CHILLING PROSPECTS

Tracking Sustainable Cooling for All

2021

SUSTAINABLE ENERGY FOR ALL

KIGALI
COOLING EFFICIENCY PROGRAM

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CHAPTER 1: GLOBAL TRACKING

In 2020, global development efforts stalled as governments worked to address the health, social and economic consequences of the COVID-19 pandemic. For the first time in 20 years, global poverty is set to increase and at the same time, 2020 tied with 2016 as the hottest year on record. The combination of these two factors contributed to growing cooling access gaps. Across 54 high-impact countries 1.09 billion people among the rural and urban poor are at high risk due to a lack of access to cooling. This includes 355 million people living in poor rural areas and 732 million living in poor urban areas. A further 2.34 billion lower-middle income people lack access to clean and efficient cooling. Compared to 2020, the analysis shows an increase of approximately 50 million people who are at high risk of a lack of access to cooling. More countries are recognizing these risks and currently over 20 countries are in the process of establishing National Cooling Action Plans.

CHAPTER 2: SUB-NATIONAL COOLING RISKS

Chilling Prospects 2021 uses geo-spatial and sub-national data to better identify regions within countries that have risks due to lack of access to cooling. It uses data on the location of where people live, their exposure to high temperatures, as well as economic and energy access trends. For example, Mexico is not a Cooling for All high-impact country, but the analysis found that the Mexican states of Guerrero and Veracruz are high-impact regions. Overall, the analysis identified 22 additional countries where cooling access risks are likely to exist for smaller pockets of the population. Among these countries 31 million people are at high risk due to a lack of access to cooling and 77 million are at medium risk due to a lack of access to efficient cooling. Across both the 54 high-impact and 22 non high-impact countries, this analysis shows a total high-risk population of 1.12 billion people in 76 countries.

CHAPTER 3: IMPACT OF COVID-19 ON ACCESS TO COOLING

The COVID-19 pandemic and the measures to limit its spread has had widespread impacts on global health, economies, social security and well-being, threatening the progress on many areas of the Sustainable Development Goals (SDGs). The economic impact of the COVID-19 pandemic was unprecedented and hardest on the vulnerable. While vaccine supply is likely to continue to be the primary constraint, it will be those living at the last mile in countries without sufficient vaccine cold chains that will be at risk of not being able to access a COVID-19 vaccine specifically due to cooling requirements. A dramatic expansion in cold chain equipment will be necessary to guarantee equitable distribution of COVID-19 vaccines. While it is evident that the pace of vaccination is uneven and inequities are likely to be exacerbated in the coming months, support for sustainable cold chains represents an opportunity to address immediate equity considerations and deliver a lasting impact in support of the economic and social recovery from the pandemic.

CHAPTER 4: SUSTAINABLE COOLING SOLUTIONS IN ACTION

As sustainable cooling solutions are piloted and demonstrated across the developing world, more data about their impacts on the local level are becoming available. Understanding these impacts is critical for governments, cities, development institutions and non-governmental organizations (NGOs) in the design of policies and implementation of new initiatives dedicated to increasing access to sustainable cooling. This chapter explores some of those solutions through case studies provided by the Ashden Foundation, the Basel Agency for Sustainable Energy, the FAO, the Million Cool Roofs Challenge, and the Sustainable Energy for All (SEforALL) Youth Summit. The examples are driven by data to show the impact that sustainable solutions have on communities and people.

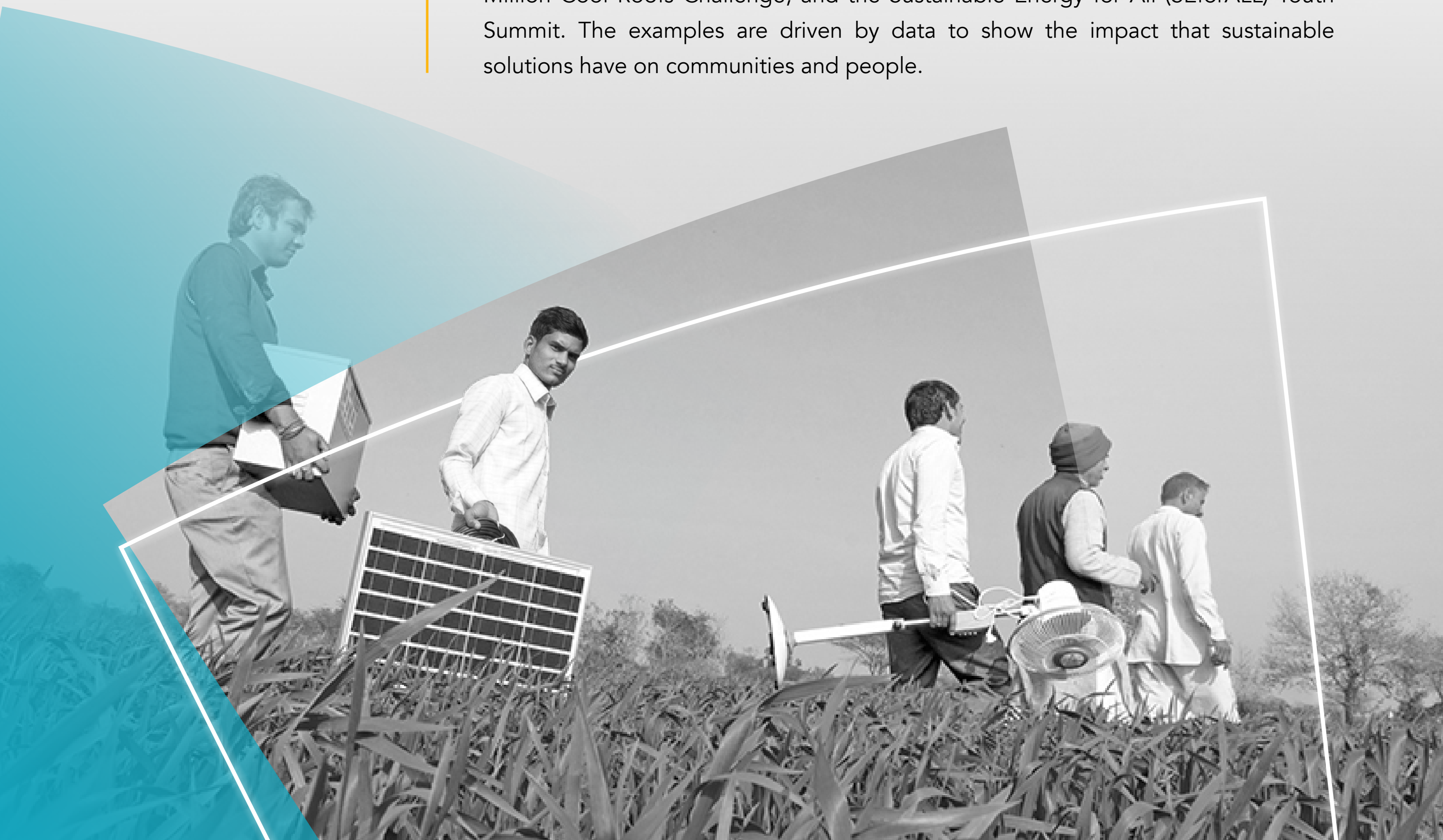

Photo by: Asian Development Bank

CHAPTER 1

Global Tracking

In 2020, global development efforts stalled as governments worked to address the health, social and economic consequences of the COVID-19 pandemic. For the first time in 20 years, global poverty is set to increase, with between 119 and 124 million people globally being forced into extreme poverty due to the pandemic. Approximately 60 percent of the increase will be among people living in South Asia and 27 percent among those living in Sub-Saharan Africa. In 2021, that figure is projected to rise to between 143 and 163 million.[1]

At the same time, 2020 tied with 2016 as the hottest year on record.[2] Heatwaves were documented in North America and Australia, and summer temperatures as high as 38°C in the Siberian region of Russia catalyzed wildfires that emitted record amounts of carbon dioxide (CO_2) and raised fresh concerns about the global warming impact of rapidly melting permafrost in the region.[3] New academic efforts also brought attention to the fact that heatwaves and their impacts are likely under-reported in Sub-Saharan Africa[4] and that in every region of the world, heatwaves have increased in their frequency and length since the 1950s.[5]

The combination of these two factors — COVID-19 and increased temperatures — coupled with persistent energy access gaps in some of the world's hottest and most populous countries, means that the challenge of delivering access to sustainable cooling is likely to continue to grow in size and scope, though changing in its dimensions as people migrate to cities and countries Recover Better from the pandemic.

This is the fourth edition of the ground-breaking *Chilling Prospects* series, which tracks immediate vulnerability due to a lack of access to cooling. The work identifies populations at risk for whom a lack of access to cooling threatens their immediate health and safety. It models risk based on a spectrum of cooling needs: human comfort and safety; agriculture, food and nutrition security; and health services and medicine. On this basis it categorizes risk across four populations: the rural poor, the urban poor, the lower-middle income, and the middle income.

Each year, the *Chilling Prospects* report projects an estimate of the current state of access to cooling gaps, based on the best available data and evidence, to provide the global community with the most up-to-date information. As new data for prior years become available, *Chilling Prospects* models are updated, and the figures are reflected in the reporting for previous years. In *Chilling Prospects 2020*, data that provided an assessment of the impacts of the COVID-19 pandemic were not yet available. With new forecasts becoming available, particularly on the poverty impact of COVID-19, Chilling Prospects 2021 is inclusive of analysis that reflects that data, and as such the fallout of the pandemic.

The analysis for 2021 shows that across 54 high-impact countries identified in previous *Chilling Prospects* reports,* 1.09 billion people among the rural and urban poor are at high risk due to a lack of access to cooling. A further 2.34 billion lower-middle income people pose a different kind of risk: they will soon be able to purchase the most affordable air conditioner or refrigerator, but price sensitivity and limited purchasing options mean they favour devices that are likely to be inefficient, threatening energy systems and resulting in increased GHG emissions.

Compared to 2020, the analysis shows an increase of approximately 50 million people who are at high risk of a lack of access to cooling. The number of urban poor at high risk has grown by approximately 19 million from

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[1] Lakner, Christoph, et al. "Updated estimates of the impact of COVID-19 on global poverty: Looking back at 2020 and the outlook for 2021," World Bank Group, 11 January 2021. Link

[2] "2020 Tied for Warmest Year on Record, NASA Analysis Shows," NASA. 14 January 2021. Link

[3] Stone, Madeline, "A heat wave thawed Siberia's tundra. Now, it's on fire," National Geographic, 6 July 2020. Link

[4] Harrington, Luke and Friederike Otto, "Reconciling theory with the reality of African heatwaves," Nature Climate Change 10, 13 July 2020. Link

[5] Perkins-Kilpatrick and S.C. Lewis, "Increasing trends in regional heatwaves," Nature Communications, 11, 3 July 2020. Link

*Note: For a list of high-impact countries, please refer to the Cooling for All Secretariat data. Link

714 to 732 million,[6] while the rural population has grown by 31 million from 324 million to 355 million. The lower-middle income population increased from 2.17 billion in 2020 to 2.34 billion in 2021. Across the 54 high-impact countries, at least 3.43 billion people still face cooling access challenges, with global risks amplified by an additional 50 million people at high risk in 2021.

TABLE 1.1

Analysis of risk from a lack of access to cooling

Risk Spectrum	**HIGH RISK**		**MEDIUM RISK**	**LOW RISK**
	• No access to electricity • Income below poverty line • Poor ventilation and construction • No access to refrigeration for food • Farmers lack access to controlled cold chains • Vaccines exposed to high temperatures		• Access to electricity • Lower income levels • Ability to run a fan, buildings constructed to older standards • Food is refrigerated • Farmers have access to intermittently reliable cold chains • Vaccines may have exposure to occasional high temperatures	• Full and reliable electricity • Middle income and higher • Well built homes can include insulation, passive design, air conditioning • Food is refrigerated reliably • Farmer's goods and vaccines have well-controlled cold chains
Populations at Risk	**RURAL POOR**	**URBAN POOR**	**LOWER-MIDDLE INCOME**	**MIDDLE INCOME**
Risk Indicators	• Lack of access to energy • Proportion of rural population living in poverty	• Lack of access to energy • Proportion of the population living in urban slums	• Proportion of the population living on less than USD $10.01 / day outside of rural or urban poverty	• Proportion of the population living between $10.01 and $20.01 / day
2021 Access Gap	**355 MILLION**	**732 MILLION**	**2.34 BILLION**	**1.38 BILLION**
2020 Access Gap	**324 MILLION**	**714 MILLION**	**2.17 BILLION**	**1.52 BILLION**
Change	**+31 MILLION**	**+19 MILLION**	**+164 MILLION**	**-140 MILLION**
Findings and Trends	Rural electricity access gains not enough to overcome population growth and increased number of poor due to COVID-19 pandemic, mostly in South Asia and Sub-Saharan Africa	• Concentrated risks in the rapidly growing cities of Africa • Lower relative growth, but poverty impact of COVID-19 has stalled gains	• Growth associated with COVID-19 related exposure to poverty, as well as general income growth for less-impacted populations • Strong growth in China, Mozambique, Namibia and Somalia	• Significant decreases in Sub-Saharan Africa and Bangladesh • China and India drive decreases by volume, likely reflecting changes in purchasing power
Notes	• 1.09 billion are at high risk, an increase of 50 million people compared to 2020. • The number of urban poor at high risk increased by 19 million, reflecting increases in poverty due to high numbers of COVID-19 cases in urban areas in urban areas and the "new poor" disproportionately working outside of the agriculture sector.[7] • The number of rural poor increased significantly, by 31 million people, the most significant increase observed during the tracking effort.			

*Note: figures may not add up due to rounding.

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[6] Note: figures may not add up due to rounding. The number of urban poor at high risk has grown from 713.5 million to 732.3 million, a difference of 18.8 million.

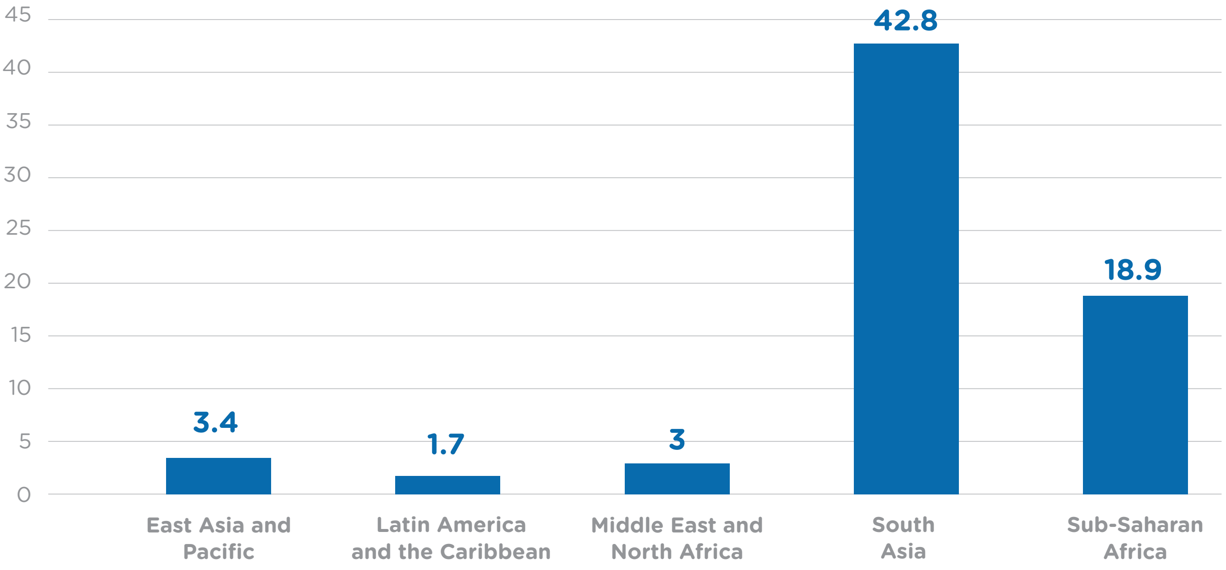
The poverty impact of the COVID-19 pandemic on increased access to cooling risks is clear. Forecasts from the World Bank, IMF and other international institutions show that just under 70 million people in the 54 high-impact countries for access to cooling were forced into extreme poverty in 2020 as a direct result of the pandemic. While this was likely counteracted by pre-existing access to electricity and established housing, the economic impact of the pandemic had cascading household impacts. Social distancing measures have had an impact on jobs and the ability to seek communal cooling resources. Faced with a decline in incomes, for example, households likely prioritized more basic or affordable services, for example favouring cereals or grains that provide higher caloric value per dollar, but do not require refrigeration.[7] Governments similarly prioritized direct stimulus payments and employment supports, and despite women facing the most significant of the economic impacts of the pandemic, only 13 percent of the COVID-19 fiscal, social protection, and labour market measures targeted the economic security of women as of March 2021.[8]

Impacts were felt significantly in Asia and the Middle East, where 28 million additional people are at high risk, and Africa, where 19.4 million additional people are at high risk, consistent with the forecasts showing South Asia and Sub-Saharan Africa to be the regions with the largest numbers of people forced into poverty due to the pandemic. Ongoing urbanization, particularly in the fast-growing cities of Africa, as well as rural population growth in both regions also contributed to the relative increases. These access gaps are in addition to those who may face temporary difficulties accessing a COVID-19 vaccine specifically as a result of a lack of rural cold chain infrastructure (See Chapter 3).

As the pandemic continues, access to cooling will play a vital role in the global economic recovery from it. From the cold chains that carry vaccines to rural health clinics, to the jobs a connected agricultural sector supports, sustainable cooling solutions are vital to Recover Better with Sustainable Energy.[9] As governments work to Recover Better by implementing policies that support sustainable cooling, the achievement of Sustainable Development Goal 7 (SDG7) and poverty reduction, access to sustainable cooling can be expected to increase. While the pace of these economic recoveries is likely to differ, over time they can be expected to reduce the number of those at highest risk due to a lack of access to cooling, including the temporary access gaps caused by the COVID-19 pandemic.

FIGURE 1.1

Estimated increase of absolute poverty in 54 *Chilling Prospects* priority countries by region (millions)



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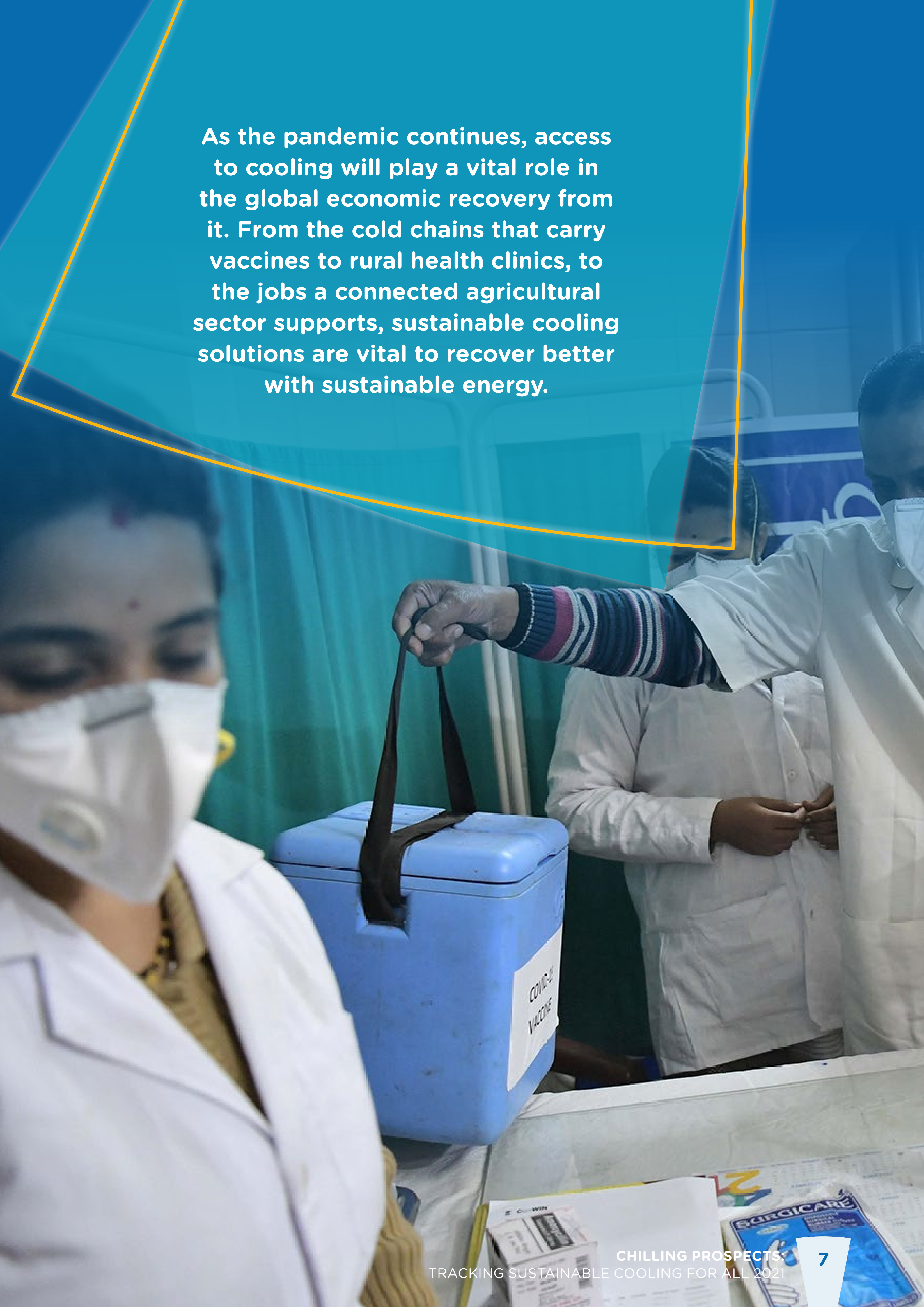
[7] Headey, Derek D and Harold H Alderman. "The Relative Caloric Prices of Healthy and Unhealthy Foods Differ Systematically across Income Levels and Continents," The Journal of Nutrition, Volume 149, Issue 11, November 2019. Link

[8] Women's absence from COVID-19 task forces will perpetuate gender divide, says UNDP, UN Women, UN Women, March 22, 2021. Link

[9] Recover Better with Sustainable Energy, Sustainable Energy for All, 2020. Link



As the pandemic continues, access to cooling will play a vital role in the global economic recovery from it. From the cold chains that carry vaccines to rural health clinics, to the jobs a connected agricultural sector supports, sustainable cooling solutions are vital to recover better with sustainable energy.

Global Access to Cooling: Populations at Risk

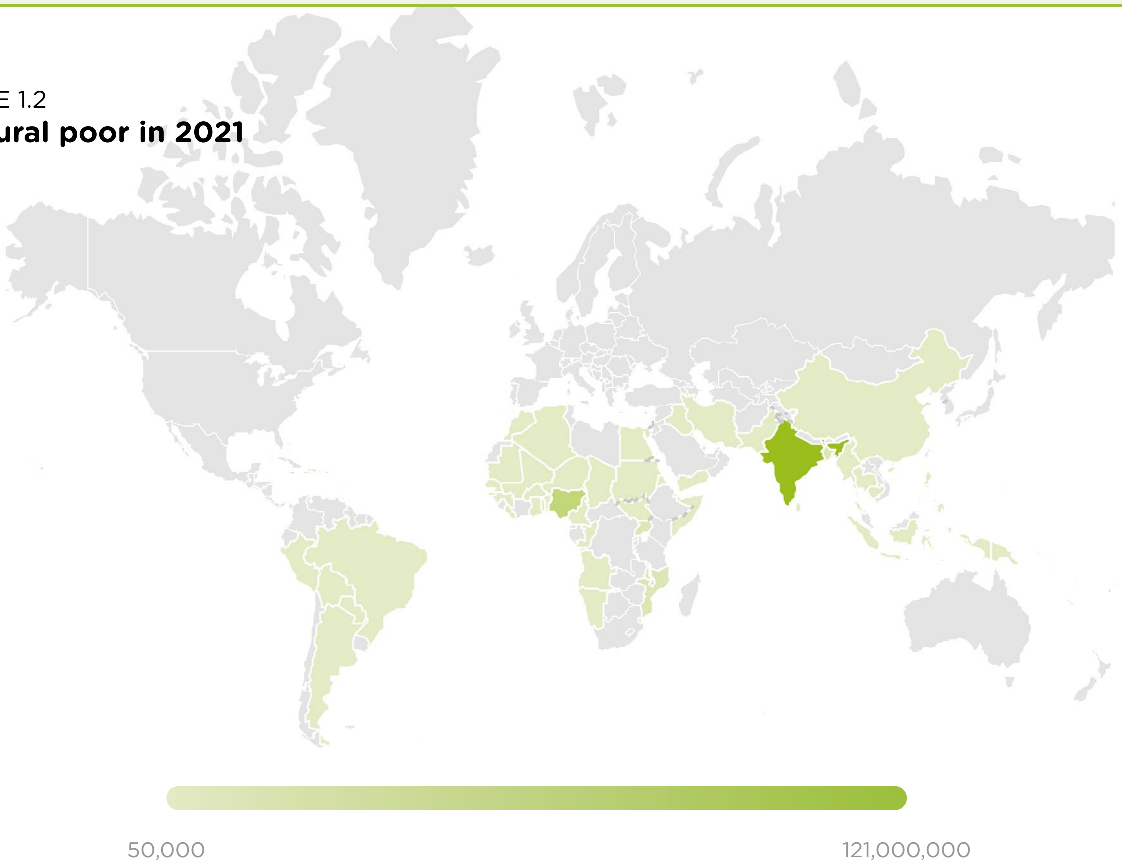
RURAL POOR

Approximately 355 million people

The rural poor lack access to electricity and are likely to live in extreme poverty. Many of the rural poor are likely to engage in subsistence farming but lack access to an intact cold chain that would enable them to sell their products further afield at a higher price. There may also be a lack of medical cold chains in rural poor communities, putting lives at risk from spoiled vaccines.

FIGURE 1.2

The rural poor in 2021



The number of those at high risk in poor, rural areas rose by 31 million from 324 million people in 2020 to 355 million people in 2021. This increase is due primarily to the poverty impact of the COVID-19 pandemic, which would have placed financial burdens on households and spending constraints on governments to deliver social services and incentivize energy access. The three countries with the highest number of rural poor at risk in 2021 are India, Nigeria and Bangladesh, with each country experiencing a gain in the number of rural poor as high as 21 percent for India and 12 percent for Nigeria. In India, the access gap for the rural poor has been updated to reflect a steady poverty gap in rural areas. Despite steady strides in delivering energy access, electricity alone has not enabled those living in poverty to access most sustainable cooling solutions. In Africa, 25 countries have experienced a growth rate in their rural poor populations of 10 percent or more since 2018: Algeria, Angola, Benin, Burkina Faso, Cameroon, Chad, Republic of Congo, Cote d'Ivoire, Egypt, Eswatini, Gambia, Ghana, Guinea, Guinea-Bissau, Liberia, Malawi, Mali, Mauritania, Morocco, Mozambique, Niger, Senegal, Sudan, Togo and Uganda. While their populations of rural poor are relatively small, many countries in Latin America experienced increases of more than 10 percent in 2021: Argentina (20,600 person increase), Bolivia (36,200 person increase), Brazil (451,000 person increase), Dominican Republic (1,800 person increase), Paraguay, (8,700 person increase), and Peru (51,400 person increase).

Cooling access gaps for the rural poor do not factor in the additional risks linked to the COVID-19 vaccine cold chains. Rural populations in a range of different climates and at different income levels will experience such challenges. For an analysis of the number of rural dwellers who may have challenges receiving a COVID-19 vaccine due to a lack of reliable medical cold chains, please see Chapter 3.

FIGURE 1.3

The rural poor since 2011 (millions)

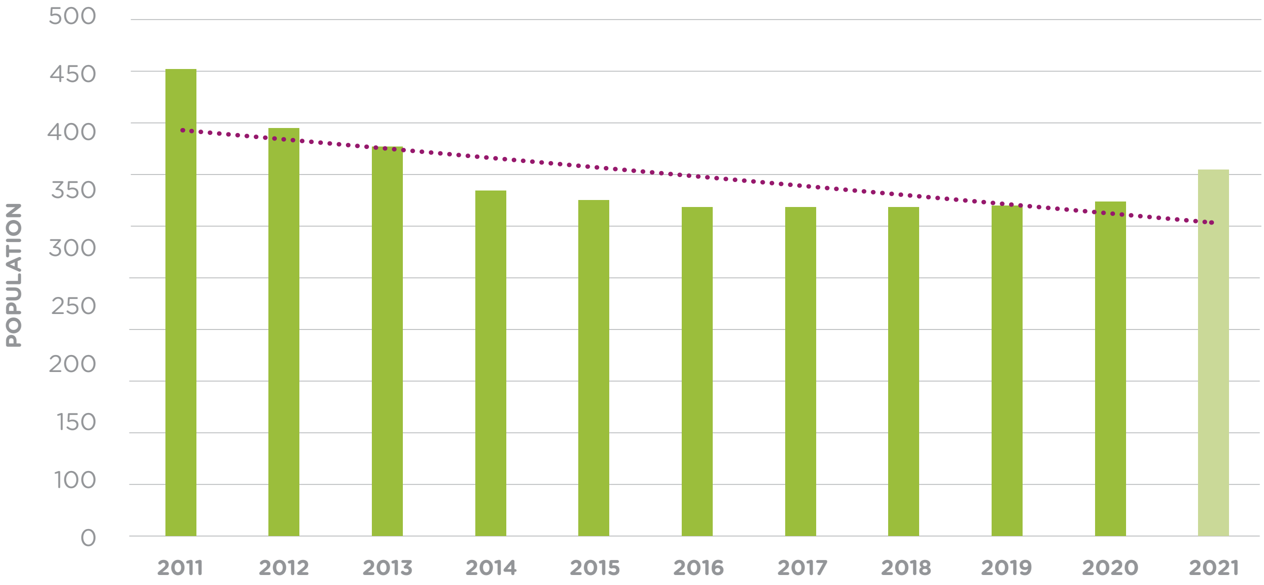


TABLE 1.2

Top 10 countries with rural poor at risk

COUNTRY	2019	2020	2021
India	106,783,930	107,393,275	121,341,399
Nigeria	47,657,103	48,416,244	51,538,109
Bangladesh	17,258,139	17,301,375	19,323,191
Uganda	14,638,948	15,087,563	16,132,540
Mozambique	13,545,331	13,867,536	14,846,199
Malawi	11,134,546	11,409,178	12,267,725
Niger	8,756,825	9,088,254	9,786,640
Angola	7,459,506	7,630,054	8,124,582
Indonesia	7,169,661	7,178,929	7,754,500
Burkina Faso	6,730,911	6,883,675	7,364,129

URBAN POOR

Approximately 732 million people

The urban poor may have some access to electricity, but the quality of their housing is likely very poor, and their income may not be sufficient to purchase or run a fan. They may own or have access to a refrigerator, but intermittent electricity supplies may mean that food often spoils and there is a high risk of poor nutrition or food poisoning.

FIGURE 1.4

The urban poor in 2021

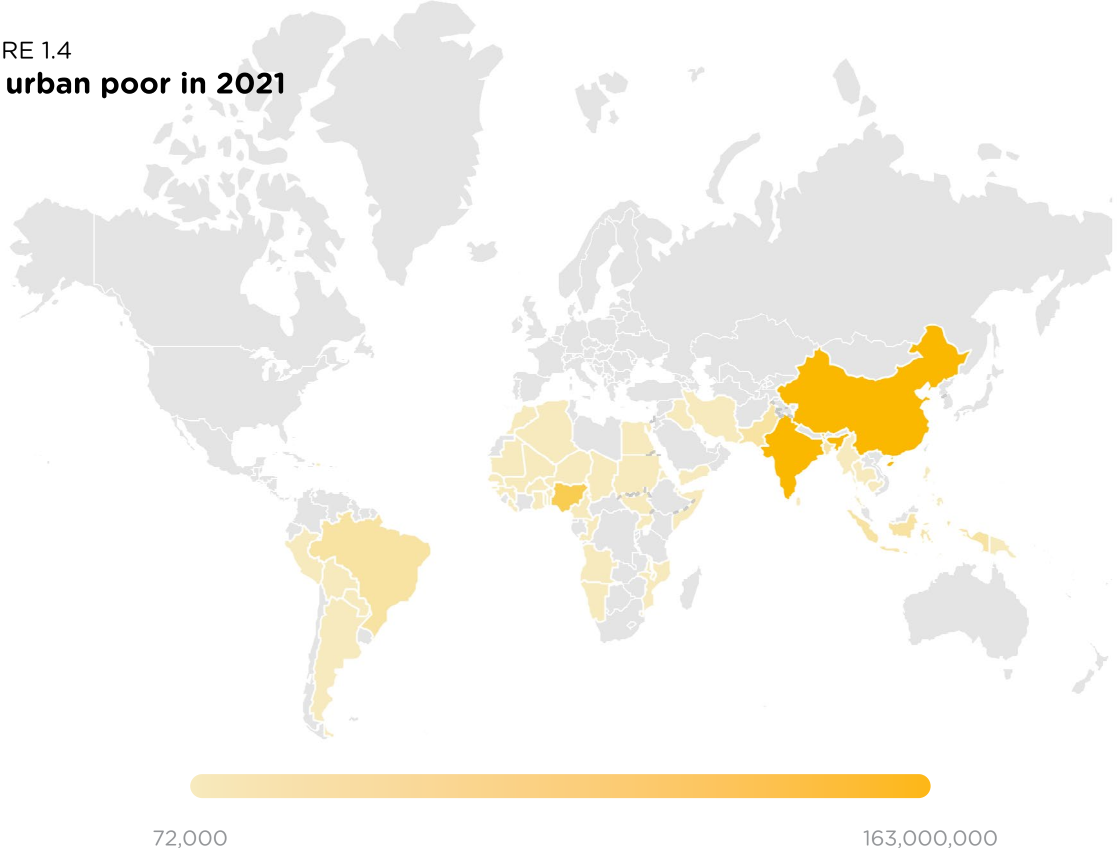


FIGURE 1.5

The urban poor since 2011 (millions)

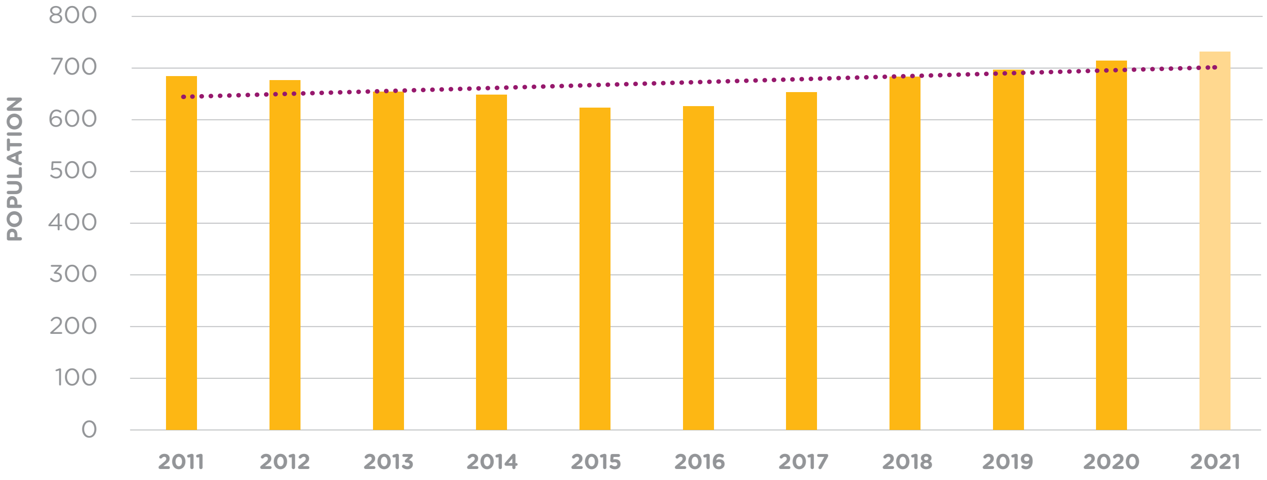


TABLE 1.3

Top 10 countries with urban poor at risk

COUNTRY	2019	2020	2021
India	157,441,529	159,951,195	163,304,685
China	143,324,111	145,782,786	149,182,384
Nigeria	76,188,432	79,178,049	81,986,457
Indonesia	38,973,545	38,206,693	39,097,731
Bangladesh	27,523,182	28,383,236	29,188,010
Brazil	27,855,878	28,159,161	28,458,215
Pakistan	24,226,605	24,692,408	25,364,133
Philippines	18,185,903	18,260,002	18,535,776
Angola	16,580,438	17,519,087	18,378,444
Sudan	11,361,224	11,395,869	11,877,422

The number of those living in poor urban settings at highest risk grew by 19 million, from 714 million people to 732 million people.[10] China and India accounted for approximately 36 percent of the growth, or 6.8 million people. None of the 54 high-impact countries saw a decrease in their number of urban poor. Increases in this population generally ranged between 1 and 6 percent, with the exception of Algeria, which saw a 16 percent increase in the number of rural poor at risk, and the Republic of Congo, which saw a 15 percent increase. While the COVID-19 pandemic played a significant role in 2021, the number of urban poor at high risk has been growing since 2015 due to urbanization trends, meaning that in hot cities, the pandemic exacerbated an already challenging situation.

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[10] Note: figures may not add up due to rounding. The number of urban poor at high risk has grown from 713.5 million to 732.3 million, a difference of 18.8 million.

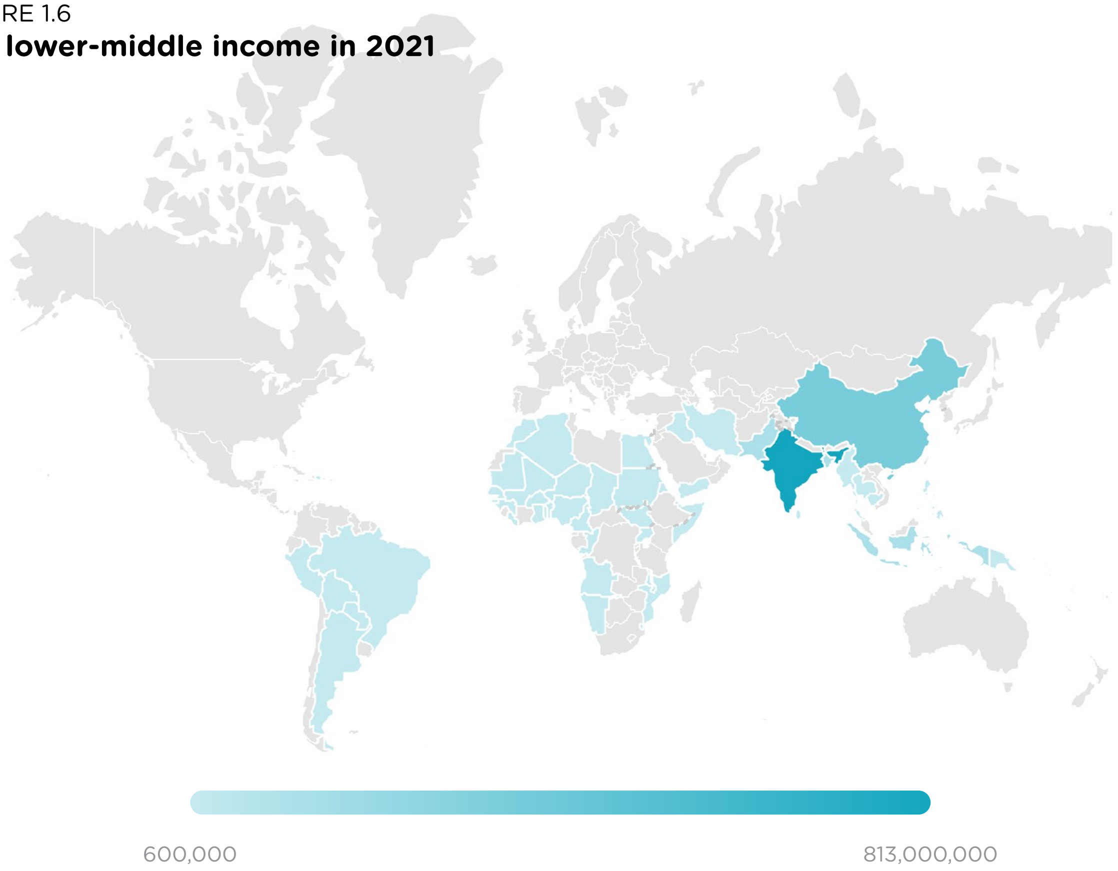
LOWER-MIDDLE INCOME

Approximately 2.34 billion people

The lower-middle income population represents an increasingly affluent lower-middle class that is on the brink of purchasing the most affordable air conditioner or refrigerator on the market. Limited purchasing choices available to this group favour cooling devices that are likely inefficient and could cause a dramatic increase in energy consumption and associated GHG emissions.

FIGURE 1.6

The lower-middle income in 2021



The lower-middle income population represents an increasingly affluent lower-middle class that is on the brink of purchasing the most affordable air conditioner or refrigerator on the market. Limited purchasing choices available to this group favour cooling devices that are likely inefficient and could cause a dramatic increase in energy consumption and associated GHG emissions.

The lower-middle income population is the estimated segment of the population outside of rural and urban poverty living on less than USD 10.01 per day. There was a significant increase in this segment between 2020 and 2021 of approximately 164 million people, reversing a trend that had seen the number of lower-middle income at risk continually decreasing since 2012. There are multiple factors that are likely to have influenced this in 2021, including the number of people who became exposed to poverty as a result of the COVID-19 pandemic and overall population growth. Significant increases were seen in China, with eight other countries experiencing growth in their lower-middle income populations of over 10 percent: Guinea, Mauritania, Mozambique, Namibia, Senegal, Somalia, South Sudan and Sri Lanka.

FIGURE 1.7

The lower-middle income since 2011 (millions)

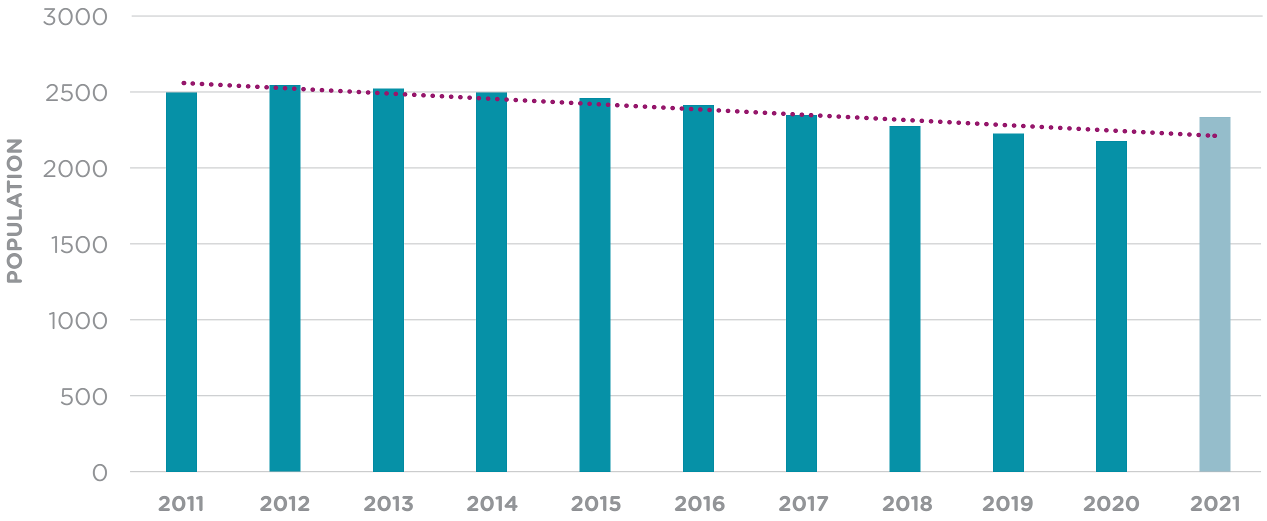


TABLE 1.4

Top 10 countries with lower-middle income populations at risk

Country	2019	2020	2021
India	794,727,475	770,924,658	812,908,662
China	316,590,867	281,341,541	366,049,651
Indonesia	169,539,989	167,355,569	168,949,407
Pakistan	158,901,862	158,910,757	166,826,222
Bangladesh	108,260,828	107,872,771	112,120,521
Egypt	84,843,706	86,889,342	86,572,021
Nigeria	69,600,358	78,355,240	83,671,102
Philippines	57,203,090	56,363,310	56,942,701
Brazil	54,256,257	54,897,796	56,540,686
Vietnam	53,347,146	50,820,234	51,683,855

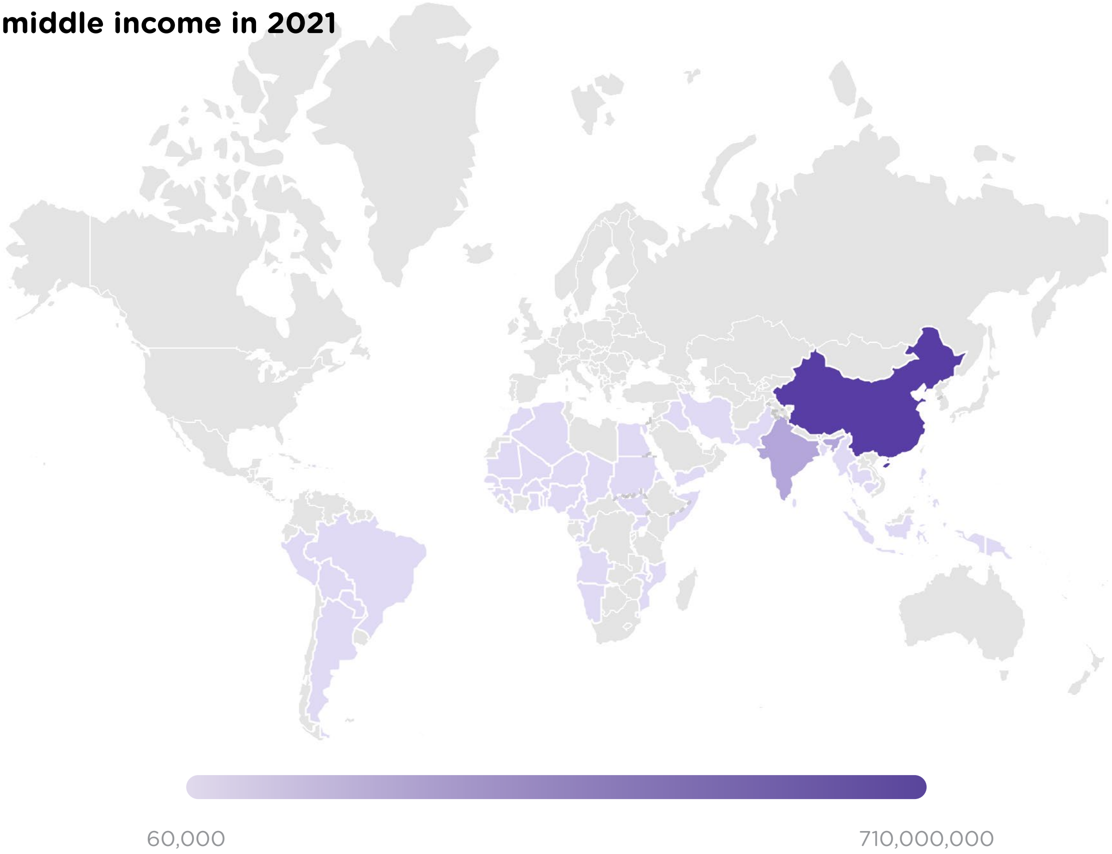
MIDDLE INCOME

Approximately 2.34 billion people

The middle-income segment of the population typically owns an air conditioner and refrigerator and may be able to afford more efficient ones. They may also be able to move to better designed, more efficient housing and working environments, where they might also make conscious choices not to own an air-conditioning unit or minimize its use.

FIGURE 1.8

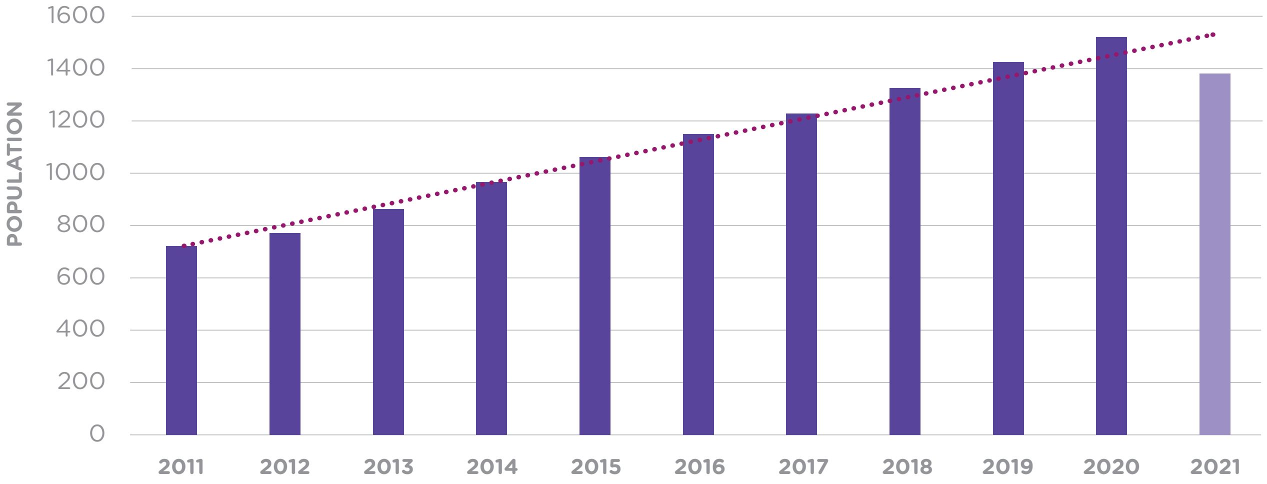
The middle income in 2021



The middle-income segment of the population lives on between USD 10.01 and USD 20 per day. In 2021 there was a decrease in the middle-income population of approximately 140 million people compared to 2020. In Sub-Saharan Africa, 20 countries saw decreases in their middle-income populations of over 10 percent: Benin, Burkina Faso, Cameroon, Chad, Republic of Congo, Cote d'Ivoire, Eritrea, Eswatini, Gambia, Ghana, Guinea, Guinea-Bissau, Mauritania, Mozambique, Namibia, Nigeria, Senegal, South Sudan, Togo and Uganda. By volume, the decrease in the overall middle-income population was driven by China, (-82.1 million) and India (-43.2 million). While a decrease in the middle-income population can likely be attributed to a general drop in income and higher exposure to poverty resulting from the COVID-19 pandemic, it can also be a result of increased incomes of some previously living on between USD 10.01 and USD 20 per day.

FIGURE 1.9

The middle income since 2011 (millions)



Populations at Risk: Regional Trends

Cooling access gaps for the rural and urban poor at highest risk grew in each region compared to the previous year, while those at medium risk, in the lower-middle income category, increased in Africa, decreased in Asia and the Middle East, and remained the same in Latin America and the Caribbean.

AFRICA

In Africa, the analysis covers 31 countries that experience high temperatures and are identified as being high-impact for access to sustainable cooling. Across the region, a combined 389 million are at highest risk among the rural and urban poor. The number living in poor rural areas at high risk due to a lack of access to cooling total approximately 174 million people, accounting for 39 percent of the total rural population of Africa and 21 percent of the continent's total population. Compared to 2020, an increase of 11.4 million was observed, which was a larger increase than previous years. This is in part due to the poverty impact of the COVID-19 pandemic, but also continues a trend that began in early 2020. The gap has continued to widen since 2018, having grown 11.6 percent from 156 to 174 million people and accounting for 49 percent of the total number of rural poor globally.

FIGURE 1.10

Trends in populations at risk across 31 high-impact countries in Africa (millions)

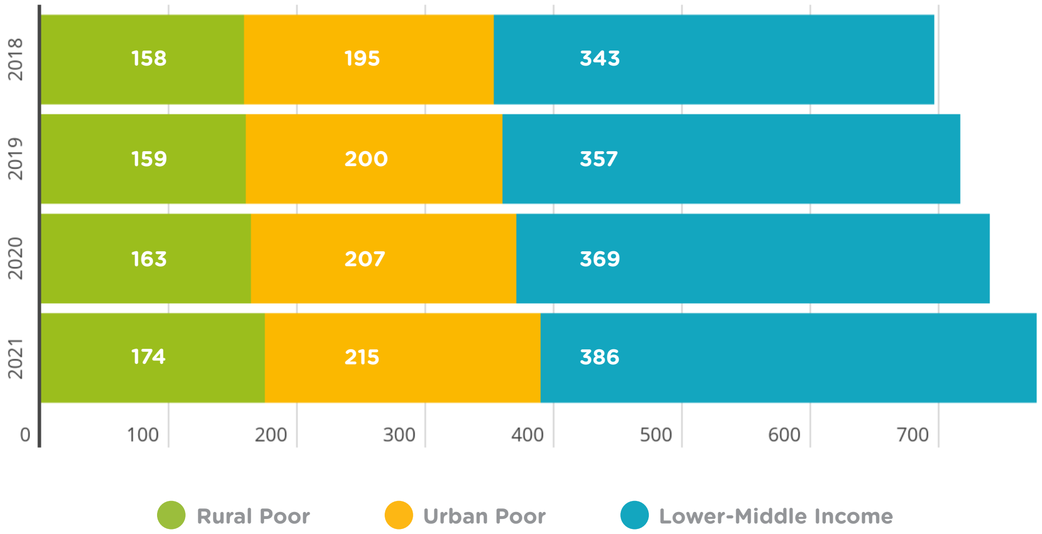


TABLE 1.5

Trends across 31 high-impact countries in Africa

High-impact countries in Africa			
Population at Risk	**Change since 2018 (%)**	**Proportion of Population (% of total population)**	**Proportion of Population (% of global total for vulnerable group)**
Rural Poor	11.6%	21%	49%
Urban Poor	12.6%	26%	29%
Lower-Middle Income	18.6%	46%	17%

In African cities, 215 million people are among the urban poor at highest risk from a lack of access to cooling, an increase of 8.0 million. These rapidly expanding cities in high-impact countries are seeing increasingly concentrated cooling access risks, with over 70 percent of the urban populations of 16 countries at high risk: Angola, Benin, Burkina Faso, Chad, Congo, Guinea-Bissau, Liberia, Malawi, Mali, Mozambique, Niger, Nigeria, South Sudan, Sudan, Togo and Uganda. The lower-middle income group, who will soon be able to purchase the most affordable air conditioner or refrigerator on the market, also continues to grow in Africa, increasing by 43 million people since 2018. Between these three groups, approximately 776 million people across the 31 high-impact countries in Africa, or 93 percent of their total population, face cooling access challenges.

ASIA AND THE MIDDLE EAST

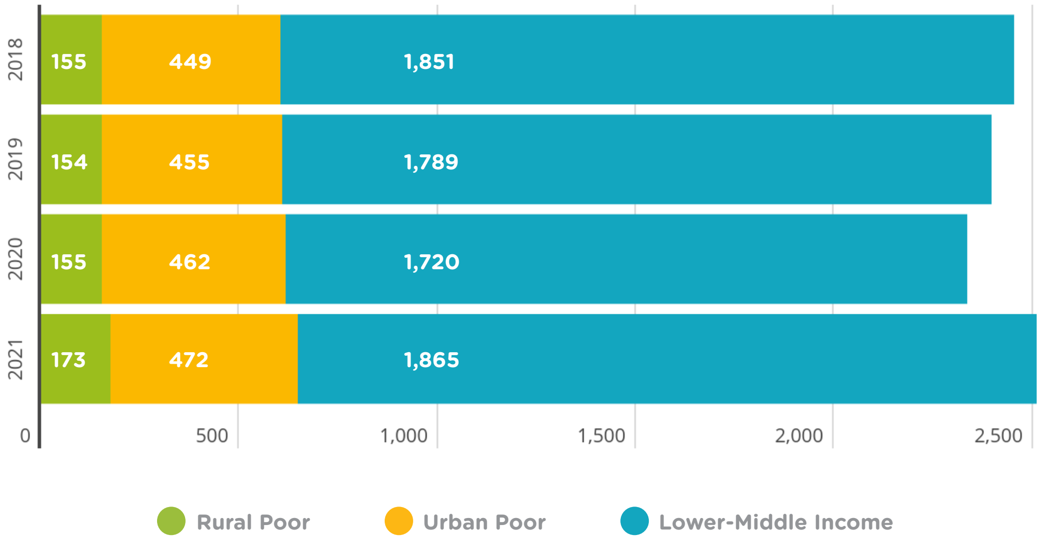
In Asia and the Middle East, significant growth in the rural poor and lower-middle income populations was observed in 2021, while the proportion of the urban poor population continued its more consistent growth. The number of people living in poor rural areas in high-impact countries in Asia and the Middle East increased by approximately 18 million people between 2020 and 2021. The most significant increases were observed in India and Bangladesh, where energy access gains have been moderated by persistent levels of extreme poverty that were exacerbated by the COVID-19 pandemic. In India, an increase of 13 percent, or 13.9 million rural poor at risk was observed, from 107.4 million in 2020 to 121.3 million in 2021. In Bangladesh, the number of rural poor increased by 2 million people or 12 percent, from 17.3 million to 19.3 million. In addition, Iran, Iraq, Pakistan and Sri Lanka also saw increases of 10 percent or higher.

Between 2020 and 2021, the number of urban poor at risk from a lack of access to cooling in Asia and the Middle East grew by 10 million people, from 462 to 472 million people across 16 high-impact countries for access to sustainable cooling. Urban populations at risk are most significant by volume in India, China, Indonesia, Bangladesh and Pakistan, though growth in this category in 2021 was relatively uniform, between 1 and 4 percent per country.

Overall, the populations at highest risk in Asia and the Middle East continue to grow, increasing 28 million to 645 million in 2021 from 617 million in 2020, itself an increase of 13 million from 604 million in 2018.

FIGURE 1.11

Trends in populations at risk across 16 high-impact countries in Asia and the Middle East (millions)



The cooling needs of Asia and the Middle East continue to grow, as shown by increases in the numbers of rural poor, (18.9 million), urban poor, (6 million), and the lower-middle income population, (164 million). The lower-middle income population had been decreasing in recent years, and this change in trend can be explained by the increase in the number of people who live on less than USD 10.01 per day as a direct result of the COVID-19 pandemic. In 2021, more than 75 percent of the total population of seven countries in Asia and the Middle East are at high or medium risk: Bangladesh, India, Indonesia, Myanmar, Pakistan, Timor-Leste and Yemen.

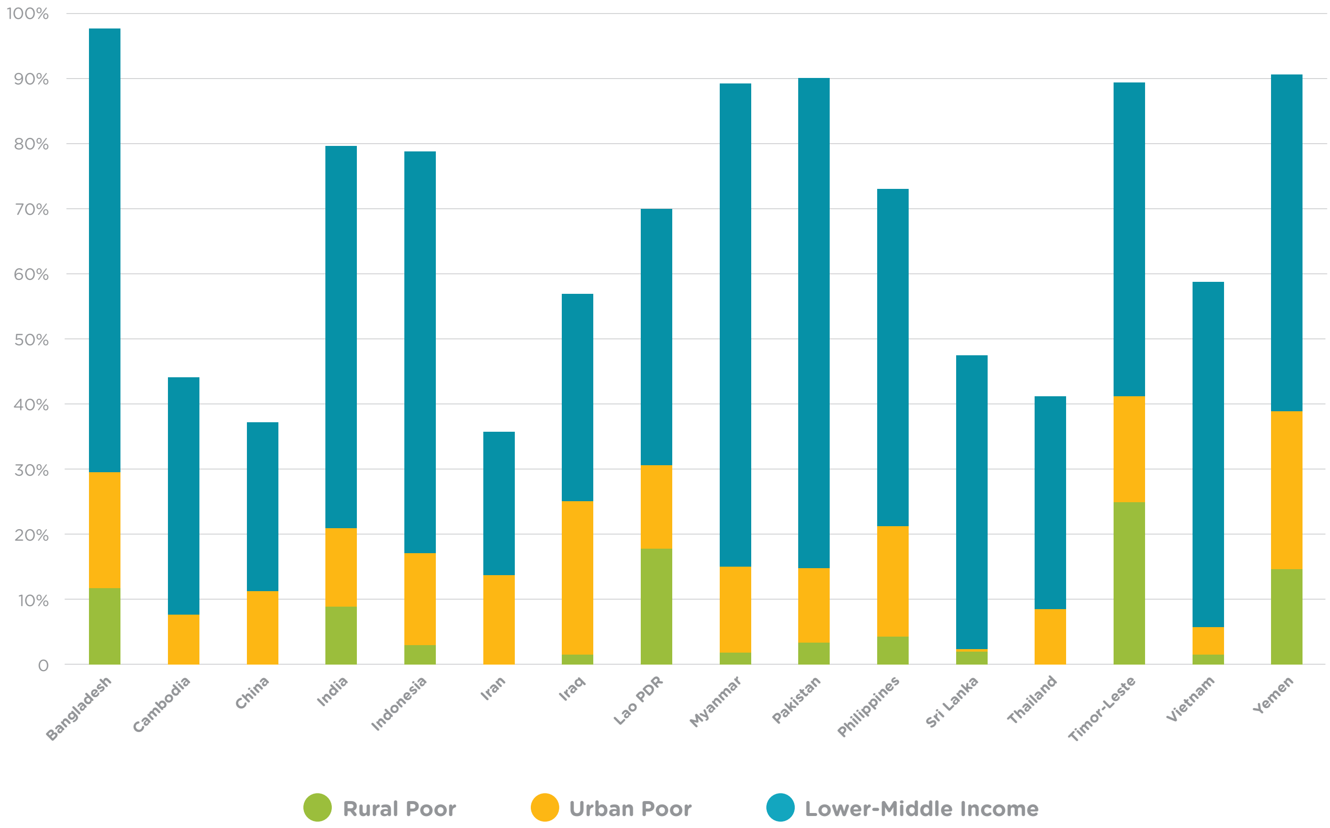
TABLE 1.6

Trends across 16 high-impact countries in Asia and the Middle East

High-impact countries in Asia and the Middle East			
Population at Risk	**Change since 2018 (%)**	**Proportion of Population (% of total population)**	**Proportion of Population (% of global total for vulnerable group)**
Rural Poor	11.5%	4%	49%
Urban Poor	12.9%	12%	64%
Lower-Middle Income	-4%	47%	80%

FIGURE 1.12

Share of rural poor, urban poor, and lower-middle income populations in select high-risk countries



LATIN AMERICA AND THE CARIBBEAN

In Latin America and the Caribbean, the number of those at highest risk in six countries high-impact countries for access to sustainable cooling grew slightly from 47.6 million people in 2020, to 48.8 million people in 2021. Of those at highest risk, the vast majority are the urban poor, which increased by 500,000 people compared to the previous year. Within the region, the most significant growth in the urban poor category was observed in Brazil (299,000 people) and Bolivia (55,000 people). Among the rural poor, each country experienced growth between 12 and 14 percent, increasing the total number of people living in rural settings who are at high risk of a lack of access to cooling by approximately 700,000.

Among the six high-impact countries identified in the region, Paraguay and the Dominican Republic saw the largest declines in their lower-middle income populations, by 12 and 5 percent respectively, though the size of the middle-income population in each country remained relatively stable. The Dominican Republic has been working with the United for Efficiency Initiative on a National Cooling Strategy that addresses many key issues related to access to affordable and sustainable cooling solutions for these two groups, including transforming the markets for refrigerators and making efficient air conditioners more affordable.

FIGURE 1.13

Trends in populations at risk across 6 high-impact countries in Latin America and the Caribbean (millions)

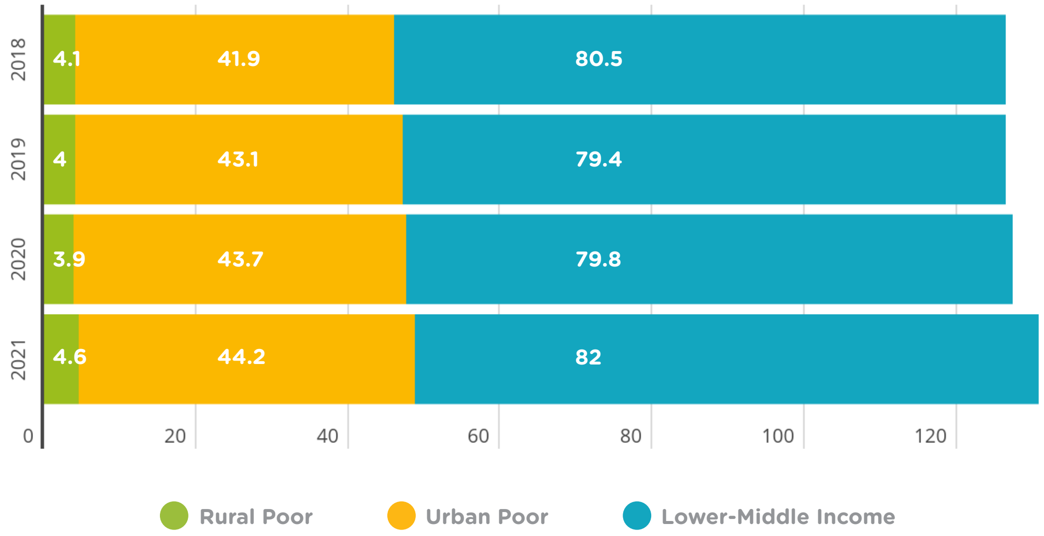


TABLE 1.7

Trends across 6 high-impact countries in Latin America and the Caribbean

High-impact countries in Latin America and the Caribbean			
Population at Risk	**Change since 2018 (%)**	**Proportion of Population (% of total population)**	**Proportion of Population (% of global total for vulnerable group)**
Rural Poor	11.5%	4%	49%
Urban Poor	12.9%	12%	64%
Lower-Middle Income	-4%	47%	80%

National Cooling Action Plans

Sustainable access to cooling is a complex issue touching on a wide range of components such as access to energy and energy-efficient appliances; community planning, affordability, and the income gap, and responding to climate adaptation challenges. In response to this challenge, in 2019 the UN Secretary-General (SG) António Guterres issued a call for countries to develop National Cooling Action Plans (NCAPs) that: "deliver efficient and sustainable cooling and bring essential life-preserving services like vaccines and safe food to all people."[11]

NCAPs are strategies or roadmaps that promote sustainable and smart cooling practices across a country. These include the identification of groups that are vulnerable due to a lack of cooling; promoting the adoption and increased stringency of MEPS, and identification of potential financial mechanisms for cooling.

NCAPs can also include measures that can that can support countries to achieve major international treaties such as the Kigali Amendment to the Montreal Protocol and the Paris Agreement. NCAPs also provide a framework for coordination and cooperation among stakeholders and government agencies recognizing the cross-cutting nature of sustainability interventions in the cooling sector.

Following the UN Secretary General's call to develop NCAPs, UNEP and UN ESCAP, through the Cool Coalition, began developing a holistic methodology for NCAPs that supports governments in meeting their Kigali Amendment obligations while supporting the achievement of the Sustainable Development Goals through access to sustainable cooling for all. The model NCAP framework also provides a platform for countries to integrate action on sustainable cooling into their NDC under the Paris Agreement on Climate Change.

The NCAP methodology by the Cool Coalition

The NCAP methodology was developed with the intention that it should be customized by countries to their national priorities and development goals as well as according to the local availability and quality of data, expertise and resources. The methodology provides countries with a guiding framework for the entire range of activities required — from the initial country assessment to the final development of the NCAP recommendations — to tackle cooling in a comprehensive and sustainable manner. An integrated and comprehensive approach is recommended by the NCAP methodology to guide the development process; this means first to reduce cooling demand by using non-energy intensive measures, such as better designs and materials, nature-based solutions, etc.; second to improve the efficiency of cooling equipment and appliances and optimize cooling operations and behaviours, such as, through good O&M practices, user adaptations etc. to ensure that cooling is delivered only where and when it is needed; third to shift to the use of low climate-impact technologies; and finally to protect the most vulnerable by ensuring access to cooling.

The NCAP methodology has two distinct elements: first, an overarching NCAP Development Methodology that lays out the sequence of activities involved, including guidelines, good practices, and available resources where applicable, and second, NCAP Data Assessment Frameworks, which give in-depth view into the data gathering and analysis.

❶ **NCAP Development Methodology:** consists of three sequential stages for NCAP development as outlined below. Each stage consists of steps with progressive activities (see Figure below).

- **STAGE I: CONTEXTUAL ASSESSMENT AND PLANNING** – This foundational stage helps inform priorities of the NCAP specific to the country and guide the overall planning process. The key stakeholders and governance are also established.

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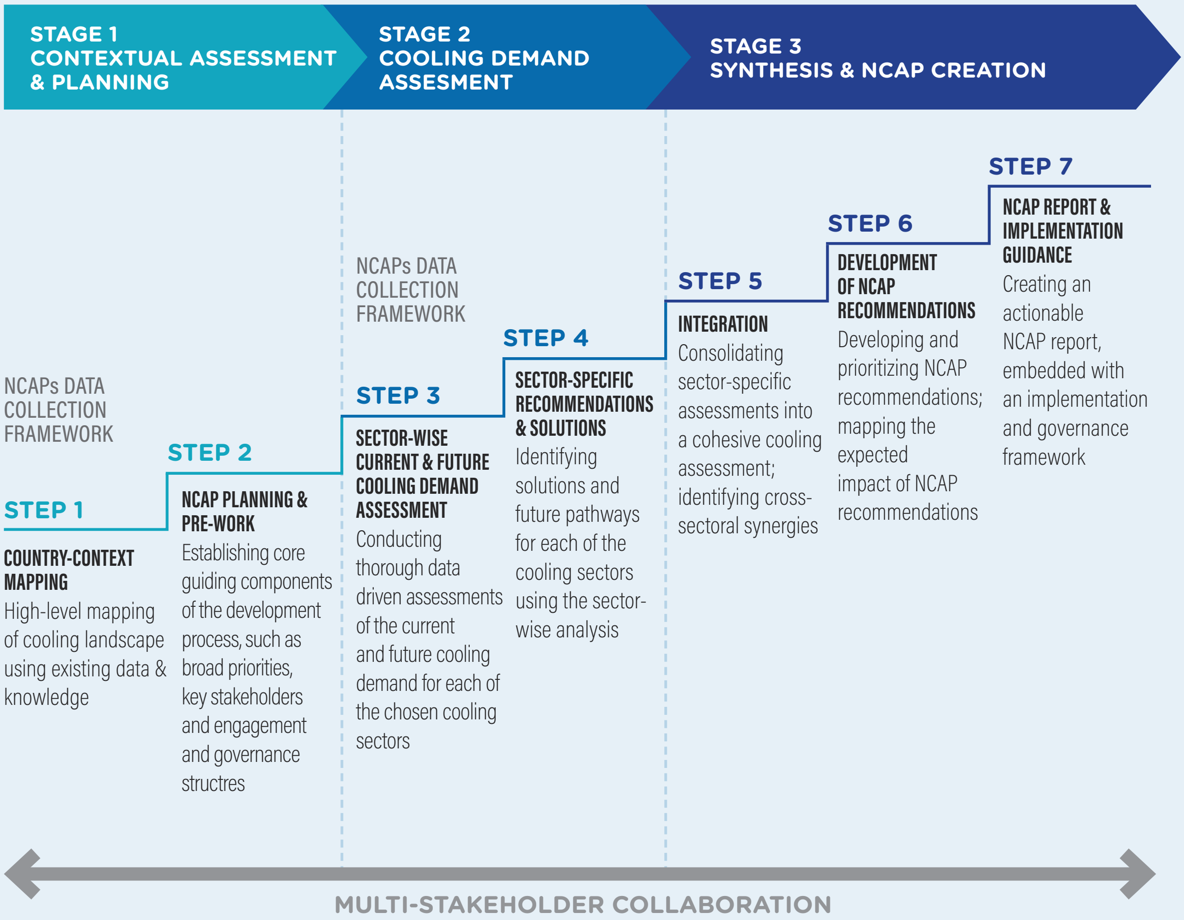
[11] Stausholm, Tine, UN Secretary General Wants National Cooling Action Plans, R477, September 18, 2019. Link

- **STAGE II: COOLING DEMAND ASSESSMENT** – Assessment of the current and future cooling demand (and impacts) that will inform sector-specific priorities, including recommended policy intervention. The methodology includes a Data Assessment Framework for each sector to provide guidance as detailed below.
- **STAGE III: SYNTHESIS AND NCAP CREATION** – Consolidating sector-specific assessments, and identifying cross-sectoral synergies, establishing country recommendations with broad buy-in. Guidance for the NCAP document creation is provided to ensure that the NCAP becomes an actionable document and has the 'ownership' and governance structure in place to guide and monitor implementation actions.



STEP 1
COUNTRY-CONTEXT MAPPING
High-level mapping of cooling landscape using existing data & knowledge

STEP 2
NCAP PLANNING & PRE-WORK
Establishing core guiding components of the development process, such as broad priorities, key stakeholders and engagement and governance structres

STEP 3
SECTOR-WISE CURRENT & FUTURE COOLING DEMAND ASSESSMENT
Conducting thorough data driven assessments of the current and future cooling demand for each of the chosen cooling sectors

STEP 4
SECTOR-SPECIFIC RECOMMENDATIONS & SOLUTIONS
Identifying solutions and future pathways for each of the cooling sectors using the sector-wise analysis

STEP 5
INTEGRATION
Consolidating sector-specific assessments into a cohesive cooling assessment; identifying cross-sectoral synergies

STEP 6
DEVELOPMENT OF NCAP RECOMMENDATIONS
Developing and prioritizing NCAP recommendations; mapping the expected impact of NCAP recommendations

STEP 7
NCAP REPORT & IMPLEMENTATION GUIDANCE
Creating an actionable NCAP report, embedded with an implementation and governance framework

② **NCAP Data Assessment Frameworks:** The methodology includes a toolkit of Data Assessment Frameworks, one for each of the cooling sectors, to provide directional rather than prescriptive guidance on data analysis, identifying the key data inputs that can be used to estimate current and future cooling demand and its impacts, and different pathways that the countries could adopt to go about the calculations. (Sections include: Space cooling in buildings; Food cold chains; Healthcare cold chains; Mobile air-conditioning; and Industrial process cooling). The framework also incorporates relevant parameters including from the SEforALL Cooling For All Needs Assessment, SEforALL's upcoming solutions tool, and work from the University of Birmingham, to help ensure that the NCAP methodology promotes access to cooling while avoiding locking in emissions through low-efficiency or high-GWP mechanical cooling.

Pilot activities of NCAP methodology: Cambodia and Indonesia are currently piloting the NCAP methodology to develop NCAPs. Some key lessons learned from the NCAPs completed thus far, and that are being reinforced during the process with Cambodia and Indonesia are:

- It is important to have one nodal government entity that takes 'ownership' of driving the NCAP development and ensuring inter-ministerial coordination and engagement. Often the nodal entity has been the National Ozone Unit (NOU). In Cambodia, the NOU has partnered with the Climate Change Department within the Ministry of Environment. In Indonesia, the Ministry of Energy and Natural Resources is taking the lead.
- Complimentary capacity building and training must be delivered to ensure that the level and different types of expertise required by the country NCAP team are made available. (A training module is under preparation by the Cool Coalition and the core NCAP methodology team.)
- Given the cross-cutting and diverse areas of cooling, establishing and engaging a multi-stakeholder working group through the NCAP development process is important for data collection and ownership/buy in, ensures integrative solutions and synergies and enables effective implementation.
- When it comes to data, prioritization of the essential data elements is key – too much detail can be counterproductive causing confusion and even resistance among stakeholders.

The availability of data and analysis is a crucial issue that will impact a country's ability to fully utilize the model NCAP methodology and implement a needs-based approach. To support effective implementation SEforALL aims to support partner organizations and countries to collect and analyze data and make relevant policy recommendations to ensure that core elements of access to cooling are included in an NCAP. Such efforts are encouraged to be open source and affordable to allow developing countries to update and reconcile if needed to tailor local conditions. At a more granular level, geospatial analysis allows national and sub-national governments to be aware of the specific cooling needs in a country and might provide best measures to address them. Without an accurate assessment of overall cooling needs, informed by analysis on how to mitigate the vulnerabilities of those at highest risk, cooling demand and cooling needs cannot be quantified accurately.

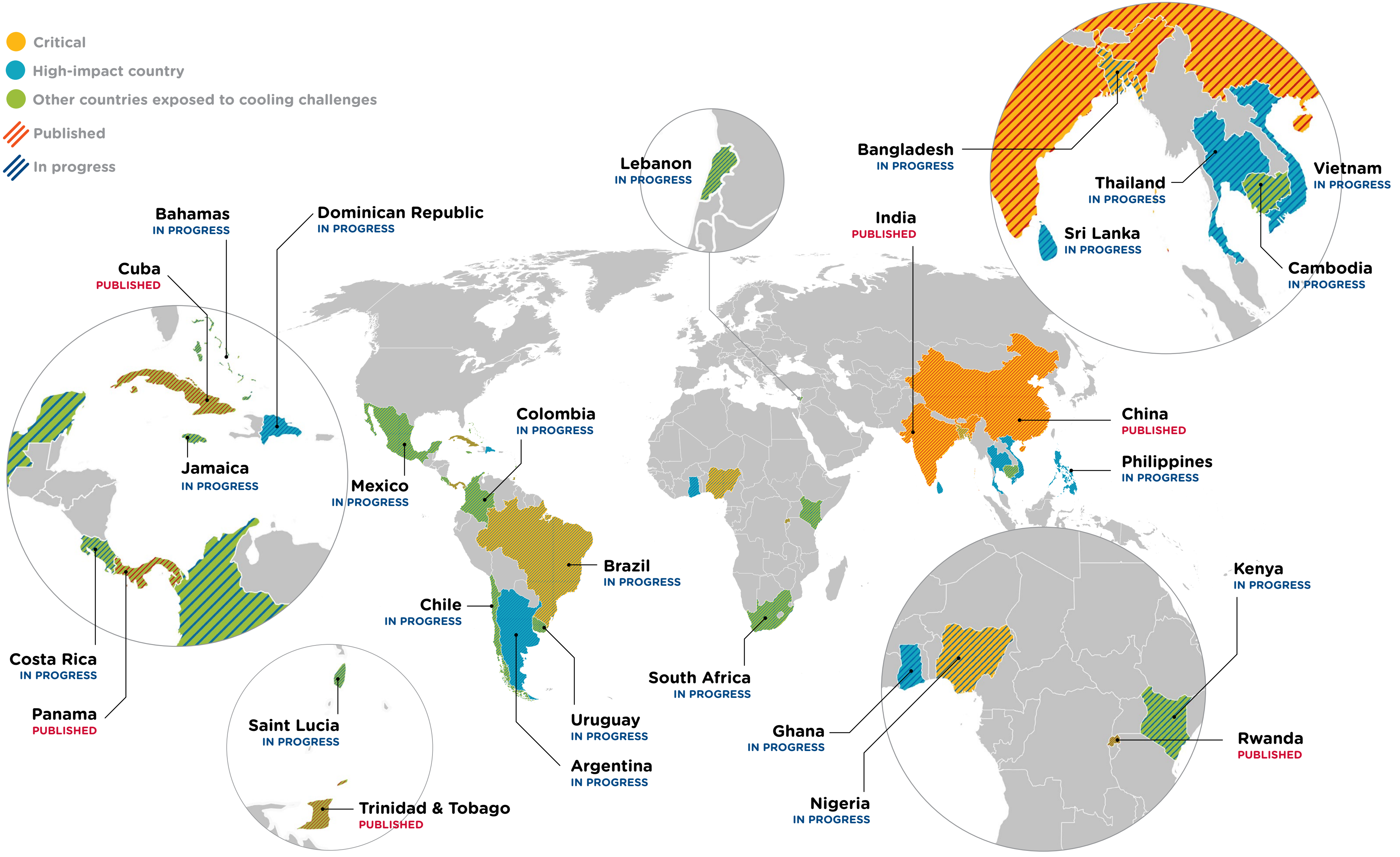
Overview of progress by countries

More countries are recognizing the risks caused by a lack of cooling and are in the process of establishing these plans. NCAPs have been published by Cuba, China, India, Panama, Rwanda and Trinidad and Tobago. In 2020 the COVID-19 pandemic caused a significant delay in the publication of other NCAPs previously in development. Currently, over 20 countries are developing NCAPs.

The map below shows an overview of countries currently working on their NCAPs, and where possible, the prevalence of SEforALL's identified groups of vulnerable populations in the country. As can be seen, half of the countries with NCAPS underway or published are part of SEforALL's list of high-impact countries, including Bangladesh, Brazil, China, India and Nigeria, which have been identified as critical countries due to their large number of vulnerable populations at high risk. The other half of the countries in the map are considered to be at a lower risk, given that many of the risk indicators such as population density or high temperatures are missing or very localized. Developing NCAPs for this set of countries would present an opportunity to target those regional needs.

FIGURE 1.14

Map of countries working on NCAPs and their risk categories



CHAPTER 2

Sub-national cooling risks

***Chilling Prospects 2020* introduced a methodology to assess the global populations that are at risk due to lack of cooling access at sub-national level, recognizing that cooling risks vary within large countries due to differences in population, climate and socioeconomic conditions. Sub-national level data can help identify regions of a country that face greater risks than other regions.**

The objective of identifying cooling risks at sub-national level is to inform and encourage policymakers to address access to cooling for populations at the highest risk. Undertaking such an exercise reduces the risk of overlooking factors that can be detrimental to people's health, productivity and quality of life. By conducting a sub-national risk assessment due to lack of access to cooling, localized plans can be developed to improve access to cooling and limited local resources can be prioritized. Sub-national access to cooling issues identified can then be accounted for in national cooling plans, especially in countries that have large economic disparities or where sub-national governments enjoy greater implementation effectiveness.

The methodology introduced in *Chilling Prospects 2020* formulated a case study for India and evaluated sub-national data for average maximum temperatures, cooling degree days (CDDs), income levels and cooling appliance ownership for determining risks[1] for populations living in different states. The India case study identified 14 states to be at high risk, nine states at medium risk and seven states at low risk. It showed that risk levels for a country with large geographical and socioeconomic diversity can be attributed to local conditions. The India case study also found that certain indicators for assessing cooling risk may not accurately reflect the comparative risks between different geographic locations. For instance, CDDs alone may not be an effective indicator; Tamil Nadu had 3,045 CDDs making it on average hotter than Andhra Pradesh that had 1,527 CDDs, but as the latter reached higher peak temperatures of 45°C, its population living in higher temperatures without access to cooling is at higher risk. Similarly, socioeconomic or other local conditions can also change the risk levels at the sub-national level for those without access to cooling.

Methodology to assess sub-national access to cooling risks

This report examines a more comprehensive methodology that evaluates key factors of the risks due to lack of access to cooling with the use of geo-spatial data and tools to more easily identify regions that experience persistent exposure to high temperatures. This level of information is helpful to identify specific pockets within sub-national regions, for example a town or district that are home to populations that could be at risk. Geographic information system (GIS) tools are proving to be efficient in identifying sub-national levels of access to cooling and provide an added advantage of rendering information, such as average temperature or average peak temperatures,[2] to visually identify zones that need additional attention or deeper analysis. GIS tools can also be used to portray economic and infrastructure-related data to better gauge the risks associated with cooling access gaps and opportunities to address them. However, the data for such analysis, particularly socioeconomic and infrastructure information, are very limited and typically not open source. *Chilling Prospects 2021* has put special emphasis on obtaining, utilizing, and analyzing open-source and internationally recognized data, so that the methodology can be easily replicated, including by countries and governments without access to extensive funding and/or expertise for the GIS tools. The resources used in these analyses are recognized globally as being derived from various projects funded by the UN, the World Bank and similar organizations. They include climate data,[3] population data and administrative boundaries[4]. Local data were used, where possible, to analyze the cooling access risks at sub-national level (Table 2.1).

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[1] High Risk: Per state capita Income less than USD 1.9/day, average maximum temperature above 35°C and CDDs above 1,900; Medium Risk: per state capita income between USD 1.9 and USD 5.5/day, average maximum temperature between 25 and 35°C; and CDDs between 1,000 and 1,900; Low Risk: per state capita income above USD 5.5/day, average maximum temperature below 25°C and CDDs below 1,000.

[2] The temperature data range from January 2014 to December 2018.

[3] WorldClim - WorldPop. An innovation of World Bank Group. Link

[4] The Humanitarian Data Exchange. UN-OCHA. Link

TABLE 2.1

Indicators for assessing cooling risks at sub-national level

GIS data	Weather data	Economic data	Infrastructure data
Geographic boundaries of states/provinces and other smaller administrative zones	Cooling degree days (CDDs)	Average income per capita per day	Electricity access as per national definition Electricity access quality and reliability
Average temperature or average peak temperature ranges over a time for a given geographical area	Temperatures and relative humidity for specific weather stations	Cooling appliance ownership (e.g., fans, air conditioners, evaporative coolers and refrigerators)	Population living in urban and rural areas
Population concentration in rural and urban areas	Heatwave occurrences/ heatwave- related health incidents	National poverty rate	Access to cold chain for agriculture and healthcare

Accounting for the limited scope and time available for analysis of quantitative data across the different indicators, the methodology for *Chilling Prospects 2021* uses GIS information specifically on temperature, visual rendering, and identification of administrative zones. Layering GIS data allows analysts to visually identify the locations that are exposed to high temperatures (above 35°C). If data are available then additional information, such as population, incomes, electricity access and electricity grid connections, can be layered on other GIS data to assess the risks associated with lack of cooling. Furthermore, information on passive cooling solutions that are relevant to local contexts such as building designs and nature-based solutions can be helpful for deeper evaluations for cooling access gaps. The 2021 sub-national cooling risk analysis uses a hybrid method, where the initial risk screening was carried out through a GIS tool[5] and subsequent risk assessment and regional cooling access disparities were analyzed with quantitative data (Figure 2.1).[6]

The key elements used in these analyses include temperature, GIS data, population density data, population data (quantitative national statistics), poverty data (quantitative national statistics or data adjusted to World Bank definitions), and tertiary data including for electricity access and appliance ownership where available. This model investigates cooling access gaps at sub-national levels mostly from a thermal comfort perspective with a limited assessment of food and nutrition security and healthcare and medical services. Further collection of cooling needs and sector specific data, as identified in Sustainable Energy for All's (SEforALL) Cooling for All Needs Assessment, is needed for sub-national and national cooling assessments.

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[5] Q-GIS software was used, which is a free and open-source cross-platform GIS software application that supports viewing, editing, and analysis of geospatial data.

[6] GIS data refer to geo-spatial data that could be used with a GIS tool. Non-GIS data refer to quantitative and statistical data.

FIGURE 2.1

Methodology to assess sub-national access to cooling risks

Selection of high-risk countries
(based on *Chilling Prospects 2020* data)

↓

Determination of hottest months of the year
(based on non-GIS data)

↓

Selecting regions (states/districts/municipalities) at risk based on average maximum temperature
(based on GIS data)

↓

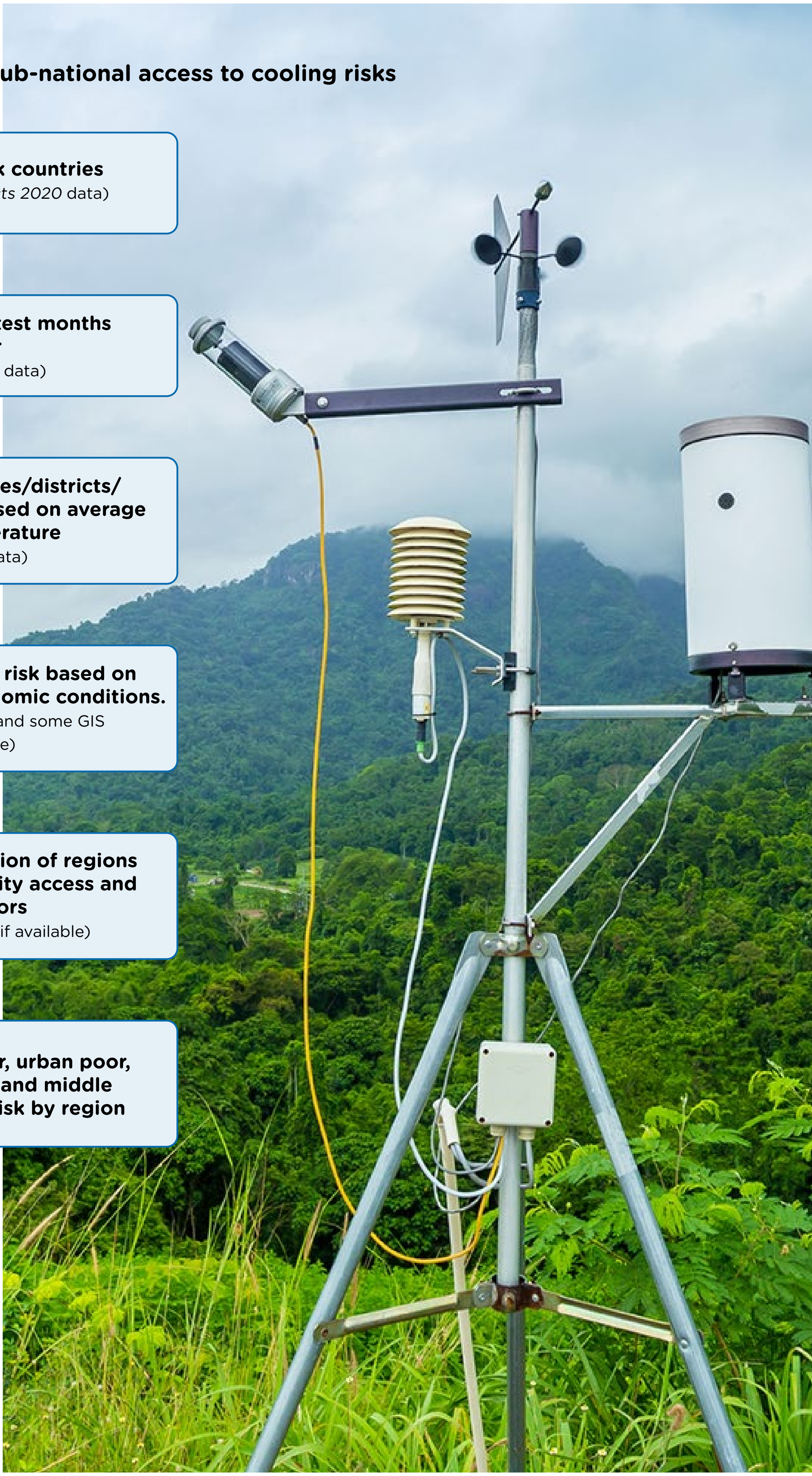
Categorizing regions at risk based on population and socio-economic conditions.
(based on non-GIS data and some GIS data if available)

↓

Refining the categorization of regions at risk based on electricity access and other indicators
(based on non-GIS data if available)

↓

Assessing the rural poor, urban poor, lower-middle income and middle income population at risk by region



Sub-national, location-specific analysis can identify populations that face cooling access challenges due to local weather, socio-economic and infrastructure conditions that may not be apparent due to higher incomes and reliable electrification at the country level. Sub-national cooling risk assessments are important to identify and close cooling access gaps and ensure that no one is left behind.

Case Studies

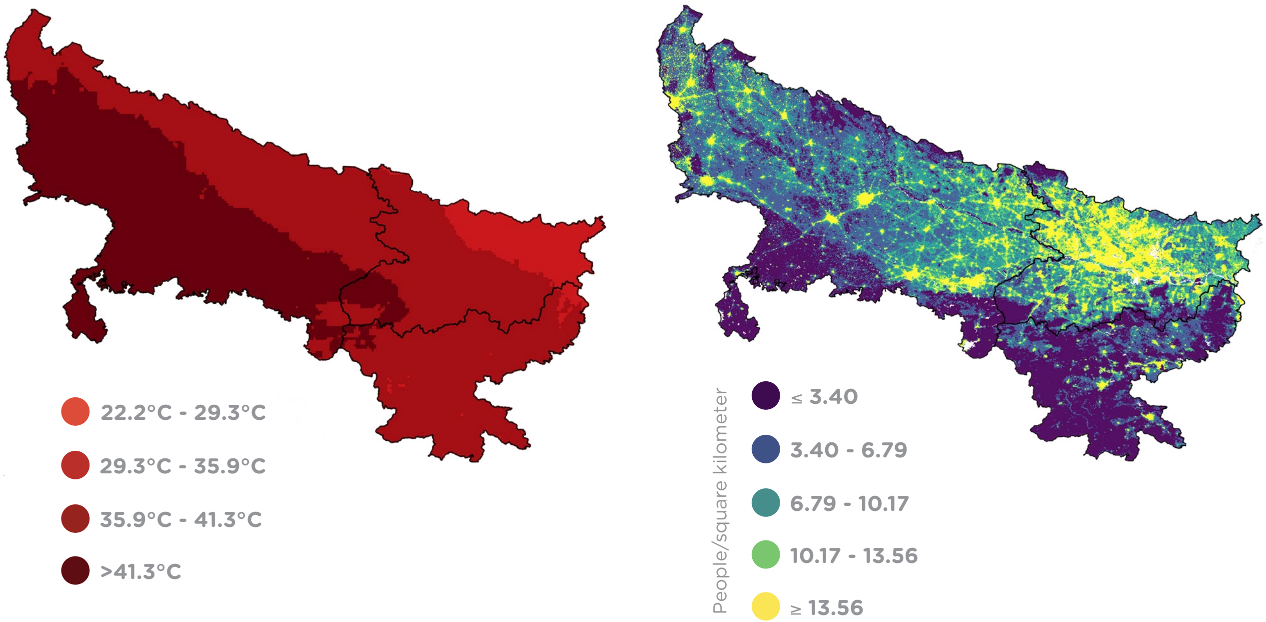
INDIA – Examining populations with lack of access to cooling at district level in Indian states

In *Chilling Prospects 2020*, 14 Indian states were assessed as high risk, with the three states at highest risk being Bihar, Jharkhand and Uttar Pradesh due to a combination of high peak temperature exposure, high CDDs and low-income levels, in addition to the rural/urban divide, electricity access rates, and appliance ownership characteristics. This case study used a hybrid approach to further identify the local districts that were at the highest risk within the three highest risk states. In terms of population, Uttar Pradesh is the largest state in the country with 238 million people, Bihar with a population of 125 million people, and Jharkhand has 38 million people.[7]

There are significant areas of Uttar Pradesh that were exposed to very high average maximum temperatures (above 40°C) from January 2014 to December 2018, and smaller regions of both Bihar and Jharkhand experienced similar temperatures during summers (Figure 2.2). GIS population data for the three states show that population density is highest in Bihar followed by Uttar Pradesh and Jharkhand. The population density and temperature data illustrate that Uttar Pradesh has the most densely populated[8] districts exposed to temperatures above 40°C.

FIGURE 2.2

Maps of Uttar Pradesh, Bihar and Jharkhand showing (LEFT) **average maximum temperatures and** (RIGHT) **population density**



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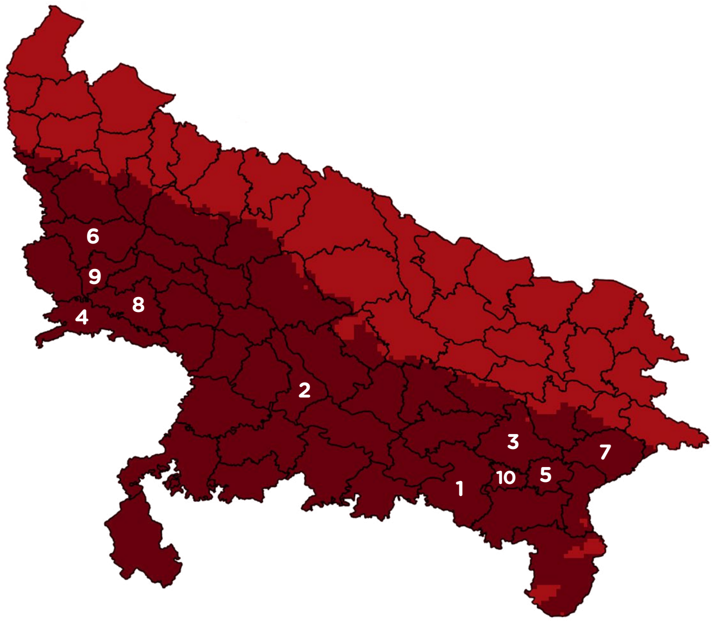
[7] Population data from http://statisticstimes.com/demographics/population-of-indian-states.php

[8] Density of population in a administrative zone exposed to high temperatures indicates how many people could be potentially at risk if they do not have access to cooling.

The assessment of local districts would allow state policymakers to identify district-level actions for sustainable cooling solutions. By layering the local districts over temperature data, localities that are at highest exposure to heat can be identified. There are 10 districts[9] in Uttar Pradesh that have high temperature exposure risk, four districts[10] in Bihar and two districts[11] in Jharkhand (Table 2.2 and Figure 2.3). Comparing the income of these three states (USD per capita per day in 2018–2019), Jharkhand has an average income of USD 3.04 per day, Uttar Pradesh has an average of USD 2.66 per day and Bihar has an average of USD 1.75 per day.[12] As of 31 March 2019, the Indian government reported[13] 100 percent electrification of households including those of Bihar, Jharkhand and Uttar Pradesh. However, the national definition of electricity access in India is that households meet Tier 1 of the Multi-Tier Framework (MTF) for Measuring Energy Access. There is a need to increase the reliability and quality of electricity particularly in the rural areas of these states to improve access to cooling. For instance, a study has shown that Tier 2 and Tier 3 electricity supply for rural households of the three states is only 19 percent in Bihar, 16 percent in Uttar Pradesh and 8 percent in Jharkhand.[14] Although these data are difficult to obtain at a district level, more information on district-level electrification access and its quality and other specific socioeconomic indicators would be helpful in categorizing the districts in terms of risks to lack of cooling.

FIGURE 2.3

Population of high-risk districts in Uttar Pradesh (2019)



Uttar Pradesh	Population (2019)
① Allahabad	6,718,407
② Kanpur Nagar	5,169,097
③ Jaunpur	5,070,862
④ Agra	4,985,779
⑤ Varanasi	4,148,622
⑥ Aligarh	4,145,291
⑦ Ghazipur	4,084,790
⑧ Firozabad	2,818,698
⑨ Mahamaya Nagar/Hathras	1,924,590
⑩ Sant Ravi Das Nagar	1,780,716

● 22.2°C - 29.3°C ● 29.3°C - 35.9°C ● 35.9°C - 41.3°C ● >41.3°C

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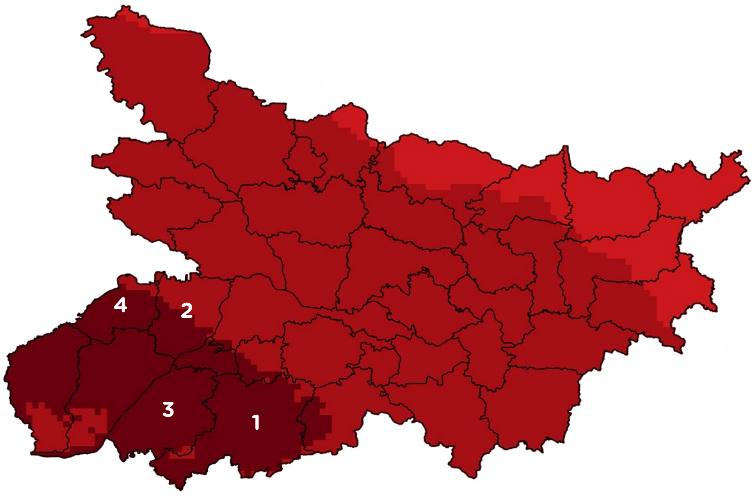
[9] Agra, Aligarh, Allahabad, Firozabad, Ghazipur, Jaunpur, Kanpur Nagar, Mahamaya Nagar/Hathras, Sant Ravi Das Nagar and Varanasi.
[10] Buxar, Bhojpur, Aurangabad, and Gaya.
[11] Garwha and Palamu.
[12] At an average exchange rate and state GDP date for 2018–19.
[13] Saubhagya Dashboard, Government of India. Link
[14] Access to clean cooking energy and electricity, survey of states 2018, CEEW.

FIGURE 2.4

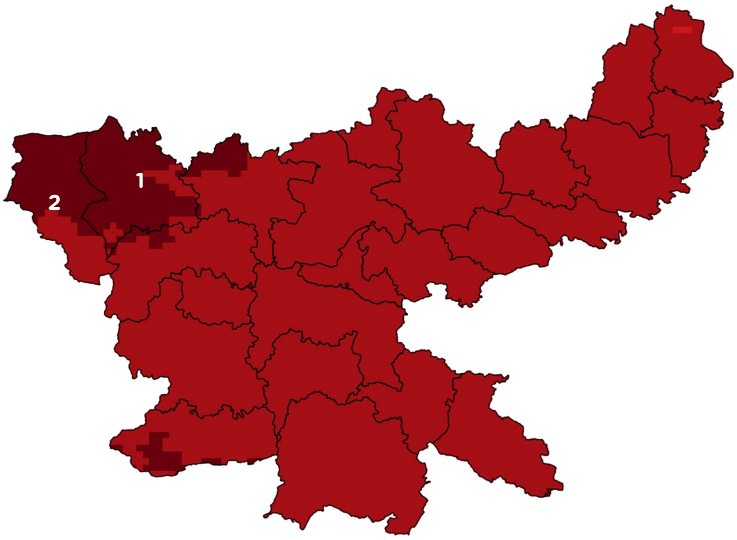
Population of high-risk districts in Bihar (2019)



Bihar	Population (2019)
① Gaya	4,956,113
② Bhojpur	3,079,254
③ Aurangabad	2,866,702
④ Buxar	1,925,773

FIGURE 2.5

Population of high-risk districts in Jharkhand (2019)



Jharkhand	Population (2019)
① Palamu	2,165,456
② Garhwa	1,476,610

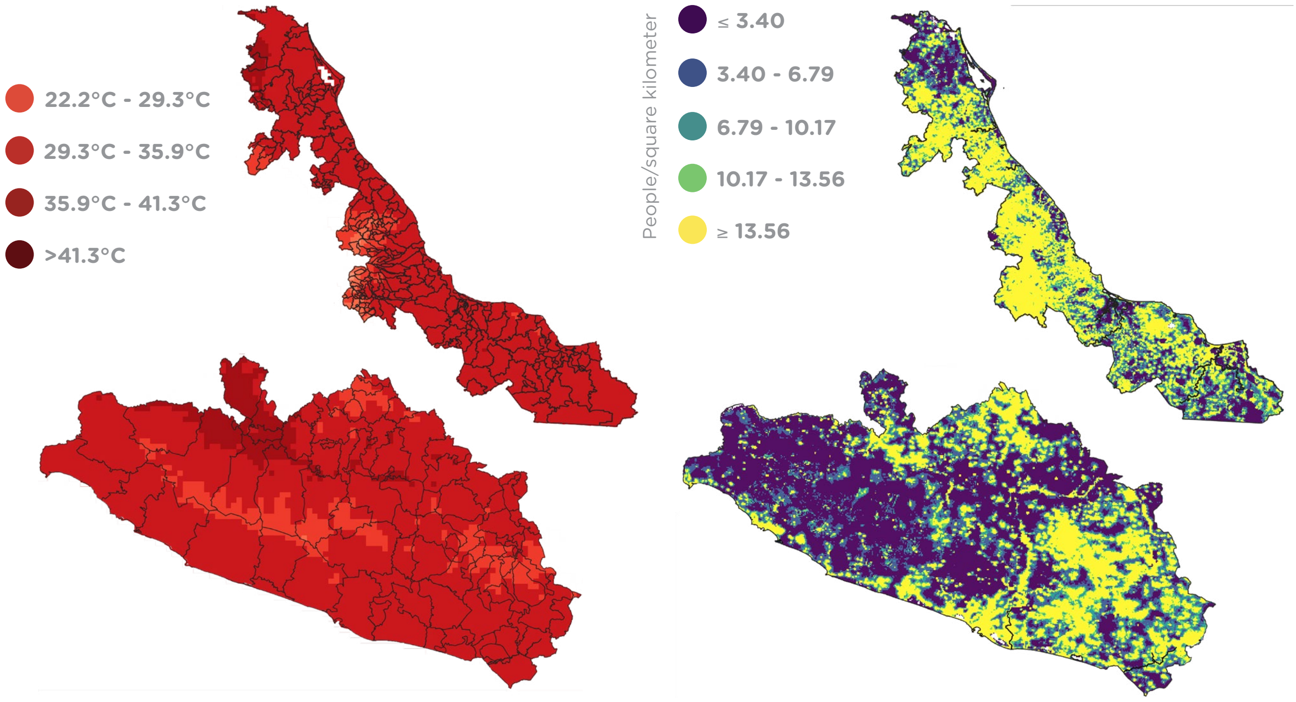
Mexico – Understanding the sub-national cooling risks of a country not considered high-impact

Mexico has not been included as one of the 54 *Chilling Prospects* high-impact countries due to its relatively mild average temperatures and the country's relatively high performance in terms of electricity access and poverty alleviation. However, there are specific regions that experience very high temperatures. Although the population that resides in these locations is a small proportion of the national population, this case study looks more deeply at access to cooling within the whole of Mexico.

This analysis first examines monthly average maximum temperatures over a period of five years (2014 to 2018) using GIS data. The list of states was reduced using income data by sub-national region, by state (*estado*) and by municipality (*municipio*). Guerrero and Veracruz have higher maximum average temperatures during the summer months[15] (May, June and July) and lower average income per capita than other states in Mexico. The municipalities of these states were assessed by electrification rates[16](%) and income-level data as an indicator for access to cooling to identify regions at highest risks.

FIGURE 2.6

Maps of Guerrero and Veracruz showing (LEFT) **average maximum temperatures in July 2016 and** (RIGHT) **population density**



Parts of both Guerrero and Veracruz witness temperatures of over 40°C while most areas are over 35°C and some higher elevation regions experience temperatures ranging from 28°C to 35°C (Figure 2.7, Figure 2.8). The population of Veracruz (8,062,579) is more than twice that of Guerrero (3,540,685) and it has a higher population density ((Figure 2.6).[17] Electricity access is very good across Mexico, however there are some regions that have less than 99 percent access including three municipalities in Guerrero and three in Veracruz (Table 2.3).

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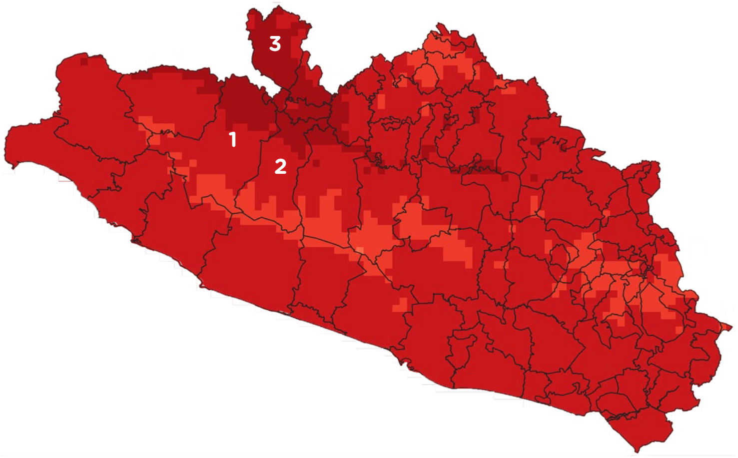
[15] Annual Climate data for Mexico. Link

[16] Electricity access in Mexico is defined as the private dwellings that have electric power as per Conformación de la base de Datos. Instituto Nacional de Estadística y Geografía (INEGI). 2020. Link

[17] Year 2020, https://www.inegi.org.mx/default.html

FIGURE 2.7

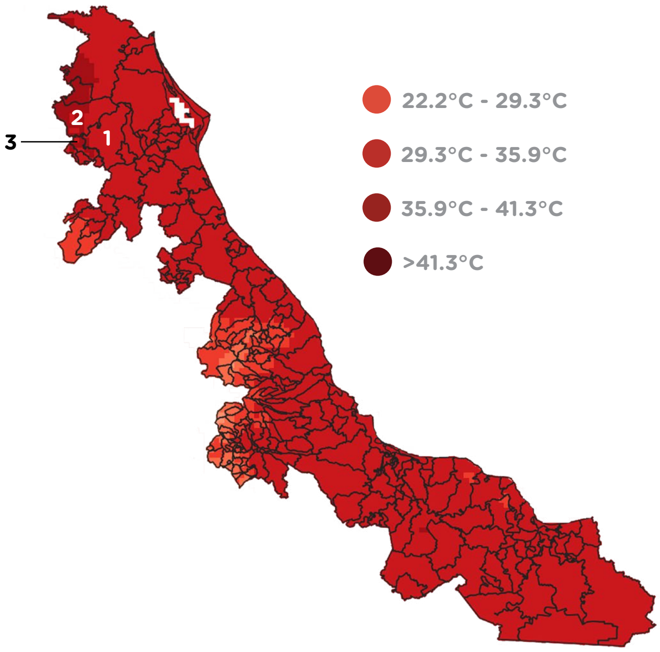
Map of average maximum temperature by district in Guerrero



Guerrero	Population (2020)
① Coyuca de Catalan	38,554
② Ajuchitlan del Progresso	37,655
③ Cutzamala de Pinzon	20,537

FIGURE 2.8

Map of average maximum temperature by district in Veracruz



Veracruz	Population (2020)
① Tantoyuca	99,959
② Tempoal	34,408
③ Platon Sanchez	18,053

The average income of the states of Guerrero and Veracruz is between UDS 7 and 8 per day[18] which puts them in a lower middle-income group according to international standards. However, according to national standards, the extreme poverty rate[19] in different zones of these high-risk regions ranges from 19 to 38 percent of the population.[20] The lack of location-specific income data and electrification tier data makes it difficult to further assess the type of access to cooling that these populations may have in terms of food security and healthcare. But what is clear is that while Mexico as a whole does not have very high risks associated with lack of access to cooling, it does have regions with populations that face such challenges due to local weather, socioeconomic and infrastructure conditions.

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[18] OECD Statistics. Link

[19] As per the multidimensional poverty measurement in Mexico. Link

[20] CONEVAL. Medición de la Pobreza (Poverty Measurement). Link

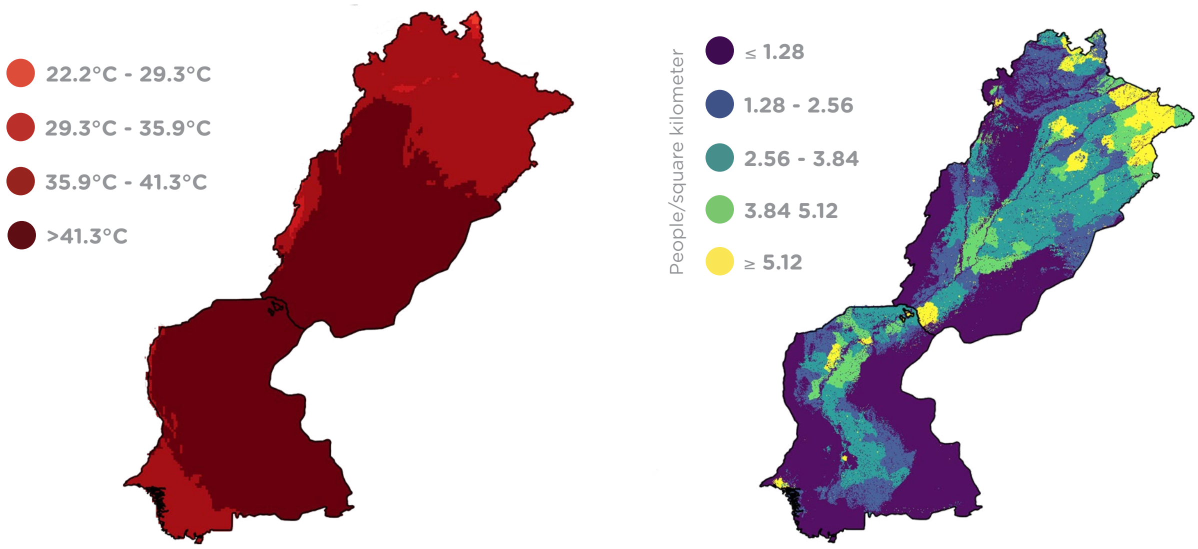
Pakistan – Assessing sub-national levels at risk due to lack of access to cooling

Pakistan has a significant population of approximately 216 million[21] and temperatures that remain roughly the same year-round. Northern parts of the country experience arid heat, while the southern regions witness a more humid heat because of their proximity to the Arabian Sea and the Gulf of Oman. Pakistan is comprised of four provinces – Punjab, Khyber Pakhtunkhwa, Sindh and Balochistan, and three territories – Islamabad Capital Territory, Gilgit-Baltistan and Azad Kashmir.

The average maximum temperatures across Pakistan in May, June and July between 2014 to 2018 showed that among the four provinces and three territories, Punjab and Sindh were exposed to the highest temperatures. The majority of regions of both provinces experienced temperatures greater than 40°C, putting the population in these areas at an extremely high risk of a lack of access to cooling. The two provinces have similar income levels, Punjab and Sindh have an overall average per capita income of USD 3.3 and USD 3.2[22] respectively, and the average income in urban areas is about 2.5 times more than the rural areas in Sindh and 1.5 times in Punjab. On top of the geo-spatial data, other quantitative indicators (based on non-GIS data) of the respective districts in these provinces were assessed, including population (quantity), the average per capita income levels, average yearly CDDs,[23] and electricity access less than 90 percent.[24] Two districts from each of the two provinces were identified as high risk (Figure 2.10 and Figure 2.11).

FIGURE 2.9

Maps of Pakistan showing (LEFT) **average maximum temperatures and** (RIGHT) **population**



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[21] World Bank. Link

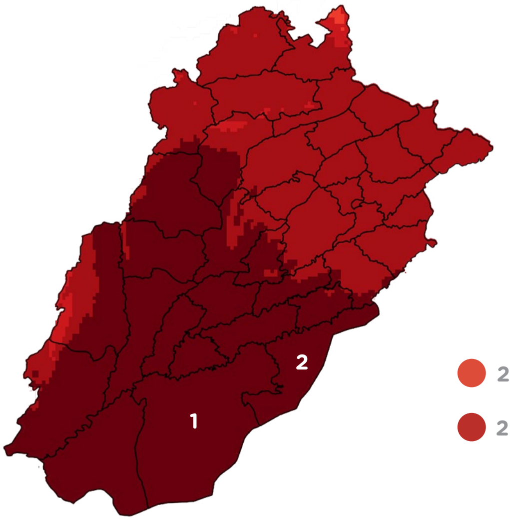
[22] Household Integrated Economic Survey (HIES) 2018-19. USD to PKR conversion for 2019 average exchange rates. Link

[23] Above base level 21°C.

[24] As per national statistics 2014–2015. Link

FIGURE 2.10

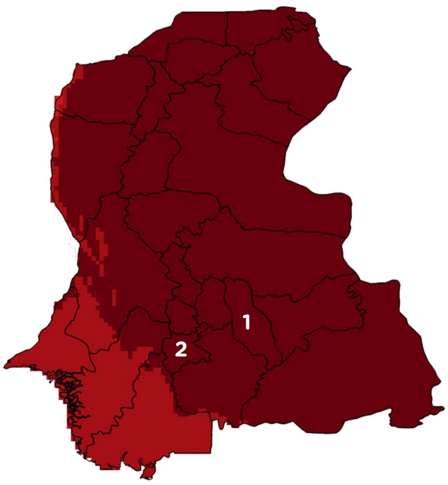
Map of average maximum temperatures by district in Punjab



Punjab	Population
① Bahawalpur	3,668,106
② Bahawalnagar	2,981,919

FIGURE 2.11

Map of average maximum temperatures by district in Sindh



Sindh	Population
① Mirpur Khas	1,505,876
② Tando Muhammed Khan	677,228

The average income of Punjab and Sindh is under USD 3.5 per day[25] which puts their populations in the lower middle-income group risk according to international standards. However, according to national standards, all high-risk regions have a greater percentage of rural populations with lower income levels that put them at even higher risk of lack of cooling access. Electrification rates in these districts vary from 79.5 percent to 89.7 percent[26] with those without access to electricity further at risk. The lack of location-specific data makes it difficult to further assess the type of lack of access that these populations may have in terms of thermal comfort, food and healthcare. However, it is evident from the case of Pakistan that in a country that already has high risks from lack of access to cooling, there are certain regions where these risks are further amplified due to local climatic and socioeconomic conditions.

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[25] Household Integrated Economic Survey (HIES) 2018–19. Link

[26] Pakistan Social and Living Standards Measurement Survey (2014–15). Link

Leaving No One Behind: Populations at Risk in Countries Not Considered High-impact

The *Chilling Prospects* series tracks access to cooling risks across 54 countries considered high-impact due to their geographical exposure to high temperatures and vulnerability to high electrification rates and harsh economic conditions. While these 54 countries, and in particular the Critical 9,[27] should remain a priority for access to cooling interventions, this does not preclude the fact that middle-income and developed economies are likely to have populations who face cooling access risks due to localized vulnerabilities related to heat stress and socioeconomic factors such as poverty, homelessness and urbanization. Given their potential risk of poverty, these populations are likely to have lower mobility, fewer and less reliable public services, and a smaller impact on policymaking processes, all factors that affect their ability to access sustainable cooling solutions.

Chilling Prospects 2021 has identified 22 countries where cooling access risks are likely to exist for smaller pockets of the population, pinpointing an additional 147 million people that are likely at risk. This includes over 5.8 million people living in poor rural settings and 25.1 million people living in poor urban settings who are at high risk due to a lack of access to cooling. It also includes 77.0 million people among the lower-middle income group, and a further 64.6 million among the middle income that are at risk of purchasing inefficient and non climate-friendly cooling appliances.

TABLE 2.2

Populations at risk in 22 additional countries beyond the 54 high-impact countries

Risk Category	Population at Risk
Rural Poor	5,822,625
Urban Poor	25,073,789
Lower-middle Income	77,041,734
Middle Income	64,564,370
Total in Non High-Impact Countries at Risk	**172,502,519**

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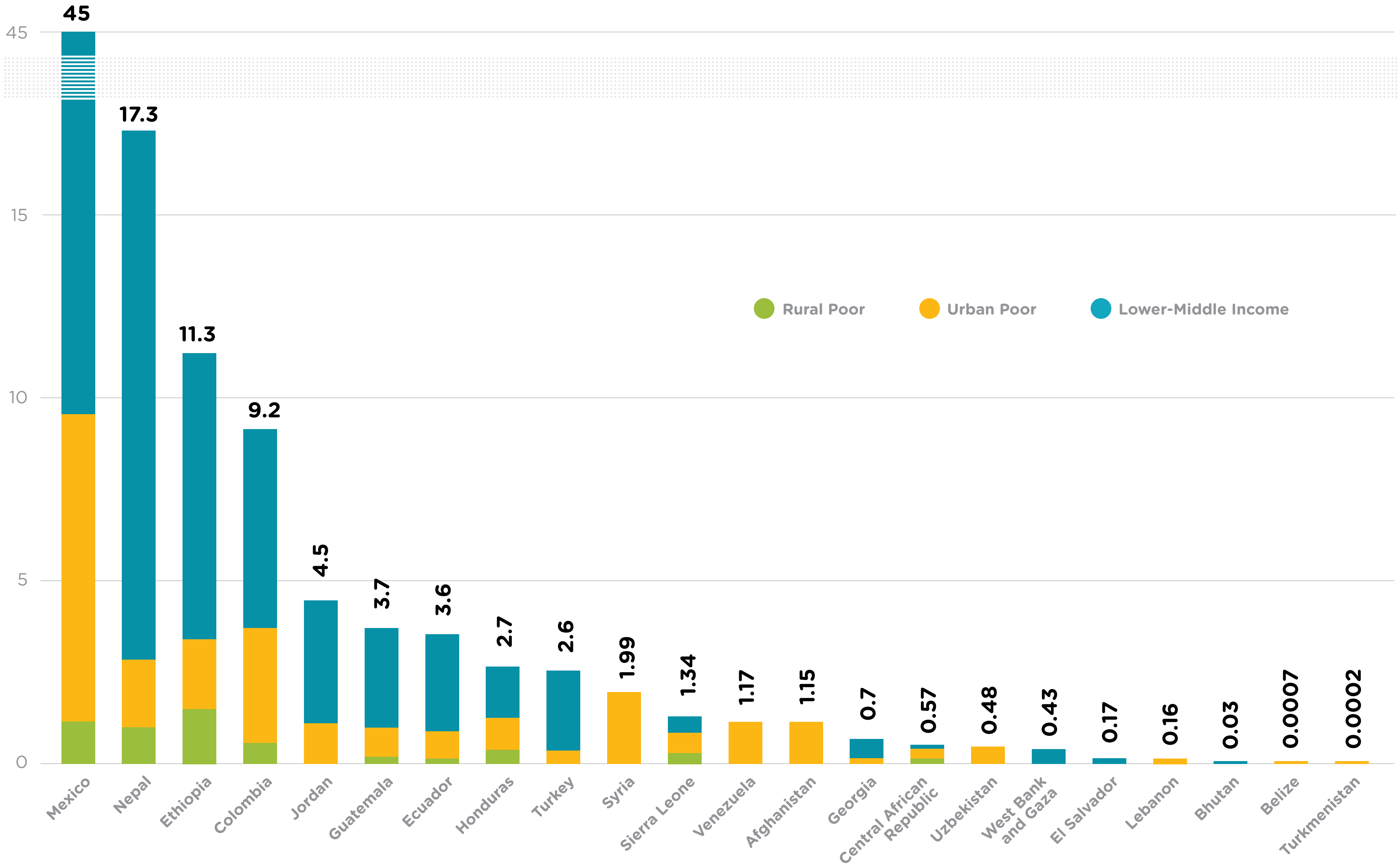
[27] The Critical 9 countries are: Bangladesh, Brazil, China, India, Indonesia, Mozambique, Nigeria, Pakistan, Sudan.

FIGURE 2.12

Populations at risk in non high-impact countries (millions)



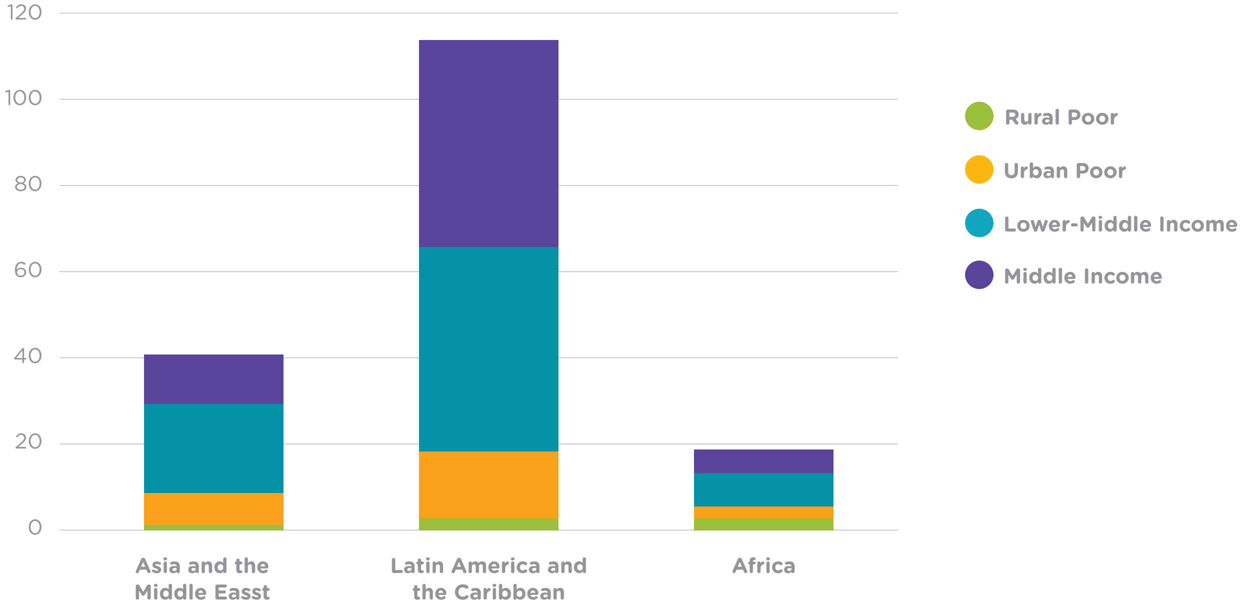
Of the countries not considered high-impact, Mexico (discussed further in Chapter 2) has the highest number of people at high risk: 1.2 million people among the rural poor, 8.4 among the urban poor, 35.4 million among the lower-middle income and 33.2 million among the middle income.

To derive the populations at risk, applicable sub-national units, such as provinces, states, or departments (departamentos), were identified for potential exposure to dangerous heat levels based on a World Bank Group methodology measuring the frequency of daily maximum wet bulb temperatures above 32°C.[28] In Colombia, for example, the main cities of Bogotá and Medellín experience colder climates than much of the rest of the country. For the analysis, eight Colombian departments with approximately 33 percent of the country's total population were exposed to high levels of heat stress. Among those departments, approximately 3.7 million people live in poor urban settings and are at high risk due to a lack of access to cooling.

Chilling Prospects 2021 allows for a more comprehensive, global assessment of cooling access risks than previous editions. Including the rural and urban poor at high risk in the 22 non high-impact countries, as well as those in the 54 high-impact countries, the analysis shows that the total high-risk population across 76 countries is 1.12 billion people.

FIGURE 2.13

Populations at risk by region in non high-impact countries (millions)



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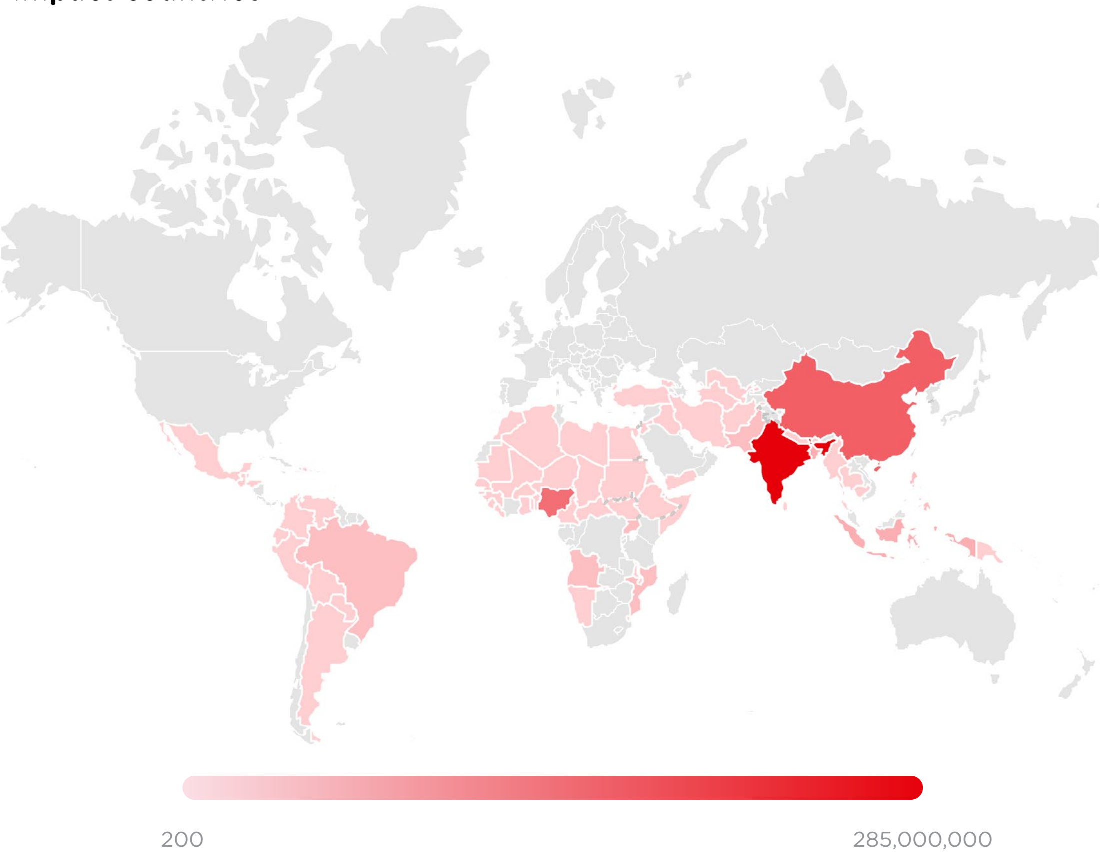
[28] Douglas, John et al. ThinkHazard!: Methodology report, Version 2. September 2017. Link

FIGURE 2.14

Populations at high risk by country, including high-impact and non high-impact countries



CHAPTER 3

Impact of COVID-19 on access to cooling globally

In 2020, the COVID-19 pandemic and the measures to limit its spread had widespread impacts on global health, economies, social security and well-being, threatening the progress on many areas of the Sustainable Development Goals (SDGs). The economic impact of the COVID-19 pandemic was unprecedented and hardest on the vulnerable. According to the World Bank, between 119 and 124 million people were driven into extreme poverty as a result of the pandemic alone, with this group described as the "new poor." The economic impacts have been most significantly felt by women, particularly those in developing countries where 70 percent of the female workforce is in the informal sector.[1]

Social impacts have also been evident. Since stay-at-home measures were implemented, domestic violence against women has intensified evidenced by the increased reports of domestic violence around the world.[2] Approximately 1.5 billion students have faced some type of school closure,[3] and 370 million children globally, many of whom are reliant on school meals as a main source of their daily nutrition, have on average missed around 40 percent of these meals.[4] Routine vaccinations are one health service that has suffered. As of October 2020, 94 million children in 26 countries had missed out on a measles vaccine.[5]

With a series of COVID-19 vaccine approvals beginning in late 2020 and recognition that, with time, these vaccines can be adapted for virus mutations, there is consensus among public health experts globally that vaccination for a large portion of the population is necessary to reduce hospitalizations and excessive mortality. Achieving global herd immunity however is estimated to require vaccinating at least 60–70 percent of the population against COVID-19 effectively and equitably, posing a massive distribution challenge.

COVID-19 vaccines are characterized by a range of factors that affect their potential role in achieving global herd immunity. In addition to regulatory approval, this includes their efficacy and risks across age, gender, race and ethnicity demographics, production capacity in 2021, price, dose quantity and cold chain requirements. Each of these factors plays a role in their suitability to support herd immunity in different geographic locations.

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[1] Policy Brief: The Impact of COVID-19 on Women, UN Women, 9 April 2020. Link

[2] The Shadow Pandemic: Violence Against Women and Girls and COVID-19, UN Women. Link

[3] Blake, Paul and Divyanshi Wadhwa, "2020 Year in Review: The impact of COVID-19 in 12 charts," World Bank Group, 14 December 2020. Link

[4] Borkowski, Artur, et. al. "COVID-19: Missing More Than a Classroom: The impact of school closures on children's nutrition," UNICEF and World Food Programme, January 2021. Link

[5] Mulholland, Kim, Katrina Kretsinger, Liya Wondwossen and Natasha Crowcroft, "Action needed now to prevent further increases in measles and measles deaths in the coming years," The Lancet, Volume 396, Issue 10265. 12 November 2020. Link

TABLE 3.1

Key characteristics of leading vaccines with traffic-light system signalling potential for achieving global herd immunity (Adapted from the Lancet[6])

	Development and Production		**Allocation**		**Deployment**	
Vaccine Producer (Common Name)	Efficacy in phase 3 trials	Estimated production capacity for 2021 (doses)	Percentage of doses pre-purchased by High- Income Countries (based on known deals)	Supply agreement with COVAX	Number of doses	Storage requirement during transport
Pfizer/BioNTech	🟩 **95%**	🟩 **2 billion**	🟥 **77%**	🟩 **Yes**	🟧 **2**	🟥 **-70°C**
Moderna	🟩 **94%**	🟧 **1 billion**	🟥 **97%**	🟩 **Yes**	🟧 **2**	🟥 **-20°C**
Gamaleya (Sputnik V)	🟩 **92%**	🟧 **1 billion**	🟩 **0%**	🟥 **No**	🟧 **2**	🟥 **-18°C**
Sinopharm with Beijing Institute	🟩 **79%**	🟧 **1 billion**	🟩 **8%**	🟥 **No**	🟧 **2**	🟧 **2-8°C**
AstraZeneca with Oxford University	🟧 **70%**	🟩 **3 billion**	🟧 **27%**	🟩 **Yes**	🟧 **2**	🟧 **2-8°C**
Johnson & Johnson	🟧 **66%**	🟩 **1 billion**	🟧 **38%**	🟩 **Yes**	🟩 **1**	🟧 **2-8°C**
CanSino Biologics	🟧 **66%**	🟥 **320 million**	🟩 **0%**	🟥 **No**	🟩 **1**	🟧 **2-8°C**
Sinovac Biotech	🟧 **50%**	🟧 **1 billion**	🟩 **18%**	🟥 **No**	🟧 **2**	🟧 **2-8°C**

Following the first regulatory approvals of the Pfizer and Moderna vaccines, requiring storage at -70°C and -20°C respectively, cold storage requirements quickly became one major concern for all countries seeking to utilize these products given that most routine immunization vaccines require temperatures between 2 and 8°C at all stages in the distribution cold chain. Almost simultaneously there was public recognition that the first vaccines requiring sub-zero storage temperatures meant they were inaccessible for certain countries and regions that lack extensive cold-chain infrastructure, raising concerns about equitable access. For example, Dr. Gagandeep Kang, Professor of Microbiology at Christian Medical College, Vellore, said that with its cold storage requirement at -70°C to -80°C, the Pfizer vaccine is "very unlikely to be a solution for India."[7] Among other factors, it would require the procurement of significant volumes of sub-zero cold storage at a high cost. Cold boxes equipped to perform at -80°C typically cost between USD 10,000 and USD 20,000 USD, a prohibitive price for the scale needed to achieve herd immunity, and most developing countries outside those that vaccinated against Ebola would have few of these types of cold boxes already.[8]

VACCINE READINESS

Initial findings of the World Bank's vaccine readiness assessment across 128 participating countries revealed that "while 85 percent of countries have developed national vaccination plans and 68 percent have vaccine safety systems, only 30 percent have developed processes to train the large number of vaccinators who will be needed for the campaign and only 27 percent have created social mobilization and public engagement strategies to encourage people to get vaccinated."[9]

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[6] Wouters, Oliver J et al. "Challenges in ensuring global access to COVID-19 vaccines: production, affordability, allocation, and deployment. Health Policy, Vol. 397, Issue 10278, 13 March 2021. For a full description of the methodology used for the traffic light system, please see Appendix 1.

[7] Interview with Gagandeep Kang, The Wire, 17 November 2020. Link

[8] Baskar, Pranav, "What Is A Cold Chain? And Why Do So Many Vaccines Need It?" NPR, 24 February 2021. Link

[9] Assessing Country Readiness for COVID-19 Vaccines, the World Bank Group, March 2021. Link

At the time of writing, the World Health Organization (WHO) had issued "Emergency Use Listings" for vaccines from Pfizer/BioNTech, AstraZeneca with Oxford University, the Serum Institute of India, Moderna and Johnson and Johnson to expedite country authorization of vaccine distribution. Additional vaccines from Novovax, Sonofi, and others are expected to complement those vaccines as part of the supply secured by the COVAX initiative, a platform to secure and distribute COVID-19 vaccines.With the exception of Pfizer/BioNTech, these vaccines require storage at 2°C to 8°C, the conventional cold storage range for influenza-type and other routine vaccines and are viewed as more practical solutions in countries where logistics and cold chain challenges exist because existing cold chains can be expanded rather than new systems having to be built.[10]

As of April 2021, vaccine rollout across the developing world has proceeded slowly. The COVAX initiative has forecast that by the end of 2021, it would be able to make approximately 2.16 billion doses available, including 1.7 billion doses made available to 92 low- and middle-income countries participating in the Gavi-COVAX Advance Market Commitment (AMC) Facility. Current estimates are that vaccines provided through this initiative would protect 26 percent of the population of AMC countries in 2021. Countries participating in COVAX may also self-finance vaccine purchases, with those making up a larger proportion of the supply forecast for developed countries.[12]

While the COVAX effort and self-financed purchases amongst low- to middle-income countries will support many vaccinations, it will not reach the necessary target of 60–70 percent necessary to achieve herd immunity in these regions in 2021.

WHO and UNICEF have developed interim guidance for ultra-cold chain (UCC) to help countries identify their needs and plan for procurement of required equipment for vaccine doses secured by the COVAX facility. The guidance provides equipment deployment options based on travel distance from central storage, as well as recommendations for setting up ultra-low-temperature freezers with large storage capacity. To note however is that only 0.2 percent of vaccines procured for COVAX require sub-zero temperatures (40 million Pfizer-BioNTech doses).[11]

Photo: UNICEF

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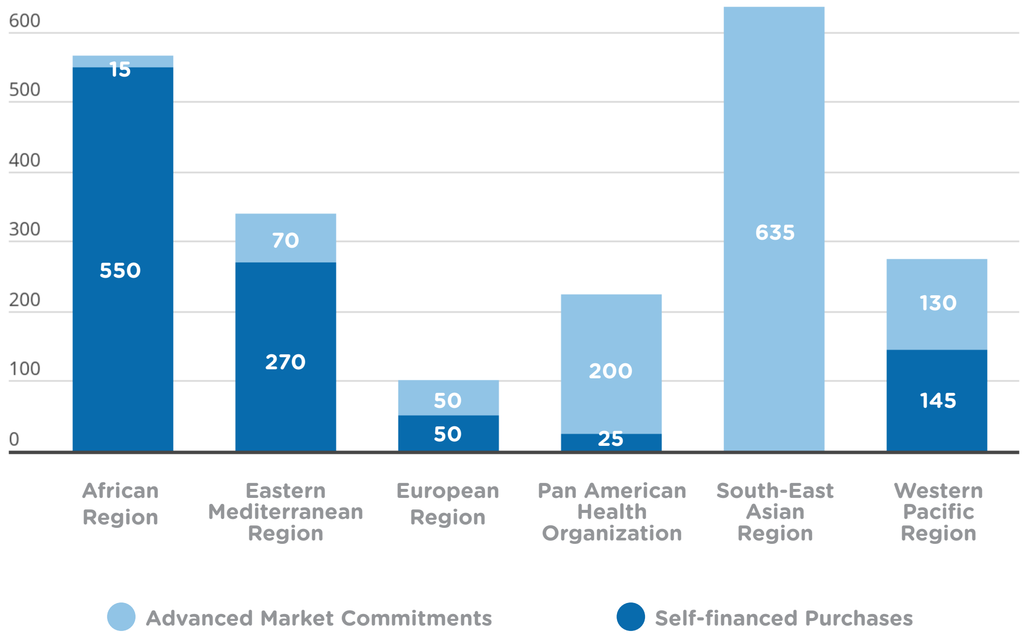
[10] COVAX Global Supply Forecast, CEPI, Gavi, UNCEF and WHO, 7 April 2021. Link
[11] COVID-19 vaccination: supply and logistics guidance: interim guidance, WHO and UNICEF, 12 February 2021. Link
[12] COVAX Global Supply Forecast, CEPI, Gavi, UNCEF and WHO, 7 April 2021. Link

FIGURE 3.1

COVAX Regional Supply Forecast for 2021 (millions)



Challenges in Vaccine Rollout Linked to Cooling

Even though supply challenges are the primary vaccine delivery constraint, the scale of the cold chain challenge to reach herd immunity, even at conventional storage temperatures between 2°C to 8°C, is still immense and has exacerbated existing cooling access gaps and created new ones. The herd immunity threshold for COVID-19 has been estimated to be at least 60–70 percent, which translates into 4.7 to 5.5 billion people.

Challenges could also persist if, given the emergence of mutations and unknowns on the longevity of immunity, regular booster shots are required over time. India has one of the world's largest routine immunization programmes targeting 29 million pregnant women and 26.7 million newborns every year, yet this is far from the scale needed to immunize India for COVID-19.[13]

The inequalities between richer and poorer nations in vaccine distribution are clear, including secured vaccines and cold chains needed to distribute the vaccines. Ellen Johnson Sirleaf, the former President of Liberia and current Co-Chair of the Independent Panel for Pandemic Preparedness & Response (IPPR) recently expressed her disappointment that based on current plans, vaccines would not be widely available in Africa until 2022 or 2023. Similarly, the Economist Intelligence Unit forecasts that 85 poor countries will not have widespread access to COVID-19 vaccines before 2023, including all African countries with the exceptions of Egypt, Ethiopia, Gabon, Kenya, Morocco and South Africa.[14]

Temperature control and vaccine cold chains are certainly a key contributing factor. A recent DHL logistics study concluded that even with conventional cold storage requirements, the proportion of the world's population with good access to a vaccine, based on available logistics and supply capabilities, would only be about 70 percent. On this basis, approximately 2.7 billion people would lack dependable access to vaccines as a result of insufficient supply chains and logistics capabilities related to cold chains.[15]

In Sub-Saharan Africa, where vaccine cold chain challenges are significant, reliable energy access in hospitals and clinics is a key need. Long before the

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[13] Roadmap for achieving 90 percent full immunization coverage in India, Ministry of Health & Family Welfare, Government of India, January 2019. Link

[14] "More than 85 poor countries will not have widespread access to coronavirus vaccinations before 2023," The Economist Intelligence Unit, 27 January 2021. Link

[15] DHL White Paper, 'Delivering Pandemic Resilience: How to secure stable supply chains for vaccines and medical goods during the COVID-19 crisis and future health emergencies.' DHL, September 2020.

COVID-19 pandemic made daily headlines, a lack of reliable power in healthcare facilities was undermining the quality of healthcare for millions of people in Sub-Saharan Africa. While data on the size of the energy access gap in the health sector are sparse, a handful of multi-country studies all point in the same direction. A 2013 WHO-led review in 11 countries in Sub-Saharan Africa estimates that one in four health facilities had no access to electricity at all,[16] while only 28 percent of health facilities and 34 percent of hospitals were considered to have 'reliable' electricity. A different study[17], focusing on 'reliability' of electricity in health facilities in low- to middle-income countries, estimates that 59 percent lack reliable electricity that would be necessary to power vaccine storage appliances that must be connected to electricity. Globally, the International Renewable Energy Agency (IRENA) has estimated that approximately 1 billion people rely on health facilities that have no electricity supply.[18]

To address challenges related to electricity access and power fluctuations that can impact the efficacy of vaccine refrigerators, Gavi has been engaged in the procurement of 65,000 off-grid-ready, solar direct-drive refrigerators for nearly 50 countries and is now prioritizing them for last-mile vaccine delivery. To support the vaccine rollout under COVAX, in late 2020, UNICEF began purchasing 92,000 vaccine fridges, 11,325 of them solar-powered, as well as cold boxes and vaccine carriers.[19]

Such solutions are relatively expensive but are good in areas with limited energy access and help replace reliance on diesel. Portable cold boxes and refrigerated vans are other solutions that can support countries in reaching the last mile. Innovative business models can also make these solutions more accessible, in particular pay-as-you go (PAYG) models for technologies previously deployed in the agricultural cold chain.

Approximately 2.7 billion people would lack dependable access to vaccines as a result of insufficient supply chains and logistics capabilities related to cold chains.

The World Bank Group has made a USD 12 billion financing envelope available to developing countries to support the purchase of vaccines and strengthened health systems, including cold chains. One of the first approved projects provided support to Cabo Verde to purchase and deploy vaccines for 35 percent of its population, which included the financing of cold chain equipment and transport.[20] Similarly, the World Bank's Energy Sector Management Assistance Program (ESMAP) also provides technical and investment support for reliable and climate-friendly health facilities and vaccine cold chains in Sub-Saharan Africa.

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[16] Adair-Rohani, Heather et al, "Limited electricity access in health facilities of Sub-Saharan Africa : a systematic review of data on electricity access, sources, and reliability, » Global Health : Science and Practice, August 2013. Link

[17] Cronk, Ryan and Jamie Bartram, "Environmental conditions in health care facilities in low-and middle-income countries: Coverage and inequalities," International Journal of Hygiene and Environmental Health, Volume 221, Issue 3, April 2018. Link

[18] "Healthcare," International Renewable Energy Agency. Link

[19] UNICEF Gearing Up for Historic Immunization Drive, UNICEF, 12 November 2020. Link

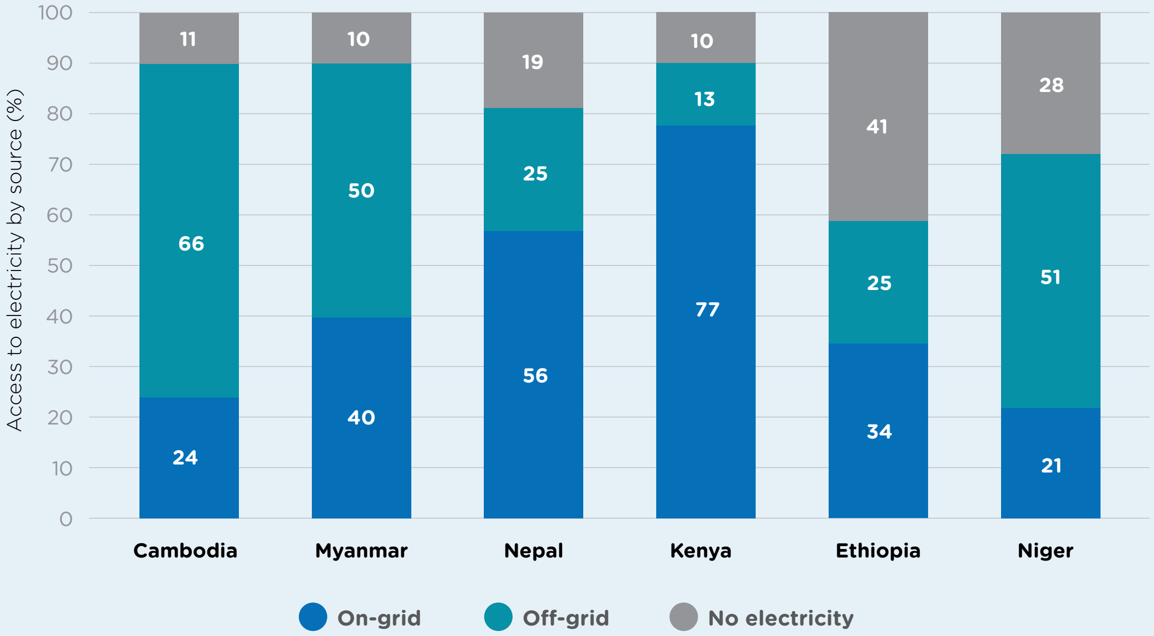
[20] "First World Bank Support for COVID-19 Vaccine Rollout in Africa," Press Release, World Bank Group, 11 February 2021. Link

Health facility electricity access

The World Bank surveyed 730 health facilities in six countries (Cambodia, Ethiopia, Kenya, Myanmar, Nepal and Niger) under its Multi-Tier Framework (MTF) approach in 2013. Off-grid solutions can be sufficient provided there is enough capacity, and moreover the surveys also highlight that approximately 25 percent of health facilities lack a primary source of electricity, in line with estimates from previous studies (Figure 3.2). Additionally, the surveys showcase significant differences between countries, with half or more of health facilities in Cambodia, Myanmar and Niger relying on an off-grid power solution. The surveys also highlight that grid power does not always equate to quality and reliable electricity, with 25 percent of surveyed on-grid health facilities reporting outages that affect health facilities' ability to offer health services. Unreliable power and voltage surges contribute significantly to equipment breakdown and can cause vaccine losses with associated human health implications.

FIGURE 3.2

Electrification of health institutions in select MTF countries, by source (2013)



In India, improving energy access issues in primary health centres (PHCs) was identified as a key need for the COVID-19 vaccine rollout. It is estimated that approximately 28.2 million people living rurally depend on PHCs that do not have power supply.[21] A 2017 survey of Chhattisgarh province also revealed that 48 percent of PHCs, both on- and off-grid, experienced power deficits, with 90 percent reporting frequent power outages between 9am and 4pm.[22]

In the Indian province of Assam, 6.7 percent of PHCs lack a functional electricity supply and 10.6 percent lack a connection to an all-weather road. Moreover, 62.3 percent of sub-health centres at the district level lack a functioning electricity supply.[23] In addition to reliability and connectivity, a lack of training and technical knowledge can be an impediment to the proper use of cooling equipment. According to official data, around 6.5 percent of COVID-19 vaccines have gone to waste

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[21] Rawat, Mukesh, "How preparation for Covid vaccination drive is also an opportunity to make PHCs energy efficient," India Today, 1 December 2020. Link

[22] "Research Summary: Powering Primary Healthcare through Solar in India: Lessons from Chhattisgarh," CEEW and Power for All, August 2017. Link

[23] Rural Health Statistics 2018-19, Ministry of Health and Family Welfare, India. Via India Today. Link

In Sub-Saharan Africa, where vaccine cold chain challenges are significant, reliable energy access in hospitals and clinics is a key need. Long before the COVID-19 pandemic made daily headlines, a lack of reliable power in healthcare facilities was undermining the quality of healthcare for millions of people in Sub-Saharan Africa.

to date, with four states and a Union Territory having much higher levels of wastage: Telangana (17.6 percent), Andhra Pradesh (11.6 percent), Uttar Pradesh (9.4 percent), Karnataka (6.9 percent) and Jammu & Kashmir (6.6 percent).[24] The high wastage rates are mainly attributed to a lack of trained personnel and planning at site level with not enough people coming to get vaccinated, causing opened vials go to waste.[25] In the Cachar district of Assam, approximately 1,000 doses of the Covishield (AstraZeneca) vaccine were spoiled at the Silchar Medical College and Hospital because they were improperly stored at temperatures that were too cold. These vaccines were unintentionally frozen, rendering them unusable, likely due to a lack of staff training.[26] To mitigate these issues in the province, the efficiency and efficacy of solar vaccine fridges for COVID-19 vaccines were tested during a January 2021 polio vaccination drive targeting 4.7 million children. The units being tested can maintain a 2°C to 8C temperature range for seven days after charging for one day in the sun.[27]

Even in richer countries and in those that do not consistently experience high outside temperatures, access to reliable refrigeration that can store vaccines at sub-zero temperatures is not a given. Mendocino County California's Ukiah Valley Medical Center was forced to distribute more than 800 Moderna vaccines in two hours after a freezer was found to have malfunctioned, bringing the doses up to room temperature.[28]

The Crucial Role of End-to-End Visibility for Cold Chains

Courtesy of Nexleaf Analytics

While many countries have robust temperature monitoring in national and regional storage points, the ability to monitor temperature during transportation has historically received less attention. Yet there is evidence that irregularities can occur at any point in the cold chain system and each irregularity cumulatively contributes to the degradation of the vaccines, especially those that are heat sensitive. Though there are limited studies on cold chain temperatures during transport, a 2016 literature review reports 19.3 percent of shipments to lower-income countries registered freezing temperatures or temperatures out of the recommended range of 2°C to 8°C.[29]

This continues to be a challenge as highlighted by a transport monitoring study carried out in 2018 in Kenya showing that vaccines in transit are exposed to the most extreme temperature irregularities; out of 113 hours of vaccines being in transit, over half of the time (64 hours) was spent in temperatures outside the recommended 2°C to 8°C.[30]

To monitor vaccines during transport, the humanitarian non-profit Nexleaf is piloting a Bluetooth-based data logger that functions in hard-to-reach and low-connectivity areas. This device is being tested in Tanzania and offers opportunities for other countries to have end-to-end visibility of their cold chains.

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[24] Dey, Sushmi, 'Centre urges states to minimise vaccine wastage,' The Times of India, 18 March 2021. Link

[25] Sheriff, Kaumain, 'Centre tracks COVID-19 vaccine wastage: Lack of trained personnel, planning at site level,' Times of India, 19 March 2021. Link

[26] Goswami, B and Kangkan Kalita, "Assam: Storied at sub-zero temp, 1,000 Covishield doses get spoiled at Silchar hospital," The Times of India, 19 January 2021. Link

[27] Kalita Kangkan, "Assam: Solar storages for Covid-19 vaccines to be tested during polio drive on January 31," The Times of India, 20 January 2021. Link

[28] Chan, Stella and Christina Maxouris, "After a freezer filled with Covid-19 vaccines broke, a California hospital scrambled to administer more than 800 doses in about 2 hours," CNN, 6 January 2021. Link

[29] C. M. Hanson, A. M. George, A. Sawadogo, and B. Schreiber, "Is freezing in the vaccine cold chain an ongoing issue? A literature review," Vaccine, vol. 35, no. 17, pp. 2127–2133, 2017.

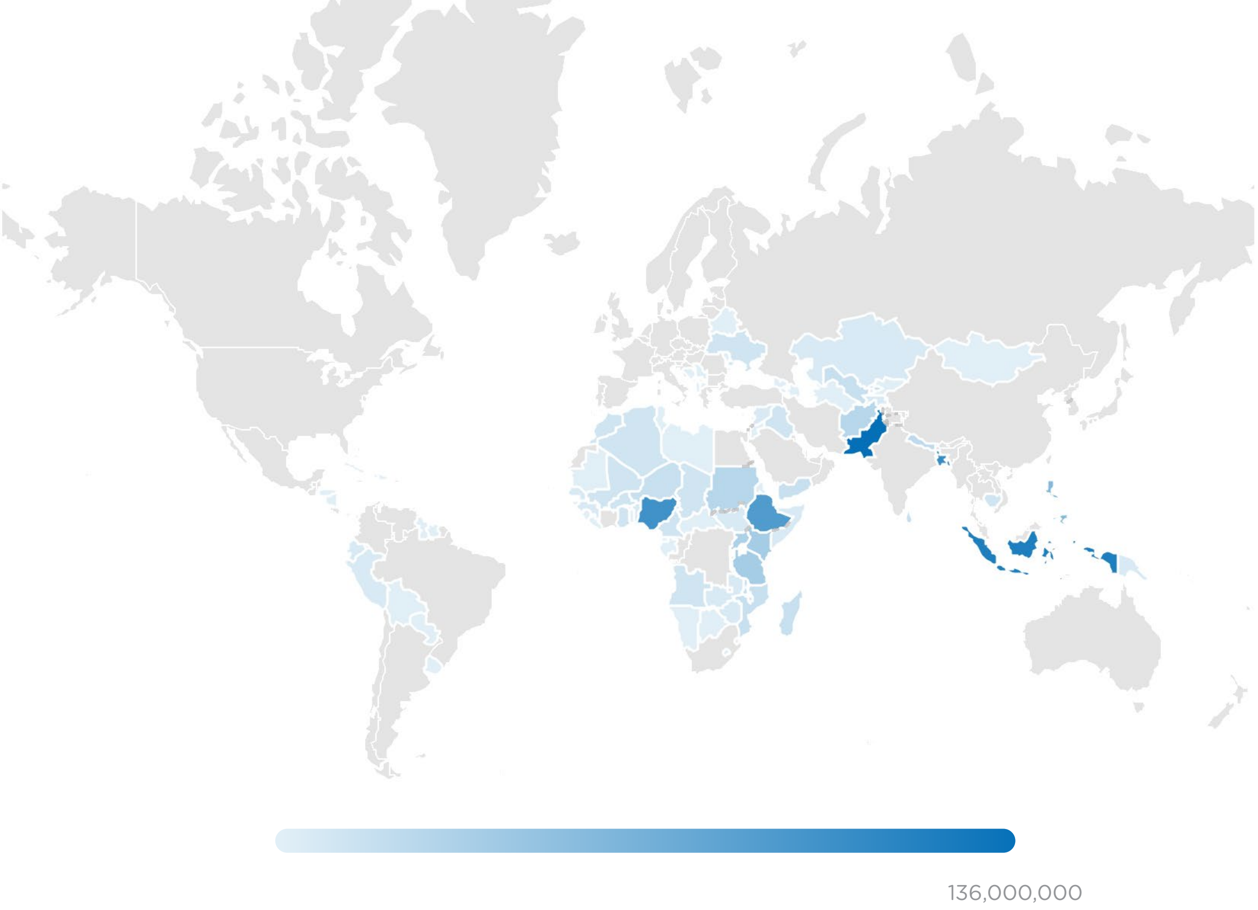
[30] Kenya National Vaccines and Immunization Program (NVIP) with support from UNICEF and implementing partners, including Nexleaf Analytics, conducted a Temperature Monitoring Study starting July 2018, to assess storage temperatures of vaccine supply chain from the central store up to the service delivery points.

Addressing Vaccine Cold Chain Access Gaps at the Last Mile

While vaccine supply is likely to continue to be the primary constraint, it will be those living at the last mile in countries without sufficient vaccine cold chains that will be at risk of not being able to access a COVID-19 vaccine specifically due to cooling requirements. Compared to urban dwellers, rural populations face a number of challenges including less reliable electricity supply, greater risk of vaccine spoilage in transit over large distances, and health facilities with fewer capacities.

To understand the scope of this population, Sustainable Energy for All (SEforALL) surveyed three key studies: (1) the Economist Intelligence Unit (EIU) work on countries unable to roll out vaccination plans until 2022 or 2023; (2) the DHL temperature-controlled logistics study that identified countries with medium-to-low feasibility for vaccine rollout at conventional 2°C to 8°C storage temperatures; and (3) the WHO list of countries that failed to reach the target rate of 90 percent immunization coverage or higher for the commonly used DPT3 vaccine. From this survey, a list of 108 countries were identified as either not predicted to have widespread access to the vaccine until 2023 or later (EIU) or were assessed to have medium-to-low feasibility of in-country logistics for vaccine distribution under conventional temperature requirements of 2°C to 8°C (DHL). Within those countries it can be expected that those living rurally will face more serious risks from a lack of access to vaccine cold chains. It is estimated that 1.42 billion people living in the last mile in these countries are at high risk, if temporarily, from a lack of access to cooling that prevents them from accessing the COVID-19 vaccine.

FIGURE 3.3
Rural populations in countries expected to experience cold chain challenges



The additional infrastructure, services, and equipment to be procured and deployed to facilitate the COVID-19 vaccination present opportunities for many countries to improve their current cold chain systems, but also to strengthen health systems for the long term and help address climate change. Investments in off-grid renewable energy solutions for health facilities, for example, can deliver reliable and cost-effective electricity in countries with electricity access gaps, but short-term impact requires commitments to long-term financing, better data, and enabling policy environments at the local level.

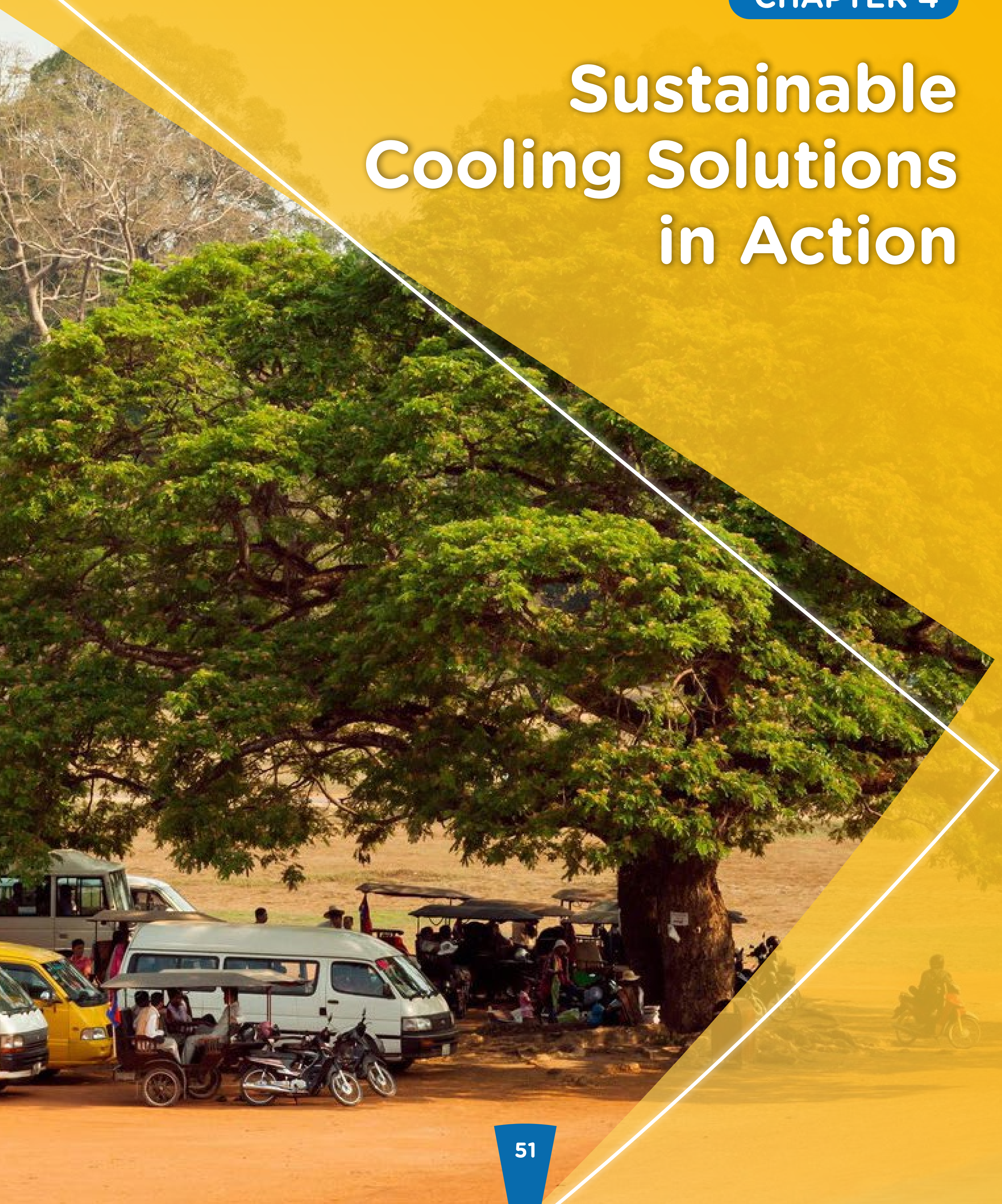
Cold chain equipment expansion must also recognize the long-term risks of using unsustainable technologies. As the equipment deployed as part of the vaccination programmes will be in place or in circulation at least 10 years, deployment of inefficient and high-GWP cooling technologies to meet the demand quickly may potentially become a barrier for achieving global climate change and development goals, targets and commitments. Sustainability standards for energy consumption and refrigerants must be strongly embedded into the qualification of equipment being assessed for procurement by development entities and governments supporting vaccine rollout.

New business models and innovations can support more sustainable solutions at the local level. Cooling as a Service (CaaS) is one such model that can optimize for short term medical needs in light of 10-year equipment lifespans. Community cooling hubs can similarly provide refrigeration services for a variety of different cooling needs, delivering legacy infrastructure that can also be utilized for agricultural production and communal food refrigeration. New innovations in temperature monitoring, including from vaccine and cooling equipment suppliers, can also reduce wastage and support the digitalization of routine COVID-19 immunizations if they become necessary.

Ultimately, a dramatic expansion in cold chain equipment will be necessary to guarantee equitable distribution of COVID-19 vaccines. While it is evident that the pace of vaccination is uneven and inequities are likely to be exacerbated in the coming months, support for sustainable cold chains represents an opportunity to address immediate equity considerations and deliver a lasting impact in support of the economic and social recovery from the pandemic.

CHAPTER 4

Sustainable Cooling Solutions in Action



Across human comfort and safety and medical and agricultural cold chains, small- to mid-size cooling businesses are working to generate technological solutions and take advantage of new business models. However, challenges that remain in bringing these new solutions to scale across markets in the developing world highlight the need for innovation and intervention not only in technologies, but also in the services, policies and financial solutions that are needed to support them.

As sustainable cooling solutions are piloted and demonstrated across the developing world, more data about their impacts on the local level are becoming available. Understanding these impacts is critical for governments, cities, development institutions and non-governmental organizations (NGOs) in the design of policies and implementation of new initiatives dedicated to increasing access to sustainable cooling.

Scaling up Access to Cooling Solutions

A major barrier to scale small- to mid-size cooling businesses is access to financing due to the relatively small size of the projects. Dedicated funding structures that enable the bundling of such projects could relieve companies from their cash constraints and enable them to implement business models that require more patience for the return on investment. In addition, when exploring innovative business models, such cooling businesses are exposed to new risks such as payment delays and defaults. These risks may limit the users that can benefit from sustainable cooling solutions; payment guarantees could significantly support cooling providers to increase the size of their portfolios and hence diversify their risk.

Scaling up the Cooling as a Service (CaaS) business model, for example, will require solution providers to shift their organizational culture, moving away from selling assets and starting to focus on selling services. Unlocking commercial debt is key to scale up the adoption of CaaS, as was the case with power purchase agreements and solar photovoltaics.

For agricultural cold chains, training, capacity building and data availability remain key barriers to scale, and it is this that the Africa Centre of Excellence for Sustainable Cooling and Cold-chain (ACES) aims to address in Sub-Saharan Africa. The centre is designed to respond to these specific needs with training on how to make the right technology and business model choices for different markets and cooling needs.

In the public sector, increasing easy-to-access funding is crucial to create enabling environments for sustainable cooling solutions across a variety of sectors. Further support of technology innovation and scaling is also essential for cooling technology development, as through the Global Cooling Prize[1] and the Chill Challenge[2].

Passive cooling solutions also require wider demonstration in developing economies that can be facilitated through subsidies, grants and other incentives, as has been achieved with the Million Cool Roofs Challenge[3] and the Fair Cooling Fund[4]. Public policy also remains a key enabler, with important steps including the inclusion and promotion of passive cooling solutions as well as nature-based solutions as seen in Medellín Colombia, in municipal planning processes and building codes.

This chapter explores some of those solutions through case studies provided by the Ashden Foundation, the Basel Agency for Sustainable Energy, the FAO, the Million Cool Roofs Challenge, and the Sustainable Energy for All (SEforALL) Youth Summit. The examples are driven by data to show the impact that sustainable solutions have on communities and people. By highlighting the sustainable development benefits, including employment, income, climate change mitigation and adaptation, these solutions show different approaches through which access to sustainable cooling can advance the Sustainable Development Goals (SDGs) and contribute to the emissions reductions necessary to achieve the Paris Agreement.

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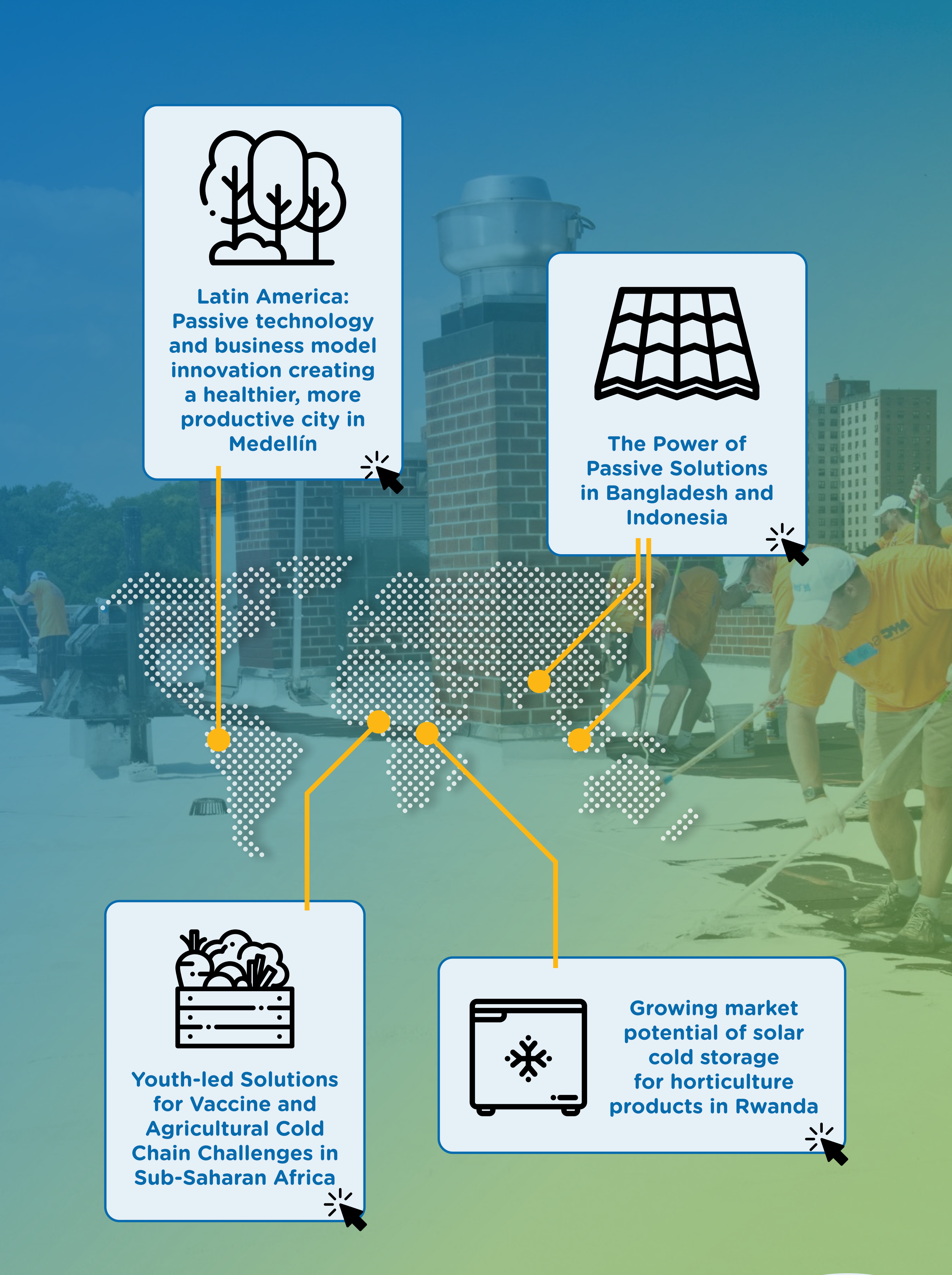
[1] The Global Cooling Prize, Rocky Mountain Institute. Link
[2] Chill Challenge, Engineers Without Borders, USA. Link
[3] The Million Cool Roofs Challenge. Link
[4] Ashden Fair Cooling Fund, Ashden Foundation. Link



Latin America: Passive technology and business model innovation creating a healthier, more productive city in Medellín

The Power of Passive Solutions in Bangladesh and Indonesia

Youth-led Solutions for Vaccine and Agricultural Cold Chain Challenges in Sub-Saharan Africa

Growing market potential of solar cold storage for horticulture products in Rwanda

Latin America: Passive technology and business model innovation creating a healthier, more productive city in Medellín

Credit: Ashden Foundation and Basel Agency for Sustainable Energy

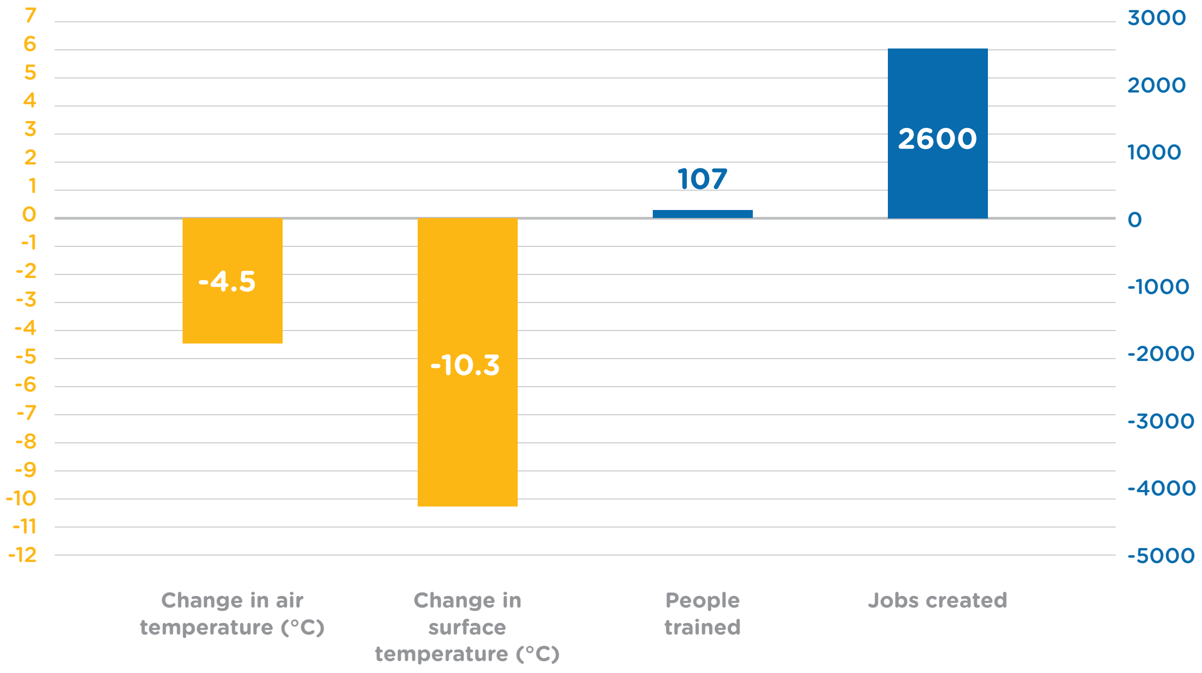
After enduring years of high crime and violence, the Colombian city of Medellín faces a new threat – rising urban temperatures, driven by climate change. The city and its businesses are turning to new sustainable cooling solutions, both indoors and outdoors, to protect their citizens and workers.

The City of Medellín responded to the challenge of rising urban heat by bringing people together and planting vegetation along busy streets and former waterways to create a better environment for everyone, while at the same time reducing city temperatures. The Green Corridors project provides shade for cyclists and pedestrians, cools built-up areas and cleans the air along busy roads. As a result of the project, almost 880,000 trees and 2.5 million smaller plants have sprung up around the city.[5] As part of the initiative, Medellín's botanical gardens train people from disadvantaged backgrounds to become city gardeners and planting technicians. The city's Secretary of Environment Sergio Orozco explains: "The programme came from the need to connect people to nature – recovering spaces that were occupied by concrete."

The programme has achieved significant heat reductions. From 2016 to 2019 average air temperatures in the city's Green Corridors locations fell from 31.6C to 27.1C, and average surface temperatures dropped by over 10 degrees, from 40.5C to 30.2°C. The programme also brought training and employment opportunities. From 2016 to 2019, 107 people from disadvantaged communities were trained as gardeners, and 2,600 workers were employed through the project.

FIGURE 4.1

Impacts of the Green Corridors Project in Medellín, Colombia



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[5] Data for this story provided by the Ashden Foundation, the Basel Agency for Sustainable Energy, and project teams implementing solutions.

Just as impressive are the numerous other benefits of the programme – including improvements in air quality. In the same three-year period, levels of the particulate pollutant PM 2.5 fell from 21.81 μg/m3 to 20.26 μg/m3, and levels of PM 10 from 46.04 μg/m3 to 40.4 μg/m3. Ozone levels dropped from 30.1 μg/m3 to 26.32 μg/m3. This brought huge health benefits. From 2016 to 2019, the city's morbidity rate from acute respiratory infections fell from 159.8 per thousand inhabitants to 95.3. Cycling rose by 34.6 percent, and walking by 4 percent. The surge in cycling was aided by the construction of 80km of new bike paths as part of the project.

Every aspect of the programme – from lower temperatures and better health to training opportunities – has driven progress towards a fairer, more equal city. It has created 1.5 million m^2 of public space for people of all ages and from diverse economic backgrounds to enjoy together.

Inside Medellín's buildings, innovative business models are also delivering access to cooling in support of greater workplace productivity, energy savings and lower carbon emissions. Q Group in Medellín is a LEED-certified commercial building built in 2017, accommodating 100 offices. To offer its occupants the best comfort standards while optimizing capital expenditures, the building's constructors and manager turned to MGM Innova Group (www.mgminnovagroup.com) who teamed up with AireVerde to design and supply a high-efficiency HVAC solution to deliver cooling to the building under a CaaS model. MGM Innova Group carried out the full investment and jointly with AireVerde operates and maintains the system, covering all associated costs including electricity and applicable insurance.

A monthly payment is billed to every office on the CaaS model. Common areas are charged a fixed amount every month, while individual offices pay a variable fee based on the amount of cooling they use. The main CaaS contract was signed between MGM Innova Group and the building constructor and manager for a term of 20 years, with the possibility to end the contract earlier. Each end user then signs an internal agreement with the building operator and manager when acquiring an office, accepting the cooling service as part of the operating expenses.

> **Cooling as a Service helped an office building in Medellín, Colombia reduce its energy use by 1.2 GWh and reduced emissions by 440 tonnes of CO$_2$e per year.**

Thanks to CaaS, both the client and the final users enjoy high-quality cooling delivered by efficient technology, while focusing on their core business and avoiding capital expenditures. The system amounts to an annual energy saving of about 1.2GWh compared to an average cooling system, while GHG emissions are reduced by an estimated 440 tons of CO$_2$e per year. The Basel Agency for Sustainable Energy (BASE) (www.energy-base.org), prepared a full case study on this project that can be found on the website of the CaaS Initiative that it is leading (www.caas-initiative.org/case-studies).

Growing market potential of solar cold storage for horticulture products in Rwanda

Credit: Manas Puri, Luis Rincon & Irini Matsoglou, UN FAO

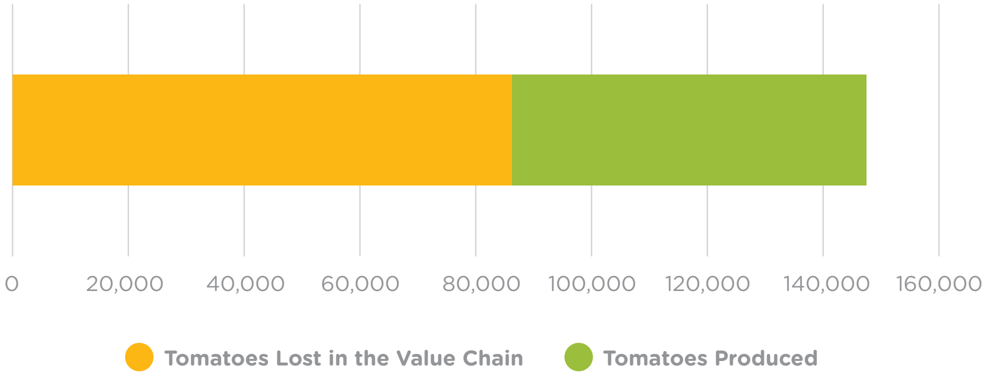
A well-functioning food value chain is essential for sustainable nutrition. A food value chain combines the necessary and interlinked stages through which the food grown passes through a distribution cold chain before reaching the final consumer. In many developing countries, the lack of proper cold storage is a bottleneck that causes food losses due to biological degradation and jeopardizes profits for the farmers. Food losses due to lack of proper cold storage are particularly high in perishable products like fruits, vegetables and dairy.

While the most effective way to slow down the rate of spoilage is cooling, there is a deeper challenge in deploying cold storage in rural parts of developing countries: the lack of access to reliable electricity. In Rwanda for example, only 23 percent of the rural population had access to electricity in 2018 (World Bank Data 2021) which makes it difficult to deploy cold storage technologies for fruits, vegetables and other perishable goods that require reliable energy access.

In 2013 horticulture accounted for an estimated 3.2 percent of domestic GDP and 9.7 percent of agricultural GDP (Government of Rwanda 2014). Despite the importance of horticulture products in Rwanda's agriculture economy, large quantities of crops are often lost. Tomatoes for instance, are widely produced and consumed in Rwanda. The production reached 154,000 tonnes in 2014, compared to 135,000 tonnes in 2010. However, according to USAID (2018) it is estimated that 56 percent of the tomatoes produced in Rwanda are lost along the value chain, with the lack of cold storage being a major factor for this loss.

FIGURE 4.2

Tomato Production in Rwanda (2014)



While it is challenging to deploy traditional cold storage in areas where the electricity grid is unreliable, there are nevertheless decentralized technologies that are suited for areas that are not grid connected. One such technology is solar cold storage. A recent assessment conducted by the FAO in Rwanda estimated the market potential of several solar energy technologies across all food value chains in Rwanda, including the market potential to deploy solar cold storage across the horticulture value chain. The assessment focused on the Government of Rwanda's export target of 46,000 tonnes of horticulture products by 2024. The results indicate that if the target is met, the market potential for solar cold storage could be as high as USD 6,105,000 with a 75 percent adoption rate of cold storage for horticulture products for export. The estimation, based on a new methodology developed by the FAO, aims to mobilize energy investments along food value chains in developing countries. The methodology first maps the food value chains to identify energy bottlenecks and then matches available energy technologies that can be deployed along the value chain to increase market output and efficiency and reduce food losses.

The Africa Centre of Excellence, Kigali, Rwanda

Despite large-scale investments in food production, hunger and malnourishment remain a persistent challenge globally. In Africa, agricultural households have persistently high levels of poverty, notably among smallholder farmers who represent 80 percent of African farms and produce 70 percent of the continent's food.[6] The expansion of sustainable cold chains is integral to preventing food loss and expanding the economic productivity of the agricultural sector. In 2020, the Africa Centre of Excellence for Sustainable Cooling and Cold-chain (ACES) was established by the Governments of Rwanda and the United Kingdom, the UN Environment Programme's (UNEP) United for Efficiency Initiative and the University of Birmingham to demonstrate technology, build capacity and test business models for agricultural cold chains.

The mission of ACES is to develop and accelerate the uptake of sustainable cold chain solutions in the agriculture and health sectors. ACES will economically empower farmers, increase export revenues, enhance job creation in rural areas, mitigate climate and environment impacts, and foster low-carbon development. It will bring partners together to:

- Create fit-for-market step-change pathways to net zero cold chain and cooling and to affordably meet the portfolio of rural community cooling needs.
- Understand policy and financing mechanisms.
- Build capacity and train the workforce.
- Build out Living Labs in strategic locations to act as deployment and implementation arms, driving the adoption and uptake of energy-efficient and climate-friendly solutions by showcasing how such solutions can be used by communities.

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[6] United for Efficiency and the University of Birmingham, Africa Centre of Excellence for Sustainable Cooling and Cold-chain, 7 October 2020. Link

Youth-led Solutions for Vaccine and Agricultural Cold Chain Challenges in Sub-Saharan Africa

Credit: Bisolar Tech Fridge Technology

Triomphant Tchulang grew up between Bafoussam (West Cameroon) and Yaoundé (Central Cameroon), an area with a cold and mild climate. He later moved to Maroua (Northern Cameroon) for his schooling, where high temperatures and heatwaves threatened the health and safety of the community and created challenges in storing agricultural produce. Following the development of the renewable energy sector in recent years, Triomphant worked to address the challenges caused by excessive heat with the use of solar energy, building a prototype for an absorption solar refrigerator. There were a number of challenges at the outset, notably that the prototype only produced energy for portions of the day, the useful part of the refrigerator was very small compared to its overall size, and it could not reach freezing temperatures. After working to address these over a two-year period, the Bisolar Tech Fridge was created.

While more than 780 million people worldwide do not have access to reliable electricity, the FAO has estimated that around 37 percent of food products in Sub-Saharan Africa are lost between harvest and consumption due to inadequate conservation and storage.[7] Meanwhile, the rollout of COVID-19 vaccines has highlighted the need for cold chains and cooling systems powered by reliable and sustainable energy. Despite many new energy policies and efforts on energy access for remote areas in Sub-Saharan Africa, the necessary infrastructure for cold storage for vaccines and other medical goods remains insufficient in many of these areas. The fact that solar energy is abundant in Sub-Saharan Africa led the Bisolar Tech Fridge team to create solar-powered cold storage units using one compressor for multiple applications, including pre-cooling, cold storage and charging a cold storage unit.

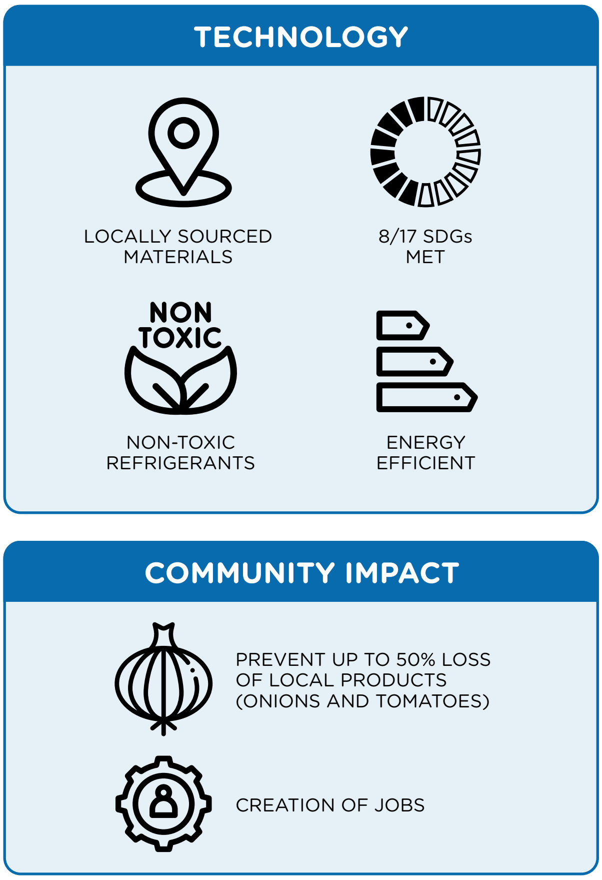
The team behind the Bisolar Tech Fridge was able to set up a remarkably high-impact project that contributes to eight of the 17 SDGs. Technically, the units make use of solar power and non-toxic refrigerants, achieving thermal conversion efficiency of 70 percent and PV conversion efficiency of 15 percent, with overall device efficiency of about 45 percent. By using solar energy, the solution can enable reliable access to cooling for vaccines and medical goods in off-grid settings, and at scale the solution could store over 360,000 vaccine doses in rural areas.

When applied to the agriculture cold chain, these systems can support meaningful benefits for community nutrition by reducing energy needs for food storage and supplying any excess energy to power lighting or charge phones. To produce the units, the team recycles old refrigerator appliances and refurbishes them. This helps to create jobs in particular for women and young people, who have traditionally been involved in collecting the materials for manufacturing. Already, the project has created 15 jobs and the company hopes to employee over 135 people at scale.

As a result of these efforts, the Bisolar Tech Fridge Technology was the runner up out of 130 teams competing in the innovation competition of the SEforALL Youth Summit in February 2021.

FIGURE 4.3

Benefits of the Bisolar Tech Fridge



TECHNOLOGY

LOCALLY SOURCED MATERIALS

8/17 SDGs MET

NON-TOXIC REFRIGERANTS

ENERGY EFFICIENT

COMMUNITY IMPACT

PREVENT UP TO 50% LOSS OF LOCAL PRODUCTS (ONIONS AND TOMATOES)

CREATION OF JOBS

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[7] Is Post-Harvest Loss Significant in Sub-Saharan Africa? FAO. Link

The Power of Passive Solutions in Bangladesh and Indonesia

Credit: James P Grant School of Public Health, the Department of Architecture of BRAC University, Bangladesh and the Architecture Study Programme, Universitas Pendidikan Indonesia

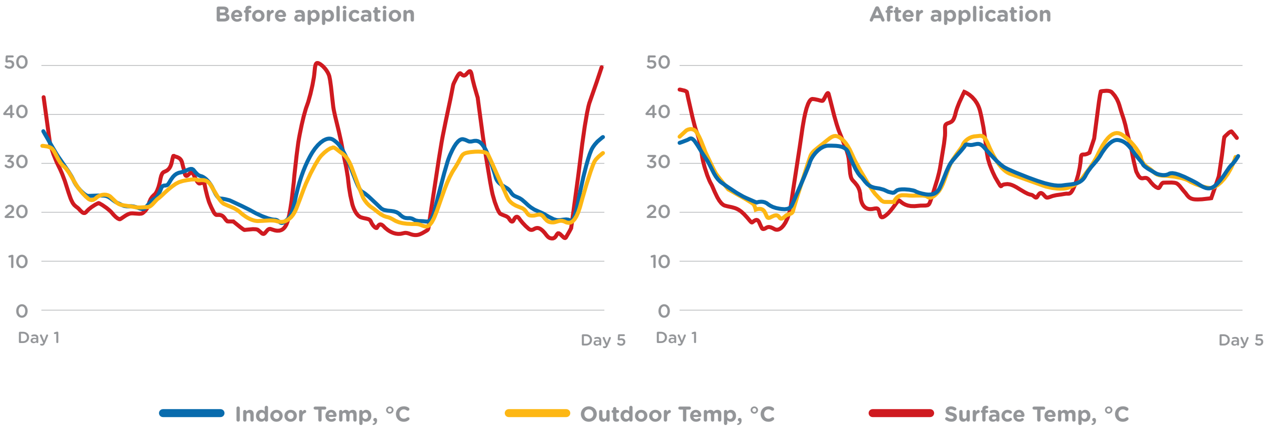
Bangladesh is a tropical warm and humid country. Dhaka, the capital city, has approximately 16–18 million people, of whom about 40 percent live in low-income communities or slums. After becoming one of the finalists in the Million Cool Roofs challenge in 2019, the Bangladesh team from the James P Grant School of Public Health (JPGSPH) and the Department of Architecture of BRAC University embarked on the work for deployment of cool roofs, a simple and sustainable cooling solution appropriate for houses in the slums and garment factories where the majority of the workers are female.

The team selected two garment factories and 105 buildings, including a day care centre and a school, in the Kerail slum on which to test the cool roofs, consisting of reflective paint. Implementation was initially challenging, and while the COVID-19 pandemic caused a delay, other issues also needed to be overcome. This included a lack of locally available paints that met reflectivity requirements, and the fact that some roofs were so thin that it was difficult to work on them and apply the paint, since roofs in Kerail are typically made from the least expensive and thinnest corrugated iron sheets.

Initial results from implementation show significant impacts on temperature. In one building indicated the cool roof produced a dramatic decline in surface temperature of 12.3°C during times of peak temperature, demonstrating the efficacy of the cool roof in reflecting thermal energy. The cool roof also had the effect of reducing indoor air temperature during peak heat by 7.72°C. Crucially, cool roofs had the effect of keeping indoor air temperatures lower than outdoor temperatures, which exceeded outdoor air temperatures at peak heat prior to their application, and on average achieved a temperature reduction of 3.5°C in indoor temperatures relative to before the coating.

FIGURE 4.4

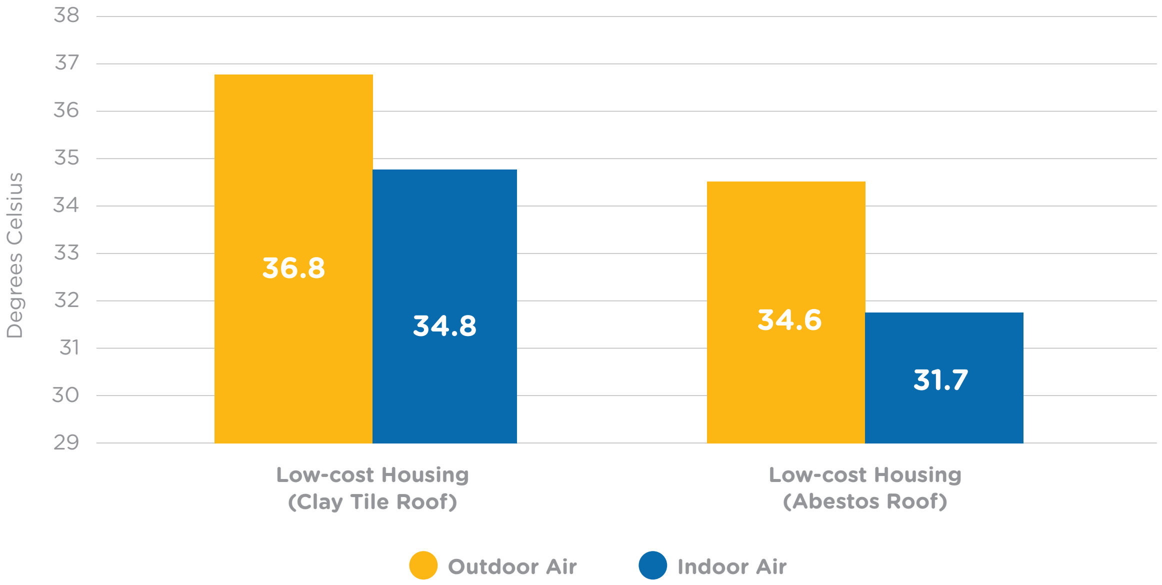
Temperatures before and after the application of cool roofs in Bangladesh



In Indonesia, a team from the Universitas Pendidikan Indonesia is applying cool roofs to homes, religious institutions, schools and factories, and is securing important impacts for these communities. In low-cost housing in Jakarta, cool roofs were applied to dwellings with clay tile and asbestos roofs. A sampling of the data shows that on warm days, with temperatures of 34°C and higher, the cool roofs reduced the indoor air temperature relative to outdoors by 2°C on a clay tile roof and 2.9°C on an asbestos roof. This effect alone can make a huge difference during a heatwave and provide thermal comfort benefits, which can be further enhanced with other passive solutions or fans.

FIGURE 4.5

Temperatures following the application of cool roofs to low-cost housing in Indonesia

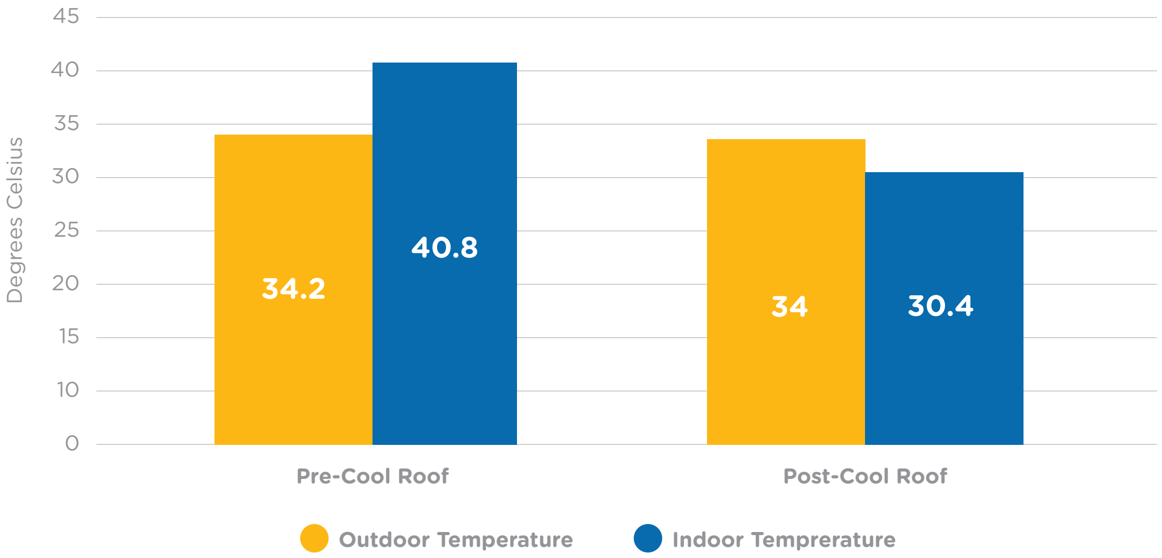


In an industrial building in Indonesia, a 5,200m² cool roof created a temperature reduction of 10.4°C for the 500 people working there as shift workers. With outdoor, noon-time temperatures of approximately 34°C at both measurement points, indoor air temperatures dropped to 30.4°C after the cool roof was applied compared to 40.8°C before it.

The impacts of the overall project are evident, not simply in terms of greater productivity for workers in an industrial building or people in low-cost housing. A survey of project beneficiaries indicated that 100 percent of the participants found the cool roof helpful or very helpful. Prior to the cool roof application, 94 percent of beneficiaries described temperatures as hot or very hot, while 100 percent indicated they were neutral, cool, or cold for them subsequently.

FIGURE 4.6

Effects of a cool roof on an Indonesian industrial building



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