooling needs.

FIGURE A.5

Estimated Space Cooling Saturation Levels



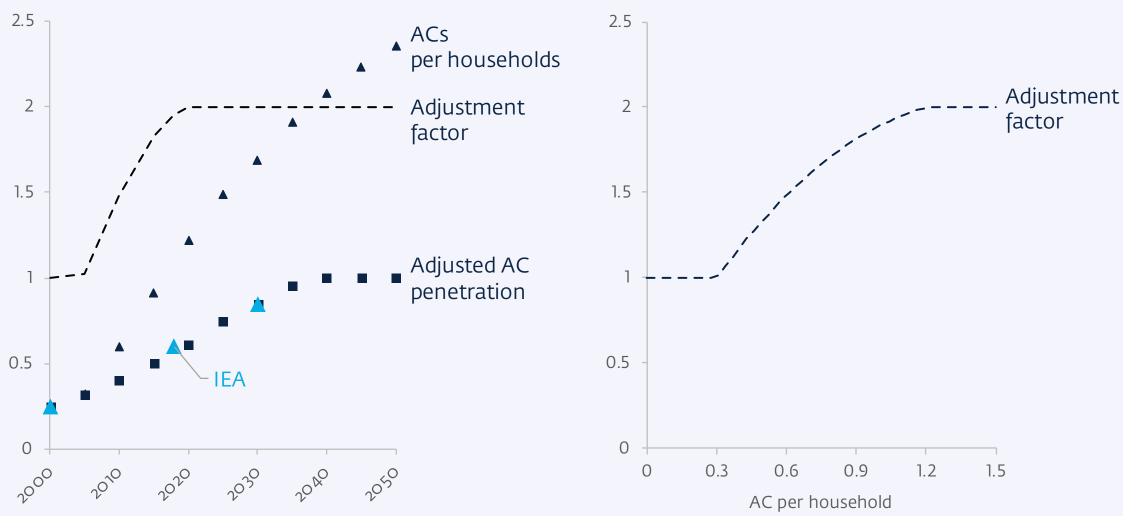
Source: Various surveys, International Energy Agency

The model assumes that satisfied cooling demand is proportional to the value added generated by firms. The unsatisfied SME cooling demand is calculated as proportional to the total satisfied demand, with the factor determined by two terms: the percentage of SMEs that are financially constrained (θ) and the share of overall value added generated by SMEs (g_f):

$$\text{Non-Residential Cooling Gap} = \frac{\theta}{1-\theta} * g_f * \text{Value of Non-Residential Cooling Stock}$$

FIGURE A.6

Air Conditioning Per Household, Penetration Rates and Adjustment Factor in China



Source: IEA (2019), estimates from authors.

Note: Adjustment factor is a number of air conditioners per household for households that own at least one

The methodology is outlined below:

Data Sources for Baseline

The percentage of SMEs that are fully financially constrained is obtained from the IFC and SME Forum MSME Finance Gap dataset.

The share of value added generated by SMEs is obtained from several sources, including the IFC SME database, OECD, CEPAL, Asian Development Bank, and various studies for African countries. [217]

The value of the non-residential cooling stock is an outcome from the global market size model.

Estimating Methodology

Based on the data available, the share of value added generated by MSMEs is estimated as a fifth-degree polynomial based on GDP per capita. Figure A.8 shows the fitted line.

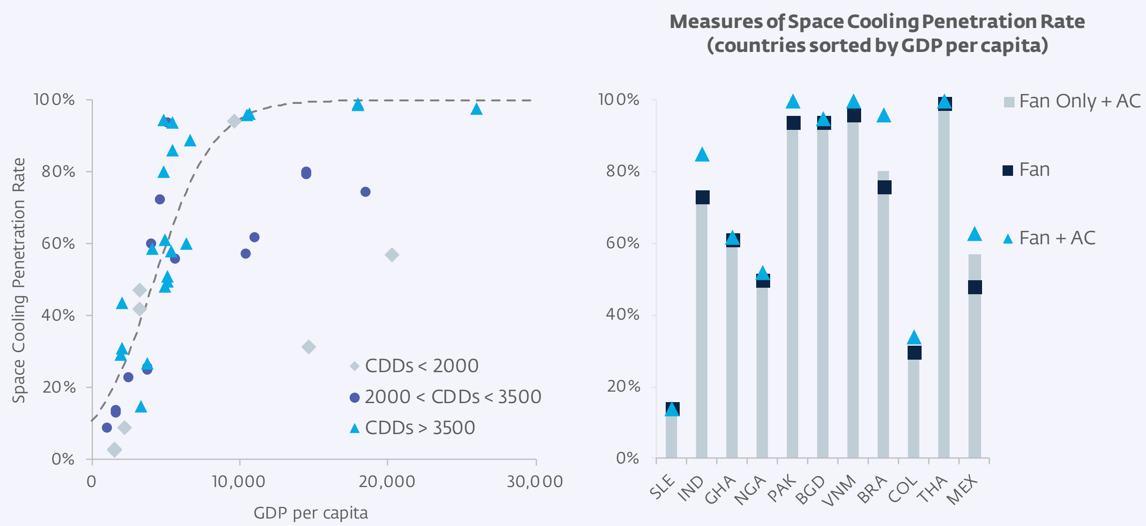
The percentage of SMEs that are fully financially constrained is estimated as a second-degree polynomial based on GDP per capita. Figure A.8 shows the fitted line.[218]

217 It is worth noting that there is no consistency across these datasets on the definition of the firms being included in their estimated share of GDP. There is also lack of clarity about the inclusion of micro and SME firms, or only SME firms in the estimate.

218 There is substantial cross-country variation at similar levels of GDP, especially for the percentage of SMEs that are fully constrained.

FIGURE A.7

Space Cooling Penetration Rates and GDP Per Capita Across Countries



Source: Various surveys, International Energy Agency, World Development Indicators

Note: GDP per capita is measured in constant 2017 International $ at PPP

The estimates are plugged into the formula above to estimate the total cost to close the SME cooling gap.

Evolution of Estimated Costs to Close the SME Cooling Gaps

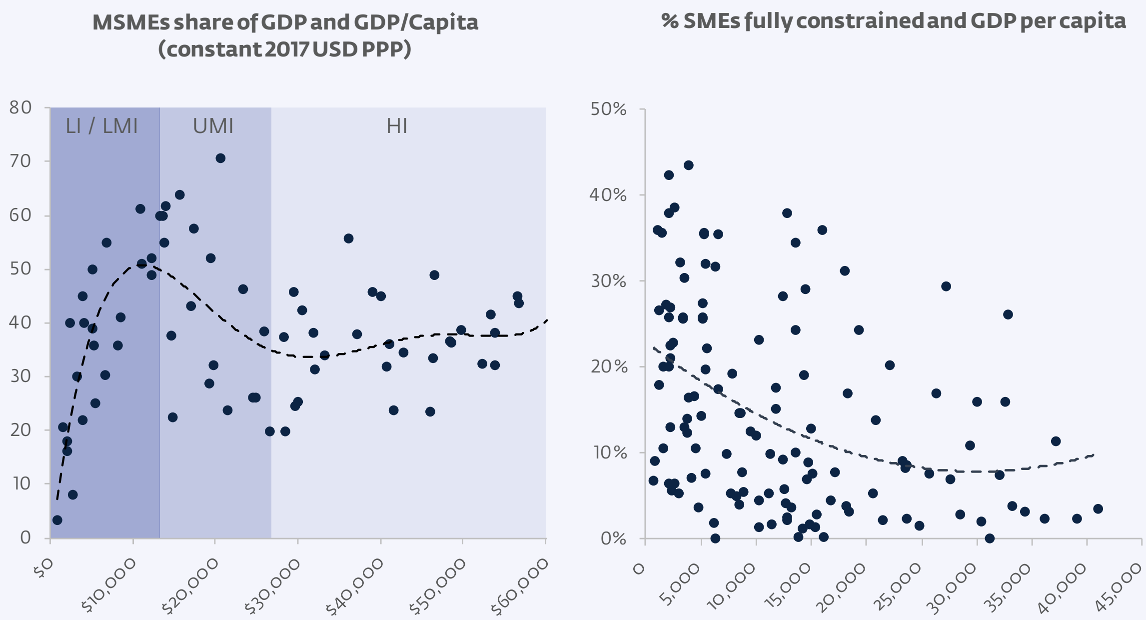
The projection of estimated cots to close SME Cooling Gaps through 2050 depends on the underlying assumptions regarding the evolution of access to financing by SMEs.

Following the assumption that SME access to finance will improve in the next three decades across developing economies, the cost to close SME cooling gaps would decline from $268 billion in 2023 to $179 billion in 2050. Under this scenario the share of the total cost for China would decline from 69 percent in 2023, to 25 percent in 2050, while South Asia's total cost share would increase from 7 percent to 20 percent, reaching $36 billion. Africa's share would increase from 2 percent to 19 percent, or $33 billion in 2050, implying a fivefold increase.

On the other hand, under a status quo scenario where SMEs' access to finance remains broadly unchanged, the total cost to close the SME cooling gap would continue increasing in China as well, to $317 billion in 2050, accounting for 54 percent of the total. Under such a scenario, the cost to close the SME cooling gap for Africa would increase by seven times in 2050 to

FIGURE A.8

SME Financial Constraints and Share of GDP Related to GDP Per Capita



Source: IFC and SME Forum MSME Finance Gap, IFC SME database, OECD, CEPAL, Asian Development Bank, and various studies for African countries.

$48 billion, while the cost for South Asia and the Middle East would increase by four and four-and-a-half times respectively.

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The UNEP-led Cool Coalition is a global multi-stakeholder network that connects a wide range of key actors from government, cities, international organizations, businesses, finance, academia, and civil society groups to facilitate knowledge exchange, advocacy and joint action towards a rapid global transition to sustainable cooling. The Cool Coalition is now working with over 130 partners, including 23 countries. The Cool Coalition is one of the official outcomes and "Transformation Initiatives" put forward by the Executive Office of the Secretary-General for the 2019 UN Climate Action Summit and the technical delivery partner to COP28 UAE Presidency on the Global Cooling Pledge.

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