2020 CHILLING PROSPECTS

TRACKING SUSTAINABLE COOLING FOR ALL

SUSTAINABLE ENERGY FOR ALL

#CoolingforAll

KIGALI COOLING EFFICIENCY PROGRAM

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Notes on all maps contained in this report: 1. The dotted line represents approximately the Line of Control in Jammu and Kashmir by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties. 2. All maps were produced by SEforALL. They are based on the UN Map of the World, which can be found here: http://www.un.org/Depts/Cartographic/map/profile/world.pdf. The boundaries, colours, denominations and any other information shown on these maps do not imply, on the part of SEforALL, any judgment on the legal status of any territory or any endorsement or acceptance of such boundaries.

EXECUTIVE SUMMARY

GLOBAL ACCESS TO COOLING IN 2020

Across 54 high-impact countries, 1.02 billion people among the rural and urban poor remain at high risk in 2020. This includes 318 million people living in poor rural areas and 699 million living in poor urban areas. A further 2.2 billion lower-middle income people pose a different kind of risk: limited purchasing choices mean they are likely to favour cooling devices that are typically inefficient and could cause a dramatic rise in energy demand and associated emissions. In Africa, the rural poor population continues to grow, to 204 million in 2020, whereas in Asia, the number of urban poor continues to grow, up to 484 million people in 2020. A case study on India also shows the sub-national dimensions of measuring and addressing sustainable cooling for all.

COOLING FOR ALL AND COVID-19

The COVID-19 pandemic that has dominated headlines since early 2020 has reshaped economic systems, changed human behaviour across the globe and demanded that the world rethink its response to climate change. Less widely appreciated are the impacts the pandemic has had on the developing world, how COVID-19 amplified other risks, and the opportunity to recover better with sustainable energy for all.[1] From finding social distance when temperatures rise to ensuring an affordable nutritious diet despite the economic downturn, access to cooling supports human needs highlighted by the pandemic. But perhaps most significant is the rapid expansion of the medical cold chain that may be necessary to deliver a vaccine. Most temperature-sensitive vaccines, such as influenza vaccines, require cold storage between 2°C and 8°C, but close to half of the vaccine candidates currently in Phase 1 or later trials will require storage in a -80°C cold chain, which would require building a new cold chain for low-income countries.

THE PRODUCTIVITY PENALTY OF FAILING TO DELIVER SUSTAINABLE COOLING

As global temperatures rise, it has become clear that a dramatic expansion of air conditioning and the associated energy demand could have serious environmental consequences, and a lack of access to cooling, particularly for those working outdoors, poses a significant challenge for economic development. In 2019 the International Labour Organization (ILO) estimated that by 2030 the global economy would suffer lost productivity worth USD 2.4 trillion annually due to heat stress, the equivalent of 80 million full-time jobs. In the aggregate, these are alarming figures. But they also belie the disproportionate impact on developing economies experiencing increasing heat stress, and the long-term impact heat stress will have on economic growth. It will be these countries, and the sectors that support their growth, that face the most significant productivity penalty due to a lack of access to sustainable cooling. The analysis suggests that across 54 high-impact countries, the estimated annual economic loss due to heat stress is currently USD 630 billion, including USD 301 billion in the agricultural sector.

SUSTAINABLE COOLING SOLUTIONS

Cooling for all does not mean an air conditioner or a refrigerator in every home; it means providing more sustainable and affordable solutions to address the needs of the vulnerable. Beyond achieving the basic needs for cooling, these same sustainable cooling solutions also deliver significant benefits across the economy to countries, companies and the population at large. The consideration of cooling solutions must be grounded

[1] Sustainable Energy for All (2020), The Recover Better with Sustainable Energy Guide for African Countries. June 30, 2020. Available: https://www.seforall.org/RecoverBetter

in an understanding of cooling needs that span multiple sectors, as identified in the Cooling for All Needs Assessment. This chapter explores sustainable cooling solutions, from the perspective of three cooling needs, five solution approaches, and four solution pillars that can be used to optimize cooling solutions for sustainability and for access to cooling. The goal is to build a conversation with partners that can support the achievement of cooling for all, and serves as a starting point from which to develop the Cooling for All Solutions Assessment toolkit, which will support users to understand the right solutions based on their cooling needs.

1. GLOBAL ACCESS TO COOLING IN 2020

As governments across the globe respond to the COVID-19 pandemic, extreme heat continues to increase, threatening immediate public health and safety, as well as the long-term economic recovery from the pandemic. Intolerable levels of heat and humidity, previously forecast for mid-century, were already occurring prior to 2020, and more than doubled in their frequency between 1979 and 2017.[2] Existing forecasts are also being challenged, and current projections are that intolerable heat will become worse without drastic action to combat climate change, including in seven South Asian countries that are home to 1.5 billion people where the number of days with extreme heat could rise from 45 days annually now to 78 days in 2050.[3]

Vaccination campaigns have stalled during the pandemic, with 13.5 million people in Least Developed Countries (LDCs) having already missed routine vaccinations by 3 April 2020. Significantly higher rates of poverty and malnutrition are forecast through 2020.[4] Taken together with the challenges of social and physical distancing during extreme heat, 2020 has highlighted the need to deliver sustainable cooling as a means of underpinning the recovery from the pandemic, as well as achieving the Sustainable Development Goals (SDGs) by 2030.

The *Chilling Prospects* series tracks immediate vulnerability to a lack of access to cooling, identifying populations at risk whose lack of access threatens their immediate health and safety. It models risk on the basis of a spectrum of access to cooling that crosses human safety and comfort, food and nutrition security and agriculture, and health services for four populations: the rural poor, the urban poor, the lower-middle income, and the middle income.

In 2020, a significant reduction in the number of the rural poor was driven by increased access to electricity in India but was partially offset by an increase in the number of urban poor, who are also at high risk from a lack of access to cooling.

The analysis for 2020 shows that across 54 high-impact countries 1.02 billion people among the rural and urban poor remain at high risk. A further 2.2 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.

2 Raymond, Colin, et al. "The Emergence of Heat and Humidity Too Severe for Human Tolerance," Science Advances, Vol. 6, no 19. 8 May 2020. Available: https://advances.sciencemag.org/content/6/19/eaaw1838

3 Xu, Yangyang and Wu, Xiaokang, et al. "Substantial increase in the Joint Occurrence and Human Exposure of Heatwave and High-PM Hazards Over South Asia in the Mid-21st Century," Advancing Earth and Space Science, Vol. 1, no. 2, June 2020.

4 COVID-19: Massive impact on lower-income countries threatens more disease outbreaks, Gavi: The Vaccine Alliance, 3 April 2020. Available: https://www.gavi.org/news/media-room/covid-19-massive-impact-lower-income-countries-threatens-more-disease-outbreaks

A NOTE ON THE DATA

Previous *Chilling Prospects* reports have detailed the data challenges in measuring access to cooling. In the first half of 2020, Sustainable Energy for All (SEforALL) undertook a review of new data sources and updates to existing data sets in order to provide a 10-year review of trends in access to cooling. This report represents the updates to the figures for 2018 and 2019, includes two additional high-impact countries, and provides a data annex that tracks access gaps for the rural poor, urban poor and lower-middle income populations from 2010, which is also available for download at the SEforALL website.

FIGURE 1.1: SPECTRUM OF RISKS IN HIGH TEMPERATURE ENVIRONMENTS

HIGH 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

MEDIUM RISK

- 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

LOW RISK

- Full and stable access to electricity
- Middle income and higher
- Well-built home, can include insulation, passive design, air conditioning
- Food is refrigerated reliably
- Farmer's goods and vaccines have well-controlled cold chains

TABLE 1.1: POPULATIONS AT RISK: 2020 ACCESS TO COOLING GAPS

POPULATIONS AT RISK	HIGH RISK		MIDDLE RISK	LOW 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 USD 10.01 and USD 20.01 / day
2019 ACCESS GAP	358 million	681 million	2.22 billion	1.32 billion
2020 ACCESS GAP	318 million	699 million	2.20 billion	1.42 billion
CHANGE	-40 million	+18 million	-26 million	+97 million
FINDINGS AND TRENDS	• Continued rural electricity access gains • Increased vulnera-bility in Bangladesh and Angola	• Continued urbaniza-tion • Consistent increase in vulnerability among top 10 • Nexus challenges with COVID-19	• Purchase of cooling devices associated with income growth, • Strong growth in India with consis-tent decreases in China	• Increased purchasing power and growth of an established middle class • COVID-19 may challenge purchasing power in the future
NOTE	• Over 1 billion remain at high risk, 22 million less than in 2019. • The dominant urbanization trend from 2019 continues to be felt in Asia and Africa, where the number of urban poor continues to increase. • Energy access and poverty reduction gains have decreased the number of rural poor at risk, but the shockwaves of COVID-19 may impact this significantly in 2020 if poverty increases.			

Note: Figures may not sum up due to rounding.

Compared to 2019, the analysis shows a decrease of approximately 22 million people who are at high risk of a lack of access to cooling, from 1.04 billion to just under 1.02 billion. The number of urban poor at high risk has grown by approximately 18 million from 681 to 699 million, while the rural population has decreased by approximately 40 million from 358 million to 318 million. The lower-middle income population has decreased, but only slightly, from 2.22 billion in 2019 to 2.20 billion in 2020. Across the 54 high-impact countries, at least 3.2 billion people still face cooling access challenges, with only minor improvements noted between 2019 and 2020.

GLOBAL ACCESS TO COOLING: POPULATIONS AT RISK

Rural poor – approximately 318 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.

The number of those at high risk in poor, rural areas decreased by 40 million from 358 million in 2019 to 318 million in 2020. This decrease in numbers was driven by enhanced access to electricity, a key enabler of access to cooling, notably in India, Indonesia, and Myanmar. In Bangladesh however, the number of rural poor increased due to declining energy access rates in rural areas. In Angola, the number of rural poor at risk was also revised upward due to updated rural poverty figures. In 2020, Nigeria surpassed India as the country with the highest number of rural poor at risk from a lack of access to cooling.

FIGURE 1.2: THE RURAL POOR IN 2020

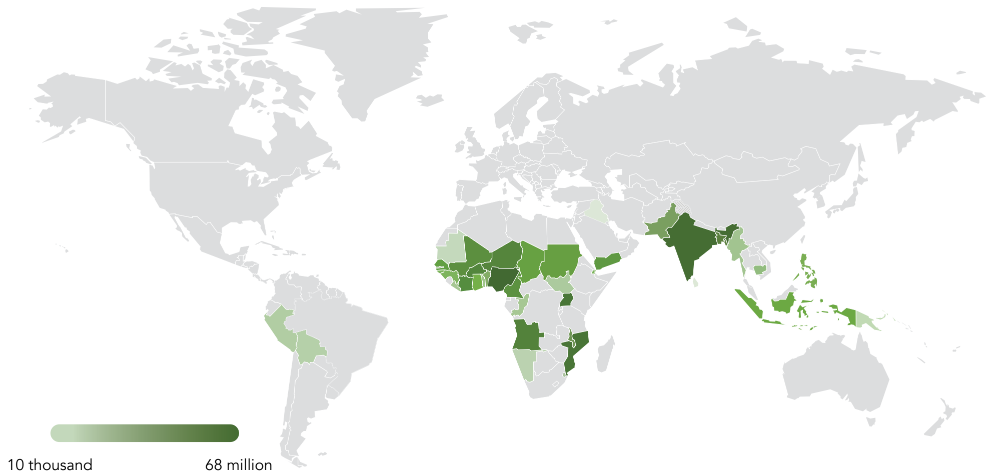


FIGURE 1.3: THE RURAL POOR SINCE 2018

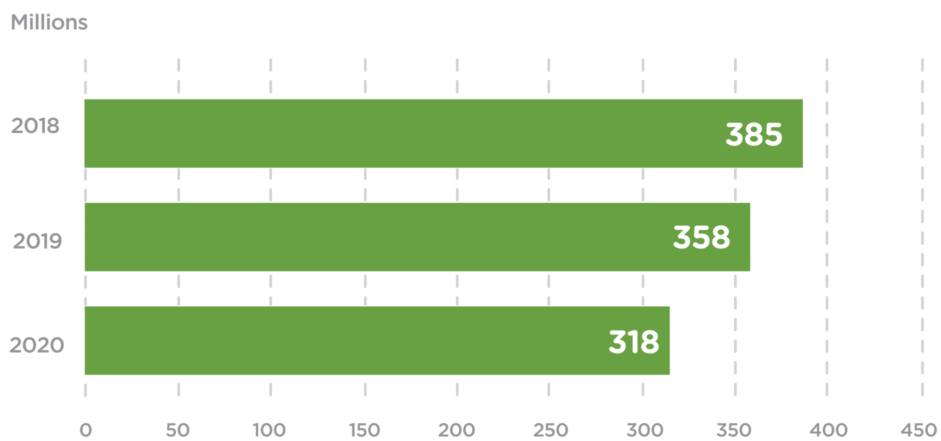


TABLE 1.2: TOP 10 COUNTRIES WITH RURAL POOR AT RISK

COUNTRY	2018	2019	2020
Nigeria	63,011,491	74,561,781	67,159,666
India	129,511,367	94,960,997	63,093,075
Bangladesh	23,379,684	18,874,198	22,221,547
Uganda	16,533,010	17,164,748	17,815,549
Mozambique	17,144,712	17,400,838	17,371,746
Malawi	12,095,318	12,422,193	12,754,750
Angola	10,340,319	10,483,867	10,200,052
Niger	9,251,033	9,613,100	9,987,112
Burkina Faso	8,148,467	8,387,465	8,631,421
Pakistan	7,941,464	8,107,971	8,276,386

Urban poor – approximately 699 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.

In 2020, the number of those living in poor urban settings at highest risk grew from 681 million to 699 million, reflecting a consistent pattern of urbanization across developing Asia and Africa. In each of the top 10 countries vulnerability has increased year on year since 2018. Urban centres projected to see an increase in heat stress will see compounding risks for those who are at high risk from a lack of access to cooling if these challenges are not addressed. Many vulnerable groups including the elderly, those with pre-existing health conditions, and those living in poor quality housing are also more susceptible to COVID-19 and may have significantly more exposure to air pollution and the urban heat island effect (UHIE).

FIGURE 1.4: THE URBAN POOR IN 2020

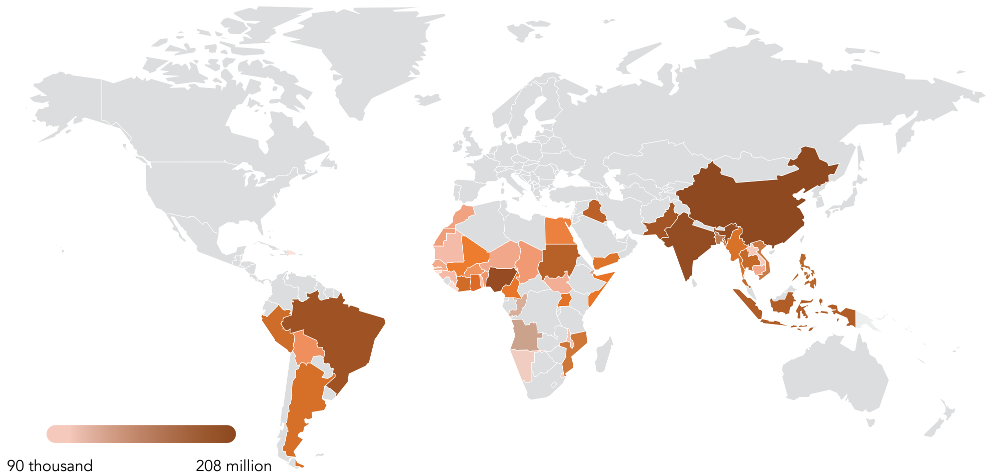


FIGURE 1.5: THE URBAN POOR SINCE 2018

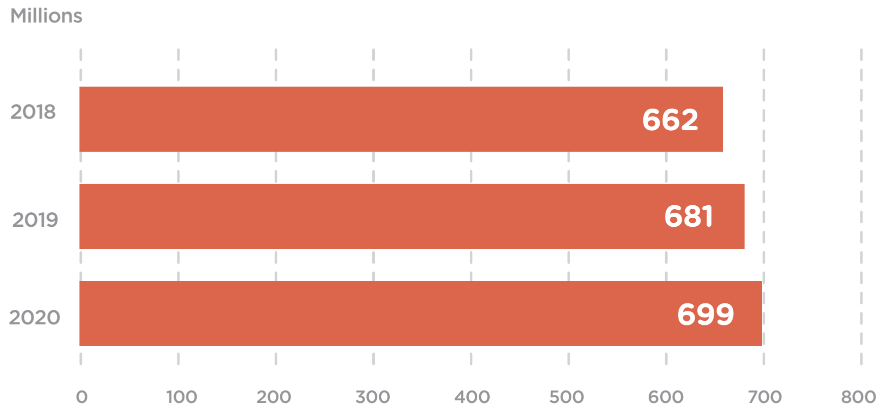


TABLE 1.3: TOP 10 COUNTRIES WITH URBAN POOR AT RISK

COUNTRY	2018	2019	2020
China	197,114,242	202,495,745	207,604,568
India	105,479,705	107,949,448	110,470,962
Nigeria	45,446,586	47,448,315	49,502,812
Brazil	39,557,260	40,001,584	40,437,818
Pakistan	33,570,951	34,471,578	35,403,897
Bangladesh	30,536,921	31,547,329	32,568,477
Indonesia	30,783,891	31,534,309	32,282,485
Philippines	18,452,101	18,804,145	19,160,424
Sudan	12,454,252	12,849,249	13,264,493
Iraq	12,112,396	12,456,714	12,784,267

Lower-middle income – approximately 2.2 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.

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 decrease in this segment between 2019 and 2020 of approximately 26 million people, a decline indicative of a growing global middle class and lower prices for entry-level air-conditioning and refrigeration units. In China, rapid growth in air-conditioning markets has reduced its lower-middle income populations, while in India the opposite effect is observed; income growth has led to the purchasing power necessary to purchase a household electrical cooling device, but without significant market penetration as of yet (see India case study).

FIGURE 1.6: THE LOWER-MIDDLE INCOME IN 2020

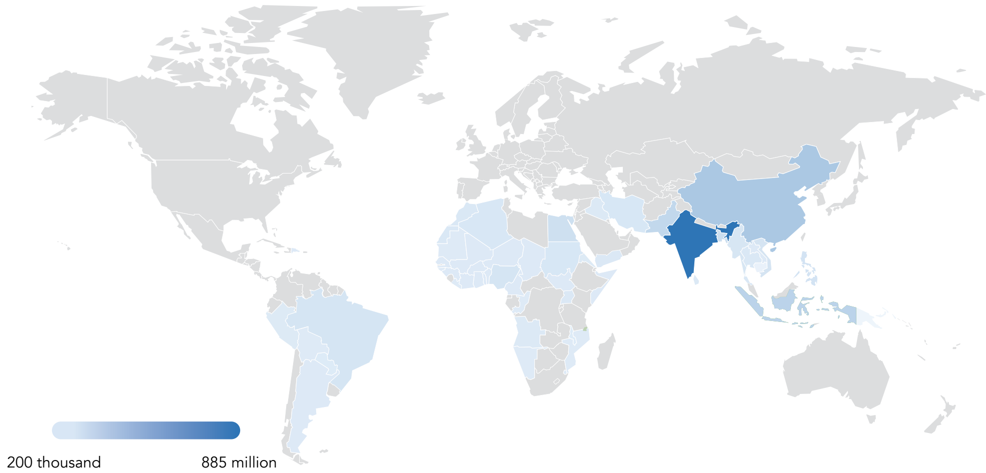


FIGURE 1.7: THE LOWER-MIDDLE INCOME SINCE 2018

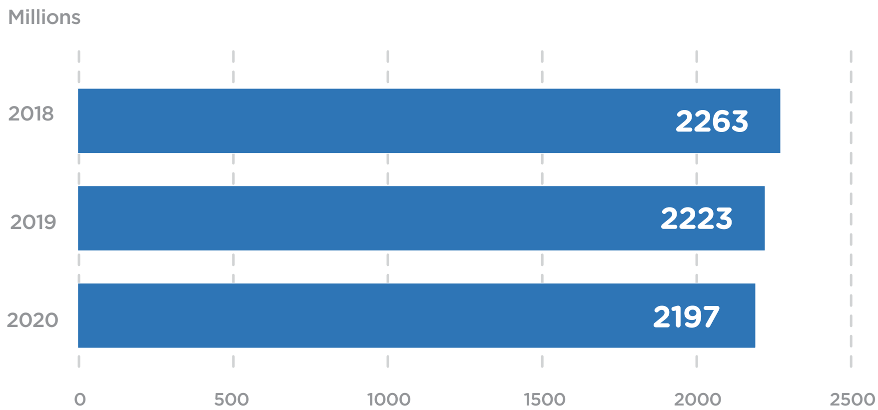


TABLE 1.4: TOP 10 COUNTRIES WITH LOWER-MIDDLE INCOME POPULATIONS

COUNTRY	2018	2019	2020
India	865,329,473	876,726,294	885,388,896
China	324,895,632	290,384,458	256,145,964
Indonesia	185,045,367	181,611,818	179,590,227
Pakistan	146,451,598	145,966,902	145,448,605
Bangladesh	99,125,544	102,620,623	98,252,126
Egypt	82,702,630	85,528,445	85,438,875
Philippines	56,281,385	55,932,719	56,207,120
Vietnam	53,611,241	51,797,703	49,231,996
Brazil	45,806,702	46,644,340	44,879,041
Nigeria	49,027,366	37,025,813	43,923,897

Middle income: approximately 1.4 billion people

The middle-income segment of the population own an air conditioner and may be able to afford a more efficient one. They might also make conscious choices not to own an air-conditioning unit or minimize its use. They may represent the established middle class where affordability may also allow them to move to better designed, more efficient housing and working environments.

The middle-income segment of the population are the people who live on between USD 10.01 and USD 20 per day. There was an increase in the middle-income population of approximately 97 million people between 2019 and 2020, likely indicative of growing purchasing power in Asia and in Latin America and the Caribbean. However, it should not be assumed that an increase in the middle-income population implies an associated increase in income. It is expected that as a result of the COVID-19 pandemic, most households will have decreased purchasing power and income, which may affect this group substantially in the future.

FIGURE 1.8: THE MIDDLE INCOME IN 2020

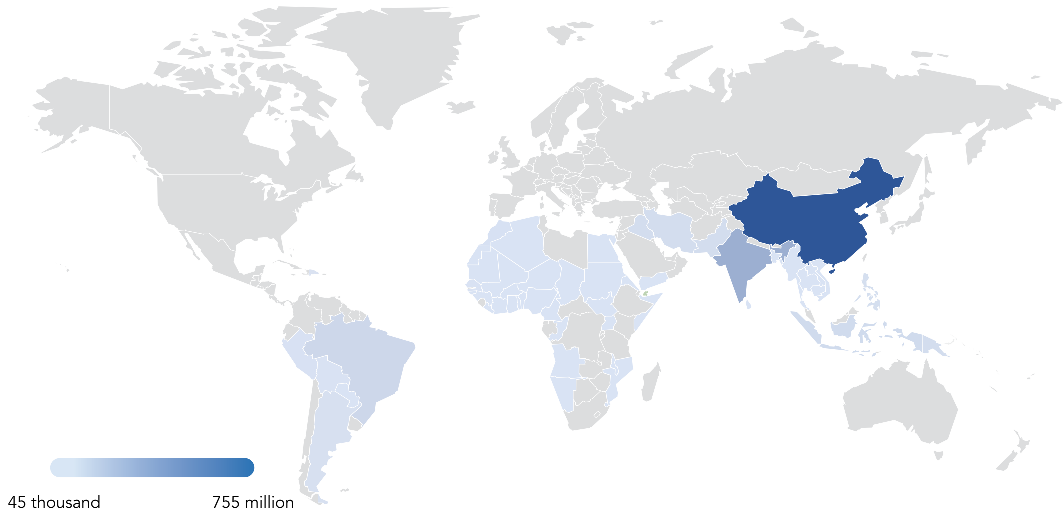
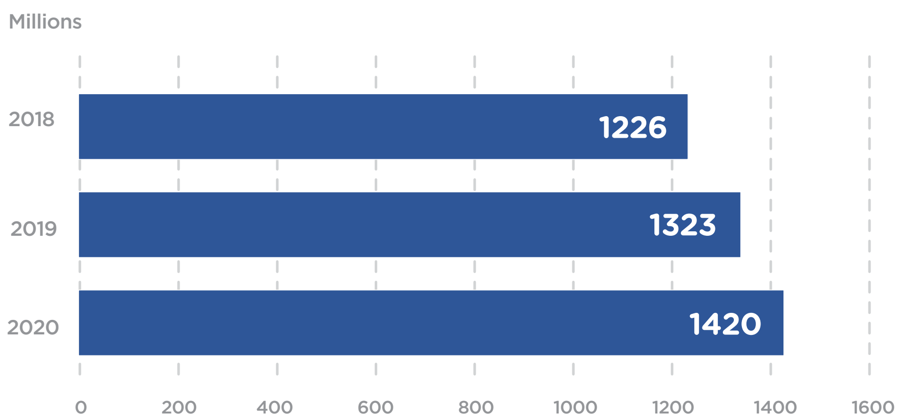


FIGURE 1.9: THE MIDDLE INCOME SINCE 2018



POPULATIONS AT RISK: REGIONAL TRENDS

In addition to providing an understanding of the global populations at risk, additional analysis allows for geographic comparison, in particular to highlight where those at highest risk are concentrated.

Africa

In Africa, 31 countries are identified as being high impact for access to sustainable cooling. Within these countries, it is the rural poor segments of the population that face the most significant risks. Across the countries assessed, the rural poor at risk account for 48 percent of the total rural population, or 26 percent of the total population. Since 2018, the number of rural poor facing cooling access risks has grown 4 percent, from approximately 197 to 204 million people, accounting for 64 percent of the total number of rural poor globally.

By contrast, the urban poor at risk from a lack of access to cooling in Africa account for 22 percent of the global total but they are the category with the highest rate of growth on the continent. Currently, the urban poor account for 20 percent of the total population assessed, but when looking specifically at those living in cities, the number rises to 43 percent, meaning that in Africa, almost half of urban dwellers in the high-impact countries for access to sustainable cooling are at high risk. This includes 19 countries where more than half of the urban population is at high risk. With urbanization expected to grow, we can expect a continued increase in the number of those at risk in poor urban centres unless cities adapt to the challenge. The reduction in size of the lower-middle income population of 8 percent relative to 2018 may be as indicative of exposure to poverty and risk as it is of income growth in the African countries.

FIGURE 1.10: TRENDS IN POPULATIONS AT RISK ACROSS 31 HIGH-IMPACT AFRICAN COUNTRIES

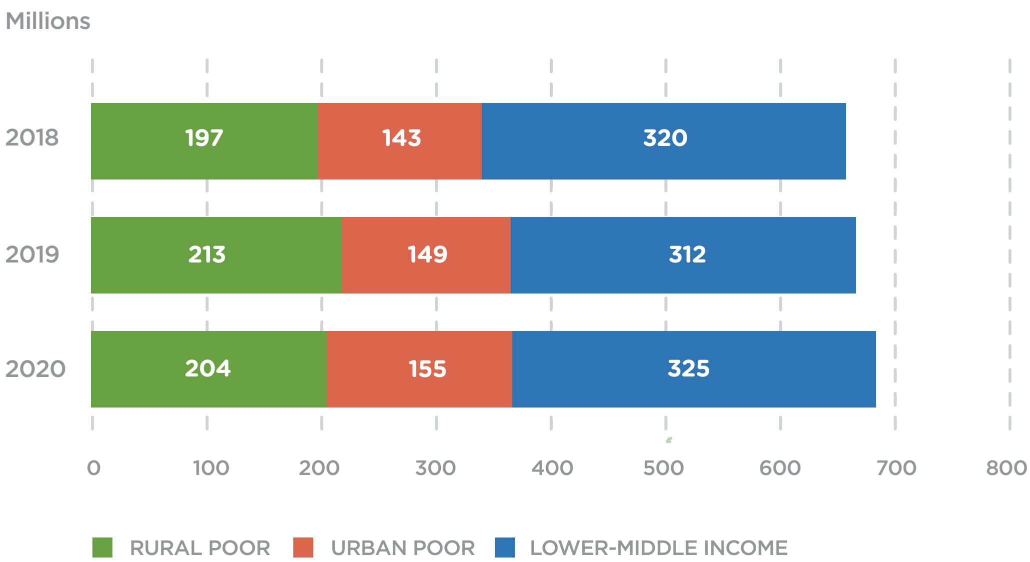
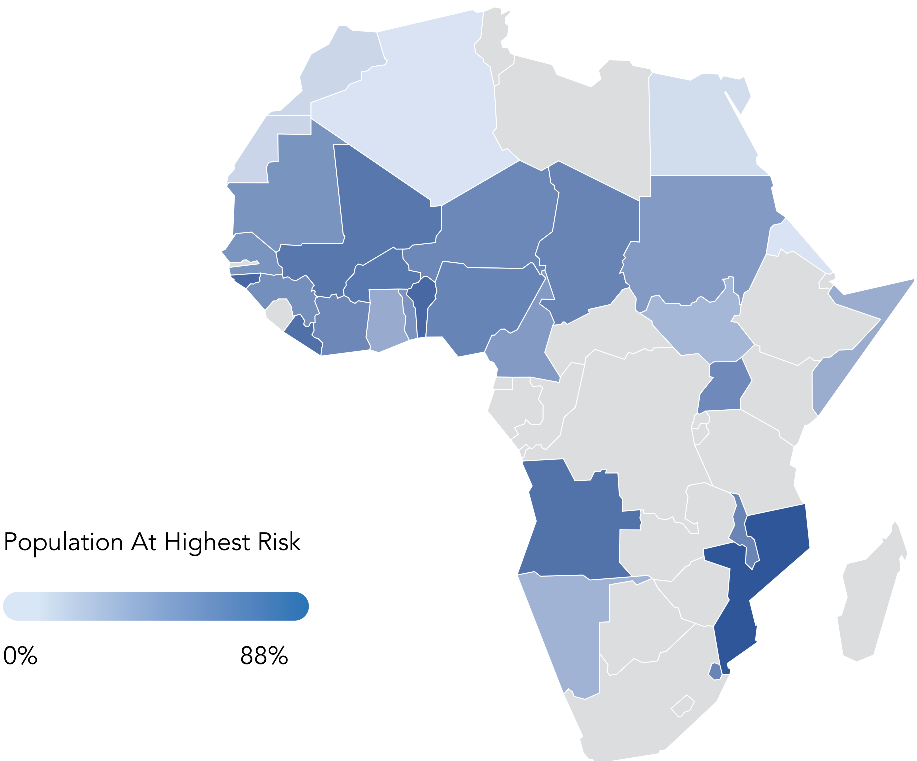


TABLE 1.5: TRENDS ACROSS 31 HIGH-IMPACT COUNTRIES IN AFRICA

Population at Risk	Change since 2018 (%)	Proportion of Population (% of total population)	Proportion of the Population (% of global total for vulnerable group)
Rural Poor	4%	26%	64%
Urban Poor	8%	20%	22%
Lower-Middle Income	1%	41%	15%

In total, approximately 359 million people in Africa are at high risk due to a lack of access to cooling. **Of the African countries identified as high impact, 10 still have over 60 percent of their populations at highest risk – Angola, Benin, Burkina Faso, Djibouti, Guinea-Bissau, Liberia, Malawi, Mali, Mozambique and Togo.** Overall, of the high-impact countries in Africa, 45 percent of their total populations are categorized as high risk, compared to 47 percent in 2019 and 45 percent in 2018.

FIGURE 1.11: SHARE OF POPULATION AT HIGHEST RISK, 2020



Asia and the Middle East

In Asia progress in terms of energy access, poverty reduction and energy security has meant that the challenges for access to cooling are growing in cities, rather than in rural areas. Between 2019 and 2020, the number of urban poor at risk from a lack of access to cooling grew by 12 million people, from 472 million to 484 million across 16 high-impact countries for access to sustainable cooling. In Bangladesh, Cambodia and Yemen, urban risks are particularly acute, with over 50 percent of all urban residents in each country at high risk from a lack of access to cooling.

For rural poor populations in high-impact countries in Asia and the Middle East, significant progress in energy access that can enable electrical cooling has reduced risk, notably in India, Indonesia, Myanmar and the Philippines. This has led to a substantial decrease in the number of rural poor at risk, from 182 million in 2018 to 108 million in 2020. In Bangladesh, where rural energy access stalled in 2020, there was an increase of 3.5 million people in rural settings at high risk.

Overall, the populations at highest risk in Asia and the Middle East decreased by 19.5 million to 592.7 million in 2020, compared to 612.2 million in 2019 and 642.6 million in 2018. This represents 15.2 percent of the total population, relative to 15.8 percent in 2019 and 16.8 percent in 2018.

A key issue for Asia and the Middle East is the growing middle class and increasing demand for electrical cooling, particularly as it relates to changes in the size of the lower-middle income population, categorized as those who live on less than USD 10.01 per day, but are not in poverty. One example of how this dynamic is changing is the varying trajectories of the lower-middle income population in China and India. In China, where income is growing and sales of devices such as air conditioners are increasing, the lower-middle income population is in consistent decline as people gain the ability to afford higher efficiency devices. In India, where millions are moving out of poverty, the lower-middle income population is growing, indicative of a group prepared to purchase their first cooling device. Across the remaining high-impact countries, the numbers of the lower-middle income population remained relatively stable in 2020 compared to 2019.

FIGURE 1.12: TRENDS IN POPULATIONS AT RISK ACROSS 16 HIGH-IMPACT COUNTRIES IN ASIA AND THE MIDDLE EAST

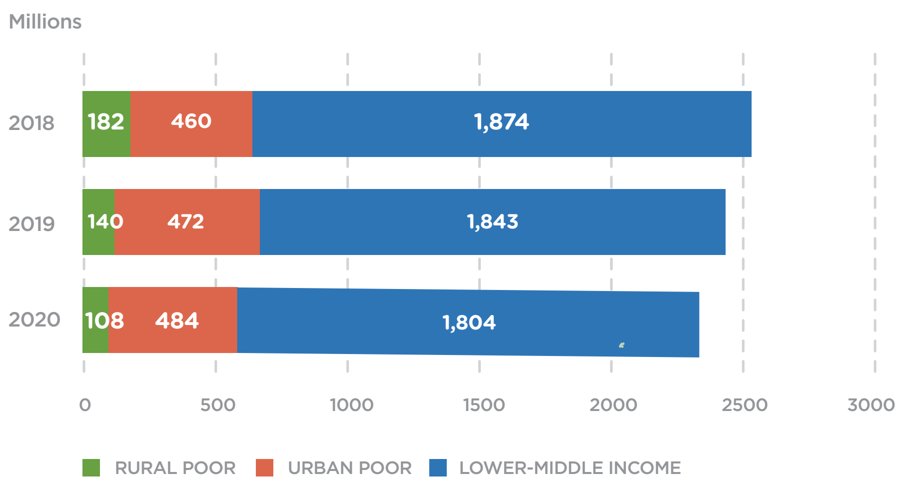
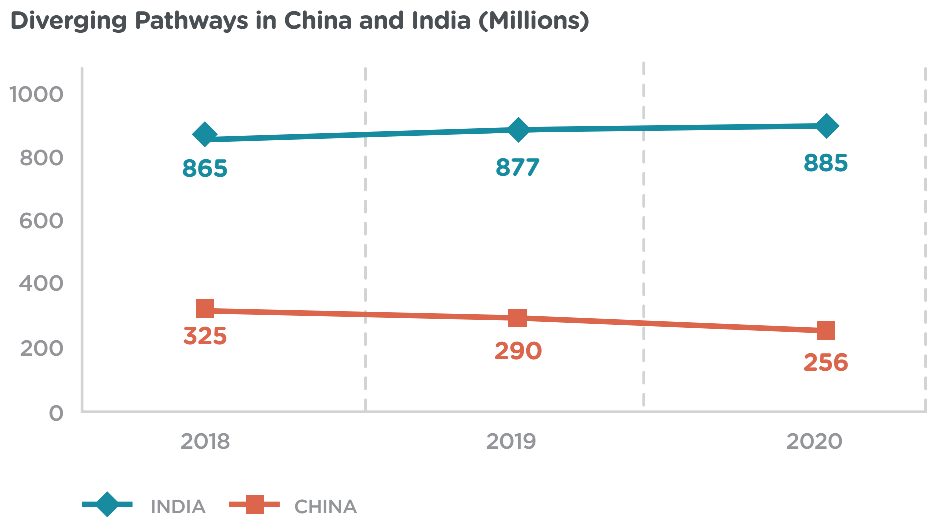


TABLE 1.6: TRENDS ACROSS 16 HIGH-IMPACT COUNTRIES IN ASIA AND THE MIDDLE EAST

Population at Risk	Change since 2018 (%)	Proportion of Population (% of total population)	Proportion of the Population (% of global total for vulnerable group)
Rural Poor	-40%	3%	34%
Urban Poor	5%	12%	69%
Lower-Middle Income	-4%	46%	82%

FIGURE 1.13: DIVERGING PATHWAYS IN CHINA AND INDIA FOR THE LOWER-MIDDLE INCOME



Latin America and the Caribbean

In six countries considered to be high impact for access to sustainable cooling in Latin America and the Caribbean, the number of those at highest risk grew slightly to 61.6 million people in 2020, up from 61.3 million in 2019. Of those at highest risk, the vast majority are the urban poor, where the population continues to increase slightly year on year. Small, but important populations of rural poor at risk due to a lack of access to cooling are observed only in Bolivia and Peru in 2020.

Of those at highest risk among the rural and urban poor, Brazil accounts for 66 percent of both populations, including 40.4 million urban poor in 2020. Brazil also accounts for 69 percent of the region's lower-middle income population, with 44.9 million people in this category. Here, a convergence between the urban poor through growth and the lower-middle income through a decrease in their numbers is indicative of increased economic strain being placed on urban residents who live in poverty or may become exposed to it. Across four high-impact countries, Argentina, Bolivia, the Dominican Republic and Peru, similar, marginal increases in urban poor populations are observed with the lower-middle income populations remaining consistent.

FIGURE 1.14: TRENDS IN POPULATIONS AT RISK ACROSS 6 HIGH-IMPACT COUNTRIES IN LATIN AMERICA AND THE CARIBBEAN

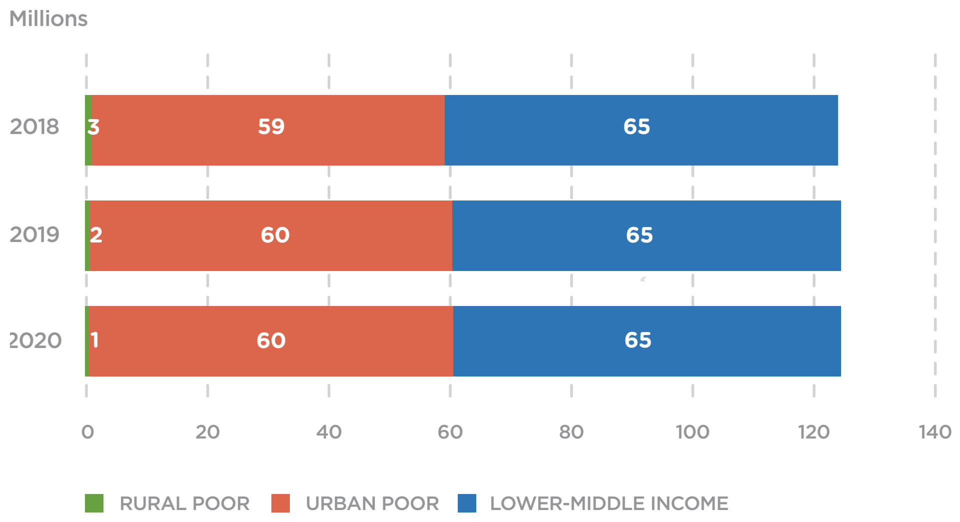
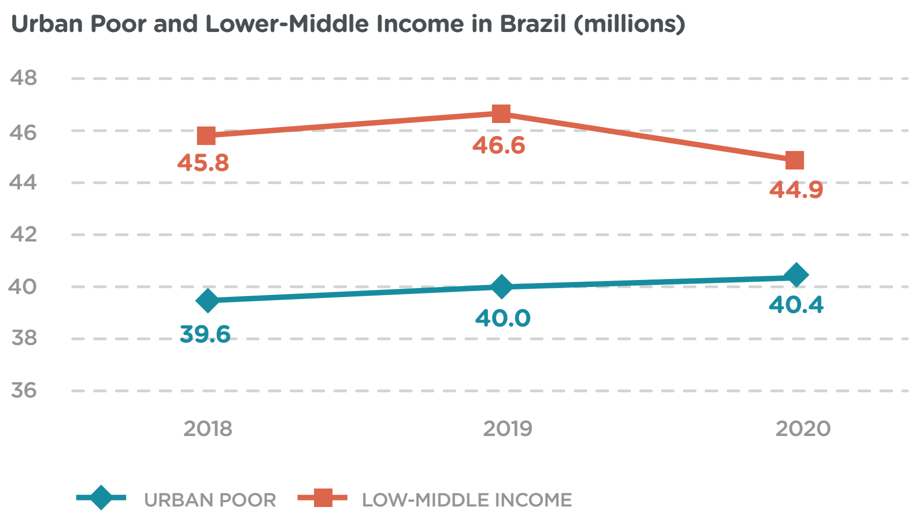


TABLE 1.7: TRENDS ACROSS 6 HIGH-IMPACT COUNTRIES IN LATIN AMERICA AND THE CARIBBEAN

Population at Risk	Change since 2018 (%)	Proportion of Population (% of total population)	Proportion of the Population (% of global total for vulnerable group)
Rural Poor	-48%	0.4%	0.4%
Urban Poor	3%	19%	9%
Lower-Middle Income	-	21%	3%

FIGURE 1.15: TRENDS IN THE URBAN POOR AND LOWER-MIDDLE INCOME IN BRAZIL



DATA ANNEX: THE RURAL POOR

COUNTRY	CONTINENT	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Algeria	Africa	173,653	176,669	179,887	183,307	186,919	165,577	60,382	27,267	4,034	0	0
Angola	Africa	6,530,386	7,170,798	7,847,699	8,562,004	9,315,042	9,885,476	10,038,994	9,803,992	10,340,319	10,483,867	10,200,052
Argentina	South America	160,777	177,517	365,942	262,771	197,080	214,228	0	68,286	11,274	0	0
Bangladesh	Asia	28,283,617	28,601,260	28,924,784	28,063,470	27,181,405	26,275,524	25,341,307	24,375,979	23,379,684	18,874,198	22,221,547
Benin	Africa	4,499,202	4,559,525	4,681,487	4,608,310	4,645,205	4,741,261	4,725,428	4,846,277	4,880,244	4,926,058	4,941,806
Bolivia	South America	1,069,360	1,028,017	889,300	745,546	850,969	727,424	620,978	695,663	783,259	649,186	487,377
Brazil	South America	2,542,655	1,974,556	2,002,663	1,156,386	834,749	742,776	614,792	514,304	441,102	0	0
Burkina Faso	Africa	8,123,418	8,373,027	8,267,644	8,147,096	8,010,540	7,856,891	7,685,089	7,914,343	8,148,467	8,387,465	8,631,421
Cambodia	Asia	0	0	0	0	0	0	0	0	0	0	0
Cameroon	Africa	4,582,135	4,710,001	4,841,215	4,975,720	5,113,493	5,254,397	5,398,282	5,545,012	5,694,516	5,846,719	6,001,464
Chad	Africa	4,294,498	4,439,096	4,589,620	4,746,620	4,909,344	5,076,643	5,246,807	5,418,614	5,591,680	5,766,441	5,943,456
China	Asia	14,226,397	11,281,251	4,013,115	1,688,469	339,343	0	0	0	0	0	0
Congo, Rep.	Africa	1,378,104	1,399,517	1,383,974	1,378,695	1,444,460	1,352,212	1,372,472	1,270,533	1,367,190	1,372,973	1,384,747
Cote d'Ivoire	Africa	5,705,221	5,811,421	5,922,289	6,038,228	6,159,418	6,285,473	6,415,765	6,549,772	6,718,005	6,891,366	7,069,523
Djibouti	Africa	122,618	129,707	136,839	143,929	154,676	157,642	162,914	160,710	158,939	155,535	162,313
Dominican Republic	Caribbean	200,404	186,595	163,155	185,597	185,602	153,216	144,367	134,064	106,116	0	0
Egypt	Africa	124,982	886,165	585,050	376,820	85,874	189,508	142,112	291,134	0	0	0
Eritrea	Africa	0	0	0	0	0	0	0	0	0	0	0
Eswatini	Africa	440,977	444,136	426,543	408,597	390,394	372,009	342,699	334,998	311,423	279,968	258,139
Gambia, The	Africa	424,011	436,810	450,092	408,440	363,857	316,157	265,150	210,672	217,063	223,603	230,290
Ghana	Africa	2,827,659	2,900,513	2,973,554	3,046,525	3,119,574	3,279,392	3,443,896	3,613,434	3,788,099	3,873,156	3,959,025
Guinea	Africa	3,437,794	3,517,458	3,597,838	3,678,426	3,760,166	3,845,162	3,936,295	4,035,527	4,143,670	4,259,841	4,382,254
Guinea-Bissau	Africa	877,928	894,567	892,580	900,159	901,294	901,230	929,025	930,713	936,355	945,938	955,581
India	Asia	306,243,016	289,905,383	269,618,847	265,061,211	238,806,049	229,374,226	198,836,743	146,482,572	129,511,367	94,960,997	63,093,075
Indonesia	Asia	14,613,221	14,101,344	12,891,927	11,866,400	8,918,925	8,475,639	7,279,211	6,130,772	5,942,570	4,763,295	3,810,483
Iran	Asia	721,206	729,248	571,660	410,492	245,505	76,482	0	12,013	0	0	0
Iraq	Asia	475,605	478,763	476,357	614,506	154,590	388,599	318,070	224,860	111,583	33,853	11,348
Lao PDR	Asia	1,372,583	1,395,737	1,418,560	1,440,898	1,462,908	1,292,385	1,079,170	645,239	605,986	433,046	134,177
Liberia	Africa	1,392,634	1,449,095	1,502,063	1,550,733	1,596,364	1,639,857	1,682,769	1,777,711	1,875,996	1,923,211	1,970,962
Malawi	Africa	9,842,897	10,129,887	10,424,902	10,692,923	10,967,088	11,245,881	11,527,564	11,811,020	12,095,318	12,422,193	12,754,750
Mali	Africa	7,014,448	7,246,970	7,479,528	7,710,752	7,941,811	8,175,582	8,416,307	8,667,073	8,928,818	9,200,660	8,203,547
Mauritania	Africa	355,994	339,341	321,466	302,286	281,698	259,590	235,854	242,778	249,812	256,954	264,199
Morocco	Africa	315,368	319,291	323,434	327,819	332,419	337,157	341,923	37,245	52,708	0	0
Mozambique	Africa	15,056,083	15,379,377	15,711,248	15,742,939	16,119,283	16,324,783	16,533,997	17,009,419	17,144,712	17,400,838	17,371,746
Myanmar	Asia	3,095,638	3,115,523	3,137,251	3,161,418	3,187,649	3,214,852	3,241,410	3,266,205	2,174,854	1,067,652	1,074,168
Namibia	Africa	461,807	470,316	446,376	421,276	395,061	367,785	339,499	310,197	315,977	321,949	328,066
Niger	Africa	7,671,207	7,969,096	8,281,405	8,608,725	8,606,941	8,592,142	8,561,870	8,900,740	9,251,033	9,613,100	9,987,112
Nigeria	Africa	65,158,856	66,152,417	68,500,390	62,479,354	66,075,495	63,272,752	66,402,358	70,009,569	63,011,491	74,561,781	67,159,666
Pakistan	Asia	14,246,866	14,568,626	14,892,245	14,483,907	13,109,703	11,667,038	9,765,341	7,777,652	7,941,464	8,107,971	8,276,386
Papua New Guinea	Oceania	2,650,956	2,715,015	2,777,993	2,839,436	2,899,781	2,959,584	3,019,758	3,080,955	3,143,269	3,206,451	3,270,400
Paraguay	South America	166,706	133,090	141,857	94,935	125,086	55,111	59,241	37,208	104,310	39,650	0
Peru	South America	2,570,609	2,015,486	1,596,522	1,521,745	1,386,819	1,280,281	1,113,343	1,096,946	1,082,411	1,069,106	831,721
Philippines	Asia	9,908,314	10,073,143	10,117,090	9,753,425	9,916,304	8,881,187	7,555,046	6,228,906	6,323,500	5,594,637	4,238,471
Senegal	Africa	4,561,786	4,687,332	4,728,057	4,952,847	5,054,381	5,169,466	4,562,081	4,882,629	4,468,910	5,307,441	4,670,361
Somalia	Africa	0	0	0	0	0	0	0	0	0	0	0
South Sudan	Africa	2,048,219	2,044,125	2,503,320	2,142,198	1,905,055	1,961,007	1,921,381	2,142,275	2,566,582	2,612,311	917,695
Sri Lanka	Asia	479,616	482,964	452,512	421,573	388,075	391,115	394,782	398,430	169,624	407,436	90,276
Sudan	Africa	5,355,856	5,472,974	5,354,477	5,231,753	5,103,323	4,967,722	4,823,162	4,940,675	5,060,625	5,183,301	5,308,795
Thailand	Asia	66,531	133,734	67,195	67,515	67,836	68,145	68,439	68,715	0	35,159	0
Timor-Leste	Asia	324,017	329,803	335,712	341,737	347,829	354,062	360,520	367,265	280,709	245,624	182,691
Togo	Africa	3,297,214	3,387,953	3,480,550	3,422,960	3,515,177	3,535,745	3,401,308	3,552,588	3,549,293	3,648,296	3,571,094
Uganda	Africa	13,572,554	14,009,349	13,522,546	12,989,045	12,406,741	13,332,174	14,321,913	15,385,745	16,533,010	17,164,748	17,815,549
Vietnam	Asia	5,051,887	3,292,916	1,276,198	888,716	847,859	898,089	703,345	185,917	749,110	0	0
Yemen	Asia	4,115,723	4,233,094	4,353,113	4,475,827	4,600,957	4,727,656	4,854,815	4,981,603	5,107,623	5,232,946	5,357,753

DATA ANNEX: THE URBAN POOR

COUNTRY	CONTINENT	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Algeria	Africa	0	141,448	104,149	64,680	191,487	10,408	1,576	0	0	0	0
Angola	Africa	8,320,179	8,745,531	8,900,057	9,042,462	9,171,420	9,284,603	9,379,970	9,818,796	10,268,702	10,729,749	11,202,513
Argentina	South America	7,547,190	7,636,563	7,403,769	7,193,398	6,974,294	6,746,909	6,511,348	6,590,996	6,670,071	6,748,582	6,826,476
Bangladesh	Asia	25,750,051	26,705,324	27,107,520	27,500,335	27,875,982	28,227,502	28,551,904	29,538,230	30,536,921	31,547,329	32,568,477
Benin	Africa	2,553,778	2,658,442	2,701,231	2,742,751	2,782,742	2,820,882	2,857,385	2,972,099	3,091,019	3,214,248	3,341,791
Bolivia	South America	3,013,462	3,085,083	3,106,675	3,126,687	3,144,977	3,158,873	3,169,177	3,233,848	3,298,626	3,363,430	3,428,635
Brazil	South America	43,261,524	43,833,544	42,881,313	41,889,926	40,854,717	39,776,018	38,656,330	39,108,722	39,557,260	40,001,584	40,437,818
Burkina Faso	Africa	1,712,274	1,760,894	1,979,677	1,857,048	1,904,387	2,367,744	3,116,695	3,280,692	3,451,850	3,630,005	3,815,515
Cambodia	Asia	353,237	472,707	320,078	662,235	1,027,956	1,418,445	1,834,659	1,897,587	1,961,750	2,027,109	2,094,077
Cameroon	Africa	4,468,804	4,648,611	4,660,752	4,665,419	4,662,005	4,649,697	4,627,763	4,806,566	4,990,517	5,179,433	5,373,422
Chad	Africa	2,187,241	2,264,293	2,340,735	2,422,406	2,509,221	2,600,680	2,696,108	2,802,190	2,912,495	3,027,495	3,147,871
China	Asia	179,396,026	185,485,521	186,486,821	186,978,287	187,102,513	186,948,926	186,540,293	191,778,829	197,114,242	202,495,745	207,604,568
Congo, Rep.	Africa	1,248,000	1,299,049	1,332,772	1,363,621	1,392,086	1,419,087	1,445,955	1,492,747	1,541,842	1,592,969	1,645,870
Cote d'Ivoire	Africa	5,195,450	5,363,555	5,519,963	5,683,428	5,854,157	6,031,935	6,216,300	6,431,003	6,654,484	6,887,104	7,128,746
Djibouti	Africa	236,227	234,681	233,253	232,004	263,579	357,964	455,800	464,176	472,531	480,896	489,257
Dominican Republic	Caribbean	998,054	1,028,179	1,019,653	1,007,450	992,168	974,786	955,331	977,426	999,406	1,021,195	1,042,520
Egypt	Africa	4,491,951	4,574,468	4,485,985	4,398,057	4,305,328	4,209,054	4,106,124	4,192,464	4,278,067	4,365,696	4,455,266
Eritrea	Africa	229,332	238,518	247,389	255,941	0	0	0	0	0	0	0
Eswatini	Africa	76,252	74,787	82,784	70,666	62,172	65,390	82,890	84,118	85,455	86,891	88,421
Gambia, The	Africa	352,604	353,661	354,096	353,892	353,003	374,688	412,252	429,924	448,127	466,876	486,162
Ghana	Africa	4,663,222	4,849,278	4,983,869	5,117,331	5,249,699	5,381,019	5,511,812	5,708,695	5,909,967	6,115,291	6,324,540
Guinea	Africa	1,011,500	989,749	965,123	937,505	947,972	1,303,476	1,682,012	1,739,513	1,802,341	1,870,272	1,942,669
Guinea-Bissau	Africa	420,362	431,586	538,664	455,421	468,034	481,007	581,039	602,240	623,936	646,135	668,852
India	Asia	106,767,446	109,504,980	108,115,329	106,519,379	104,749,278	102,805,224	100,696,430	103,062,877	105,479,705	107,949,448	110,470,962
Indonesia	Asia	26,177,291	26,966,080	27,473,398	27,928,526	28,383,931	28,834,054	29,274,599	30,029,907	30,783,891	31,534,309	32,282,485
Iran	Asia	72,393	0	13,673	2,287	0	11,059	0	0	0	0	0
Iraq	Asia	10,330,554	10,552,443	10,621,582	10,760,584	10,946,942	11,150,154	11,330,402	11,739,811	12,112,396	12,456,714	12,784,267
Lao PDR	Asia	17,470	56,113	117,985	244,438	379,592	523,713	677,316	700,805	725,188	750,340	776,148
Liberia	Africa	1,621,048	1,718,808	1,676,916	1,796,725	1,704,614	1,739,755	1,834,752	1,624,797	1,521,329	1,566,215	1,619,475
Malawi	Africa	1,449,612	1,501,905	1,547,222	1,594,975	1,645,179	1,697,902	1,752,762	1,822,018	1,894,217	1,969,923	2,049,646
Mali	Africa	3,199,770	3,382,425	3,466,191	3,543,138	3,613,290	3,677,419	3,736,933	3,926,329	4,125,011	4,332,832	4,549,348
Mauritania	Africa	562,758	559,056	383,764	546,230	860,030	1,203,136	1,576,769	1,651,705	1,728,601	1,807,519	1,888,316
Mozambique	Africa	5,528,998	5,773,826	6,026,534	6,289,862	6,564,141	6,850,638	7,150,897	7,469,866	7,805,068	8,156,477	8,523,850
Myanmar	Asia	1,943,030	1,882,754	1,607,765	2,431,385	3,701,496	5,009,930	6,355,516	6,449,059	6,542,397	6,636,533	6,733,631
Namibia	Africa	271,056	283,050	294,871	306,947	319,528	332,477	345,885	360,449	375,472	390,895	406,670
Niger	Africa	2,022,132	2,100,138	2,119,946	2,138,669	2,156,216	2,171,999	2,187,513	2,278,019	2,373,938	2,475,935	2,584,064
Nigeria	Africa	39,291,230	41,208,887	41,488,148	41,676,766	41,766,709	41,746,272	41,605,033	43,499,571	45,446,586	47,448,315	49,502,812
Pakistan	Asia	27,667,997	28,458,911	29,123,505	29,791,459	30,464,020	31,141,933	31,830,413	32,689,729	33,570,951	34,471,578	35,403,897
Papua New Guinea	Oceania	277,725	283,165	274,105	263,289	254,060	247,364	240,520	230,793	223,449	211,000	202,963
Paraguay	South America	35,321	58,527	18,664	16,760	13,900	8,958	6,707	7,504	4,136	8,419	0
Peru	South America	642,724	554,032	1,517,512	3,067,253	4,650,323	6,271,649	7,941,798	8,061,366	8,201,070	8,357,970	8,523,279
Philippines	Asia	16,899,671	17,149,054	17,200,677	17,341,251	17,481,847	17,618,460	17,744,206	18,101,376	18,452,101	18,804,145	19,160,424
Senegal	Africa	2,000,396	2,075,167	2,159,907	2,248,462	2,340,863	2,437,209	2,537,530	2,634,273	2,734,913	2,839,565	2,947,904
Somalia	Africa	3,020,722	3,246,588	3,484,555	3,734,673	3,889,253	4,049,502	4,216,579	4,391,417	4,574,658	4,766,524	4,967,497
South Sudan	Africa	1,533,770	1,349,638	1,630,266	1,509,623	1,532,180	1,512,231	1,879,451	1,931,231	1,977,145	2,017,920	2,058,198
Sri Lanka	Asia	231,695	208,027	162,488	117,759	99,857	74,921	77,325	56,076	38,825	9,248	0
Sudan	Africa	3,441,264	4,681,440	3,487,711	4,301,012	6,633,221	9,102,768	11,719,572	12,078,162	12,454,252	12,849,249	13,264,493
Thailand	Asia	7,408,451	7,680,733	7,838,768	7,906,994	7,953,637	7,995,409	8,031,798	8,193,175	8,353,808	8,512,813	8,669,713
Timor-Leste	Asia	49,355	46,050	50,340	38,655	34,558	29,999	23,608	15,892	5,823	2,982	0
Togo	Africa	768,903	740,005	807,338	554,394	802,109	1,112,713	1,446,476	1,503,532	1,562,185	1,622,449	1,684,434
Uganda	Africa	3,362,337	3,563,802	3,695,904	3,830,211	3,966,801	4,107,074	4,254,547	4,519,839	4,807,841	5,117,752	5,444,151
Vietnam	Asia	8,842,585	9,123,979	8,990,392	8,838,810	8,668,282	8,475,968	8,260,990	8,522,628	8,789,605	9,060,406	9,334,266
Yemen	Asia	377,374	368,882	894,695	1,873,877	2,942,429	4,104,787	5,364,137	5,602,824	5,846,477	6,095,193	6,349,033

DATA ANNEX: THE LOWER-MIDDLE INCOME

COUNTRY	CONTINENT	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Algeria	Africa	26,747,021	26,602,557	26,636,638	28,050,981	27,695,956	27,673,771	27,563,192	27,373,277	27,182,839	26,973,202	26,759,532
Angola	Africa	5,645,300	3,941,646	2,472,329	977,729	0	0	0	0	0	3,965,254	8,350,422
Argentina	South America	5,522,493	4,476,494	4,373,011	3,036,628	2,869,652	3,205,550	5,197,163	4,735,309	4,399,327	3,315,657	5,307,175
Bangladesh	Asia	89,734,316	88,461,400	87,735,680	89,749,873	91,801,985	93,902,040	96,057,550	97,582,246	99,125,544	102,620,623	98,252,126
Benin	Africa	1,400,160	1,235,172	1,070,422	1,847,704	2,031,300	2,157,586	2,397,398	2,422,319	2,474,856	2,511,237	2,573,372
Bolivia	South America	2,242,929	1,969,994	1,889,880	1,816,382	1,595,546	1,450,254	1,650,897	1,677,096	1,542,134	1,612,913	1,821,867
Brazil	South America	56,067,929	53,442,404	51,404,084	50,279,305	45,379,153	42,689,966	40,333,920	42,840,438	45,806,702	46,644,340	44,879,041
Burkina Faso	Africa	5,061,635	4,763,405	6,000,619	6,495,221	6,835,863	6,777,581	6,451,857	7,064,266	7,031,177	6,986,216	6,928,943
Cambodia	Asia	7,241,253	7,121,783	7,274,412	6,913,849	6,529,721	6,120,825	5,686,205	5,604,870	5,460,288	5,314,511	5,167,124
Cameroon	Africa	8,611,063	8,303,389	8,160,034	8,615,217	9,075,213	9,540,973	10,013,376	9,687,844	9,451,718	9,207,929	8,956,524
Chad	Africa	4,414,063	4,192,411	3,965,446	4,779,106	4,603,270	4,418,214	4,226,324	4,022,137	4,010,813	3,993,100	3,967,755
China	Asia	679,118,898	642,835,482	615,963,249	585,317,464	537,839,738	474,309,451	422,145,133	370,482,428	324,895,632	290,384,458	256,145,964
Congo, Rep.	Africa	1,071,849	999,385	981,206	1,410,372	1,244,626	1,238,356	1,119,712	1,103,342	978,21	941,918	897,861
Cote d'Ivoire	Africa	7,573,657	7,403,935	7,241,242	7,632,997	8,012,237	8,379,562	8,736,064	9,058,512	8,654,077	8,235,376	7,802,858
Djibouti	Africa	440,128	434,585	428,88	411,003	356,643	296,228	204,677	210,062	216,464	224,491	209,352
Dominican Republic	Caribbean	4,814,986	4,622,247	4,567,368	4,682,122	4,850,293	4,874,808	4,488,101	4,074,589	3,789,736	3,909,464	3,637,683
Egypt	Africa	70,591,379	70,519,908	71,681,735	73,653,895	75,713,572	77,027,038	78,498,190	79,583,655	82,702,630	85,528,445	85,438,875
Eritrea	Africa	5,003,604	4,994,418	4,985,547	5,125,220	5,529,386	5,677,610	5,825,835	5,974,060	6,119,285	6,264,510	6,409,735
Eswatini	Africa	462,62	460,926	465,892	491,327	513,395	523,932	531,113	467,814	550,566	559,515	558,746
Gambia, The	Africa	917,597	903,741	890,023	982,8	1,079,194	1,156,131	1,220,496	1,308,223	1,301,587	1,294,255	1,286,240
Ghana	Africa	15,496,070	15,237,160	15,029,528	14,293,621	13,558,731	13,946,114	14,329,337	14,641,435	14,004,610	13,938,702	13,868,056
Guinea	Africa	5,407,527	5,349,614	5,293,860	5,571,386	5,809,675	5,355,579	4,872,313	4,701,983	4,435,832	4,156,550	3,866,560
Guinea-Bissau	Africa	176,042	148,179	43,09	133,167	133,833	135,338	21,926	13,451	2,701	0	0
India	Asia	778,412,867	792,012,966	822,304,546	837,073,525	843,186,346	832,649,782	843,383,618	871,458,902	865,329,473	876,726,294	885,388,896
Indonesia	Asia	184,318,581	185,884,593	184,105,194	181,643,054	185,211,125	183,323,077	186,709,582	188,348,533	185,045,367	181,611,818	179,590,227
Iran	Asia	26,728,234	26,792,585	26,679,379	26,594,810	26,504,963	26,405,805	28,267,253	30,011,259	30,870,838	29,373,386	29,373,386
Iraq	Asia	16,795,007	16,569,960	16,503,227	16,817,455	17,682,392	16,209,837	15,064,783	13,713,249	12,669,977	11,619,424	10,530,412
Lao PDR	Asia	4,232,958	4,171,160	4,086,465	4,227,922	4,361,005	4,130,231	3,932,667	4,085,933	3,992,312	4,031,608	4,196,178
Liberia	Africa	977,969	823,747	812,672	724,931	852,149	854,253	797,081	1,382,334	1,136,256	1,399,920	1,654,675
Malawi	Africa	3,053,726	2,714,443	2,374,112	2,547,294	2,711,883	2,869,323	3,021,737	3,157,982	3,072,950	3,173,155	3,263,659
Mali	Africa	4,298,678	3,883,501	4,331,930	4,448,619	4,572,267	4,699,227	4,823,847	4,808,545	4,750,562	4,673,344	5,856,387
Mauritania	Africa	2,066,651	2,252,041	2,610,243	2,610,002	2,459,836	2,281,884	2,075,034	1,702,485	1,655,114	1,605,612	1,554,130
Mozambique	Africa	1,377,416	1,342,425	1,290,977	1,608,563	1,570,544	1,691,152	1,794,285	412,17	240,683	0	0
Myanmar	Asia	42,357,929	42,398,320	42,651,581	42,014,567	40,928,998	39,804,135	38,642,764	38,735,200	39,802,394	40,884,640	40,141,127
Namibia	Africa	998,774	978,271	973,901	970,436	967,58	965,419	963,807	962,056	942,395	922,144	901,395
Niger	Africa	5,806,262	5,430,367	5,098,251	6,211,623	6,888,899	7,580,955	8,288,752	6,902,342	7,001,915	7,083,635	7,147,278
Nigeria	Africa	47,096,999	44,185,781	42,289,861	48,853,595	45,898,826	49,453,322	47,196,270	42,425,836	49,027,366	37,025,813	43,923,897
Pakistan	Asia	131,660,535	130,547,861	129,559,647	132,299,959	136,548,830	140,860,810	143,929,924	146,914,195	146,451,598	145,966,902	145,448,605
Papua New Guinea	Oceania	3,981,746	3,912,247	3,450,891	3,445,344	3,439,308	3,431,280	3,423,029	3,416,639	3,416,855	3,421,307	3,420,581
Paraguay	South America	3,454,048	3,519,094	3,375,859	3,261,780	2,981,227	2,942,377	2,891,960	2,937,131	3,050,042	3,077,130	2,948,678
Peru	South America	15,123,675	15,497,873	14,154,529	12,030,208	9,799,151	8,222,328	6,688,134	6,854,058	6,426,943	6,672,404	6,374,117
Philippines	Asia	49,821,835	49,407,622	44,299,650	48,687,869	52,549,523	54,059,626	55,871,619	57,452,189	56,281,385	55,932,719	56,207,120
Senegal	Africa	4,967,476	4,767,159	4,641,694	5,420,631	5,233,794	5,029,460	5,543,623	5,133,429	5,556,994	4,724,298	5,363,525
Somalia	Africa	6,310,278	6,084,412	5,846,445	5,763,527	5,776,147	5,783,098	5,783,221	5,775,583	5,732,942	5,681,676	5,621,303
South Sudan	Africa	5,206,465	5,394,690	4,654,868	5,136,632	5,351,219	5,315,215	4,987,622	4,714,948	4,244,727	4,158,223	5,812,560
Sri Lanka	Asia	16,490,264	16,510,583	13,700,833	15,003,047	16,280,993	14,646,757	12,984,554	11,346,024	15,943,997	12,677,704	9,946,055
Sudan	Africa	23,155,587	21,798,293	32,377,154	30,466,947	27,043,536	23,489,960	19,798,084	28,961,816	28,833,418	28,683,387	28,510,293
Thailand	Asia	29,549,510	27,558,091	26,726,355	25,129,753	23,142,366	21,783,738	21,239,447	18,378,727	19,186,445	18,146,271	18,872,582
Timor-Leste	Asia	791,094	788,614	778,415	784,074	782,08	780,406	780,339	781,31	877,934	915,86	981,775
Togo	Africa	2,370,864	2,309,023	2,149,092	2,459,627	2,302,243	2,153,620	2,136,843	2,111,054	2,149,788	2,084,614	2,193,923
Uganda	Africa	13,288,866	12,650,606	15,390,912	16,101,473	16,858,554	17,108,186	17,286,312	17,272,527	16,915,028	16,693,833	16,437,088
Vietnam	Asia	67,545,183	63,380,033	59,887,611	60,269,272	60,323,253	60,002,814	59,950,011	57,323,606	53,611,241	51,797,703	49,231,996
Yemen	Asia	20,062,454	19,953,576	19,307,744	18,205,848	17,012,165	15,723,108	14,336,600	14,327,148	14,416,332	14,501,151	14,581,363

1.1 CASE STUDY ON SUB-NATIONAL COOLING VULNERABILITIES IN INDIA

To maintain an equitable understanding of access to cooling risks globally, the *Chilling Prospects* series has utilized data on temperature, income, and electricity access, among others, that are available at the national level, to determine priority countries. For large countries, in terms of population and geography however, these national level data can belie the fact that some parts of a country could face greater risks than others. In China, for example, the summer season in the northern part of the country is drastically cooler than that experienced in the southern tropical zone. In addition, some countries that are not classified as high risk due to aggregate national level data may have geographies where there are populations at risk. In Mexico, for example, Hermosillo experiences summer maximum temperatures between 35°C and 39°C, while in Mexico City maximum summer temperatures average between 24°C and 28°C.[1]

India is both a large country with a wide range of geographies and one of the Critical 9 high–risk countries for access to cooling with 63 million rural poor, 110 million urban poor, and a growing lower middle-income population of 885 million who may soon acquire a cooling appliance (Table 1).

India is also a country where the need for cooling is expected to increase over time. India's average temperature increased by 0.7°C between 1901 and 2018 and by the end of this century the average temperature is expected to rise by 4.4°C relative to the 1976–2005 average,[2] with the resulting number of cooling degree days (CDDs) increasing up to 42 percent (Figure 1).[3] Since 2013, rising temperatures and incomes, and the resulting increase in cooling demand, led to increased ownership of cooling devices (Figure 2).[4] **Currently only 18 percent of Indian households own a cooling system (air conditioner or cooler),[5,6] and of these, only 10 percent have an AC unit.[7]**

DISAGGREGATING VULNERABILITY BASED ON GEOGRAPHY AND CLIMATE

The national data tell a compelling story but given India's size and geographic diversity, disaggregating vulnerabilities can help inform a more granular understanding of cooling needs and therefore the most appropriate sustainable solutions for those populations at risk. Consider the difference between Mumbai and New Delhi. During India's summer months, the two cities experience vastly different temperature highs, with significantly higher temperatures in New Delhi (Figure 2). Both cities have large urban poor populations, many of whom live in slums, but those in Mumbai are less likely to be at high risk than those in New Delhi.

TABLE 1.8: INDIA POPULATION AT RISK TREND, 2016-2020

Risk Category	2016	2017	2018	2019	2020
Rural Poor	198,836,743	146,482,572	129,511,367	94,960,997	63,093,075
Urban Poor	100,696,430	103,062,877	105,479,705	107,949,448	110,470,962
Lower-Middle Income	843,383,618	871,458,902	865,329,473	876,726,294	885,388,896

1 Mexico Average Temperatures, Climate-data.org. Accessed 23 June 2020.: https://en.climate-data.org/north-america/mexico-179/
2 Assessment of Climate Change over the Indian Region, Ministry of Earth Sciences, Government of India, June 2020.
3 KAPSARC Data Portal, World Average Degree Days Database (baseline) & World Bank Climate Change Knowledge Portal (projection).
4 Japan Refrigeration and Air Conditioning Industry Association, "World Air Conditioner Demand by Region," June 2019. Available: https://www.jraia.or.jp/english/World_AC_Demand.pdf & World Development Indicators, World Bank.
5 Note: including vapor compression (air conditioners) and evaporative (coolers) appliances.
6 National Family Health Survey 2015-16, International Institute for Population Study, December 2017. Available: http://rchiips.org/NFHS/NFHS-4Reports/India.pdf pg. 66
7 Motilal Oswal, "Sector Update: Room Air Conditioners," 17 April 2018. Available: https://www.motilaloswal.com/site/rreports/636596385051621278.pdf

FIGURE 1.16: TREND OF AVERAGE ANNUAL COOLING DEGREE DAYS IN INDIA, 1986-2099

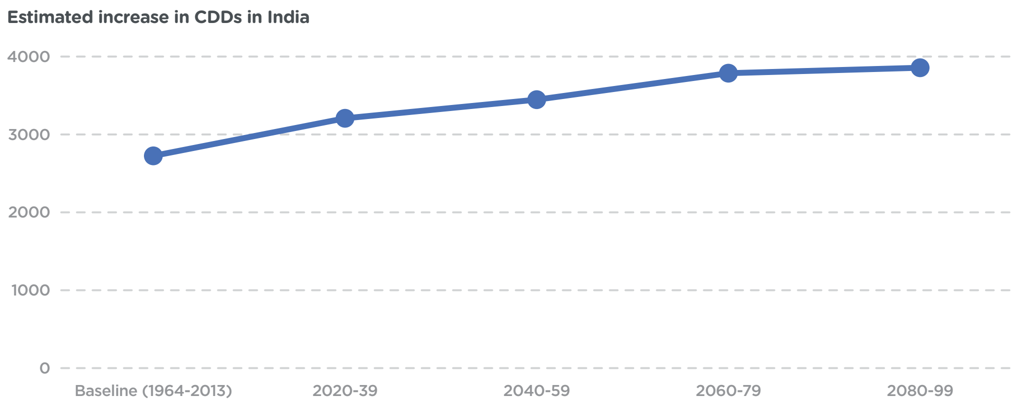
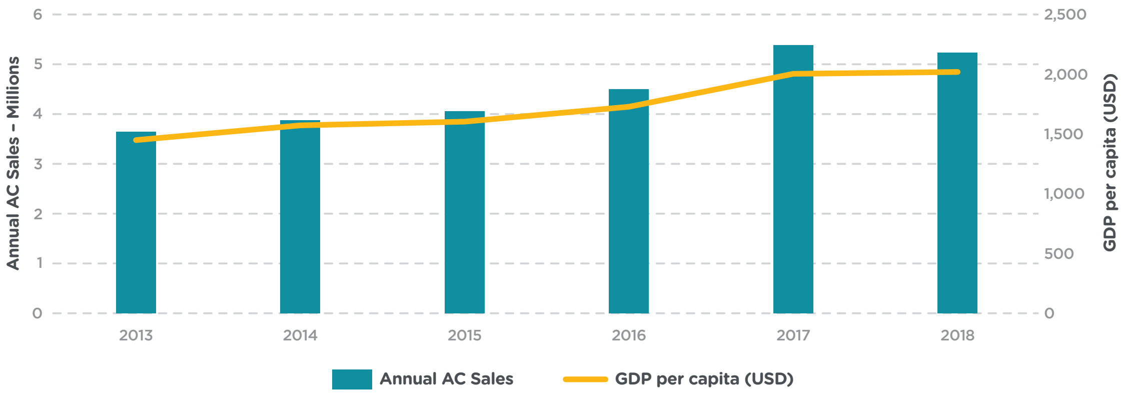


FIGURE 1.17: COMPARISON OF ESTIMATED AIR CONDITIONER SALES AND INCOME IN INDIA



For people living in New Delhi and Mumbai, differences in temperature, humidity and relative heat sensitivity can affect the types of solutions that may be best suited to their circumstances. **For example, studies indicate that enhancing thermal comfort in the workplace can increase productivity by 12 percent.[8] Cooling below optimal temperatures however may also not be ideal for productivity.[9]** Depending on geography, affordable passive solutions like shading or behaviour changes such as the dress code can support access to thermal comfort in Mumbai but may not suffice in New Delhi on the hottest days of the year.

8 "Cooling comfort at workplace can up productivity by 12 per cent: Indian Institute of Management Ahmedabad" The Economic Times, 4 July 2016. Available: https://economictimes.indiatimes.com/jobs/cooling-comfort-at-workplace-can-up-productivity-by-12-per-cent-iima/articleshow/53049438.cms?from=mdr

9 *Ibid.* Note: Studies indicate 25-30-degree Celsius as the optimum temperature range in workplace.

While CDDs and peak temperatures are good indicators, they do not give the complete story in terms of vulnerability and susceptibility to heat waves and public preparedness. For instance, the average annual number of CDDs in Tamil Nadu is 3,045 and in Andhra Pradesh it is 1,527,[10] but Andhra Pradesh has persistent annual heat wave–related deaths and heat strokes as temperatures there can climb to 45°C.[11] From 1990 to 2010, the number of annual heat waves in India has increased from less than 500 to about 670.[12] Rapid

10 Degree Days Calculated via Degreedays.net, using a 21°C base temperature and averaging between 2015 and 2019.

11 "Heat Takes Heavy Toll Across India," The Weather Channel, 31 May 2019. Available: https://weather.com/en-IN/india/news/news/2019-05-31-heatwave-maharashtra-telangana-andhra-pradesh-rayalaseema-vidarbha

12 Roadmap for Planning Heatwave Management in India, Institute for Global Change and Sustainable Health, Taru Leading Edge and Climate & Development Knowledge Network, September 2016. Available: https://www.preventionweb.net/files/50954_50954roadmapforurban heatwavewarning.pdf

FIGURE 1.18: AVERAGE AND RECORD MAXIMUM SUMMER TEMPERATURES IN MAJOR INDIAN CITIES, 1956–2010

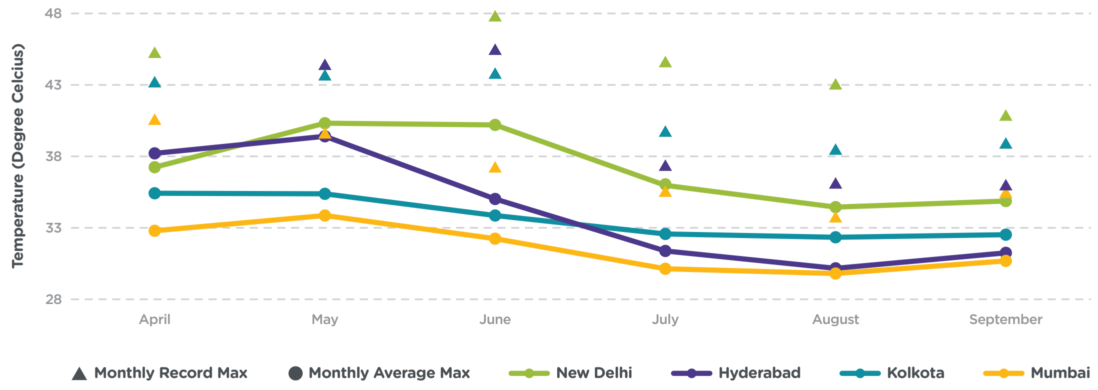
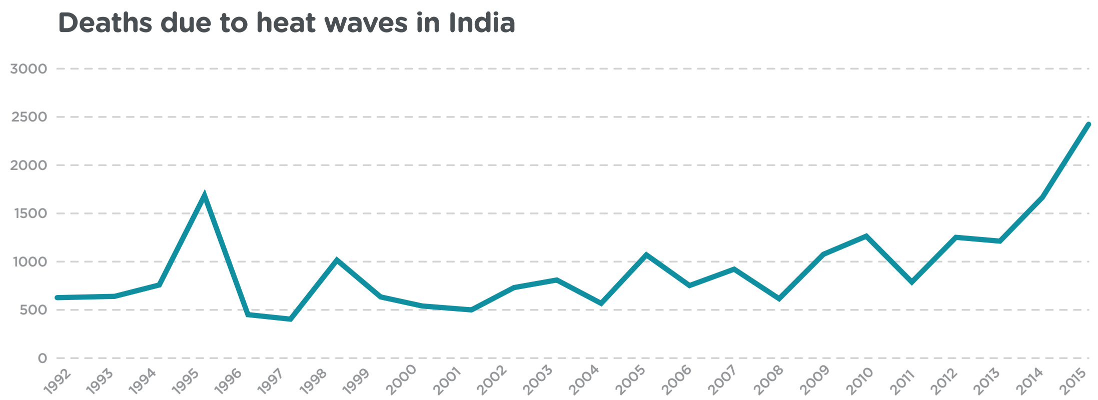


FIGURE 1.19: DEATHS DUE TO HEAT WAVES IN INDIA, 1992–2015



urbanization has also contributed to UHIEs that further increase urban temperatures and exacerbate the magnitude and frequency of heat waves.

One key measure to protect vulnerable populations that cities can take is to develop heat action plans to provide early warnings of heat waves, public cooling resources, and emergency response protocols for public health officials. In Ahmedabad, effective heat action planning was found to have avoided an estimated 2,380 deaths since 2010 relative to a 2007–2010 baseline.[13]

Vulnerability also has different dimensions for rural populations throughout India. For example, Bihar and Rajasthan (Table 2) have similar annual average temperatures and CDDs but are vulnerable for different reasons. In Rajasthan, a desert state, summer temperature spikes that can exceed 50°C create acute and life-threatening vulnerability.[14] In Bihar, by contrast, vulnerability is generated as a result of sustained high temperatures throughout the year, lower income and higher rural poverty, factors that help explain lower ownership of both cooling systems and refrigerators compared to Rajasthan.

13 "Ahmedabad Heat Action Plan: Guide to Extreme Heat Planning in Ahmedabad, India. Amdavad Municipal Corporation, 2019. Available: https://www.nrdc.org/sites/default/files/ahmedabad-heat-action-plan-2018.pdf

14 "India reels as summer temperatures touch 50°C," BBC, 3 June 3 2019. Available: https://www.bbc.com/news/world-asia-india-48495492

TABLE 1.9: COMPARATIVE ASSESSMENT OF RAJASTHAN AND BIHAR

	Rajasthan	Bihar
Average number of CDDs (2015–2019)[15]	2443	2235
Maximum May temperature[16]	41.5°C	38.9°C
Average May temperature	34.4°C	32.4°C
Average annual temperature	25.1°C	26.0°C
Rural poverty rate[17]	16%	34%
Cooling system ownership rate (% households)	38%	2.1%
Refrigerator ownership rate (% households)	32.6%	4.6%
Fan ownership rate (% households)[18]	83.4%	42.5%
Per capita state net domestic product (2015–2016)	$1227	$447

Note: Estimated from India Ministry of Statistics Data

TOWARDS A SUB-NATIONAL ASSESSMENT OF ACCESS TO COOLING AND ASSOCIATED RISK

As a first effort to examine access to cooling in India more deeply this case study examines income, temperature, CDDs and ownership of cooling solutions to support a sub-national assessment of vulnerability to a lack of access to cooling.

The methodology for this assessment uses three primary factors to support an initial ranking of Indian states[19] for their risk from a lack of access to cooling. The criteria include income, average maximum temperature and CDDs, with criteria to indicate the level of risk. Initially, a state is considered to be high risk if two or more of the high-risk criteria are met.

The initial rankings are then adjusted for ownership of cooling appliances (refrigerator, ACs and fans) to assess the overall vulnerability of each state, such that states with fewer cooling appliances, high average temperatures (or CDDs) and low income will have a higher risk than states with more cooling appliances, lower temperatures (or CDDs) and relatively higher incomes. This assessment can be used over time to track progress on access to cooling.

The result of this assessment includes 14 states (including one union territory) at high risk, nine states at medium risk and seven states (including one union territory) at low risk (Tables 4, 5 and 6).[20]

14 "India reels as summer temperatures touch 50°C," BBC, 3 June 3 2019. Available: https://www.bbc.com/news/world-asia-india-48495492

15 Degreedays.net, Cooling Degree Days Average, 2015-2019, using a 21°C set point.

16 For maximum and average temperatures, data from the cities of Jodhpur (Rajasthan) and Patna (Bihar) were retrieved from climate-data.org

17 Rajasthan, Poverty, Growth & Inequality, World Bank Group, 2016. Available: http://documents.worldbank.org/curated/en/423761467995629413/pdf/105877-BRI-P157572-ADD-SERIES-India-state-briefs-PUBLIC-Rajasthan-Proverty.pdf and Bihar: Poverty, Growth & Inequality, World Bank Group, 2016. Available: http://documents.worldbank.org/curated/en/781181467989480762/pdf/105842-BRI-P157572-PUBLIC-Bihar-Proverty.pdf

18 Air conditioner, refrigerator and fan ownership rates are expressed as a % of the population. Source: National Family Health Survey 2015–16, International Institute for Population Study, December 2017. Available: http://rchiips.org/NFHS/NFHS-4Reports/India.pdf

19 Note: the scope of this assessment is for 28 Indian states and two union territories (Delhi and Jammu and Kashmir). The reference to *states* in this case study is defined in the above-mentioned scope.

20 Based on available data, this assessment includes the 28 states and only two of the eight union territories of India.

TABLE 1.10: CRITERIA TO DETERMINE RISK

	High Risk	Medium Risk	Low Risk
Income per day	Less than $1.90/day	Between $1.90–$5.50/day	Above $5.50/day
Average maximum temperature	Above 35°C	Between 35°C and 25°C	Below 25°C
Cooling degree days	Above 1,900	Between 1,900 and 1,000	Below 1,000

TABLE 1.11: INDIAN STATES ASSESSED AS HIGH RISK TO LACK OF ACCESS TO COOLING

High Risk States	AC Ownership (% household)	Refrigerator Ownership (% household)	Fan Ownership (% household)	Population[21]
Bihar	2.1	4.6	42.5	124,799,926
Jharkhand	8.3	11.8	56.7	38,593,948
Uttar Pradesh	8.2	22.2	61.9	237,882,725
Odisha	9.1	14.3	71.3	46,356,334
Chhattisgarh	4.9	33.4	72	29,436,231
Rajasthan	6.1	32.6	83.4	81,032,689
West Bengal	3	18	86.5	99,609,303
Gujarat	10.5	46.1	92.2	63,872,399
Telangana	7.9	27.3	92.7	39,362,732
Haryana	16.8	64.8	97.2	28,204,692
Delhi-NCR	29.4	90	98	18,710,922
Punjab	18.9	84.9	98.8	30,141,373
Assam	0.9	10.7	63.6	35,607,039
Madhya Pradesh	3.7	18.2	70.3	85,358,965

TABLE 1.12: INDIAN STATES ASSESSED AS MEDIUM RISK TO LACK OF ACCESS TO COOLING

Medium Risk States	AC Ownership (% household)	Refrigerator Ownership (% household)	Fan Ownership (% household)	Population
Nagaland	1.5	24.4	35.8	2,249,695
Karnataka	4.3	25	79	67,562,686
Tripura	1.2	20.7	86.9	4,169,794
Maharashtra	10	37.1	88	123,144,223
Andhra Pradesh	6.8	24.8	94.4	53,903,393
Tamil Nadu	8.7	38.2	95.5	77,841,267
Kerala	10	71.8	96.4	35,699,443
Goa	18.9	69.5	98	1,586,250
Meghalaya	0.5	11.7	33.6	3,366,710

21 2019 population estimates as per Statistics Times, http://statisticstimes.com/demographics/population-of-indian-states.php

TABLE 1.13: INDIAN STATES ASSESSED AS LOW RISK TO LACK OF ACCESS TO COOLING

Low Risk States	AC Ownership (% household)	Refrigerator Ownership (% household)	Fan Ownership (% household)	Population
Sikkim	0.6	22.3	26.9	690,251
Mizoram	2	62.7	44.8	1,239,244
Manipur	0.7	23.2	49.4	3,091,545
Arunachal Pradesh	1.2	20.9	53.4	1,570,458
Himachal Pradesh	11.1	62.3	69.7	7,451,955
Jammu and Kashmir	NA	47.2	71.2	13,606,320
Uttarakhand	NA	42.4	72.8	11,250,858

FIGURE 1.20: COMPARATIVE SUB-NATIONAL RISK IN INDIA, BY STATE

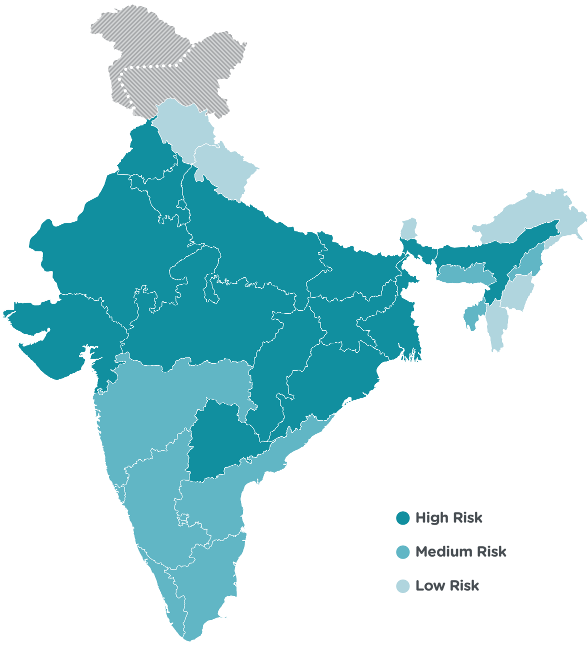
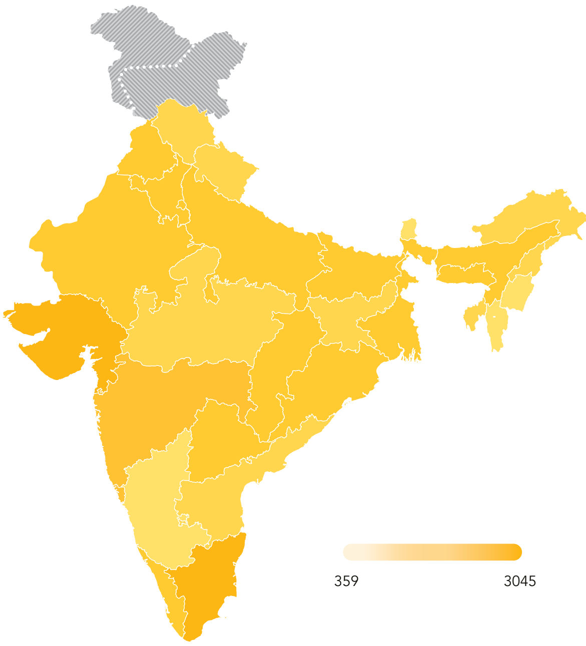


FIGURE 1.21: AVERAGE COOLING DEGREE DAYS (CDDS) IN INDIA, BY STATE



The case of India demonstrates the need for a sub-national, disaggregated assessment of vulnerabilities due to a lack of access to cooling. Vastly different geographies, climates and incomes across geographies are just some of the factors that show why this is the case. Moreover, a thorough assessment that also includes appliance ownership, the degree of risk and the reasons risks exist can help determine the most appropriate sustainable solutions to alleviate those risks.

Fan ownership across the 800 million people living in high-risk Indian states, for example, can serve as an effective proxy for electricity access that is nominally sufficient for cooling. Those without access to electricity or a fan would be in significant danger when temperatures spike and heat waves occur, meaning public cooling resources may be necessary. If electricity is unreliable, or a fan does not provide sufficient cooling as a result of the relative temperature differential, solutions will also be necessary to protect health and safety. As demonstrated by the case of India, optimizing the most appropriate sustainable solutions depends significantly on a disaggregated understanding of risk and cooling needs.

ANNEX: INDIA DATA BY STATE[22]

TABLE 1.14: OWNERSHIP RATES OF SELECTED COOLING APPLIANCES IN INDIAN STATES

State[23]	CDD Average (2015-2019)[24]	AC Ownership[25] (% households)	Evaporative Cooler Ownership (% households)	Refrigerator Ownership (%households)	Fan Ownership (%households)	State per capita net state domestic product[26] (2015-2016) USD
Andhra Pradesh	1,527	6.8	6.4	24.8	94.4	1,588
Arunachal Pradesh	1,400	1.2	-	20.9	53.4	1,648
Assam	1,900	0.9	-	10.7	63.6	894
Bihar	2,235	2.1	-	4.6	42.5	447
Chhattisgarh	2,535	4.9	12.8	33.4	72	1,082
Delhi	2,343	29.4	25.6	90	98	4,019
Goa	2,410	18.9	0.2	69.5	98	4,920
Gujarat	2,855	10.5	0.2	46.1	92.2	2,048
Haryana	2,184	16.8	42.6	64.8	97.2	2,426
Himachal Pradesh	1,303	11.1	-	62.3	69.7	1,993
Jammu and Kashmir	359	NA	-	47.2	71.2	1077
Jharkhand	1,632	8.3	-	11.8	56.7	776
Karnataka	1,272	4.3	0.7	25	79	2,178
Kerala	2,467	10	-	71.8	96.4	2,178
Madhya Pradesh	2,025	3.7	24.8	18.2	70.3	921
Maharashtra	2,775	10	NA	37.1	88	2,151
Manipur	927	0.7	-	23.2	49.4	815
Meghalaya	1.900	0.5	-	11.7	33.6	1,012
Mizoram	900	2	-	62.7	44.8	1,677
Nagaland	1,619	1.5	-	24.4	35.8	1,213
Odisha	2,382	9.1	-	14.3	71.3	950
Punjab	1,903	18.9	45.1	84.9	98.8	1,748
Rajasthan	2,443	6.1	31.9	32.6	83.4	1,227
Sikkim	1,675	0.6	-	22.3	26.9	3,617
Tamil Nadu	3,045	8.7	-	38.2	95.5	2,065
Telangana	2,373	7.9	14.3	27.3	92.7	2,071
Tripura	1,919	1.2	-	20.7	86.9	1,231
Uttar Pradesh	2,369	8.2	12.4	22.2	61.9	693
Uttarakhand	1,303	NA	-	42.4	72.8	2170
West Bengal	2,304	3	-	18	86.5	1,118

22 Based on available data, this assessment includes the 28 States and only two of the eight union territories of India.
23 Jammu and Kashmir and Uttarakhand data are not available for air conditioner ownership.
24 Cooling degree days were calculated via Degree Days.net with a base temperature of 21°C.
25 Estimates for all cooling appliances are based on NFHS-4 Survey of the Indian Institute for Population Studies and Motilal Oswal, Room Air Conditioner Sector Report 2018.
26 Based on data from Ministry of Statistics, Government of India.

2. COOLING FOR ALL AND COVID-19

The COVID-19 pandemic that has dominated headlines since early 2020 has reshaped economic systems, changed human behaviour across the globe, and demanded that the world rethink its response to climate change. Less widely appreciated are the impacts the pandemic has had on the developing world, how COVID-19 amplified other risks, and the opportunity to recover better with sustainable energy for all. The impact on poverty, for example, is stark. Due to COVID-19 alone, it is expected that at least 26 million people in Sub-Saharan Africa and 32 million people in South Asia will be forced into extreme poverty, measured at an income of USD 1.90 per day.[1]

The pandemic, and the global response to it, will also have profound implications for how we deliver critical services that rely on the ability to achieve cooling for all. The need to develop a vaccine is well understood, but the scope, requirements, and scale of cold chain and cooling solutions likely to be necessary to support a vaccine are not. Food systems and supply chains are being stretched and the ability of people to maintain nutritious diets will be negatively impacted by the economic downturn. When temperatures rise, social distancing will become much more complicated for those without access to cooling.

This chapter explores three areas where the COVID-19 pandemic will have significant implications for how we deliver cooling for all and summarizes guidance provided for how to shape a global response to the issues.

1 Mahler, Daniel G, et al. "Updated estimates of the impact of COVID-19 on global poverty" World Bank Group, 8 June 2020. Available: https://blogs.worldbank.org/opendata/updated-estimates-impact-covid-19-global-poverty

THE DRIVERS OF CHANGE FOR COOLING FOR ALL

Cold Chain to Deliver a Vaccine

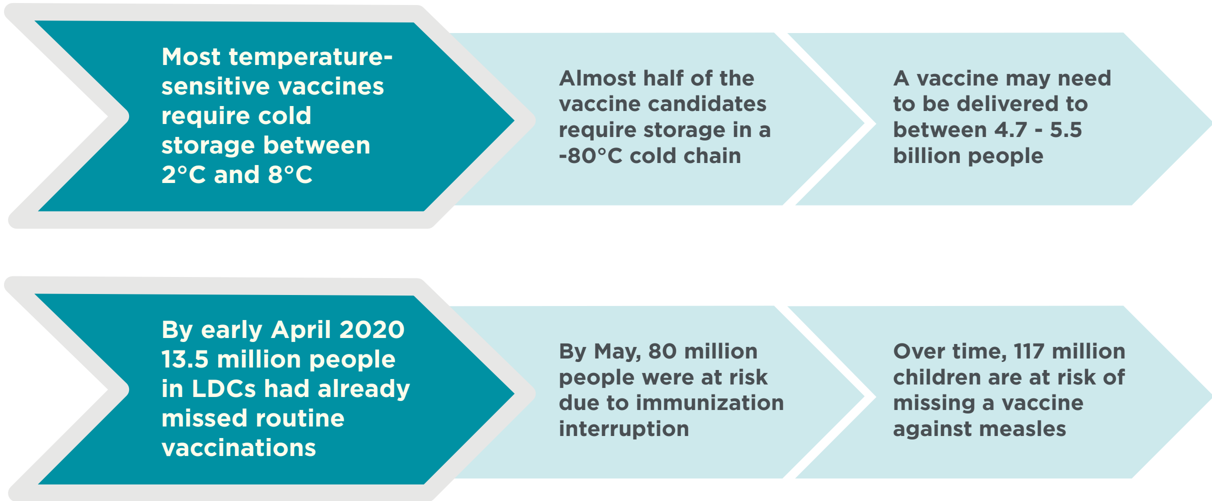
The global race to develop a vaccine for COVID-19 has preoccupied governments and the health community since the scale of the pandemic was realized. Considerably less attention has been paid to the cold chains that are likely to be necessary to deliver that vaccine. **Close to half of the vaccine candidates currently in Phase 1 or later trials will require storage in a -80°C cold chain, which would require building a new cold chain for low-income countries.[2]** The temperature stability requirements of the vaccine candidates that receive approval is as yet unknown, but it is likely that at least the first approved vaccine will require some form of refrigeration. Most temperature-sensitive vaccines, such as influenza vaccines, require cold storage between 2°C and 8°C.[3] Even if we are to build on the existing cold chain already in place for routine immunization, there are a number of issues that are key to understanding the scope of this challenge and the issues faced in the unprecedented attempt to reach an entire population, including the elderly or otherwise vulnerable, especially in low-income countries.

Prior to the pandemic, there were vast inequities in the health cold chain and challenges in achieving universal immunization coverage. In 2018, coverage for the vaccine protecting against diphtheria, tetanus, and pertussis (DTP3), which requires storage between 2°C and 8°C, was at 86 percent globally, meaning 19.4 million children went unvaccinated against preventable diseases. In Africa, coverage was only 76 percent, a figure that has

2 "COVID-19 vaccine tracker," Regulatory Affairs Professionals Society. Accessed 17 June 2020. Available: https://www.raps.org/news-and-articles/news-articles/2020/3/covid-19-vaccine-tracker

3 Weintraub, Rebecca, Prashant Yadav and Seth Berkley. "A Covid-19 Vaccine Will Need Equitable, Global Distribution," Harvard Business Review, 2 April 2020. Available: https://hbr.org/2020/04/a-covid-19-vaccine-will-need-equitable-global-distribution

FIGURE 2.1: TWIN CHALLENGES OF DELIVERING A COVID-19 VACCINE

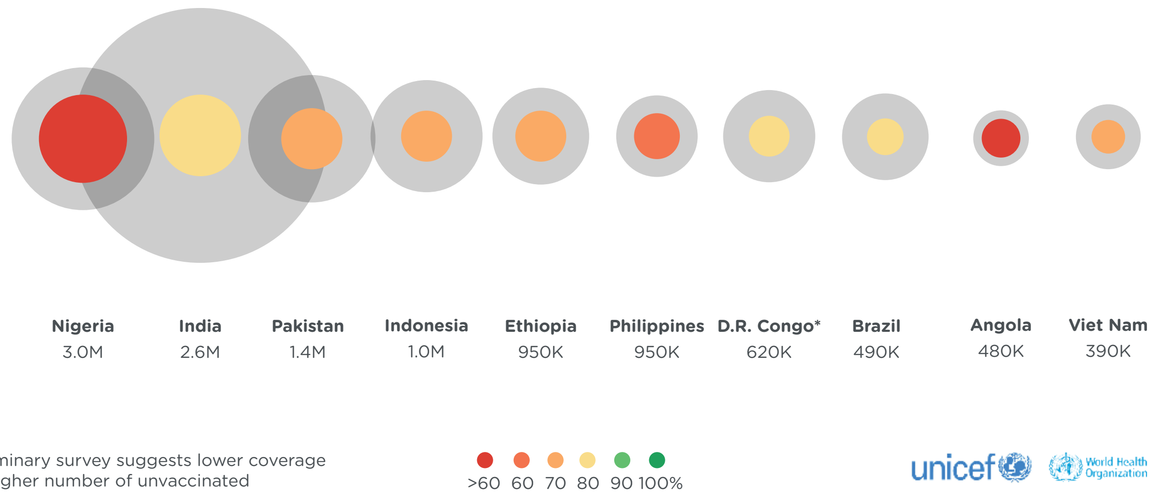


plateaued since 2015.[4] Of the 10 countries that account for 60 percent of unvaccinated children, five are in the critical nine for access to cooling.[5]

These inequities in delivering safe vaccines have been compounded by the COVID-19 pandemic. **As of 3 April 2020, 13.5 million people in the world's least developed countries (LDCs) had already missed routine vaccinations,** risking their health and safety.[6] By mid-May 2020, it was estimated that 80 million children in 68 countries were at risk of diphtheria, measles and polio be-

FIGURE 2.2: 60% OF UNVACCINATED CHILDREN LIVE IN 10 COUNTRIES

Just 10 countries account for 60% of unprotected children



*Preliminary survey suggests lower coverage and higher number of unvaccinated

unicef World Health Organization

4 Progress and Challenges with Achieving Universal Immunization Coverage, UNICEF and the World Health Organization, July 2019. Available: https://www.who.int/immunization/monitoring_surveillance/who-immuniz.pdf?ua=1

5 Progress and Challenges with Achieving Universal Immunization Coverage, UNICEF and the World Health Organization, July 2019. Available: https://www.who.int/immunization/monitoring_surveillance/who-immuniz.pdf?ua=1

6 COVID-19: Massive impact on lower-income countries threatens more disease outbreaks, Gavi: The Vaccine Alliance, 3 April 2020. Available: https://www.gavi.org/news/media-room/covid-19-massive-impact-lower-income-countries-threatens-more-disease-outbreaks

cause of complications from the pandemic. **Over time, 117 million children are at risk of missing another temperature-sensitive vaccine against measles,[7] compared to 182 million children who missed the vaccine between 2010 and 2018.[8]**

These challenges are immense and will be compounded further if the delivery of a COVID-19 vaccine to 60–70 percent of the population, or 4.7–5.5 billion people, is dependent on cold chain capacity.[9] To put the development challenge into perspective, since its launch in 2000, Gavi has helped vaccinate more than 760 million children. A 2017 study on cold chain availability showed that only 10 percent of health facilities in Gavi-supported countries were equipped with the recommended cold chain equipment.[10] The remainder lacked functional devices or were equipped with poor performing devices. Not only will massive amounts of new cold chain equipment be necessary, but difficult trade-offs between the delivery of the vaccine and other temperature-sensitive vaccines and medical products could also be required.

Further complicating the delivery of a COVID-19 vaccine is the lack of reliable electricity supply in rural hospitals and health clinics. In Ghana, for example, only 27 percent of health facilities have stable access to electricity and in Uganda the figure is 29 percent.[11] Across Sub-Saharan Africa only 28 percent of healthcare facilities enjoy the reliable electricity supply that is necessary to keep vaccines cool and power ventilators.[12]

Other gaps in the current routine immunization system will most certainly be exacerbated. These include transport and delivery capacity at the last mile to ensure potency, where the volume and effectiveness of cold packs play a crucial role. In addition, most low-income countries rely on campaign and outreach models for distributing vaccines, especially during outbreaks. This will most likely also be the case for COVID-19 vaccines. Such efforts require some form of cooling, often off-grid and powered by ice, in order for healthcare workers to travel to communities to deliver much needed vaccines.

Nutritional preferences and malnourishment

Access to cooling, in terms of commercial and household cold storage and cold chains, is necessary to support changing consumer preferences and behaviour during and after the pandemic. Refrigeration of food prevents spoilage, reduces trips to the market, and supports a healthy diet. A recent survey of Asian countries found an increase in the consumption of food products that are perceived to be healthy, notably fresh foods that require cold chains to maintain their nutritional value.[13] Consumer spending elsewhere is expected to follow suit. In India, for example, 34 percent of households reported that they now anticipate spending 20 percent of their income or more on fresh food than they did prior to the pandemic, with that number increasing to 52 percent after the pandemic vs. during. Yet the necessary infrastructure is lacking

7 More than 117 million children at risk of missing out on measles vaccines, as COVID-19 surges, Statement by the Measles and Rubella Initiative, 14 April 2020. Available: https://www.who.int/immunization/diseases/measles/statement_missing_measles_vaccines_covid-19/en/

8 Over 13 million children did not receive any vaccines at all even before COVID-19 disrupted global immunization, UNICEF, 24 April 2020. Available: https://www.unicef.org/press-releases/over-13-million-children-did-not-receive-any-vaccines-all-even-covid-19-disrupted

9 Gaveriaux, Laura Mai. "French scientists are using the measles vaccine to develop a "Trojan horse' against the coronavirus," Business Insider, 14 April 2020. Available: https://www.businessinsider.com/french-scientists-using-measles-vaccine-against-covid-19-2020-4?r=US&IR=T

10 Azimi T, Franzel L, Probst N.. Seizing market shaping opportunities for vaccine cold chain equipment. Vaccine, April 2017. https://doi.org/10.1016/j.vaccine.2016.12.073.

11 Franco, A. et al (2017). A review of sustainable energy access and technologies for healthcare facilities in the Global South. Available: https://www.sciencedirect.com/science/article/pii/S2213138817301376?via%3Dihub

12 Diop,Makhtar,"WhatWouldItTaketoDeployCOVID-19Vaccinesthrough Sustainable Cold Chains?" World Bank Group, 1 May 2020. Available: https://www.linkedin.com/pulse/what-would-take-deploy-covid-19-vaccines-through-sustainable-diop/?trackingId=q7ycufxcTJ20Hccby-L6agA%3D%3D

13 Kujopers, Dymfke, Simon Wintels and Naomi Yamakawa, "Reimagining food retail in Asia after COVID-19," McKinsey & Company, March 2020. Available: https://www.mckinsey.com/~/media/McKinsey/Industries/Retail/Our%20Insights/Reimagining%20food%20retail%20in%20Asia%20after%20COVID%2019/Reimagining-food-retail-in-Asia-after-COVID-19.ashx

TABLE 2.1: NUTRITIONAL PREFERENCES AND FOOD LOSS DUE TO LACK OF COLD CHAIN

COUNTRY	INDIA	INDONESIA	THAILAND
% of respondents selecting stable availability of fresh food products among top 3 factors for store selection	39%	41%	34%
Anticipated consumption of fresh foods during COVID-19 (% of households reporting an increase in spending of 20% or more)	34%	31%	23%
Anticipated consumption of fresh foods after COVID-19 (% of households reporting an increase in spending of 20% or more)	52%	30%	14%
Production of milk, meat, seafood, fruit and vegetables lost due to lack of cold chain	18%	22%	22%

to support increased demand. India loses approximately 18 percent of its domestic production of milk, meat, seafood, fruit and vegetables due to a lack of cold chain,[14] and only 30 percent of Indian households have access to a refrigerator.[15]

These trends however, account only for consumer preferences and the baseline of existing cold chain systems, and not for the expected impact of increased poverty. Previous research has shown that in poor countries, calories from nutritious foods are often as much as 10-times more expensive than cereals or grains in caloric terms, and when faced with significant reductions in income, vulnerable groups typically prioritize less nutritious foods with higher caloric value.[16] As a result of the crisis, an estimated 320 million children have lost their access to school meal programmes, with rural households feeling the effects more acutely.[17] Prior to the pandemic, 135 million people, including 73 million in Africa, were facing crisis or emergency levels of food insecurity.[18] **Should the pandemic produce a reduction on global GDP between 2 percent and 10 percent, the number of undernourished people in net-food importing countries could increase from 14.4 to 80.3 million.[19]**

The economic impact on smallholder farmers reliant on the production and sale of goods requiring cold storage for their incomes and livelihoods is another key issue exacerbated by COVID-19. Among other issues, access to trade routes and labour has been reduced as a result of social distancing measures. In Ethiopia, prices for vegetables are declining and there are examples of farmers leaving fresh crops to rot due to a lack of markets.[20]

Finding social distance when temperatures rise

On 28 April 2020, at the height of the pandemic, Delhi recorded its highest temperature of the year at 43.7°C, eclipsing the previous hottest day

14 SEforALL estimate based on FAO production statistics, FAOSTAT, and the Global Food Cold Chain Council, (2015). "Assessing the potential of the cold chain sector to reduce GHG emissions through food loss and waste reduction." Available: http://www.foodcoldchain.org/wp-content/uploads/2016/07/Reducing-GHG-Emissions-with-the-Food-Cold-Chain-NOV2015.pdf

15 The Demographic and Health Surveys (DHS) Program.

16 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. Available: https://academic.oup.com/jn/article/149/11/2020/5535433

17 Social protection and COVID-19 response in rural areas, Food and Agriculture Organizations of the United Nations, 8 April 2020. Available: http://www.fao.org/3/ca8561en/CA8561EN.pdf

18 Global Report on Food Crises 2020: Joint Analysis for Better Decisions, Food Security Information Network and the Global Network Against Food Crises. Available: https://www.fsinplatform.org/sites/default/files/resources/files/GRFC_2020_ONLINE_200420.pdf

19 COVID-19 global economic recession: Avoiding hunger must be at the centre of economic stimulus, The Food and Agriculture Organization of the United Nations, 24 April 2020. Available: http://www.fao.org/3/ca8800en/ca8800en.pdf

20 Tamru, Seneshaw, Kalle Hirvonen and Bart Minten, "Impacts of the COVID-19 crisis on vegetable value chains in Ethiopia," 13 April 2020.

of 42.1°C five days earlier on 23 April.[21] Later in May, nearly 80 migrant workers in India died of starvation or heat stress while moving from crowded cities to their home villages.[22] **The health and economic risks of heat stress are well known – declining productivity, safety concerns for vulnerable groups, and higher peak energy demand – but will be exacerbated by a pandemic response that requires social distancing, particularly for those who already lack access to cooling.** The amplified risks of hot weather are summarized concisely by the Global Heat Health Information Network:

- Many vulnerable groups are susceptible to both heat stress and COVID-19, including the elderly, those with pre-existing health conditions, limited access to healthcare, or those living in poor quality housing
- People at risk in hot weather may see an already precarious socioeconomic condition exacerbated by COVID-19
- Inhabitants of dense urban centres with limited green space have amongst the worst COVID-19 outcomes due to pre-existing exposure to air pollution and high rates of non-communicable diseases
- Inhabitants of slums and informal urban settlements will not be able to stay indoors during a heat wave due to an inability to cool their homes.[23]

Consider a crowded urban slum experiencing a heat wave. Housing quality is likely to be low, with higher temperatures brought on by corrugated metal roofs and the urban heat island effect (UHIE), and intermittent electricity access that means families cannot rely on electrical cooling devices, such as fans.

21 Delhi: Palam records highest April temperature since 1970 at 45.3 degree Celsius, The Times of India, 1 May 2020. Available: https://timesofindia.indiatimes.com/city/delhi/delhi-palam-records-highest-april-temperature-since-1970-at-45-3-c/articleshow/69122413.cms

22 "COVID-19: 80 migrants died on special trains between May 9 to May 27, Railway Protection Force says," Scroll.in, 30 May 2020. Available: https://scroll.in/latest/963323/covid-19-80-migrants-died-on-special-trains-between-may-9-to-may-27-railway-protection-force-says

23 Technical Brief: Protecting Health from Hot Weather During the COVID-19 Pandemic, Global Heat Health Information Network, 25 May 2020. Available: http://www.ghhin.org/assets/technical-brief-COVID-and-Heat-final.pdf

In these circumstances, common responses cannot be reconciled with public health measures needed to prevent COVID-19 transmission, including public cooling centres, gathering in green spaces, checking on vulnerable people, and seeking medical care if necessary.

MOVING FORWARD

Guarantee a Vaccine with Sustainable Cold Chain

Delivering a vaccine that must be kept between 2°C and 8°C to 4.7–5.5 billion within 12–18 months will require a massive expansion in health cold chain infrastructure. As with efforts to develop vaccine manufacturing capacity prior to its discovery, cold chain infrastructure investment must begin immediately – to serve both ongoing and pandemic-related cooling needs. In order to prevent a lock-in of highly inefficient technologies that are procured on an expedited basis, countries, philanthropies and development institutions must utilize procurement standards that prioritize affordable, energy-efficient equipment powered by renewable energy that meets the standards of the Kigali Amendment to the Montreal Protocol.

Existing platforms must be leveraged and scaled up. Gavi's Cold Chain Equipment Optimisation Platform (CCEOP) has already committed USD 250 million and delivered over 60,000 new pieces of cold chain equipment over the past two years.[24] At the same time, we must invest in data and monitoring tools to understand the scope of cold chain gaps, where and why they break down, as well as the human resources necessary to maintain the equipment into the future. Gavi launched INFUSE – Innovation for Uptake, Scale and Equity in Immunization – to focus on high-impact innovations for addressing country-level needs and in collaboration with Nexleaf Analytics that is developing the

24 Weintraub, Rebecca, Prashant Yadav and Seth Berkley, "A Covid-19 Vaccine Will Need Equitable, Global Distribution," Harvard Business Review, 2 April 2020. Available: https://hbr.org/2020/04/a-covid-19-vaccine-will-need-equitable-global-distribution

Intelligent Maintenance and Planning Tool (IMPT), which aims to integrate data across GAVI countries. As demand and price of vaccines increase, and with them the volume of equipment procurement, monitoring is necessary in order to make the deployment manageable, cost-effective and right-sized.

These cooling efforts must be aligned with energy access strategies, including stimulus efforts to recover better with sustainable energy for all. Hospitals and clinics must be guaranteed the energy necessary to power additional cooling needs with renewable energy. Demand-side solutions to maximize energy efficiency and cooling solutions that use no energy can help reduce these added energy requirements.

Using Sustainable Cold Chain to Recover Better in Agriculture

Data gaps in agricultural cold chains can be filled with rapid assessments and recovery packages can invest in the delivery of sustainable cooling technologies to ensure functioning supply chains for nutritious food. The FAO has called for assessments of food stocks and yields to determine gaps, surpluses and potential shortages, as well as taking inventory of cooling infrastructure and cold chains.[25] With these data in hand, investment in an increasing supply of sustainable cooling solutions for the agricultural cold chain can be leveraged through trade and public procurement policies, among others. In low-income countries, interventions are needed to provide cold storage directly after production and at the last mile. Training programmes for installation and maintenance of cooling equipment and resources in off-grid communities are fast ways to boost economic activity and create new jobs.

Governments and multilateral development institutions can also use the social programmes and finance at their disposal to improve the nutritional quality of diets and stimulate demand for nutrient-rich foods, both in terms of the immediate economic stimulus and recover better efforts. Levers include cash transfers, communications campaigns, and social protection programmes.

Protecting the Vulnerable from Heat Stress and COVID-19 Simultaneously

There are practical steps countries and cities can take. The WHO has recommended the implementation of heat-health action plans, including a specific review for 2020 that considers the implications of the pandemic and strategies to reduce and prevent COVID-19 transmission.[26] The Global Heat Health Information Network has prepared a planning checklist to guide this process,[27] and key among the actions is providing practical information on how vulnerable groups can protect themselves from both heat stress and COVID-19 simultaneously.

Local and national governments also have an important role in educating the public on affordable and sustainable cooling solutions and providing the financial and technical support necessary to ensure vulnerable groups can access them. This includes efforts that make efficient fans more accessible, such as the Global LEAP results-based financing facility that resulted in more than 193,000 verified fan sales in developing markets.[28] It may also require financial tools to make efficient air conditioning or refrigeration more affordable, particularly in the light of economic recession, and proactively implementing evaporative cooling and passive cooling solutions in buildings, including cool roofs, shading and vegetation.

25 Responding to the impact of the COVID-19 outbreak on food value chains through efficient logistics, FAO, 4 April 2020. Available: http://www.fao.org/3/ca8466en/CA8466EN.pdf

26 Preparing for a long, hot summer with COVID-19, World Health Organization, 11 May 2020. Available: http://www.euro.who.int/en/health-topics/health-emergencies/coronavirus-covid-19/news/news/2020/5/preparing-for-a-long,-hot-summer-with-covid-19

27 Planning Checklist: Managing Heat Risk During the COVID-19 Pandemic, The Global Heat Health Information Network. Available: http://www.ghhin.org/assets/Checklist-COVID-HEAT-final.pdf

28 Global LEAP Finance Facility: Accelerating Early Stage Appliance Markets, Efficiency for Access Coalition.

3. THE PRODUCTIVITY PENALTY OF FAILING TO DELIVER SUSTAINABLE COOLING

Between 1960 and 1991, Singapore experienced rapid economic growth, with an average annual GDP growth rate of 8.25 percent.[1] Its Prime Minister during much of this time, Lee Kuan Yew, credited cooling and the advent of air conditioning as crucial for this growth "by making development possible in the tropics."[2] During this time, Singapore led by example by installing air conditioning in public buildings, jump-starting the sector's productivity. As global temperatures rise, it has become clear that a dramatic expansion of air conditioning and the associated energy demand could have serious environmental consequences, and a lack of access to cooling, particularly for those working outdoors, poses a significant challenge for economic development. In 2019 the International Labour Organization (ILO) estimated that by 2030 the global economy would suffer lost productivity worth USD 2.4 trillion annually due to heat stress, the equivalent of 80 million full-time jobs.[3] Another recent study estimated that the world may already be experiencing an annual productivity loss of 1.96 percent of global GDP due to increased heat exposure.[4]

In the aggregate, these are alarming figures. But they also belie the disproportionate impact on developing economies experiencing increasing heat stress, and the long-term impact heat stress will have on economic growth. It will be these countries, and the sectors that support their growth, that face the most significant productivity penalty due to a lack of access to sustainable cooling.

THE GLOBAL PRODUCTIVITY CHALLENGE

A 2019 study (Chavaillaz et. al) assessed how exposure to heat affects labour productivity according to different scenarios of climate warming: Representative Concentration Pathway (RCP) 4.5, where emissions peak in 2040, and RCP 8.5, a worst-case scenario for climate change.[5] The study found that the impact on labour productivity, in terms of GDP loss across the agriculture, mining and quarrying, manufacturing, and construction sectors would disproportionately affect low- and low-middle income countries.

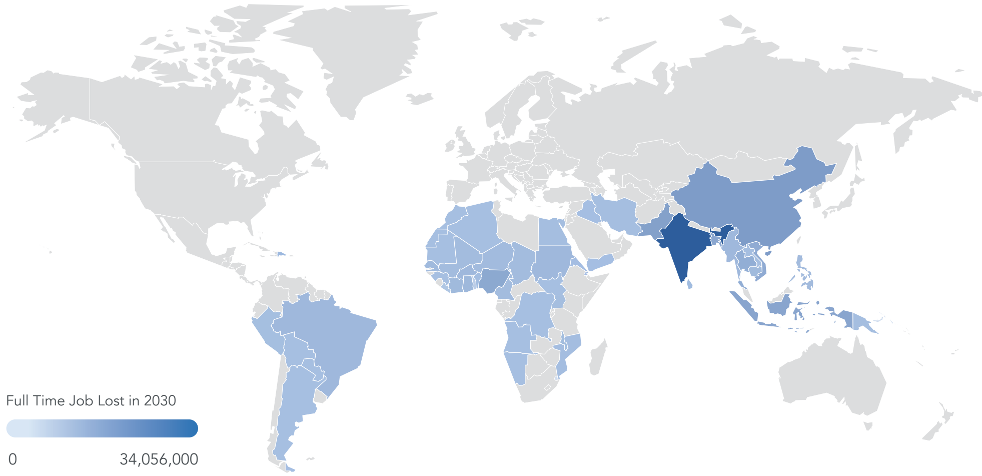
TABLE 3.1: ESTIMATED ANNUAL LABOUR PRODUCTIVITY LOSS DUE TO INCREASE IN HEAT EXPOSURE IN VULNERABLE SECTORS, CLASSIFIED BY INCOME GROUP (CHAVAILLAZ ET. AL)

Income classification	GDP per capita* [USD]	2040 emission peak scenario RCP4.5 [% GDP]	Worst-case climate scenario RCP8.5 [% GDP]
Global		2.96	3.61
Low	<995	4.37	5.91
Low-middle	996–3,895	5.06	5.65
High-middle	3,896–12,055	1.96	2.24
High	>12,056	0.47	0.66

1 Van Elkan, Rachel (1995). "Accounting for Growth in Singapore," from "Singapore: A Case Study in Rapid Development," Ed. Kenneth Bercuson. International Monetary Fund.
2 Lee, Katy, "Singapore's Founding Father Thought Air Conditioning was the Secret to his Country's Success," Vox, March 2015. Available: https://www.vox.com/2015/3/23/8278085/singapore-lee-kuan-yew-air-conditioning
3 "Heat stress spike predicted to cost global economy $2.4 trillion a year," (July 2019) UN News. Available: https://news.un.org/en/story/2019/07/1041652
4 Chavaillaz, Yann, et al., "Exposure to excessive heat and impacts on labour productivity linked to cumulative CO_2 emissions," Scientific Reports, 9 September 2019. Available: https://www.nature.com/articles/s41598-019-50047-w
5 Representative Concentration Pathways (RCPs) are scenarios that include time series of emissions and concentrations of the full suite of greenhouse gases and aerosols and chemically active gases, as well as land use and land cover. For a full definition of the four RCPs used by the Intergovernmental Panel on Climate Change, please see the IPCC Data Distribution Centre: https://www.ipcc-data.org/guidelines/pages/glossary/glossary_r.html#:~:text=RCPs%20usually%20refer%20to%20the,Models%20produced%20corresponding%20emission%20scenarios.

Assuming a current climate change trajectory aligned with the RCP 4.5 scenario, this allows for an initial quantification of net economic losses in those vulnerable sectors across the 54 high-impact countries for access to cooling. **Across these countries, the estimated annual economic loss due to heat stress is currently USD 630 billion, including USD 517.5 billion in the critical nine countries.** In GDP per capita terms, 23 high-impact countries already exhibit losses over USD 100.

FIGURE 3.1: 23 COUNTRIES WITH PER CAPITA GDP PRODUCTIVITY LOSSES DUE TO HEAT STRESS OVER USD 100



Per capita GDP losses will be felt across entire economies, but job losses will affect vulnerable groups most intensely. Of the 80 million job losses due to productivity declines associated with heat stress by 2030, **73.7 million jobs will be lost in countries considered to be high impact for access to cooling.** India alone accounts for 34 million job losses, and together, the critical nine countries account for 57.6 million job losses. Of the top 10 countries for expected job losses, eight gain over 40 percent of their GDP from labour income.

FIGURE 3.2: ESTIMATED NUMBER OF FULL-TIME JOBS THAT WILL BE LOST DUE TO PRODUCTIVITY DECLINES ASSOCIATED WITH HEAT STRESS BY 2030 IN 54 COUNTRIES CONSIDERED HIGH IMPACT FOR ACCESS TO COOLING

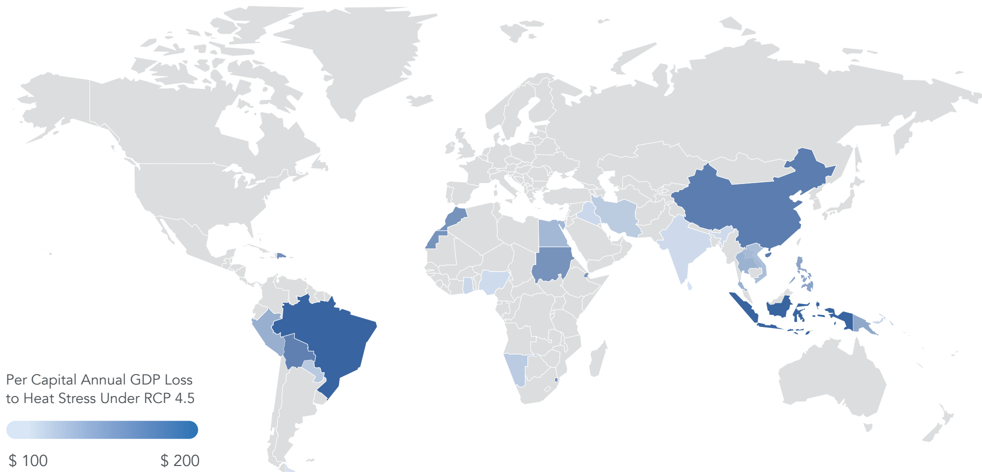


TABLE 3.2: PROJECTED TOP 10 COUNTRIES FOR JOBS LOST TO HEAT STRESS BY 2030 AND ASSOCIATED GDP LOSS

Country	Estimated number of full-time jobs lost due to heat stress (2030)	Labour income as a share of GDP (2017) (%)	Estimated annual GDP lost due to effect of heat stress on labour productivity (2030) (millions)
India	34,056,000	49.2	$134,256
China	5,479,000	51.5	$38,012
Pakistan	4,603,000	42.7	$14,605
Indonesia	4,018,000	38.6	$51,253
Bangladesh	3,833,000	42.4	$13,032
Nigeria	3,639,000	67.0	$19,014
Vietnam	3,062,000	40.3	$11,436
Thailand	2,637,000	47.7	$8,901
Philippines	1,217,000	27.0	$15,831
Ghana	1,038,000	49.7	$2,956

PRODUCTIVITY LOSSES IN THE AGRICULTURAL SECTOR

The agricultural sector warrants close attention due to the relative size of the sector in low and low-middle income countries, and its role in ensuring the sustenance and incomes of poor, rural communities. Of the 54 high-impact countries for access to cooling, 36 have agricultural sectors where productivity losses due to heat already account for more than 1.5 percent of GDP annually. Working hour losses are projected to increase over time in each country, with varying impacts on agricultural labour productivity. Across the countries, **the estimated annual economic loss in the agriculture sector resulting from productivity losses associated with heat stress is currently USD 301 billion.**

The significance of these losses will be felt differently across economies. The implications of a 2.2 percent GDP loss in Morocco's agricultural sector, for example, will be less severe than a 2.2 percent loss in Mali, one of many least-developed countries (LDCs) captured in the table. The effects will also be felt more severely by smallholder farmers who rely on production for subsistence. In Sub-Saharan Africa, these farmers make up 70 percent of the population.[6] These estimates do not account for the impacts of the COVID-19 pandemic or the locust invasion of 2020. Together, these two shocks are expected to increase malnutrition and poverty, placing more strain on agricultural systems, particularly those in rural areas.

Of the 54 high-impact countries, Nigeria relies most heavily on agriculture, for 66.5 percent of GDP, and experiences the highest productivity losses in the agricultural sector, at 3.36 percent. This is a serious issue in broad economic terms but becomes even more acute at the farm level. Of Nigerian farmers, a full 80 percent are smallholder farmers who generally live in rural areas.[7]

6 Kalibarta, Dr. Agnes, "Africa's Growth lies with Smallholder Farmers," Agra, Growing Africa's Agriculture, 23 November 2017. Available: https://agra.org/news/africas-growth-lies-with-smallholder-farmers/

7 Sabo, B.B. et al, "Role of Smallholder Farmers in Nigeria's Food Security," Scholarly Journal of Agricultural Science, 7(1), February 2017. Accessed 29 May 2020.

TABLE 3.3: THE PRODUCTIVITY PENALTY IN THE AGRICULTURAL SECTOR

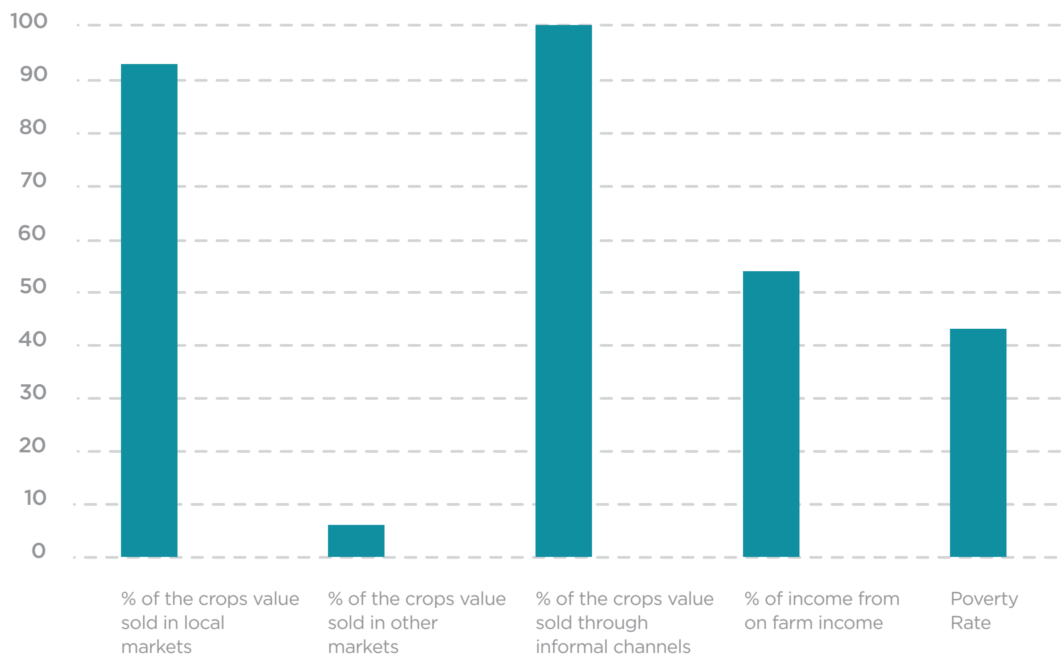
Country	Working hours lost to heat stress in 1995 (agriculture) (%)	Income share of agriculture as a ahare of GDP (%) (2017)	Estimated proportion of annual GDP lost in the agricultural sector due to heat stress under RCP 4.5	Estimated annual agricultural labour productivity losses due to increase in heat stress (USD per capita)	Estimated working hours lost to heat stress in 2030 (agriculture) (%)
Nigeria	5.40	66.5	3.36%	$66.24	9.79
Bolivia	0.88	54.4	2.75%	$92.24	1.97
Congo, DR	1.58	53.2	2.69%	$45.83	4.15
Guinea	2.17	58.1	2.54%	$21.72	4.44
Laos	3.18	49.7	2.51%	$60.96	5.71
India	5.87	49.0	2.48%	$49.12	9.04
Chad	4.87	55.6	2.43%	$16.14	8.80
Ghana	6.54	47.8	2.42%	$49.00	11.69
Timor-Leste	0.16	46.8	2.37%	$30.66	0.70
Myanmar	5.21	44.4	2.25%	$28.08	8.71
Mali	4.24	50.9	2.22%	$18.43	7.45
Morocco	0.13	43.5	2.20%	$66.83	0.39
Mauritania	4.09	43.3	2.19%	$25.10	7.26
Mozambique	1.32	49.7	2.17%	$10.02	2.52
Bangladesh	6.28	42.2	2.14%	$33.40	9.58
Pakistan	6.19	42.2	2.14%	$31.28	8.83
Burkina Faso	4.62	48.5	2.12%	$13.62	8.50
Djibouti	3.17	40.8	2.06%	$60.50	6.48
Vietnam	5.71	40.5	2.05%	$48.48	9.71
Benin	7.21	46.6	2.04%	$23.15	12.43
eSwatini	0.71	39.6	2.00%	$79.21	1.35
Indonesia	4.00	38.1	1.93%	$73.97	7.68
Cambodia	9.05	37.6	1.90%	$26.36	14.52
Yemen	1.10	42.6	1.86%	$17.94	2.00
Cameroon	2.26	36.4	1.84%	$26.18	4.60
Egypt	0.35	34.9	1.77%	$43.10	1.05
Sudan	6.21	34.4	1.74%	$52.48	10.57
Gambia	4.21	39.7	1.73%	$11.79	7.08
Somalia	3.62	39.6	1.73%	$5.35	7.42
Guinea-Bissau	3.17	39.4	1.72%	$12.68	6.20
Togo	5.84	39.4	1.72%	$10.78	10.61
Liberia	4.29	38.9	1.70%	$11.88	7.79
Uganda	0.33	38.8	1.70%	$10.71	1.01
Senegal	3.69	32.5	1.64%	$22.48	6.55
Papua New Guinea	2.26	30.7	1.55%	$41.87	4.36
Malawi	0.26	35.1	1.53%	$5.47	0.51

Note: Countries in bold connote least-developed country (LDC) status.

According to *Tracking SDG7: The Energy Progress Report 2020*, only 31 percent of rural Nigerians have access to basic electricity services that would likely be necessary to power electrical cooling solutions. For subsistence farmers, electricity can power refrigeration and support cold chains that could enable them to shift from lower-value crops distributed locally to higher value, more nutritious crops that can be transported to markets further afield. Data from the FAO show how this affects both the markets and the incomes of smallholder farmers in Nigeria, with a strong preference for sale of crops locally and through informal channels. These factors are indicative of a lack of access to cooling that could enable the production of higher-value goods fit for transport to and sale in higher value markets.

The experience in Nigeria is replicated across the African continent, where agriculture employs 60 percent of the total labour force and accounts for 32 percent of GDP. With 70 percent of Sub-Saharan Africans engaged in smallholder farming, the economic environment needs to be conducive to growth. It is also essential for gender equality. Women make up 50 percent of the agricultural labour force in Sub-Saharan Africa but face a wage gap of 15–60 percent compared to men, depending on the country. Land ownership rates among women are also significantly lower than those of men, and where women do own land, they face significant barriers to access finance, agricultural inputs, and information services.[8] The economic productivity of these farmers will also be affected by changes in precipitation, which become more consequential for agricultural yields as exposure to heat stress increases. Even if precipitation remains constant, water stress will increase, particularly in semi-arid regions.[9]

FIGURE 3.3: MARKETS AND INCOME FOR SMALLHOLDER FARMERS IN NIGERIA IN 2013



8 "Economic Empowerment of African Women through Equitable Participation in Agricultural Value Chains," (2015). African Development Bank. Available: https://www.afdb.org/fileadmin/uploads/afdb/Documents/Publications/Economic_Empowerment_of_African_Women_through_Equitable_Participation_in___Agricultural_Value_Chains.pdf

9 Pereira, Laura, "Climate Change Impacts on Agriculture Across Africa," Oxford University Press, March 2017. Available: https://oxfordre.com/environmentalscience/view/10.1093/acrefore/9780199389414.001.0001/acrefore-9780199389414-e-292

THE IMPACT OF HEAT ON THE WELL-BEING OF WORKERS

The economic impact of a lack of access to cooling is severe, but so too is the human toll. A recent study on the impacts of heat stress on cardiac mortality for Nepali migrant workers in Qatar revealed a death rate of 150 per 100,000 workers, with the major cause listed as cardiovascular problems. Of 571 deaths associated with cardiovascular diseases among this group between 2009 and 2017, 200 could have been prevented with effective heat protection.[10] These are among the 166,000 documented cases of people dying from heat stress between 1998 and 2017.[11]

The opportunity, therefore, is not simply to avoid productivity losses in terms of GDP, but to increase economic competitiveness, safeguard jobs in crucial sectors, and avoid the unnecessary loss of human life. Singapore demonstrated the economic benefits of increased access to cooling through the second half of the 20th century. Now, as temperatures rise and the effects of heat stress become increasingly apparent, sustainable cooling for all offers developing economies an immediate opportunity to mitigate emissions and build resilient, productive economies.

10 Pradhan, Bandana, "Heat Stress Impacts on Cardiac Mortality in Nepali Migrant Workers in Qatar," *Cardiology,* 143(1): 1-12. July 2019. Available: https://www.researchgate.net/publication/334436946_Heat_Stress_Impacts_on_Cardiac_Mortality_in_Nepali_Migrant_Workers_in_Qatar

11 "Heatwaves," World Health Organization, Available: https://www.who.int/health-topics/heatwaves#tab=tab_1

4. SUSTAINABLE COOLING SOLUTIONS

#ThisIsCool

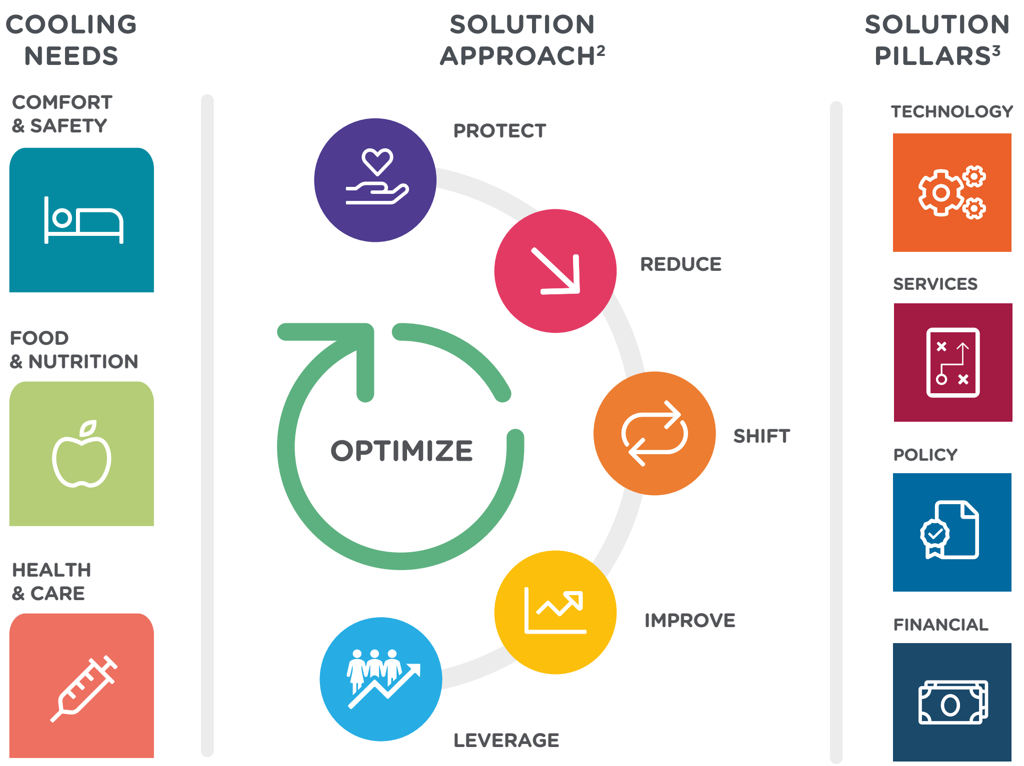
Green, clean, efficient and climate friendly are all terms that are used to describe sustainable cooling.[1] *But what are sustainable cooling solutions?*

There are a range of sustainable cooling solutions that need to gain a larger market share to achieve global climate and the Sustainable Development Goals (SDGs). These include some of the most efficient fans, air conditioners and refrigerators; measures to reduce the need for cooling through insulation, shading, reflectivity or ventilation; and using collective effort to deliver more sustainable products, services, policies and financial solutions to meet cooling needs and provide cooling benefits.

COOLING FOR ALL SOLUTIONS

In a warming world, access to sustainable cooling is not a luxury. It is an issue of equity and a service that must be delivered to all to achieve SDG7. Cooling for all does not mean an air conditioner or a refrigerator in every home; it means providing more sustainable and affordable solutions to address the needs of the vulnerable, such as access to nutritious food and safe medicines, and protection from heat as the world transitions to clean energy. Beyond achieving the basic needs for cooling, these same sustainable cooling solutions also deliver significant benefits across the economy to countries, companies and the population at large.

FIGURE 4.1: COOLING NEEDS, SOLUTION APPROACH AND SOLUTION PILLARS



1 For example, a range of partners use these terms to support sustainable cooling:
1. Green Cooling Initiative uses "green" to describe energy efficient technologies that use natural refrigerants.
2. Centre for Sustainable Cooling uses the term "clean" for delivering comprehensive access to cooling efficiently and sustainably.
3. The Kigali Cooling Efficiency Program (K-CEP) uses "efficient and climate friendly" for energy efficiency with a focus on the greatest potential to reduce emissions.

2 These round icons are used in the sustainable cooling solution tables below to indicate how the measures support increased sustainability.

3 The term technology used in this chapter is based on a broad definition, as *the application of scientific knowledge* for practical purposes to include both the use of materials and products (e.g. nature-based systems, passive systems and active systems).

The purpose of this chapter is to explore what sustainable cooling solutions are and to build a conversation with partners that can support the achievement of cooling for all. It is a starting point from which to develop the *Cooling for All Solutions Assessment toolkit,* which will support users to understand the right solutions based on their cooling needs. The framework used in this chapter for sustainable cooling solutions is to meet the *three Cooling for All Needs* with an *optimized five-solution approach* across the *four solution pillars.* This is described in more detail below, with the majority of the chapter examining the sustainable cooling solutions in the four solution pillars.

COOLING FOR ALL NEEDS

A necessary first step was taken in 2019, when the Cooling for All Secretariat at Sustainable Energy for All (SEforALL) and Heriot-Watt University partnered to create the Cooling for All Needs Assessment to understand cooling needs across buildings, cities, agriculture and health services. The consideration of cooling solutions must be grounded in an understanding of cooling needs that span multiple sectors, as identified in the Cooling for All Needs Assessment.

While these fundamental needs are the focus of this chapter, sustainable cooling solutions can also support the transition to highly productive economies through other sectors, for example, industrial optimization or data centre cooling.

This year, the ***Cooling for All Secretariat*** is partnering again to create the Cooling for All Solutions Assessment toolkit that will launch in autumn 2020. This toolkit will include a process that will support governments and organizations to identify sustainable cooling solutions. If you would like to be involved in further developing or testing the toolkit, please contact us at: coolingforall@seforall.org.

COMFORT & SAFETY

Human Comfort, Productivity and Safety

Comfort & Safety includes the need for people to have access to cooling for living, learning, working and mobility. There are levels of need, including for human thermal comfort and associated well-being; for productivity and linked incomes; and safety and health in extreme weather conditions.

FOOD & NUTRITION

Food, Nutrition Security and Agriculture

Food & Nutrition includes the need for the agriculture sector to have access to cooling for food and nutrition security, rural incomes, and the agriculture cold chain.

HEALTH & CARE

Health Services and Infrastructure

Health & Care includes the need for the healthcare sector to have access to cooling for safe medical clinics and the secure transport and storage of vaccines and medical products.

SOLUTION APPROACH TO ACHIEVING SUSTAINABLE COOLING

To enable analysis and optimization of cooling solutions, the first layer of classification is *Protect, Reduce, Shift, Improve and Leverage* – approaches or measures used to deliver more sustainable cooling, as distinguished by the Cool Coalition.[4] While *"avoid, shift, improve"* or *"reduce, shift, improve"*, are already in use, this framework expands those concepts further in recognition of the needs of vulnerable populations with *Protect* as a starting point and the approach for delivering the solutions, and *Leverage* as an effective means for achieving impact.

PROTECT

Affordability
Safety
Reliability

Protect approaches and measures reduce the vulnerability of people, businesses and governments to heat by using cooling solutions that are affordable, safe and reliable.

REDUCE

Passive cooling
Urban planning
Building design
Nature

Reduce approaches and measures reduce the need for active or mechanical cooling solutions, and include using planning and design to reduce or even avoid the demand for active cooling.

SHIFT

Cooling approach
System type
Refrigerant type
Energy source

Shift approaches and measures are those where simply a change of approach can deliver energy or emissions savings, such as through the use of renewable energy, natural refrigerants or conservation measures.

IMPROVE

Equipment efficiency
Operation efficiency

Improve approaches and measures include pure efficiency measures to achieve the same cooling service while using less energy (i.e. not using energy conservation measures).

LEVERAGE

Partnership
Cooperation
Collective impact

Leverage approaches and measures support the achievement of a collective impact that is greater than the sum of individual efforts through cooperation and collaboration.

This five-solution approach supports a combination of both *early wins* and more systemic changes that are essential to achieve sustainable cooling for all. Optimization can support systemic changes to deliver against the consequences of cooling (energy, emissions) across multiple sectors that have inherent interdependencies across economic, energy, technology, mitigation, adaptation, social and political systems.

SUSTAINABLE COOLING SOLUTION PILLARS

There are a range of sustainable cooling solutions that can be grouped into four key solution categories and that together can meet the needs and desires for cooling.

While technology solutions are the first type of solution that comes to most people's minds when thinking about the best cooling solutions, a **combination of these solutions** is essential to building an enabling environment for investment in more sustainable cooling solutions and achieving long-term benefits. Programmes (initiatives or market-based instruments) are an important delivery mechanism for more sustainable solutions. Successful market transformation programmes include a combination of these solution types to create an enabling environment for investment in sustainable cooling and increased access to cooling (e.g. a programme that supports policy development, technology research, and financing the design, installation and maintenance of solutions).

TECHNOLOGY

Passive
Active

SERVICES

Preparation
Operation

POLICY

Regulation
Information
Incentives

FINANCIAL

Funding
Finance
Fiscal

SUSTAINABLE COOLING SOLUTION MEASURES

The categories above highlight a framework of three cooling needs, five solution approaches and four solution pillars that can be used to optimize cooling solutions for sustainability and access to cooling. While this chapter will not go into the details of each solution, the following sections explore where different measures fit within this framework. The tables below include general descriptions of key solutions and the associated coloured symbol for the solution approach achieved through the measure. While these are not comprehensive or definitive, they are a starting point to better understand the solutions that will be optimized in the *Cooling for All Solutions Assessment toolkit.*

Technology solutions deliver sustainable cooling through a range of materials, products and devices to support delivery of passive cooling and active cooling and include: (1) those measures that use no operational energy and no refrigerants (i.e. nature-based and passive technology solutions), and (2) those measures that use energy and refrigerants, but do so efficiently (i.e. active technology solutions).

Nature-based and *passive* technology solutions include a combination of traditional or indigenous low-tech and modern high-tech solutions. Some of the most effective low-tech solutions include nature-based solutions such as water, trees, plants and earth. Passive technologies are all *Reduce* measures, while most are also *Protect* measures for their ability to increase reliability of cooling and increase safety for vulnerable populations in extreme weather events.

Active technology sustainable cooling solutions are a much wider group[5] of solutions that range from a simple fan to a large district cooling system. Each technology has a range of achievable sustainability, and those technologies that are more efficient and have a smaller emissions impact are often more sustainable than others. In Table 4.2, the sustainability drivers include device efficiency, refrigerant type (impacting both efficiency and emissions),[6] and energy source. While the key factors of efficiency and emissions are fundamental to active technology sustainability, the *Cooling for All Solutions Assessment toolkit* will further enable an assessment, which is not possible in this chapter, to optimize the combination of cooling solutions based on life-cycle sustainability.

5 See the Centre for Sustainable Cooling Technology Landscape website for a broader list of technology types.
6 As controlled by the Kigali Amendment to the Montreal Protocol.

TABLE 4.1: NATURE-BASED AND PASSIVE TECHNOLOGY SOLUTIONS

Nature-based and Passive Technology Solutions		
Shade		Umbrellas, overhangs, fins, external blinds, solar panels and plants as shades
Insulation		Roof and wall insulation, insulated windows, insulated containers
Reflection		Cool roofs, walls, vehicles, containers and other surfaces
Airflow		Natural ventilation, building or vehicle openings, exhaust
Water		Flowing water, mist, pools, rivers, lakes, ocean, heat sinks
Plants		Ground cover, green roofs, green walls, shade trees
Earth		Earth tunnel, earth berm, heat sinks
Thermal		Thermal mass, thermal storage

TABLE 4.2: ACTIVE TECHNOLOGY SOLUTION SUSTAINABILITY DRIVERS

Active Technology Solution Sustainability Drivers	
Device efficiency	The features of the device impact how efficient the technology is at delivering cooling (e.g. how it controls, makes, stores, moves and uses cold[7]).
Refrigerant type	The type of refrigerant impacts the global warming potential emissions from owning, operating and decommissioning a technology.
Energy source	The type and source of energy used by the technology impacts the emissions and in some cases the efficiency of the technology

Service solutions support the organization and delivery of cooling technologies and include (1) activities that support the preparation (e.g. theory and practical skills) to create or deploy more sustainable cooling solutions and (2) operational (e.g. operation, management and maintenance) activities to deliver and use more sustainable cooling. Without these services more sustainable technology solutions may not be available; in other words, the manner in which technologies are developed, sold, installed or used all have a bearing on sustainability, which are all dependent on services.

Preparational services, including fundamental education, skills development and project services, are key to improving behaviour and long-term decision-making on cooling. Education includes basic learning from primary school to university that can support better decision-making for a larger share of the population or increased innovation for a smaller group. Skills development is a form of education that can support practical decision-making through vocational and professional training. Project services, often by engineers, designers, architects or contractors, are fundamental to achieving more sustainable cooling access (e.g. urban planning enables the use of passive technologies and building design enables the use of more sustainable cooling technologies).

Operational services include the direct operation of cooling services, the management that supports cooling services and the maintenance that ensures that cooling services and technologies are operating sustainably. The operation of more sustainable cooling services can provide a one-stop-shop (e.g. a cooling centre or district cooling) or be a portion of the solution within a wider business model (e.g. cold chain). Management as a sustainable cooling service includes a range of activities that enable improved decision-making or behaviour. Maintenance services enable more sustainable technologies and services to operate at their optimal performance and increase their reliability during peak hours or for vulnerable populations.

7 The stages of the systems approach to cooling as developed by the University of Birmingham.

TABLE 4.3: PREPARATIONAL SERVICES

Preparational Services			
Education	Primary	Secondary	University
Skill development	Vocational education	Professional training	Partner training
Project services	Analysis & modelling	Planning & design	Installation & quality assurance

TABLE 4.4: OPERATIONAL SERVICES

Operational Services			
Operation	Cooling as a Service (CaaS)	Community cooling centre / hub	District cooling & cold chain
Management	Procurement & Purchase	Monitoring & Evaluation	Optimization
Maintenance	Refrigerant charge & servicing	Cleaning & maintenance	Repairs

Policy solutions deliver more sustainable cooling through a range of measures that include a blend of (1) legally binding or *stick* measures (Regulatory), (2) teaching or *tambourine* measures (Information) and (3) motivational or *carrot* measures (Incentives).

Regulatory policies can be one of the most effective measures but are often the hardest to adopt and implement, depending on the cultural context and enforcement procedures. While regulatory policies are often difficult to enforce when they are initially created, having the policy in place can support common understanding of what is more sustainable. Codes and standards are commonly used, but there are significant gaps in the enforcement of both building codes and cooling product standards in many of the vulnerable high-risk countries. These minimum standards are an important baseline for market-based approaches and voluntary high-performance standards to enable market transformation over time.

TABLE 4.5: REGULATORY POLICIES

Regulatory Policies	
Codes	Building energy codes, planning and zoning codes
Standards	Minimum energy performance standards
Disclosure	Mandatory labels, certificates and public disclosure
Certification	Mandatory testing, benchmarking and certification
Evaluation	Mandatory audits and evaluation
Utility obligations	Regulation of utilities to support sustainable cooling
Public procurement	Minimum sustainability of government purchases
Import/export control	Minimum sustainability of imported and exported products

Information policies, including the use of voluntary information disclosure, certification, labels that indicate the level of sustainability, voluntary standards, and awareness-raising campaigns that inform people about cost-effective sustainable solutions enable more sustainable behaviour and support better decision-making.

8 See the Cooling as a Service Initiative for more information: www.caas-initiative.org/about-us/

TABLE 4.6: INFORMATION POLICIES

Information Policies	
Disclosure	Public database of products, buildings, vehicles and services
Certification	Product, service or educational certificates
Labels	Branding, endorsement and comparison labels
Voluntary standards	High energy performance or sustainability standards
Awareness	Information and behaviour campaigns

Incentive policies can include both financial and non-financial incentives. While many first consider financial incentives to encourage people to purchase sustainable technologies or services, it is often the non-financial incentives that can be more sustainably delivered and achieve results. These policies should be considered in collaboration with the financial solutions that can enable private investment in sustainable solutions.

TABLE 4.7: INCENTIVE POLICIES

Incentive Policies	
Non-financial	Expedited permitting / approvals, expanded scope allowance
Financial	Policies to deliver financial solutions

Financial solutions deliver more sustainable cooling through a range of direct funding and indirect financial measures that can influence the cost effectiveness or first cost of more sustainable solutions, including through finance, fiscal instruments and funding measures. A combination of these financial solutions can be used together in the delivery of a financial programme; for example, a results-based financing or overseas development assistance programme should select a series of measures and work with a range of stakeholders to deliver the financial solutions to enable market transformation.

Finance solutions are intended to enable a temporary use of funds to purchase technologies or services. It is the temporary use of funds that can enable a more sustainable long-term funding approach to achieve both a lower monthly cost of solutions and the repayment of borrowed funds that can be used again for other projects. With limited funds available in many countries, finance measures can be key to creating an enabling environment for private investment in more sustainable solutions.

Fiscal solutions enable governments to influence decisions and can entail either income or expense for the government. Fiscal solutions can be created to financially support more sustainable cooling solutions and penalize the purchase of less sustainable measures. One key global expense that reduces the benefits of more sustainable cooling solutions is energy subsidies that do not properly reflect the actual cost of energy. Further influence on energy prices can be achieved by having an energy or carbon tax that reflects the societal cost of energy. Tax credits can be used to support the purchase of more sustainable measures, similar to

TABLE 4.8: FINANCE SOLUTIONS

Finance solutions	
Loans	Credit lines / loans / subordinated loan
Risk sharing	Risk sharing / loan guarantees / insurance
Contracts	Energy performance contracting / service agreements
Bulk purchase	Government or ESCO or buyer's club
Leasing	Leasing
Repayment	On-bill or on-tax repayment
Equity	Equity investment
Bonds	Green bonds / corporate bonds
Investment funds	Sustainability or energy investment funds
Crowdsourcing	Community finance / crowdfunding

a rebate or subsidy. Import/export control policy solutions and import/export duties fiscal solutions can be used in tandem to encourage the international trade of more sustainable solutions.

Funding solutions, such as grants or rebates, can be expensive compared to the total impact received, when compared to finance solutions that directly recoup the funds used to support the purchase of more sustainable cooling technologies or services. Funding provided to consumers or projects reduces the cost of more sustainable solutions without future repayment of the money received.

TABLE 4.9: FISCAL SOLUTIONS

Fiscal solutions	
Energy pricing	Energy pricing and subsidies (to reflect actual costs)
Tax	Energy or carbon tax (on unsustainable energy sources)
Tax credits	Tax credits (on more sustainable solutions)
Import/export duties	Import/export duties (reduced on more sustainable solutions)

TABLE 4.10: FUNDING SOLUTIONS

Funding solutions	
Grants	Direct financial contribution to a project
Rebates	Direct financial contribution as a result of purchasing a product or service
Subsidy	Direct financial contribution to reduce the cost of a product or service

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