CHILLING PROSPECTS:

PROVIDING SUSTAINABLE COOLING FOR ALL

SUSTAINABLE ENERGY FOR ALL

KIGALI
COOLING EFFICIENCY PROGRAM

ACKNOWLEDGEMENTS

SEforALL would like to thank the following people and organizations, without whose input the report would not have been possible:

GLOBAL PANEL MEMBERS

Achim Steiner
Administrator, UNDP

Dan Hamza-Goodacre
Executive Director, Kigali Cooling Efficiency Program

Durreen Shahnaz
Founder and CEO, Impact Investment Exchange

Erik Solheim
Executive Director, UN Environment

Iain Campbell
Managing Director, Rocky Mountain Institute

Jürgen Fischer
President, Danfoss Cooling, and Member of Group Executive Team

Kate Hampton
CEO, Children's Investment Fund Foundation

Kurt Shickman
Executive Director, Global Cool Cities Alliance

Maria Neira
Director, Public Health and the Environment Department, WHO

May Mei
Executive Director, GoalBlue Low Carbon & Promotion Center

Rachel Kyte
CEO and Special Representative of the Secretary General of the UN for Sustainable Energy for All

Tina Birmpili
Executive Secretary, Ozone Secretariat

Veerabhadran Ramanathan
Distinguished Professor of Applied Ocean Sciences at the Scripps Institution of Oceanography, University of California

SPECIAL ACKNOWLEDGEMENT FOR THEIR CONTRIBUTIONS:

Brian Holuj, Brian Motherway, Hu Min, Julia Panzer, Katharina Arndt, Meg Seki, Steve Kukoda, Professor Toby Peters, Kizzy Charles-Guzman, Daniella Henry, Nicola Twilley, Johannes Heister, Clay Nesler

ADDITIONAL ACKNOWLEDGEMENT:

CLASP: Ana Maria Carreño, Eric Gibbs, Jeff Stottlemyer, Jenny Cory Smith, Yasemin Erboy Ruff, Sam Grant, Elisa Lai, Nicole Kearney; REN21: Rana Adib, Laura Williamson; GIZ: Nika Greger; Boson Energy; EPEE: Andrea Voigt; AHRI: Joe Trauger; GFCCC: Juergen Goeller, Rajan Rajendran; ARAP: Kevin Fay

Thank you!

The Cooling for All team

FOREWORD

RACHEL KYTE

Chief Executive Officer of Sustainable Energy for All (SEforALL), and Special Representative of the UN Secretary-General for Sustainable Energy for All.

On a hot day, as I look at my own children, it is too easy to take cooling for granted. Whether it's the fresh fruit that they are eating for breakfast, the air conditioning in their school or on the bus, even the vaccine that keeps them safe from a common disease. But for hundreds of millions of children and adults across a warming world, a lack of access to cooling is increasingly impairing their ability to work, eat nutritious food, and lead healthy and productive lives.

This report—Chilling Prospects: Providing Sustainable Cooling for All—is a wake-up call. It calls our attention to the growing, unprecedented risks for people who cannot access cooling today. The report sets out the challenges—and opportunities—for finding sustainable and efficient cooling solutions for all, while at the same time protecting the climate. The report sets out that there are key paths that can be taken to provide sustainable solutions that benefit countries, economies, and our children.

Produced in partnership with the Kigali Cooling Efficiency Program, this report builds out of the intersections of three historic international agreements reached in the past two years. First, the Sustainable Development Goals (SDGs) agenda, provides a pathway for achieving established targets on poverty, health, education, sustainable energy, and food security, among others, by 2030. Second, the SDGs will need to be achieved in the context of the international Paris Agreement, which calls for building resilience and decarbonizing our economy to stabilize global warming well below 2°C. And third, the expected entry into force of the Montreal Protocol's Kigali Amendment to phase down high global warming refrigerants, known as hydrofluorocarbons (HFCs), by 80 percent in the next 30 years provides a unique opportunity to develop new thinking for refrigeration and other cooling technologies.

Together, these three landmark agreements lay down a challenge for all of us: How can we meet everyone's cooling needs efficiently, affordably, sustainably, and reliably?

This question was the starting point of the research that supports this report. It comes at a time of growing innovation in cooling technology and business models across many different sectors. However, too often these innovations take place in isolation. There is growing awareness that the sustainable energy transition—called for by the SDGs and the Paris Agreement—must be far more integrated and efficient. We often hear about the great strides made in the development of renewable energy but without addressing cooling and heating, the thermal economy, we will not meet the goals we have set for ourselves.

By looking at more than just air conditioning systems, this report explores the wide-ranging challenges for people without access to cooling. It quantifies the access gaps in key regions and countries for the first time. It also offers advice and guidance to policymakers on how to measure the gaps in their own countries and how to think more systematically about pathways that bring sustainable cooling to populations that rely on them for food security, health, and productivity.

The report looks at several specific issues: why access to cooling is so essential to meet the Sustainable Development Goals; how to identify the most vulnerable populations in a warming world; the implications for the Paris Agreement if swift, more efficient actions are not taken; and the need to think systematically about cooling technologies, finance, and access pathways that will help achieve the SDGs and the Paris Agreement.

But, most importantly, it shows that as populations grow and temperatures reach new records, the health and economic risks associated with a lack of access to sustainable cooling is higher than ever before. These risks are most severe in poor and developing countries where extreme heat stress is on the rise; however, we should also not ignore other vulnerable groups, even in developed economies, where temperatures are also increasing.

The report shows that there is a need to think more holistically. We need to consider the simple solutions of whitewashing roofs or using solar power to drive fans to help make people feel more comfortable. We need to harness new innovations in refrigeration that use very little power to keep vaccines at safe temperatures. We need to think of how to keep food safe and preserve its value along its entire journey from farm to fork in a way that also minimizes energy consumption. Sustainable cooling is the cold core of a functioning, inclusive, clean economy.

I said this report is a wake-up call. It is also a call to action. To governments, my message is that there is a huge economic and social impact to be gained by improving access to cooling: reducing the number of lost work hours, improving the productivity of the workforce, avoiding costs of healthcare for people with food poisoning or who are suffering because their vaccines weren't stored properly, increasing the incomes of farmers, and increasing the number of jobs available to service a new cool economy.

To industry, my message is simple: the HVAC and refrigeration industry has already shown commitment and the ability to innovate in response to the Montreal Protocol and it has been a driver behind its Kigali Amendment. Can you discover "cold gold" at the base of the pyramid?

Achieving Cooling for All means deploying the most efficient current technology as well as developing new, innovative, efficient solutions for those most in need. This will require new business models, training of a new workforce, and collaboration across government, industry, finance, and civil society.

It also requires all of us to act now.

Rachel Kyte
Chief Executive Officer of Sustainable Energy for All (SEforALL),
and Special Representative of the UN Secretary-General for Sustainable Energy for All.

CONTENTS

ACKNOWLEDGEMENTS 2

FOREWORD 4

EXECUTIVE SUMMARY 8

ABBREVIATIONS 16

GLOSSARY 18

1. INTRODUCTION: WHY "ACCESS TO COOLING"? 20

2. COOLING: OPPORTUNITIES AND RISKS FOR SUSTAINABLE DEVELOPMENT 24

3. DEFINING AND QUANTIFYING THE COOLING ACCESS GAP 32

4. PROVIDING ACCESS TO COOLING WITHOUT HEATING THE PLANET 42

5. THINKING THERMALLY –THE NEED FOR A HOLISTIC APPROACH TO COOLING 46

6. OPPORTUNITIES FOR PROVIDING ACCESS TO COOLING THROUGH BETTER TECHNOLOGY AND CHANGES IN LIFESTYLE 50

7. THE FINANCING GAP 54

8. RECOMMENDATIONS AND NEXT STEPS –TOWARD NATIONAL ACCESS TO COOLING ACTION PLANS 58

CONCLUSION 64

REFERENCES 66

DISCLAIMER AND COPYRIGHT 70

EXECUTIVE SUMMARY

Cooling is one of the wonders of the modern age. However, for hundreds of millions of people living in the hottest climates, the impact of not having access to modern cooling services is profound. Every year, millions of people die due to the absence of cooling that could help address hunger and malnutrition, preserve the efficacy of vaccines, and alleviate the worst of deadly heat waves. Cooling access can also help increase farmer incomes and lift people out of poverty by increasing the sales value of their produce when it meets the market.

Cooling is essential for achieving many of the Sustainable Development Goals (SDGs). Yet, lack of access to cooling threatens more people in more ways than ever before. Human exposure to heat extremes is at unprecedented levels in many parts of the world and is likely to increase with rising global temperatures. A 2017 study predicts that by the end of this century, if carbon emissions continue on their current trajectory, three-quarters of humanity will face deadly heat.[i]

The economic impact of heat stress cannot be ignored. Overall, by 2050, work-hour losses by country are expected to be more than 2% in 10 world regions and as high as 12%—worth billions of US dollars and as much as 6% of annual GDP—in the worst-effected regions of South Asia and West Africa. Even a 2% per capita loss per year means that, over 30 years, growth in GDP/capita will be less than half as much as if the excessive heat had not occurred.[ii]

This report is the first to define and quantify the magnitude of the cooling access challenge, including an assessment of countries facing the biggest risks, measured by extreme heat, food losses, and damaged or destroyed vaccines and medicines. The report illustrates the social and economic risks of ignoring the challenge and the enormous economic and business opportunities of a concerted effort to provide sustainable cooling.

These challenges and opportunities vary by geographic location, thematic area, and financial capacity. The cooling solutions need to be affordable, energy efficient, and have low life cycle climate impact. The solutions must also be systematic, holistic, and appropriate: designing an ultra-efficient air conditioner is a critical part of solving the problem of increasing energy use for space cooling, for example, but it doesn't help those with no access to electricity unless it is considered in tandem with a consideration of solar home systems or decentralized mini-grids.

Based on an analysis of the 52 most vulnerable countries, the report shows that approximately 1.1 billion people face cooling access risks. This includes an estimated 470 million people living in poor rural areas without access to electricity and cold chains for food and medicines, and 630 million slum dwellers living in hotter-climate urban areas where electricity services do not exist, are intermittent, or are too expensive. The 60-plus people who died in Karachi, Pakistan, during a May 2018 extreme heat wave[1] where temperatures eclipsed 40°C are unfortunate proof of these urban heat risks.[iii]

This report identifies another significant population group who are at risk in a different way—specifically, 2.3 billion people in the increasingly affluent lower-middle class in developing countries who are on the brink of purchasing the most affordable—and

[1] *WHO defines "heat wave" as several days. Reference: http://www.who.int/globalchange/publications/heatwaves-health-guidance/en/*

therefore likely least efficient—air conditioners. If we only look at growing air conditioning demand from this group—driven overwhelmingly by city dwellers in countries such as China, India, Indonesia, and Brazil—and ignore possible energy efficiency measures in the buildings themselves, energy demand is forecast to rise more than 33-fold by 2100.[iv] Put simply, global cooling demand, if not better managed, is a colossal climate threat.

The report identifies nine countries with the biggest populations facing significant cooling-related risks, including five in Asia, three in Africa, and one in Latin America. India has the largest number of people facing risks across all dimensions. India, Bangladesh, Nigeria, Sudan, and Mozambique have the most significant rural populations facing health risks, food and nutrition security, as well as challenges to human productivity. China, India, Nigeria, Brazil, and Pakistan have the most significant slum-dweller populations facing risks. India—followed by Indonesia, Pakistan, Bangladesh, and Brazil—has the largest population at risk of buying the least efficient appliances.

CHALLENGES AND OPPORTUNITIES

Cooling has been a focus of civilizations for centuries, although the modern age of air-conditioned buildings only took off in the 1950s. In many developed countries—particularly the United States, Australia, and parts of the Middle East—buildings are often over air-conditioned beyond the needs of thermal comfort, forcing workers to wear extra layers of clothing on even the hottest days. Although the efficiency of equipment used for cooling has been improving over time, the demand and resulting energy consumption has been growing at alarming rates: 328 million Americans consume approximately the same amount of electricity for air conditioning alone than the total electricity used for all needs by 1.1 billion people in Africa.[v]

This brings the question of equity into sharp focus: satisfying the cooling needs for the unserved and underserved—be it for thermal comfort or providing safe and valuable food or medicines—has a cost both financially and in terms of the impact on energy consumption. We need to satisfy these peoples' needs in a sustainable, efficient, and affordable way to provide the level of service they need without increasing the burden on global warming.

Two recent international agreements—the Paris Agreement and the Montreal Protocol's Kigali Amendment—have brought attention to the close linkages between cooling, energy demand, and climate change. The Paris Agreement, approved in December 2015, aims to limit the global temperature rise this century below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5°C. The 2016 Kigali Amendment calls for phasing down production and consumption of hydrofluorocarbons (HFCs) with high Global Warming Potential (GWP) by more than 80 percent over the next 30 years. HFCs were introduced as substitutes for ozone-depleting chemicals and are widely used in air conditioners and other cooling appliances. Unfortunately, they are also powerful greenhouse gases that can be thousands of times more potent than carbon dioxide in terms of GWP, so any leakage of these refrigerants contributes significantly to climate change. Changing to lower GWP refrigerants may require manufacturers to redesign cooling products, providing an opportunity to make them more energy efficient, as there is still thermodynamic potential for efficiency improvements. Thus, the phase down of HFCs presents a double opportunity to make a substantial contribution towards the targets of the

THE PEOPLE MOST AT RISK CAN BE BROKEN DOWN INTO FOUR BROAD GROUPS.

THE RURAL POOR

Approximately 470 million people

- Likely to live below the poverty line and lack access to electricity to power fridges and fans
- Subsistence farmers unlikely to have access to intact cold chain, preventing sale of goods for a higher price
- Medical clinics unlikely to have cold storage, putting lives at risk from spoiled vaccines

Potential Solutions

- Off-grid solar home systems to support fans, refrigerators
- Cold storage and pre-cooling for transportation and sale of goods
- Solar refrigeration and "last mile" transport for vaccines
- Public cooling centers and local heat action plans

THE SLUM DWELLER

Approximately 630 million people

- May have access to electricity but housing quality is very poor, income may not be sufficient to purchase or run a fan
- May own or have access to a refrigerator, but intermittent electricity can spoil food and increase risk of food poisoning
- Likely to have access to safe vaccines where health services exist

Potential Solutions

- Passive cooling through design and retrofit
- Cool roofs and walls
- Financing instruments that enable acquisition of energy efficient fans or refrigerators
- Public cooling centers and local heat action plans

THE CARBON CAPTIVE

Approximately 2.3 billion people

- Increasingly affluent lower-middle class on the brink of purchasing the most affordable AC
- Limited purchasing choices favor currently inefficient devices and could cause dramatic increase in energy consumption and GHG emissions
- Likely have access to intact food and vaccine cold chains

Potential Solutions

- Minimum energy performance standards for appliances
- Enforced building codes
- Enhanced use of vegetation and ventilation, including green roofs

THE MIDDLE INCOME

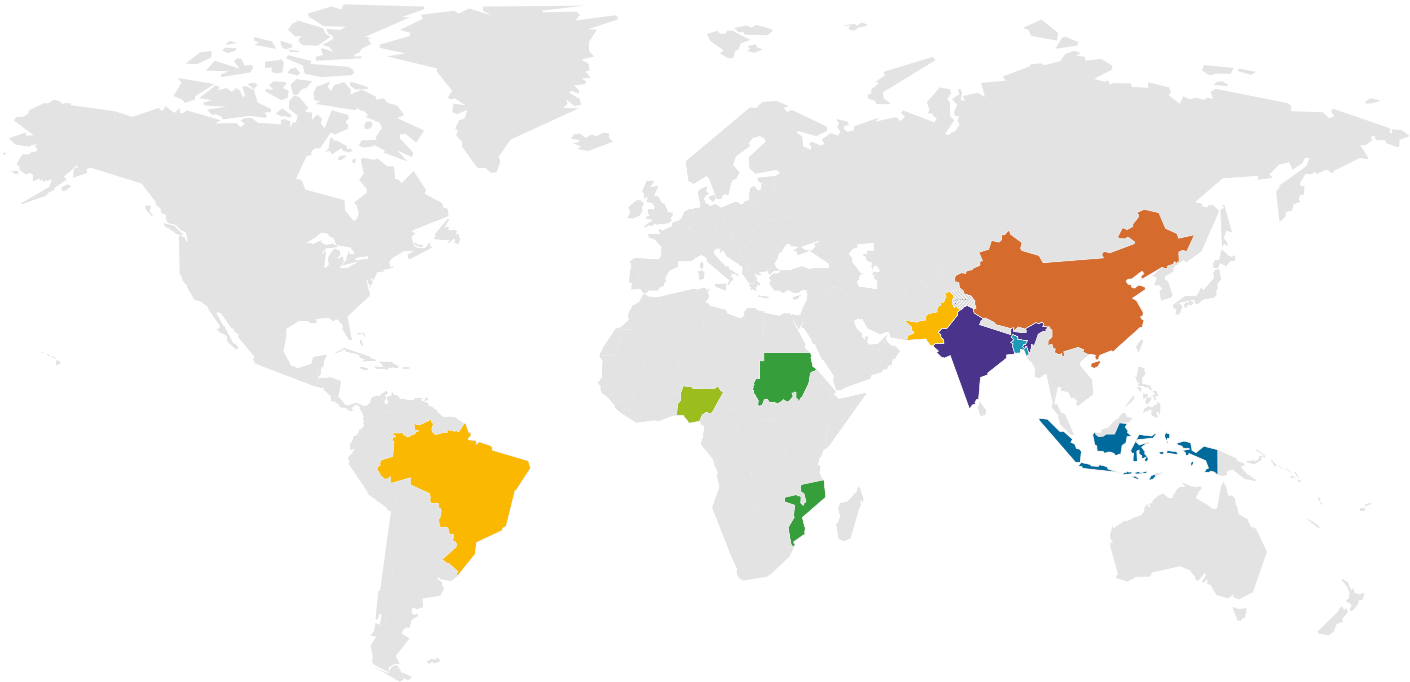
Approximately 1.1 billion people

- People that have owned an air conditioner and may be able to afford a more efficient one
- Represent an established middle class where affordability may also allow them to upgrade their housing to a more sustainable design that incorporates thermal cooling systems

Potential Solutions

- Houses with thermal cooling systems
- District cooling and thermal energy storage
- Hyper-efficient appliances

FIGURE 1: NINE COUNTRIES FACING BIGGEST RISKS



1 RISK CATEGORY

- **Rural Poor** Mozambique, Sudan
- **Slum Dwellers** China
- **Carbon Captives** Indonesia

2 RISK CATEGORIES

- **Rural Poor / Slum Dwellers** Nigeria
- **Slum Dwellers / Carbon Captives** Brazil, Pakistan
- **Carbon Captives / Rural Poor** Bangladesh

3 RISK CATEGORIES

- **Rural Poor / Slum Dwellers / Carbon Captives** India

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, colors, 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.

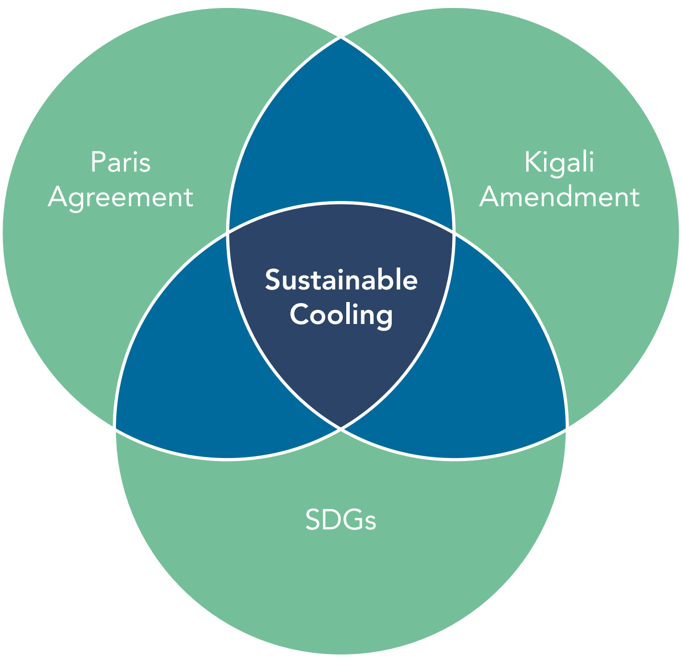
Paris Agreement.[2]

And so, the intersect of the SDGs, the Paris Agreement, and the Kigali Amendment to the Montreal Protocol provides an opportunity, but closing the world's significant cooling access gaps with sustainable, affordable solutions will require bold action and more holistic strategies.

In the hottest urban areas, heat action plans can help avoid increases in mortality, if not short-term losses in productivity. "Cool Roof" programs can reduce the internal temperatures of rooms by 20%. Strategic use of vegetation and tree-shading schemes can provide respite to people who have to move around outdoors.

The sale of small solar power systems is growing rapidly, often in combination with one or more devices such as a low-power fan or refrigerator. Much more financing is needed, however, to support the expansion of these markets and to enable consumer financing. PAYGO systems—which allow consumers to spread out payments and sellers to limit system operation if payments are not made—are one answer, but much greater efforts are required.

FIGURE 2: COOLING AT THE INTERSECT OF THE SDGS, THE PARIS AGREEMENT AND THE KIGALI AMENDMENT



A key feature of cooling technologies is the traditionally long timeframes required to make significant changes; innovations in equipment occur over years and market adoption of new products with higher first costs—even if offset by lower operating costs—can take time, as well. Policies can promote or even mandate the use of more efficient equipment, but they also take time to develop and implement. That said, new urban development does offer opportunities to radically re-think the design of buildings and cities to optimize cooling loads and the technologies that can deal with them. In India, 75% of the buildings required for 2030 have not yet been built, and so there is huge opportunity for designing for passive cooling and laying out new urban developments to use district cooling.

Access to cooling is also essential for broader economic development. Integrated cold supply chains can enable millions of small rural farmers to transport their products to higher value, more distant markets, increasing their income and prospects for economic success. Refrigeration can also substantially reduce food wastage and make a major contribution to ending hunger. Significant potential exists for new approaches to cooling as well as for further improvements in existing technology. In areas with little access to electricity, evaporative coolers are an affordable, low-tech way

[2] Scientists use climate models to estimate the warming expected to result from current trends in human activities including the choice of refrigerants and the fuel mix used to generate electricity. By using scenarios that include lower emissions—lower GWP refrigerants, less use of fossil fuels—they then estimate the potential for avoided warming. One recent example is Y. Xu and V. Ramanathan, 2017 (warming avoided by reducing HFCs and other short-lived climate pollutants is about 0.6°C by 2050 and 1.2°C by 2100). The amount of warming potentially avoided by the Kigali Amendment is the subject of an assessment currently underway under the auspices of United Nations Environment Programme.

of prolonging the shelf life of fruits and vegetables. In Nigeria, for instance, simple evaporative coolers using wet sand between two clay containers, can be constructed for less than $2 and are able to prolong the shelf life from for fruits and vegetables from as little as two days to as much as 20 days.[vi]

Preventing the degradation of vaccines and medicines also requires integrated, innovative, and affordable systems for temperature control in rural areas and sometimes over long distances. The World Health Organization has evaluated and qualified 16 designs for insulated containers with frozen water packs to transport vaccines short distances and 21 cold boxes for longer distances, although it has found that freezing can be a problem.[vii]

RECOMMENDATIONS & NEXT STEPS

The significance, urgency, and complexity of achieving access to cooling is only now becoming understood. This report identifies around 1.1 billion people most at risk from rising heat levels who need access to sustainable solutions, especially to fix or provide intact sustainable cold chains. Another 2.3 billion people need to be influenced to purchase higher rather than lower efficiency devices. All these people need to be provided with solutions they can afford. This report has provided a reference point but urgent, accelerated action is needed to clarify needs, identify priority areas and populations, engage governments and private sector partners, and propose and test solutions including business models.

- **Defining targets for the critical nine**: Our analysis has identified nine priority countries drawn from the rankings of the "rural poor", "the slum dwellers", the "carbon captives" and the "middle class". These countries have been selected to take account of the number of the population at risk (which can be a proxy for potential market size for solutions), and the presence of the country in multiple lists (which can be a proxy for the attention that Government might pay to taking action. Available data in this report provide an initial quantification and baseline but the key next step is for each of these nine countries to set specific goals for reducing these gaps, by sector, specific geographic location and with specific timelines. Countries that are already developing national plans for HFC reductions under the Kigali Amendment may have a head start. Where this is not the case there is a need to source human and financial resources to work with Governments on target setting and planning. Once these nine are complete the next step is to move to the next group of 21 countries and ultimately to complete target setting for the top 52 countries at risk.

- **Cooler cities**: Due to their growing populations and unique "heat island" challenges, cities merit special attention. There is far more that cities can do to reduce extreme heat impacts and there is much that can be learned from cities that are already taking bold innovative steps, including Ahmedabad, India, and many others in the developing world. Preparing for heat extremes has also become a significant issue in developed countries, particularly in locations not accustomed to heat extremes and where poorer residents often lack access to cooling. Cool Roofs are a specific area that has seen some success and there should be a significant scale up and replication of initiatives such as those of the Global Cool Cities Alliance. There is also a critical need to accelerate the development and uptake of Minimum Energy Performance Standards for appliances, as well as the implementation of better building codes to reduce the heat island effect.

- **Cooler Agriculture**: Having an uninterrupted cold chain is vital to reduce food loss and waste. Fresh fish kept at 0°C can be kept for 10 days but only a few hours at 30°C. Mangoes can be stored for 2-3 weeks at 13°C but only 2 days at 43°C. There are a number of emerging technologies and entrepreneurs coming up with innovative solutions but there is also a need for greater commercialization to improve designs, produce at scale and develop business models to make the solutions affordable. Setting up a network of "Business Angels" that can provide expertise and support to entrepreneurs and start-ups could accelerate the development and deployment of these new technologies. Prizes and awards such as Ashden Awards that recognize leaders in sustainable technology can give recognition and broader awareness of achievements in the space.

A thornier problem is transportation. The use of refrigerated trucks to deliver produce between storage facilities or to retail outlets has its issues. In some countries there are simply not enough refrigerated trucks, and if there were enough provided then their emissions would start to grow at significant rates. Further research, such as that being carried out by the National Centre for Cold-chain Development (NCCD) in India, and collaboration between like-mandated institutions and agribusiness and cooling industries could focus on the development of integrated cold chains that are sustainable from farm to fork, that look at the efficiency of the trucks and refrigeration units, as well as looking at alternative cooling technologies.

- **Bring industry and finance to the fore**: Industry cooperation has been a major factor in the success of the Montreal Protocol, supporting development of new technologies and rapid transfer of technologies to developing countries. There are promising cooling technologies suitable for base of the pyramid applications, but much more must be done to engage manufacturers, entrepreneurs, and financiers to identify better ways to provide cooling services to the most vulnerable populations. Stronger participation from the financial community will require new partnerships and business models, particularly to provide small entrepreneurs with growth capital and consumers with the flexible financing they require. The Global Lab for Climate Finance offers a possible model for attracting innovative ideas. **New programs must be co-created with industry and input from the financial community to harness their creativity, stimulate their interest and ensure buy-in from the start**.

- **Support for capacity building and skills development**: Many of the issues and potential solutions for access to cooling will require “out-of-the-box” thinking and new directions. There is also a need to bring policymakers up to date with current thinking and to train people to work in this area. There is therefore a need for training programs and new training materials. **Much of this work can be built into existing initiatives or incorporated into new associated initiatives at the design phase but the people designing these must be aware of the importance of cooling and its links to their programs**. There is also an opportunity, together with the cooling industry, to create dedicated centers for research and development of innovative approaches to cooling.

- **Raising awareness:** There needs to be far greater recognition and focus on the critical role of access to cooling in addressing poverty and achieving the SDGs. While the Kigali Amendment has helped to elevate focus on the linkages between cooling and climate change, the importance and complexity of the cooling access challenge has not received similar attention. There is a specific need to address policymakers across the spectrum of developed and developing economies. For developing economies, the opportunity is to link with ongoing capacity-building initiatives to incorporate thinking on access to cooling into curricula. For developed countries, there is an urgent need to transform the perception of cooling from luxury to human necessity and a development challenge.

  A response to this need is to create a “Secretariat” with a mandate to: promote awareness and provide focused responses to this issue; coordinate the many potential partners among public agencies, businesses, and civil society organizations; work with industry, donors, international organizations to co-design pilot solutions; support technical assistance to governments; and track and report on progress. The Secretariat could also manage the network of Business Angels previously suggested.

This impact shows that cooling is a development issue and we need to raise awareness much more broadly and integrate cooling into the development debate. Awareness raising activities must reach out to the climate adaptation community as well as infrastructure development, hospitals and public health, affordable housing, education departments. The donor and development partner community needs to consider clean and efficient cooling as a part of the design process for new initiatives across the spectrum of their interests

COOLING FOR ALL

Demand for cooling is driven by people. If we are to provide "Cooling for All," we cannot unwittingly deny 3 billion people access to thermal comfort, agricultural cold chains, provision of safe vaccines, and many other services that require cooling to function. There is a huge economic and social impact to be gained by improving access to cooling: reducing the number of lost work hours, improving the productivity of the workforce, avoiding costs of healthcare for people with food poisoning or who are suffering because their vaccines weren't stored properly, increasing the incomes of farmers, and increasing the number of jobs available to service a new cool economy.

The report shows that there is a need to think more holistically. **As a general principle, this calls for cooling and energy demand reduction measures to be applied first, with the remaining cooling needs met through technical solutions that minimize adverse and maximize beneficial environmental and socioeconomic impacts**. This means deploying the most efficient current technology as well as developing new, innovative, efficient solutions for those most in need. This will require new business models, training of a new workforce, and collaboration across government, industry, finance, and civil society.

ABBREVIATIONS

$	United States Dollar
AC	Air Conditioner
AIDS	Acquired Immune Deficiency Syndrome
ASEAN	Association of South East Asian Nations
Bcm	Billion Cubic meter
BMUB	The Federal Ministry of the Environment, Nature Conservation and Nuclear Safety (Germany)
CLASP	Collaborative Labeling and Appliance Standards Program
CO_2	Carbon Dioxide
DFID	Department of International Development (United Kingdom)
EESL	Energy Efficiency Services Limited
GAVI	The Global Alliance on Vaccines and Immunisation
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GW	Gigawatt
GWP	Global Warming Potential
HFCs	Hydrofluorocarbons
ICA	International Copper Association
IEA	International Energy Agency
IFC	International Finance Corporation
K-CEP	Kigali Cooling Efficiency Program
kWh	Kilowatt Hours
LEDs	Light-Emitting Diodes
LEIA	Low-Energy Inclusive Appliances
MT	Metric Ton

MTPA	Metric Tons Per Annum
NDCs	Nationally Determined Contributions
NGO	Non-Governmental Organization
NOx	Nitrogen Oxides
NRDC	Natural Resources Defense Council
OGS	Off-Grid Sector
PATH	Program for Appropriate Technology in Health
PAYGO	Pay As You Go
PM2.5	Particulate Matter with a diameter of less than 2.5 micrometers
PnP SHS	Plug and Pay Solar Home System
PV	Photovoltaic
R&D	Research and Development
SDG	Sustainable Development Goal
SEAD	Super-Efficient Equipment and Appliance Deployment
SEforALL	Sustainable Energy for All
SO_2	Sulphur Dioxide
TEAP	Technology and Economic Assessment Panel
tpd	Tonnes Per Day
TRUs	Transport Refrigeration Units
TWh	Terawatt Hours
UN	United Nations
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
WHO	World Health Organization

GLOSSARY

Base of the Pyramid is a term used to describe the most vulnerable members of the population, who live on less than $2.50 a day.

Chillers are large air conditioning systems that produce chilled water and distribute it throughout a building through pipes to an indoor system that cools the air.

Cold Chain is a temperature-controlled supply chain, consisting of a sequence of refrigerated production, storage, and distribution activities, along with associated equipment and logistics, which maintain a desired low-temperature range. It is used to preserve and to extend and ensure the shelf life of products.

Cooling Access Gap is considered to comprise (1) those who simply do not have appropriate access to cooling now or in the near future and cannot reap the many socioeconomic, health, and environmental benefits of such access, as well as (2) those who are expected to gain access to cooling in the next decade(s), however are unlikely to have access to sustainable, efficient, and affordable cooling solutions under a business-as-usual development path.

Developed Countries have highly developed economies and advanced technological infrastructures, with post-industrial economies.

Developing Countries are considered to have a standard of living or level of industrial production well below that possible with financial or technical aid. They are countries that are not yet highly industrialized.

Food loss, food waste, and food wastage are terms related to the food supply chain. Food loss is the unintended reduction in food available for human consumption, resulting from inefficiencies in supply chains: poor infrastructure and logistics or lack of technology, insufficient skills or poor management capacity. Food waste refers to discarding or alternative (non-food) use of food that is safe and nutritious for human consumption along the entire food supply chain, from primary production to end household consumer level. Food wastage encompasses both food loss and food waste.

Global Warming Potential (GWP) is a measure of the warming impact that a gas has in the atmosphere relative to the impact of CO_2, which has a GWP of 1.

Heat Wave is a period of excessively hot weather, which may be accompanied by high humidity. It is measured relative to the usual weather in the area and relative to normal temperatures for the season.

Hydrofluorocarbons (HFCs) are any of several organic compounds composed of hydrogen, fluorine, and carbon. HFCs are produced synthetically and are used primarily as refrigerants. The Global Warming Potential of HFCs can be between 140 to over 11,000 times that of CO_2.

Kigali Amendment to the Montreal Protocol represents an agreement to phase down global production and consumption of HFCs. The agreement will enter into force in January 2019.

No-to-low Global Warming Potential (GWP) is a criterion attributed to green technology, to refer to its minimal level of contribution to global warming.

Overseas Development Assistance (ODA) represents government financial flows designed to promote the economic development and welfare of developing countries, excluding loans and credits for military purposes. It may be delivered bilaterally and multilaterally.

Sustainable Cooling is providing access to cooling options that are environmentally sustainable, efficient, and affordable, as well as sufficient to meet local demands without encouraging potential over-consumption of cooling.

Sustainable Development Goals (SDGs), introduced in 2015 and officially known as "Transforming our world: the 2030 Agenda for Sustainable Development," is a set of 17 universally agreed "Global Goals," with a combined total of 169 indicators.

The Paris Agreement is a legally binding global climate agreement adopted by 195 countries in December 2015 and entered into force in November 2016. It aims to strengthen the global response to the threat of climate change by keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius.

Thinking Thermally is a holistic approach to energy that encourages a focus on understanding heating or cooling needs and then develops the most efficient way of satisfying those needs. This requires an investigation of heating and cooling sinks and sources, and whether energy can be stored thermally and not just electrically.

Urban Environment is a geographical area with a high population density and heavy infrastructure.

1. INTRODUCTION:
WHY "ACCESS TO COOLING"?

The goal: Making environmentally friendly, energy-efficient cooling accessible to all

Cooling is one of the wonders of the modern age, a central feature of life making possible everything from livable buildings in hot climates to eating fresh green beans from Kenya. However, the challenge is accessing effective vaccines and medicines, reducing food losses, enhancing incomes for subsistence farmers, and survival against more extreme heat for around 3 billion of the world's population with limited access to cooling for life's necessities.

> **Heat waves already kill an estimated 12,000 people annually across the world and the World Health Organization forecasts that, by 2050, deaths from more extreme heat waves could reach 255,000 annually, unless governments (primarily cities) adapt to the threat. (WHO, 2014)**

Cooling has been a focus of civilization for centuries. In second century China, an inventor named Ding Huan crafted a manually powered rotary fan for cooling. In the 1840s, Dr. John Gorrie, a physician, proposed cooling cities with ice to relieve residents of "the evils of high temperatures"—specifically to avoid diseases like malaria and allow patients to be more comfortable.[viii] The first mechanical engineering systems were introduced in the early part of the 20th century but were expensive and impractical for home use until the synthesis of non-flammable refrigerants, chlorofluorocarbons (CFCs) in the 1930s.[ix] However, as the International Energy Agency observes, "the widespread use of air conditioners (ACs) only started to take off in the 1950s, initially in the United States, with improvements in the performance of commercial devices, lower prices, and growing prosperity."[x] In many developed economies, particularly the United States, Australia, and parts of the Middle East, buildings are often over air-conditioned, forcing workers to bring extra layers of clothing on even the hottest days. This is despite evidence that worker productivity and errors increase when the air temperature is below, 23 to 24 degrees Celsius.[xi]

> **Stunningly, 328 million Americans consume approximately the same amount of electricity for air conditioning than total electricity used for everything by 1.1 billion people in Africa. (IEA, 2018)**

Today, cooling solutions are an essential component of everyday life. Yet, hundreds of millions of people lack access to even the most basic cooling solutions. For poor farmers in developing countries, cooling is key to unlocking a better life, through reduced food losses and increased incomes made possible by cold chains that transport crops to higher paying markets. Every year, millions of people die due to the absence of cooling that could help address hunger and malnutrition and preserve the efficacy of vaccines.

> **If the lowest levels of food loss achieved in any region at each stage of the supply chain were replicated worldwide, global food loss could be reduced by 50%, an amount sufficient to feed an additional 1 billion people. (Kummu et al, 2012)**

> **An estimated 1.5 million children under 5 die every year from vaccine-preventable diseases.[xii]**

Rising demand for air conditioning is also closely related to increasing demand for electricity and pollution, including greenhouse gas emissions, a trend driven by growing global populations and rising incomes.[3] In those countries where electricity is generated primarily by coal, such as China and India, the result could be significant increases in carbon emissions that contribute to global warming unless managed with far more efficient cooling technologies and renewable energy. This presents a significant challenge to achieving the goals of the Paris Agreement, as well as the SDGs. As discussed in some detail below, this is a topic of some urgency as decisions made in the near term will have a lasting impact on the magnitude of the problem—buildings designed today will last for decades and cooling equipment for 10 to 20 years. But, there are also opportunities: 75% of the buildings expected to exist in India in 2030 have not been built and could be designed to benefit, for example, from district cooling systems.

As the planet warms, around 30% of the world's population is currently exposed to life-threatening temperatures for at least 20 days a year. Recent research into changing patterns of extreme daily heat and rainfall in global climate projections shows how regional changes in weather extremes will manifest in response to different levels of global warming.[xiii] The result, termed the "equivalent impacts index," highlights again that the poorest will suffer the most. Africa, large parts of India, and most of South America are likely to experience changes clearly attributable to climate change early on, after a 1.5°C increase in global temperatures, whereas mid-latitude countries are not likely to see comparable extremes until the global temperature rise hits 3°C.

[3] *A new IEA report, "The Future of Cooling," projects that by 2050 around two-thirds of the world's households could have an air conditioner. Researchers at Lawrence Berkeley National Laboratory estimate the global stock of room air conditioners will rise by an additional 700 million by 2030 and 1.6 billion by 2059.*

THE KIGALI AMENDMENT TO THE MONTREAL PROTOCOL AND THE KIGALI COOLING EFFICIENCY PROGRAM

The Montreal Protocol, adopted in 1987, is a global agreement to protect the stratospheric ozone layer by phasing out production and consumption of ozone-depleting substances. The Montreal Protocol, the first treaty to achieve universal ratification by all countries in the world, has proven to be innovative and successful. The 2016 Kigali Amendment added an agreement to phase down production and consumption of high-GWP HFCs by more than 80 percent over the next 30 years. HFCs are widely used alternatives to ozone-depleting substances already controlled under the Protocol. HFCs are powerful greenhouse gases (GHGs) that can be thousands of times more potent than carbon dioxide in contributing to climate change. While phasing down HFCs can have a significant impact on global warming by the end of the century, the transition needs to be done in ways that minimize increased demand for fossil fuel-based electricity, an even larger potential source of GHG emissions.

The Kigali Cooling Efficiency Program, or K-CEP, is a philanthropic initiative focused on improving people's lives and realizing the full climate benefits of implementing the Kigali Amendment. It is supported by 18 foundations and individuals who collectively pledged $52 million to support energy efficiency enhancement alongside the Kigali Amendment. K-CEP has four areas of focus: **Strengthening for Efficiency; Policies, Standards, and Programs; Finance; and Access to Cooling**.

Meeting cooling demand with far more efficient solutions creates a direct intersect between three internationally agreed goals for the first time: the Paris Agreement; the Sustainable Development Goals; and the Montreal Protocol's Kigali Amendment, which calls for major reductions in production and use of high-GWP hydrofluorocarbons (HFCs), a potent greenhouse gas used widely in air conditioners and refrigerators.

"Until recently cooling was the Cinderella of the energy debate, but it is a pillar of civilization. Without it, the supply of food, medicine and data would simply break down."

— Professor Toby Peters,
University of Birmingham, UK —

There has been relatively little focus to date on the essential role of cooling services and how access to sustainable cooling supports the achievement of goals related to health, clean energy, ending hunger, and the other Sustainable Development Goals—the focus of the chapter that follows. The chapters thereafter review the best data available to characterize and quantify the access to cooling gap; discuss the challenges associated with providing access to cooling without adding significantly to global warming; highlight some of the many opportunities for both more efficient technologies and meeting cooling demand through more holistic approaches; consider the importance of finance; and, finally, discuss conclusions and recommendations.


PLEASE NOTE

2. COOLING:

OPPORTUNITIES AND RISKS FOR SUSTAINABLE DEVELOPMENT

> **Millions of people die every year from lack of cooling access, whether from food losses, damaged vaccines, or severe heat impact.**

As codified by the UN Sustainable Development Goals in 2015, the linkages between health, clean energy and water, education, sustainable cities, and other requirements for human well-being were recognized and quantified as key SDG targets for 2030. The Kigali Amendment to the Montreal Protocol, adopted the following year, singularly focuses on reducing use, and as a result emissions, of high-GWP HFCs that contribute to global warming. An appreciation of the links between these two international agreements is now coming about with a growing awareness of the diverse ways that cooling has become essential for social and economic development. Cooling impacts all of these SDG goals.

FIGURE 3: COOLING AND THE SDGS

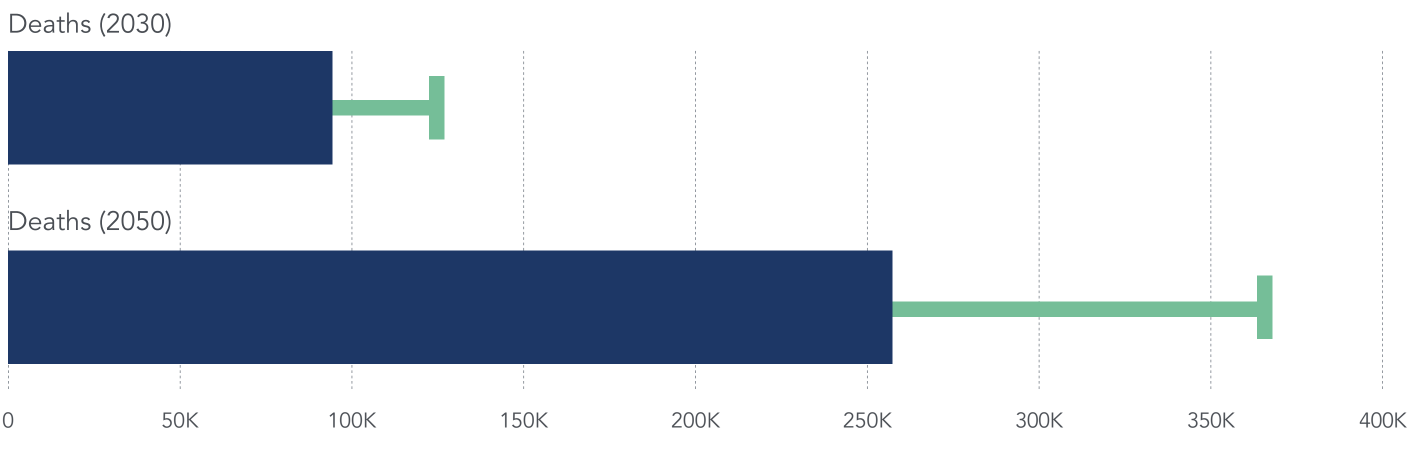
ENSURE HEALTHY LIVES AND PROMOTE WELL-BEING FOR ALL AT ALL AGES (SDG 3)

Access to cooling relates to health goals in several ways.

HEAT EXTREMES

Human-caused climate change is increasing global mean temperatures and temperature variability, which in turn is increasing the frequency and intensity of extreme heat waves, leading to higher death tolls in developed and developing countries alike.[4] In 2015, India and Pakistan suffered record-breaking heat waves over several weeks, resulting in more than 4,500 deaths; temperatures reached a staggering 49°C.[xiv] Heat wave impacts are most severe for the elderly, the young, and those who work outside—already, society's most vulnerable groups. Even though mortality from heat is highly episodic, heat waves already kill an estimated 12,000 people annually across the world. The World Health Organization forecasts that by 2030 there will be almost 92,000 deaths per year from heat waves, with that figure expected to rise in 2050 to 255,000 deaths annually unless governments (primarily cities) adapt to the threat.[xv] (See Figure 4)

FIGURE 4: CLIMATE CHANGE-ATTRIBUTABLE, HEAT-RELATED DEATHS ANNUALLY, WITHOUT ADAPTATION



Source: WHO, 2014

[4] *In developed countries, deaths from extreme heat most frequently occur in locations where such events are rare and thus the population is ill-prepared and the government has not adopted response measures. An example is the estimated 15,000 deaths in France, many isolated elderly.*
Svoboda, M. (2015). New Analysis of '03 Paris Heat Wave. Available at https://www.yaleclimateconnections.org/2015/08/new-analysis-of-2003-fatal-paris-heat-wave/

A 2015 study predicts that urban India will see at least a doubling of heat-related deaths before the end of the century, based on summer temperature increases of up to 3°C.[5] In fact, in the past 50 years, heat waves killing more than 100 people have become twice as likely to occur during India's hot summers. A recent study predicts that, based on current trends in carbon emissions, by the end of this century three-quarters of humanity will face deadly heat with significant losses in economic productivity.[xvi] Densely populated regions in the Persian Gulf, Bangladesh, and northeast India may become so hot and humid that they surpass limits on human survivability.

The availability of air conditioning has dramatically reduced mortality in countries where ACs are widely available. During the 20th century, the mortality impact of days with a mean temperature exceeding 27°C declined by 75% in the United States, almost entirely after 1960 due to widespread access to air conditioning. Unfortunately, as discussed below, costs and power requirements for household AC systems are such that this solution will not be availble to many people for decades to come. And those who are able to buy ACs could contribute significant amounts of greenhouse gases if the equipment they buy is inefficient and powered by fossil fuels, ironically accelerating the trend toward extreme temperatures. Conversely, designing buildings to minimize cooling loads, developing city-level heat action plans, using new and more efficient cooling technology, and then powering this through renewable energy can reduce these risks.

VACCINE LOSSES

Many vaccines need to be kept in carefully controlled temperatures until use, but 25% of all vaccines arrive damaged or degraded. An estimated 1.5 million people die each year from vaccine-preventable diseases. The World Health Organization (WHO) estimates that nearly 50% of freeze-dried and 25% of liquid vaccines are wasted each year, with cold chain disruptions being one of the biggest reasons why. The challenge is complicated by the need for careful management in transport—for example, availability of refrigeration does not guarantee effective transport. Many vaccines can be damaged by freezing, as often happens if cooling is done with ice packs. India, the world's third-largest pharmaceutical producer, is plagued by inadequate cold chain logistics. Nearly 20% of temperature-sensitive healthcare products in India arrive damaged or degraded because of broken or insufficient cold chains, including a quarter of vaccines. The issue has become a significant focus for the WHO, which has a program to evaluate new technologies for more effective cold boxes and vaccine carriers.[xvii]

FOOD POISONING

A 2015 WHO report, Estimates of the Global Burden of Foodborne Diseases, concluded that 600 million people—almost 1 in 10 worldwide—fall ill after eating contaminated food and 420,000 die every year, resulting in the loss of 33 million healthy life years. Children under 5 years of age carry 40% of the foodborne disease burden, with about 125,000 deaths every year. Children who survive may also suffer lasting damage, including delayed physical and mental development, impacting their quality of life permanently.[xviii] Although difficult to quantify, the absence of refrigeration is a significant contributing factor, in addition to unsafe water, poor hygiene, and inadequate conditions in food production and storage.

---

[5] *Temperature increases in many locations may significantly exceed global average warming, including in many developing countries. Harrington, L. and Friederike. O. (2018). Changing population dynamics and uneven temperature emergence combine to exacerbate regional exposure to heat extremes under 1.5°C and 2°C of warming, Environmental Research Letter 13 034011. Available at http://iopscience.iop.org/article/10.1088/1748-9326/aaaa99/pdf*

COOLING AND FISHERIES

An effective cold chain can also significantly enhance the economic productivity of small scale fisheries, a significant employer and source of nutrition in many coastal developing countries.[xix] Fishermen in poor developing countries often lose much of the economic value of their catch due to spoilage resulting from the lack of cold storage.[xx] Accordingly, for example, investment in infrastructure and storage for the fishing industry are key elements in the development plan of the Government of Senegal.[xxi] Providing cooling technology appropriate to small rural coastal communities is a challenge addressed in a GCF concept submitted by the FAO for The Gambia. If approved, the project will support solar powered cold storage to replace existing equipment with limited capacity and high fuel costs and retain the savings achieved in a community fund.[xxii]

END HUNGER, ACHIEVE FOOD SECURITY AND IMPROVED NUTRITION AND PROMOTE SUSTAINABLE AGRICULTURE (SDG 2)

Globally, it is estimated that 1.3 billion tonnes of food, representing a third of the total food produced for human consumption, is lost or wasted every year.[xxiii] This food wastage is a major reason why more than 800 million people globally are malnourished. The land area associated with this amount of lost food production is nearly twice the size of Australia. Two-thirds of global food wastage occurs in Africa and Asia, the equivalent of 400 to nearly 600 calories per person per day.[6] [xxiv] Almost half of all the fruit and vegetables produced lost due to food wastage.[xxv] In developing countries, fruit and vegetable wastage occurs overwhelmingly in the supply chain—rather than through consumer discards—and these are the countries where cold chain infrastructure is currently scant to non-existent. If the lowest levels of loss achieved in any region at each stage of the supply chain were replicated worldwide, global food loss could be reduced by 50%, an amount sufficient to feed an additional 1 billion people.[xxvi] Refrigerated storage and transport could be key measures in achieving this goal.[xxvii]

> **Halving food loss by providing refrigeration and other food-related cold chains would feed the 1 billion chronically undernourished people in the world.**

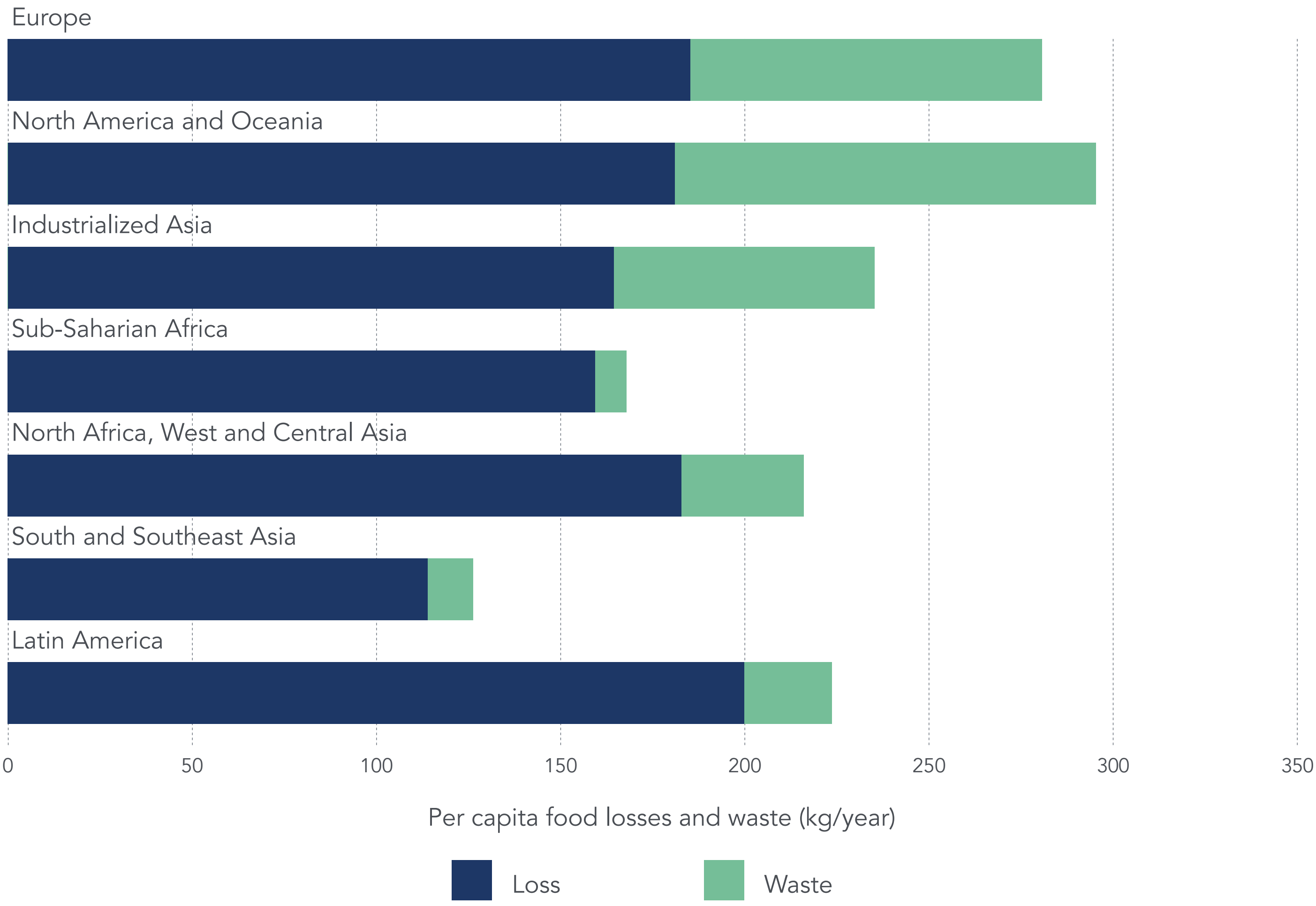
The additional availability of fresh fruits and vegetables could also help improve nutrition by decreasing nutritional deficiencies, which affect 180 million children worldwide and can lower lifetime earnings by up to 22%. Malnutrition is the largest single contributor to disease in the world, according to the UN's Standing Committee on Nutrition. More children die each year from malnutrition than from AIDS, malaria, and tuberculosis combined.[xxviii]

Food loss and waste is about one-third of all the food produced for human consumption and much greater among smallholder farmers, equating to $750 billion a year.[xxix] This depresses farmers' incomes and raises food prices, resulting in an average 15% lower income for 470 million smallholder farmers, many of whom are counted as being food insecure. In India, where a lack of refrigerated transport means just 4% of fresh produce is transported in refrigerated vehicles, economic losses alone are $4.5 billion annually. Compare that to the UK, where 90% of fresh produce is transported with refrigeration.[xxx] Meanwhile, India's demand for food is expected to grow by 40% by 2030, with the country projected to meet only 59% of this demand through domestic production.[xxxi]

---

[6] According to the same source, Asia is the continent with the highest number of hungry people—two-thirds of the global total. Sub-Saharan Africa is the region with the highest prevalence (percentage of population) of hunger. One person in four there is undernourished. The annual social and economic cost of malnutrition amounts to $3.5 trillion or $500 per person globally.

FIGURE 5: 90% OF FOOD WASTAGE IN DEVELOPING COUNTRIES OCCURS IN THE SUPPLY CHAIN

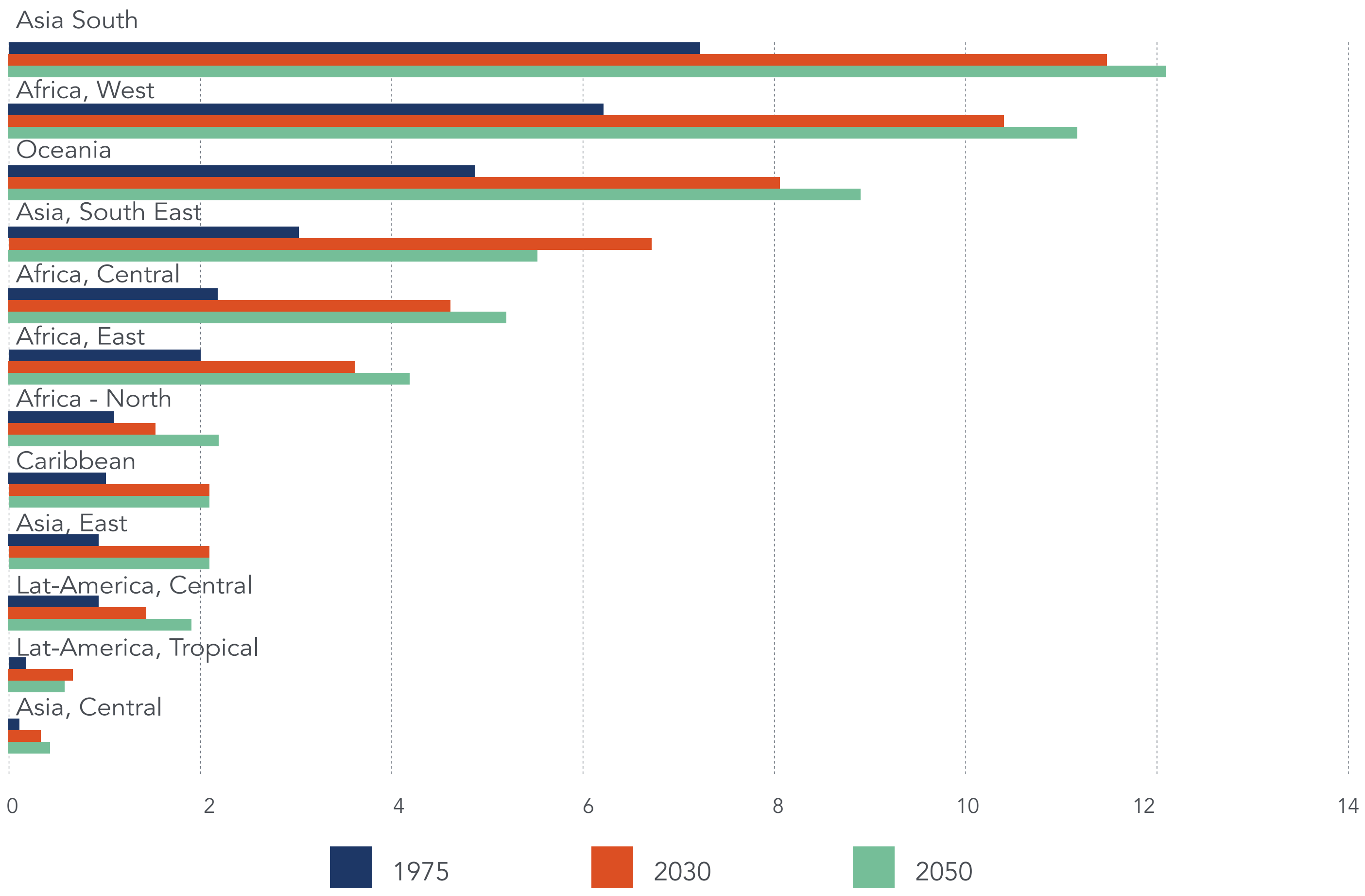


Source: FAO, 2011

DECENT WORK AND ECONOMIC GROWTH (SDG 8)

The creation of reliable, sustainable cold chains—dependable, efficient, temperature-controlled supply chains—is fundamental to improving farm income, especially for the many millions of smallholder farmers in rural areas of developing countries. Local access to cooling would allow smallholder farmers to produce higher-value processed products. Fruit and vegetable farmers, processors, and distributors, for example, could produce value-added frozen or chilled products with the potential to support many new businesses: dairy farmers could become yogurt or cheese makers, fruit growers processed fruit producers.[xxxii] Sustainable cold chains would also allow smallholder farmers to access higher-value markets, increasing their incentives to boost productivity and output. According to India's National Centre for Cold-Chain Development, sustainable cold chains are vital to achieve the government's target of doubling farmers' incomes within five years and would have a "transformative" effect.[xxxiii] Sustainable cold chains would also create non-farming jobs in transport, manufacturing, and services, raising farming incomes and thereby reducing incentives to migrate to urban slums.[xxxiv] This involves the entire value chain for agricultural products—from transport to processing to imports and exports.

FIGURE 6: ESTIMATES OF DAYLIGHT WORK HOURS LOST DUE TO EXCESSIVE HEAT BY REGION IN 1975, 2030 AND 2050



Source: Kjellstrom and Lemke, 2013

Heat extremes also threaten large economic losses as temperature maximums limit outdoor activity and labor productivity. For outdoor laborers, such as those at construction sites, modeled "work capacity losses" by 2050 for Southeast Asia during hot weather for moderate work in the shade at the height of the day are expected to be as high as 40-50%, increasing to 60-70% in the sun.[xxxv] Although morning and evening hours are somewhat cooler, the daily work capacity for such professions could be substantially reduced due to climate change. (See Figure 6)

Overall by 2050, work-hour losses by country are expected to be more than 2% in 10 world regions and as high as 12%—worth billions of US dollars—in the worst-effected regions of South Asia and West Africa. For severely impacted countries, these losses are equivalent to as much as 6% of their annual GDP/capita. Even a 2% per capita loss per year means that, over 30 years, growth in GDP/capita will be less than half as much as if the excessive heat had not occurred.[xxxvi]

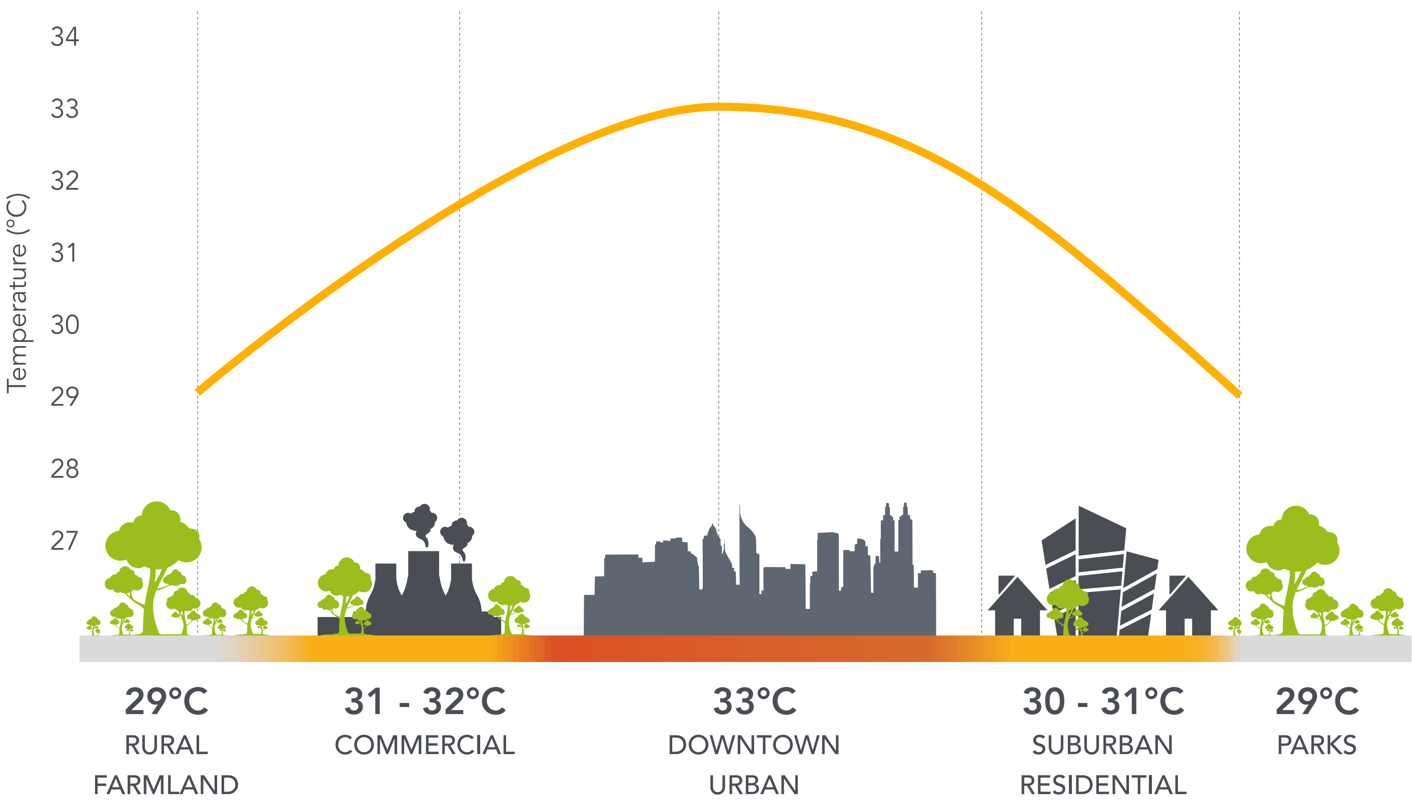
SUSTAINABLE CITIES AND COMMUNITIES (SDG 11)

Urbanization, combined with population growth, is expected to add an estimated 2.5 billion more people to the world's urban populations by 2050, with close to 90% of this increase concentrated in Asia and Africa.[xxxvii] Cities tend to be hotter than rural areas due to a combination of factors, including less vegetative cover, less reflectiveness, and lower evaporation.[xxxviii] This "urban heat island" effect exposes more people to the risks of heat extremes, adding significantly to the demand for air conditioning and creating a need for cities to prepare heat action plans, such as the one implemented in Ahmedabad and many other cities in India, as discussed below. Ironically, the release of hot air to the outside of buildings by air conditioners can raise temperatures by more than 1°C overnight.[xxxix]

> **AC units in Phoenix, USA, heat the night-time air temperature outside by up to 2°C**

Urban heat islands can also contribute to the transmission of certain diseases. In Sao Paulo, Brazil, for example, researchers found that higher surface temperatures, lower humidity, and poor vegetation cover—characteristics of urban heat islands—favored the transmission of mosquito-borne dengue fever. The disease was most common in parts of the city with temperatures over 28°C, in particular in areas with temperatures over 32°C.[xl]

FIGURE 7: THE URBAN HEAT ISLAND EFFECT



3. DEFINING AND QUANTIFYING THE COOLING ACCESS GAP

Defining the cooling access gap is key to building awareness of the magnitude of the challenge and understanding what needs to be done. These challenges will vary by location, sector (buildings/urban environments, medical, agriculture), and the willingness and ability to finance solutions. These challenges are further complicated by the need to consider the sources and availability of cooling, so as not to solve one problem while creating another. In order to be consistent with the SDGs, Paris Agreement, and Kigali Amendment, this implies that cooling be provided in a low Global Warming Potential (GWP), affordable, and energy efficient manner. **As a general principle, this calls for cooling and energy demand reduction measures to be applied first, with the remaining cooling needs met through technical solutions that minimize adverse and maximize beneficial environmental and socioeconomic impacts**.

QUANTIFYING THE ACCESS GAP

Current cooling demand consists of both met and unmet human needs for cooling, with very limited data available to quantify the latter. One challenge is the need to consider at least three distinct needs with only partial overlap in populations: health needs, including both protection from heat extremes and access to vaccines; food safety and security needs due to the absence of cold chains; and productivity needs in terms of ability to work and depressed incomes due to heat. Access to electricity is arguably a reasonable if simplified starting point for quantifying those at risk from extreme heat, particularly for those in urban areas.[7] As a starting point, we know that in 2016 roughly 1 billion people lacked access to electricity. Approximately 80% of them live in 20 countries, predominantly in Asia and Sub-Saharan Africa, and 87% of this group live in rural areas.[xli] About another 1 billion people are estimated to have unreliable access to electricity, typically necessary to run a cooling device, which can result in significant economic losses. In Tanzania, for example, power outages are estimated to cost businesses 15% of their annual sales.[xlii]

A lack of access to cooling creates vulnerability for both urban and rural populations. For example, a rural subsistence farmer in Burkina Faso who lives in extreme poverty and lacks access to electricity will be without a fan during heat waves. They will also lack access to cold chains that would enable them to sell their product further afield at a higher price and also would deliver safe vaccines to the medical clinic available to their family. A low-income urban resident in Bangladesh, by contrast, may have at least some access to electricity, but live in a poorly designed building and urban environment that heats up quickly, while also lacking the purchasing power to buy and power a cooling appliance. An estimated 1 billion urban dwellers worldwide currently live in slums, often haphazardly built and designed, and where many people live at or below the poverty line.[xliii]

Vulnerability to a lack of access to cooling can be thought of in terms of a spectrum of risks that different people face as background for this report, three specific sectors were assessed to determine risk: buildings and urban environments, agricultural cold chains, and vaccine cold chains. Populations and countries at risk

---

[7] As discussed below, urban populations tend to be at greater risk from excessive heat due to the urban heat island effect. There is also evidence that climate change will exacerbate this difference with more warming in urban areas.
Zelenakova, M. (2015). "Climate Change in Urban Versus Rural Areas." Procedia Engineering Volume 119, pp 1171 – 1180. Available at https://doi.org/10.1016/j.proeng.2015.08.968

FIGURE 8: 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

were categorized based on impacts to their health and productivity using temperature, electricity access, vaccination rates, food loss, and income as key indicators for risk. Data limitations on access to cooling prevent a disaggregated assessment of risk based on gender, health, and education level—factors where future data collection and validation are necessary.

For buildings and urban environments, populations were deemed to be at the highest risk when they live in extreme poverty—on less than $1.90 per day—and lack access to electricity and cooling. For vaccine access, rural unvaccinated residents were deemed to be at highest risk due to cold chain breakdowns. With respect to agricultural cold chains, countries that have the highest volumes or percentages of food losses due to cold chain breakdowns were identified as those with the highest risks.[8]

[8] *Primary data sources for this analysis include the World Development Indicators, the World Bank Climate Change Knowledge Portal, Global Tracking Framework (2017), WHO/UNICEF estimates of national immunization coverage (2017), Pew Research Center, a Global Middle Class is More Promise than Reality (2015), FAOSTAT (2013), and the Global Food Cold Chain Council (2015).*

The analysis produced a list of 52 countries that exhibited significant populations at risk or high degrees of cold chain breakdowns, and which are projected to at least partially have a mean monthly temperature above 30°C between the period of 2020-2039. Across those geographies, it also produced an understanding of the different types of populations at risk based on their cooling needs.

The Rural Poor – Approximately **470 million** people.

The rural poor are likely to live in extreme poverty and lack access to electricity. Many of them are likely to engage in subsistence farming and lack access to an intact cold chain enabling them to sell their products further afield at a higher price. Medical cold chains may also not be intact, putting lives at risk from spoiled vaccines.

The Slum Dweller – Approximately **630 million** people.

The slum dweller may have some access to electricity but housing quality is very poor and income may not be sufficient to even 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 food poisoning. However, given their locations within urban centers, they are likely to at least have access to safe vaccines, where health services are available.

The Carbon Captive – Approximately **2.3 billion** people.

The carbon captive represent 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 favor cooling devices that are currently inefficient and could cause dramatic increases in energy consumption and associated GHG emissions.

The Middle Income – Approximately **1.1 billion** people.

The middle income are people who have owned an air conditioner and may be able to afford a more efficient one. They might make conscious choices not to own an AC 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.


khaitan
khaitan

FIGURE 9: POPULATIONS AT RISK

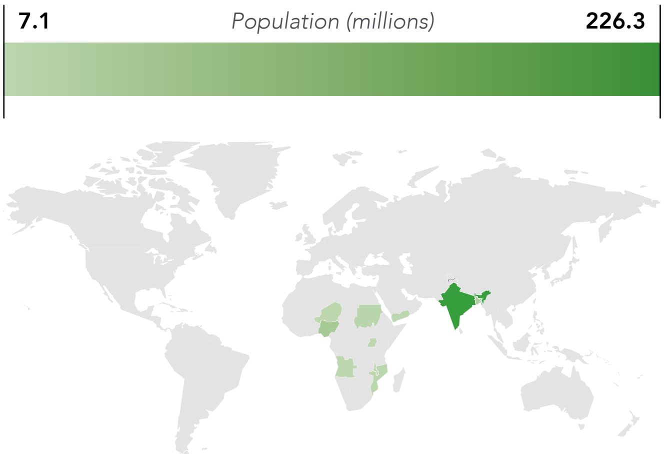
The Rural Poor

Approximately 470 million people

- Likely to live below the poverty line and lack access to electricity to power fridges and fans
- Subsistence farmers unlikely to have access to intact cold chain, preventing sale of goods for a higher price
- Medical clinics unlikely to have cold storage, putting lives at risk from spoiled vaccines

Potential Solutions

- Off-grid solar home systems to support fans, refrigerators
- Cold storage and pre-cooling for transportation and sale of goods
- Solar refrigeration and "last mile" transport for vaccines
- Public cooling centers and local heat action plans



10 countries with the largest Rural Poor populations:

01. India
02. Nigeria
03. Bangladesh
04. Sudan
05. Mozambique
06. Niger
07. Malawi
08. Uganda
09. Angola
10. Yemen

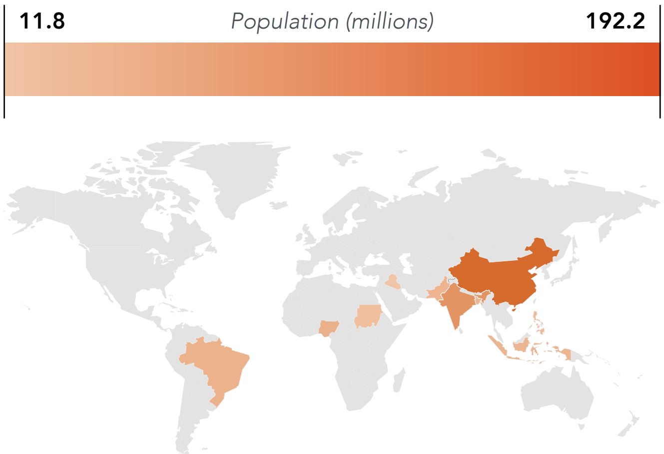
The Slum Dweller

Approximately 630 million people

- May have access to electricity but housing quality is very poor, income may not be sufficient to purchase or run a fan
- May own or have access to a refrigerator, but intermittent electricity can spoil food and increase risk of food poisoning
- Likely to have access to safe vaccines where health services exist

Potential Solutions

- Passive cooling through design and retrofit
- Cool roofs and walls
- Financing instruments that enable acquisition of energy efficient fans or refrigerators
- Public cooling centers and local heat action plans



10 countries with the largest Slum Dweller populations:

01. China
02. India
03. Nigeria
04. Brazil
05. Pakistan
06. Bangladesh
07. Indonesia
08. Philippines
09. Sudan
10. Iraq

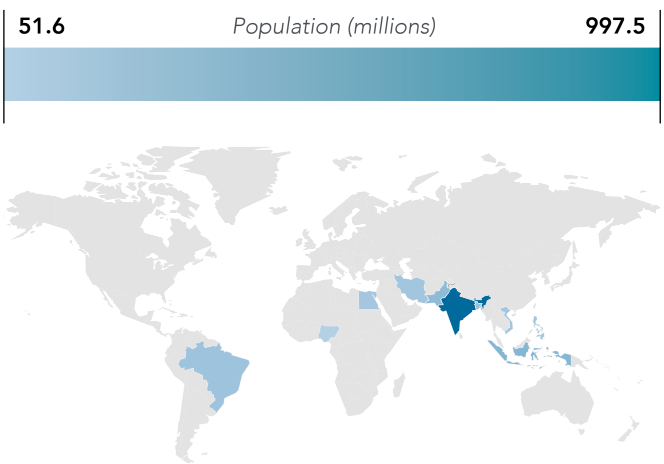
The Carbon Captive

Approximately 2.3 billion people

- Increasingly affluent lower-middle class on the brink of purchasing the most affordable AC
- Limited purchasing choices favor currently inefficient devices and could cause dramatic increase in energy consumption and GHG emissions
- Likely have access to intact food and vaccine cold chains

Potential Solutions

- Minimum energy performance standards for appliances (MEPS)
- Enforced building codes
- Enhanced use of vegetation and ventilation, including green roofs



10 countries with the largest Carbon Captive populations:

01. India
02. Indonesia
03. Pakistan
04. Bangladesh
05. Brazil
06. Vietnam
07. Philippines
08. Iran
09. Egypt
10. Nigeria

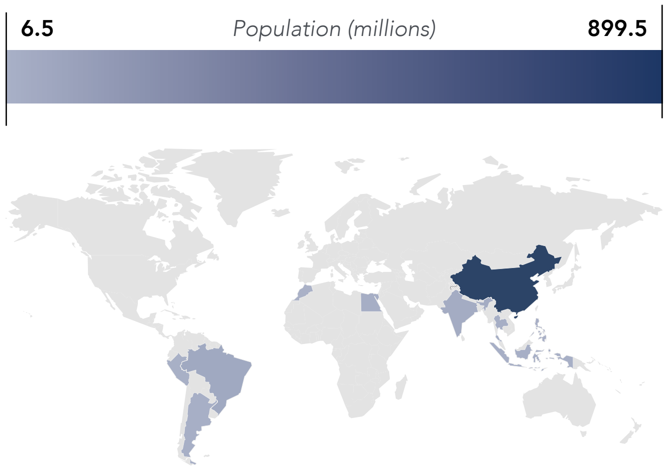
The Middle Income

Approximately 1.1 billion people

- People that have owned an air conditioner and may be able to afford a more efficient one
- Represent an established middle class where affordability may also allow them to upgrade their housing to a more sustainable design that incorporates thermal cooling systems

Potential Solutions

- Residences with thermal cooling systems
- District cooling and thermal energy storage
- Hyper-efficient appliances and MEPS



10 countries with the largest Middle Income populations:

01. China
02. Brazil
03. India
04. Thailand
05. Egypt
06. Argentina
07. Indonesia
08. Philippines
09. Peru
10. Morocco

ILLUSTRATIVE CASE STUDY: COOLING ACCESS GAP IN NIGERIA

To illustrate the access gap, this report uses the example of Nigeria and its demographic makeup to show how a country may measure its cooling access gaps for the unserved and underserved populations. While the model may see some populations overlap to an extent, and would benefit from currently unavailable granular data—including disaggregation based on gender, health, and education—it is provided as an indicative guide to measure the different markets and populations at risk, based on their cooling needs.

Nigeria is first identified as a country that is expected to experience at least partial mean monthly temperatures over 30° C for 2020-2039 under a scenario of mostly unabated global warming.[xliv] Nigeria's population is approximately 183.5 million as of 2015 and, as of 2016, approximately 75 million lacked access to electricity. A further 70%, or 130 million Nigerians, lived below the poverty line in 2013. Based on data available at the global level that allows for the broader assessment, the three groups most vulnerable to lack of access to cooling in Nigeria are derived as follows:

Rural Poor. In 2015, approximately 60% of rural Nigerians, or 58.2 million people, lacked access to electricity, with the number lacking reliable access to electricity likely to be greater still. Based on the most recent (2009) reported rural poverty headcount at the national poverty line, 52.8%, it is likely that at least 50.6 million rural dwellers live in poverty based on the national definition. Since there is a likelihood that some who lack access to electricity are not poor by national standards, and based on the balance of factors and data available, the lesser of the two figures is used to provide an illustrative assessment of rural Nigerians who are likely to live in extreme poverty and lack access to electricity. Therefore, approximately 50.6 million rural Nigerians are deemed to be at risk.

RURAL RISKS IN NIGERIA

An estimated 51.4 million people in rural areas, or 28% of the country's total population, have not been vaccinated against three common diseases.

It is estimated that a further 36.7% of Nigerian agricultural production requiring refrigeration is lost due to inefficient or non-existent cold chains. This points to a significant cold chain gap for pharmaceutical and agricultural products.

Urban slum dwellers. In Nigeria, 75 million people are without access to electricity, of which 16.8 million are estimated to live in urban areas. The urban slum population likely includes these individuals, as well as those who may have access to electricity[9] but lack the financial means to purchase and power a cooling device. Including those with and without access to electricity, Nigeria is home to approximately 44 million urban slum dwellers.

The Carbon Captives. This population group includes those with low incomes and access to reliable electricity, thus enabling them to acquire and maintain a cooling device when needed,

[9] *Yet a further challenge to quantification is to identify the share of the population with an electricity connection but without reliable service and/or the resources to pay for power, much less an air conditioner. For this population, low-power fans may be a critical short-term response.*

or in case of an emergency such as heat waves. By circumstance, they are also likely to be very price sensitive and the limited purchasing options available to them mean they favor cooling devices that are currently inefficient and which could contribute substantively to rising GHG emissions. An estimate for the size of this group is 51.5 million, derived as the population above the poverty line but below middle or higher income levels, a group defined as living on above $10.01 per day and estimated at 3.5 million (1.9% of the population).

The Middle Income. The more affluent segment of the population, most likely to acquire and utilize air conditioning throughout the day.

A RANKING OF COUNTRIES AT GREATEST RISK

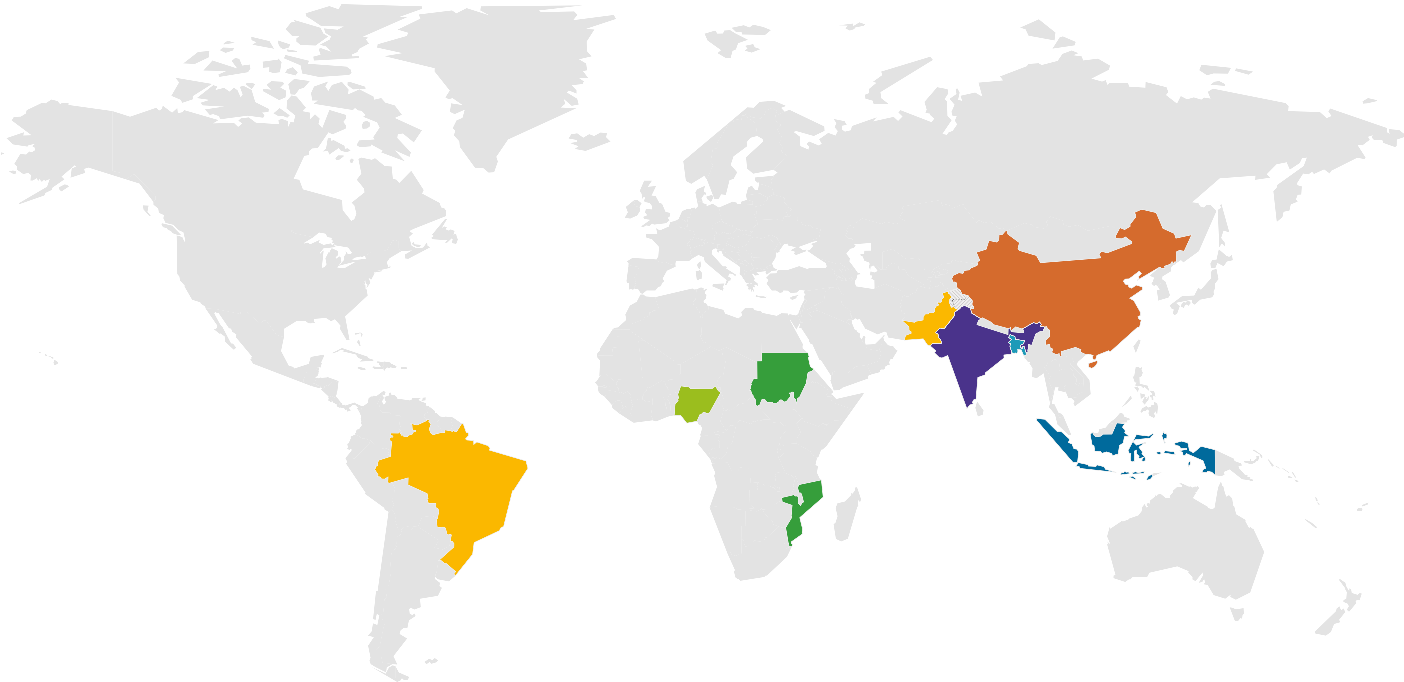
The delineation of impacts from an analysis of a lack of access to cooling also allows for assessment of risks at a country level and thus the opportunity to integrate cooling objectives with those for energy, climate, gender, health, and other linkages. To determine the highest priority countries, a ranking was done based on the volume of each sub-population and the specific risks they face.

A volume-based ranking of the rural poor, slum dwellers, and the carbon captives was derived based on the list of 52 countries that exhibited significant populations at risk or high degrees of cold chain breakdowns, and which are projected to at least partially have a mean monthly temperature above 30°C between the period of 2020-2039.[10] The available data is imperfect and required many assumptions and an acknowledgement that some sub-populations are likely to have overlap to a degree. A shortlist of priority countries, or hot spots, was identified, however, by looking at the incidence of countries that rose to the top five in volume terms for each. These are countries that require more detailed assessment and which would appear to be the most urgent for developing cooling access action plans.

The nine countries at greatest risk from lack of access to cooling are: Bangladesh, Brazil, China, India, Indonesia, Mozambique, Nigeria, Pakistan, and Sudan. India rises to the top five in all categories, followed by Brazil, Bangladesh, Nigeria, and Pakistan that rise to the top five in two categories, displayed in Figure 10.

[10] The middle income population not included due to high levels of access to cooling and correspondingly lower risks to health and productivity. This includes a substantial population in China, where air conditioning market penetration is estimated at 60% of households. IEA, The Future of Cooling (2018).

FIGURE 10: NINE COUNTRIES FACING BIGGEST RISKS



1 RISK CATEGORY

- **Rural Poor** – Mozambique, Sudan
- **Slum Dwellers** – China
- **Carbon Captives** – Indonesia

2 RISK CATEGORIES

- **Rural Poor / Slum Dwellers** – Nigeria
- **Slum Dwellers / Carbon Captives** – Brazil, Pakistan
- **Carbon Captives / Rural Poor** – Bangladesh

3 RISK CATEGORIES

- **Rural Poor / Slum Dwellers / Carbon Captives** – India

4. PROVIDING ACCESS TO COOLING WITHOUT HEATING THE PLANET

> **There is no doubt that global demand for space cooling and the energy needed to provide it will continue to grow for decades to come... Of the 2.8 billion people living in the hottest parts of the world, only 8% currently possess ACs, compared to 90% ownership in the United States and Japan. ....in all major markets today, people are typically buying air conditioners whose average efficiencies are less than half of what is available. (IEA, 2018)**

"Meeting fast-rising cooling demand with today's high global warming potential, energy sapping appliances is creating an environmental disaster—a veritable carbon time bomb"

— Dan Hamza-Goodacre, Executive Director, Kigali Cooling Efficiency Program —

The growing demand for energy—particularly in China and India—is closely related to demands for cooling. Global air conditioning energy demand, driven overwhelmingly by cities in developing countries such as China, India, Indonesia, and Brazil, is forecast to overtake that from heating by 2060 and to rise more than 33-fold by 2100.[xlv] Addressing the growing demand for cooling is closely linked to clean energy goals, as reducing power requirements for cooling—much of it during peak periods when the system is most taxed and operating with the lowest efficiency—will allow more demand to be met from solar, wind, and other clean energy sources.[11]

> **Air conditioning already accounts for about 40% of power use in Mumbai, India. More than half of Saudi Arabia's peak summer power consumption—generated by burning 1 bn barrels of oil a year—also goes on air conditioning. (Henley, 2015)**

The rate of growth in China and India is particularly important and will have significant consequences for energy demand and the environment. Refrigerator ownership in China rose from 7% of urban households in 1995 to 95% in 2007, while[xlvi] room air-conditioner ownership in India rose from 2 million in 2006 to 5 million by 2011 and is forecast to reach 200 million by 2030.[xlvii]

These trends are driven by powerful human needs. For a family living in India on less than $450 a month, the purchase of an air conditioner on credit is an investment in the ability of their children to study for college entrance exams during periods of intense heat. As one mother said, "Now that we are used to air-conditioners, we will never go back."[xlviii] This demand will only grow even more rapidly as incomes rise and urban populations in cities subject to heat extremes continue to increase.

The relationship between cooling and climate change, as already noted, is multi-faceted. The most direct connection is the use of high GWP substances as refrigerants. These chemicals have a global warming impact much greater than that of CO_2 on a molecular basis—from 140 to over 11,000 times greater. However, direct comparisons are complicated as leakage rates are low in well-maintained systems, and their lifetime

[11] The linkage between reducing cooling demand, improving the energy efficiency of air conditioning equipment, and the potential for more electricity demand to be met from non-fossil renewable energy sources with a sizable reduction in greenhouse gas emissions is a key focus of the recent IEA report, ***The Future of Cooling.***

in the atmosphere is much shorter than that of CO_2, depending on the chemical, as short as a few years in comparison with centuries for CO_2.[xlix] The Kigali Amendment to the Montreal Protocol, introduced above, addresses the need to reduce the warming impact of refrigerants and provides for significant reductions over time in the use of HFCs.

PHASING DOWN HFCS UNDER THE KIGALI AMENDMENT

The Kigali Amendment includes specific targets and timetables to replace 18 high-GWP HFCs with more planet-friendly alternatives, provisions to prohibit or restrict countries that have ratified the protocol or its amendments from trading in controlled substances with states that are not parties to it, and an agreement by developed countries to help finance the transition of developing countries to alternative safer products.

The final agreement divided the world into three groups, each with a target phasedown date. The developed countries—including the United States and those in the European Union—will reduce the production and consumption of HFCs from 2019. Much of the rest of the world—including China, Brazil, and all of Africa—will freeze the use of HFCs by 2024. A group of 10 developing countries that include some of the world's hottest countries, primarily in the Middle East, have the most lenient schedule and commit to freeze HFCs use by 2028.

As air conditioning and refrigeration is re-engineered for alternative chemicals, another issue will be to optimize the energy efficiency of cooling equipment to minimize the expected increase in demand for energy. Over the life of the equipment, if electricity is generated from fossil fuels—particularly more carbon-intensive coal—much greater warming will be attributable to the use of power than from the refrigerants. Based on current projections of the energy mix in many developing countries, electricity will be generated to a significant degree from coal and other fossil fuels. Air conditioning demand on the hottest days is responsible for 50 percent or more of peak demand in many hot locations—such as cities in India and the Middle East. This typically necessitates power generation at lower efficiencies and greater transmission losses, and thus produces even greater carbon emissions.[12]

A key feature of cooling technologies is the traditionally long timeframes required to make significant changes: innovations in equipment occur over years and market adoption of new products with higher first costs—even if offset by lower operating costs—can take time, as well. Policies can promote or even mandate use of more efficient equipment, but they also take time to develop and implement. That said, new urban development does offer opportunities to radically re-think the design of buildings and cities to optimize cooling loads and the technologies that can deal with them. In India, 75% of the buildings required for 2030 have not yet been built, and so there is an opportunity to design buildings for passive cooling and to lay out cities to use district cooling. Meanwhile, equipment purchased today may be in use for 20 years or more, and buildings will live much longer depending on location, construction, and usage. There is thus a "lock-in" effect associated with near-term decisions regarding cooling equipment, design of cities and buildings, as well as the many other cooling applications, such as for cars and data centers.

[12] Carbon emissions are usually calculated based on averages and therefore do not reflect the greater emissions associated with uses coincident with peak demand. Hotter temperatures also mean water required for cooling thermal power plants is less efficient, resulting in further reductions in generating efficiency and greater emissions.

Meanwhile, rising greenhouse gas emissions imply that remaining within atmospheric levels consistent with climate goals is becoming increasingly difficult.[13]

Agreement on the need to reduce global greenhouse gas emissions in order to avoid dangerous levels of warming and climate change were the basis for the Paris Agreement, adopted by 195 nations in December 2015 and effective after ratification by the required number of countries as of November 4, 2016.[14] The Paris Agreement aims to address climate change by limiting global warming to well below 2°C and to pursue further efforts to limit warming to 1.5°C relative to pre-industrial temperatures.[15] To achieve these goals, very substantial reductions in emissions of carbon dioxide and other greenhouse gases will be necessary in coming decades. Countries are required to submit Nationally Determined Contributions, or "NDCs," to outline and communicate their post-2020 climate actions.[l] Pledges so far announced by nations are not nearly sufficient and, in 2017, carbon emissions grew by about 1.5%,[li] further emphasizing the importance of more ambitious efforts to control GHG emissions. As cooling is now responsible for about 10% of warming and growing rapidly, future choices about refrigerants, the efficiency of cooling technologies, and how cooling is powered will have a significant impact on achieving the Paris Agreement.

The IEA assessed the climate change implications of the growing demand for air conditioning, current trendsin equipment efficiency, and the resultant potential increase in carbon emissions, depending on the fuel used to generate the required power, in a new report, The Future of Cooling. The report offers some significant insights into the importance of improvements in the energy efficiency of air conditioning equipment as a contribution to meeting the goals of the Paris Agreement, including the dual benefit of efficiency improvements that enable both direct reductions in emissions of refrigerants and the generation of a greater share of electricity from non-fossil renewable energy sources. Notably, the report indicates that for air conditioning alone, emissions could rise from 1,135 Mt in 2016 to 2,070 Mt in 2050, in addition to a 32% increase in energy consumption from 2,021 TWh in 2016 to 6,200 TWh in 2050.

While the IEA assesses emissions from air conditioning, the impact is likely to be further still. Meeting the demand of those at the base of the pyramid, who currently do not have access to cooling for all of life's needs, requires a broad assessment of the full needs of that population, including cold chains, as well as additional technologies that may enhance efficiency gains. The emissions and power generation impact of the mobile AC and refrigeration in transportation and supply-chain logistics could, for example, increase the IEA figure, while efficiencies gained through adaptive technologies, improved building design and construction, improved cold chains, and systems such as district cooling could mitigate the impacts.

A recent study by the International Institute for Applied

---

[13] Due to the long atmospheric lifetime of CO_2 and some refrigerants, the later emission reductions begin, the more rapidly reductions must occur to keep concentrations of the gases within the target levels.
Tollefson, J. (2018). Can the World Kick its Fossil-Fuel Addiction Fast Enough? Nature 556, 442-425. doi: 10.1038/d41586-018-04931-6. Available at Chemnick, J. (2017). The Window is Closing to Avoid Dangerous Global Warming. Available at https://www.scientificamerican.com/article/the-window-is-closing-to-avoid-dangerous-global-warming/

[14] The Paris Agreement entered into force on 4 November 2016, 30 days after the date on which at least 55 Parties to the Convention, accounting in total for at least an estimated 55% of the total global greenhouse gas emissions, have deposited their instruments of ratification, acceptance, approval or accession with the Depositary.

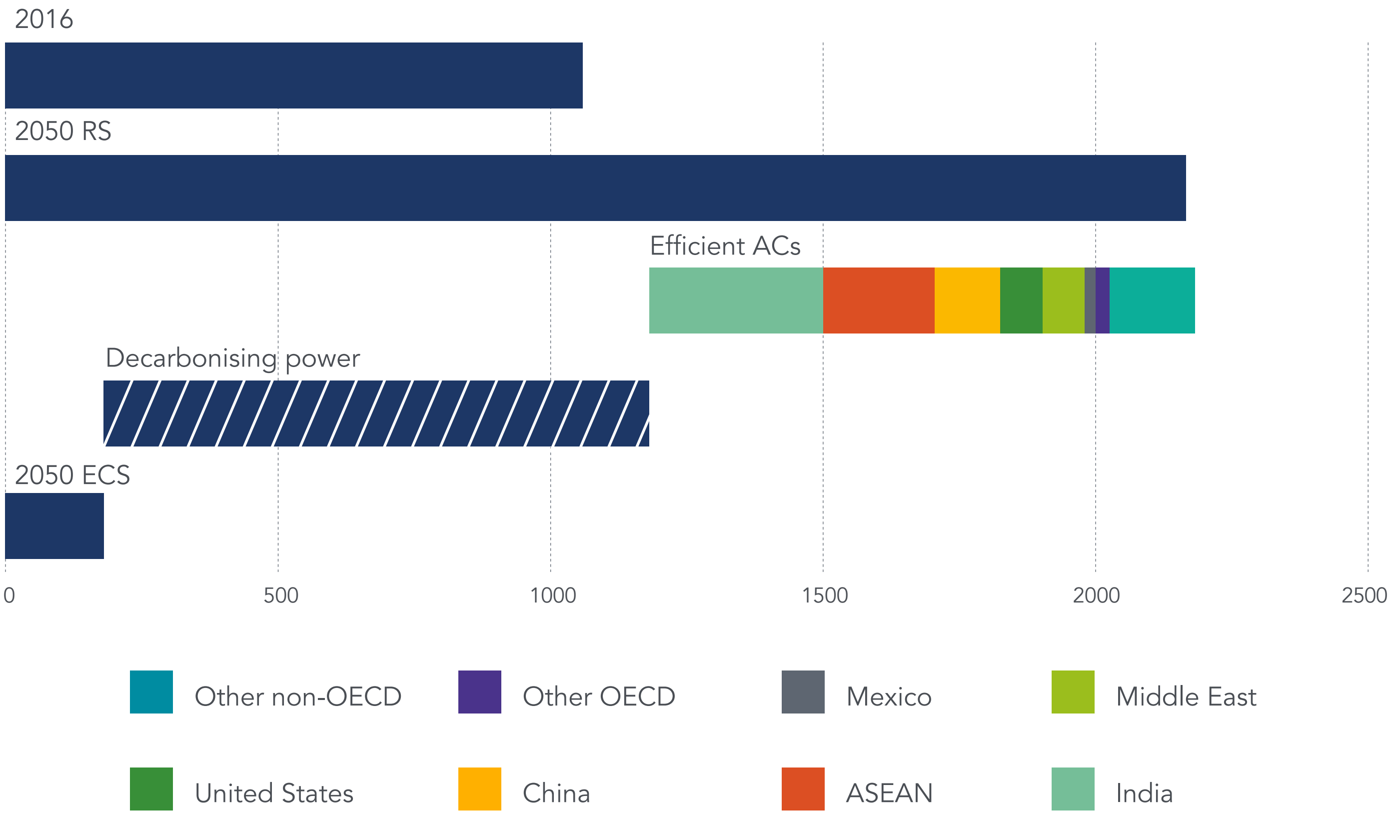
[15] References to "pre-industrial levels" are not defined by UN Agreements or the Intergovernmental Panel on Climate Change but most often refer to 1850-1900, a period when the industrial revolution and burning of fossil fuels took off. However, there is some debate about the most appropriate baseline, which in turn implies some difference in the warming estimated to have already occurred due to human activity.Hawkins, E. (2017). Defining 'Pre-Industrial'. Available at https://www.climate-lab-book.ac.uk/2017/defining-pre-industrial/Hawkins, E. (2017). Defining 'Pre-Industrial'. Available at https://www.climate-lab-book.ac.uk/2017/defining-pre-industrial/

Systems Analysis (IIASA) used an integrated modeling framework and aggressive energy efficiency assumptions to explore how resulting structural changes could reduce global energy demand. While not addressing the many barriers to their scenario, they concluded that it could meet the 1.5°C climate target, as well as many Sustainable Development Goals, without relying on negative emission technologies.[lii]

THE IEA "FUTURE OF COOLING REPORT"

The IEA developed several scenarios to assess the implications of current trends for air conditioning in buildings and the potential benefits of improvements in energy efficiency. In a reference scenario for 2050 based on current policies and market trends, CO_2 emissions almost double from 2016 and the share of air conditioning in total power sector CO_2 emissions worldwide rises from 8% to 15%. Avoiding this troubling outcome is possible if AC and chillers are much more energy efficient and the fuel mix shifts away from fossil fuels. (Figure 11)

FIGURE 11: CONTRIBUTION TO THE GLOBAL REDUCTION IN CO2 EMISSIONS FROM AIR CONDITIONING BY MEASURE IN THE EFFICIENT COOLING SCENARIO RELATIVE TO THE REFERENCE SCENARIO



Source: IEA, 2018

5. THINKING THERMALLY –

THE NEED FOR A HOLISTIC APPROACH TO COOLING

As discussed in the preceding section, as air conditioning systems being currently sold are on average far from the most efficient available, there is an enormous short-term opportunity to reduce the need for power and greenhouse gas emissions, avoid the need for dozens of costly new power plants, and provide consumers substantial cost savings. However, without other measures to provide effective access to cooling, a substantial share of the world's population would remain exposed to life threatening temperatures, levels of food loss would remain high, and medicines and vaccines will continue to spoil in the supply chain.

There is also the reality that experience has shown many proven, cost-effective energy efficiency measures are not adopted without regulation, subsidies, or other forms of government intervention.[liii] This is due to a variety of barriers including lack of financing (discussed specifically below), imperfect information (consumers do not know or are not confident energy savings will occur), and lack of product availability.[liv] Consequently, there is a need to pursue the widest possible approach to meeting access to cooling needs, including strategies for reducing the need for cooling as well as alternatives to the widely used mechanical systems for cooling buildings.[16] Fortunately, there are many opportunities for such alternative technologies, including more climate-friendly refrigerants, with some new solutions being commercially available today.

In the short term, there are many ways of reducing heat buildup through measures such as cool roofs and pavements, the use of materials and choice of coloring to reduce the albedo of buildings and city streets. As roofs and pavements typically cover about 60 percent of city surfaces, the use of reflective materials can substantially reduce urban heat island effects, reducing urban temperatures up to 4°C.[lv] The choice of materials and the optimum use of relevant principles are location and climate dependent. In Delhi, for example, the city designed a pilot program to test the benefits of a variety of materials, coatings, and tiles. !Kheis, a rural community of about 15,000 in South Africa, is another government entity developing a cool-roof approach to provide its residents with relief from extreme heat.

One promising alternative technology is district cooling—which can provide large energy savings in urban areas. The city of Thane, India, is completing a feasibility study for a district cooling system that could yield significant savings (Figure 12). Another technology is Separate Sensible and Latent Cooling (SSLC), which involves dehumidification of hot air by means of a desiccant and cooling by mechanical refrigeration or evaporative cooling; if the latter, no energy is required. Dehumidification improves system efficiency if mechanical refrigeration is required, and regeneration of the desiccant material requires only low-grade heat.[lvi]

In rural areas in developing countries, the liquid air "tank of cold" approach—explored in a recent report from the Institution of Mechanical Engineers[lvii] —could allow off-grid communities to access a wide range of cold and power services power services by storing energy as ice rather than batteries. Much of this can be powered by renewable energy. There is also an opportunity and a need to adapt current cooling technology to be served by renewable energy technologies.

---

[16] These technologies have also been identified by the Montreal Protocol Technology and Economic Assessment Panel (TEAP). The TEAP refers generally to alternatives to vapor compression cycle technology, the basis for the vast majority of building cooling systems, as "Not-In-Kind" technologies.

!KHEIS SOUTH AFRICA COOL COATINGS PROGRAM

!Kheis is a rural community of 15,000 people in one of the hottest parts of South Africa. Many homes in !Kheis are constructed of corrugated metal and were routinely too hot to enter during the day. Families would have to sleep outside. Like many rural communities, !Kheis also lacked job opportunities for many of its residents—especially young adults. Several years ago, a visionary municipal manager named Theresa Scheepers contacted national government agencies to identify opportunities to test sustainable technologies and subsequently connected with a joint initiative run by the U.S. Department of Energy and the South African National Energy Development Institute. The initiative introduced a number of cool coatings manufacturers and launched a series of pilots of highly reflective cool coatings on several homes.

The demonstration found that cool coatings in South Africa had the potential to reduce temperatures by 20% and reduce energy used on cooling by up to 15%. Residents immediately noticed the temperature difference and improvement in comfort, which led to a bigger roll out. About 500 homes have been coated so far.

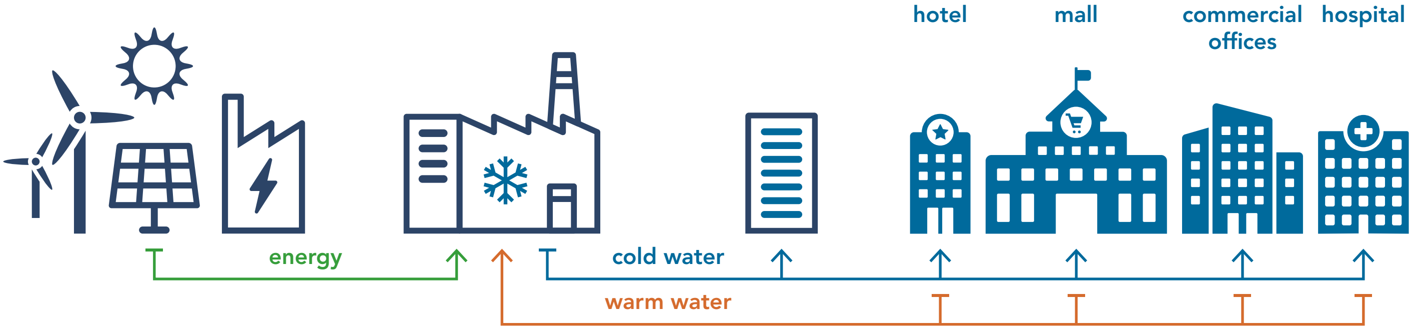
The initiative also focused on using the pilots to create a series of career and business opportunities for local residents. Initiative partners trained local labor and helped build capacity of potential local building owners. The effort created a new supply chain that is cooling down !Kheis, putting people to work, and creating sustainable economic value. Local labor formulates the coatings, mixes them, preps the surfaces, and applies the coatings to the structures. The program that started as a small pilot is now spreading to the bigger cities in South Africa.

Source: Global Cool Cities Alliance.

Ultimately, if cooling is to be sustainable, a system-level approach is needed to mitigate demand and understand the totality of multiple cooling needs; the size, location and time-bound availability of the thermal and electrical resources needs to be understood and available to be optimally integrated with sustainable cooling technologies. In order to achieve this, we need to start by asking ourselves a new question: No longer "How much electricity do I need to generate?" but rather "What is the service we require and how can we provide it in the most efficient and climate-friendly way."

FIGURE 12: DOING COLD SMARTER IN THE DEVELOPING WORLD

DISTRICT COOLING IN THANE: INDIA'S PILOT CITY



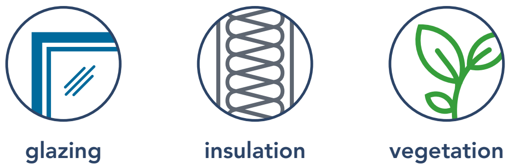
COOLING SOURCES
Renewables provided by the City of Thane, including wind and solar, or waste to energy.

DISTRICT COOLING PLANT
Centralized compression rather than distributed provides significant efficiency gains. Electric chillers used to produce chilled water.

COLD TOWER
Stores cooling to balance peak demand.

DISTRIBUTION NETWORK & DELIVERY
District energy substations deliver the chilled water via underground, insulated pipes to a network of commercial, retail and residential buildings.

District cooling promoted alongside building efficiency measures that reduce overall cooling demand, including glazing, insulation and vegetation.



Cooling demand in Thane, India is rising fast, straining electricity infrastructure as the growing population demands modern energy services. New urban areas and rising living standards, combined with increasing temperatures, necessitate increased cooling availability, presenting a significant opportunity for district cooling.

The city of Thane is testing smart and low-carbon energy solutions that can be scaled-up across the mega-city of Mumbai and ultimately across India. Thane has been selected by the SEforALL District Energy in Cities Initiative as its first pilot city to deliver district cooling in India.

Note: Case study courtesy of UN Environment, Copenhagen Center on Energy Efficiency, ICLEI South Asia Secretariat. This represents one technical option for the system and does not preclude other options under consideration in the ongoing prefeasibility study. The Initiative is working with Thane Municipal Corporation with support from UN Environment, IFC, EESL, ICLEI and Carbon Trust.

THANE AT A GLANCE

Project Location
Viviana Mall and Surrounding Area

Estimated Minimum Savings*
- CO_2 savings: 35%
- Electricity savings: 35%
- Peak power reduction: 35%
- Refrigerant saving: 15%

Economic Benefits
- Savings on building cooling costs
- Estimated ROI: 15%

*If electric chillers are powered by renewables or if waste heat is used, these savings will be much higher.

6. OPPORTUNITIES FOR PROVIDING ACCESS TO COOLING

THROUGH BETTER TECHNOLOGY AND CHANGES IN LIFESTYLE

Two of the critical needs for making cooling efficient and sustainable are improvements in technology and behavioral changes to make efficient use of technology. The two are often closely related.

In areas without access to the electricity grid, the design and marketing of low-power fans and refrigerators is closely associated with the growing market for small solar power systems as consumers seek to gain grid-like, yet affordable and reliable service levels. The latest Off-Grid Solar Market Trends Report published by the Global Off-Grid Lighting Association (GOGLA) documents this. Demand varies by country, with fans particularly popular in hot climates. Sellers of solar panels are responding with integrated packaged systems including more efficient appliances designed for the market.[lviii]

There is increasing interest in promoting a range of products well-suited to off-grid consumers, including those for income-generating activities as well as households. Currently, many of the fans and other products bundled with small off-grid power systems are not the most efficient available, making the products expensive to operate and unaffordable for the poor. This represents an enormous win-win opportunity, a challenge receiving increasing attention as both entrepreneurs and poor households can benefit. For example, with financial support from DFID, a global competition aims at spurring the development of energy-efficient fridges that are affordable and suitable for poor communities in off-grid areas.[lix]

Significant potential exists for new approaches to cooling as well as further improvements in existing technology. In areas with little access to electricity, evaporative coolers are an affordable, low-tech way of prolonging the shelf life of fruits and vegetables. They are constructed by placing a vessel containing the food inside a larger vessel, with water poured into the gap between the vessels, which cools the inner vessel as the water evaporates. In Nigeria, for instance, simple evaporative coolers using wet sand between two clay containers can be constructed for less than $2 and are able to prolong the shelf life for fruits and vegetables from as little as two days to as many as 20 days.[lx]

Considerable knowledge exists regarding the design of buildings to limit heat buildup. Many centuries past, Native Americans in the Southwest of the USA lived in southern-facing cliff villages designed to be cool in the summer and warm in the winter.[lxi] Today, this knowledge is captured in passive design principles—the use of light-colored materials for roofing, reflective window coatings, insulating roofs and walls, strategic landscaping for shading, and low-power fans to aid ventilation.[lxii] The International Finance Corporation (IFC) has developed a software-based, easily accessible tool (EDGE) for incorporating green principles in housing design suitable for use in developing countries, aligning its financial support for affordable housing with the sustainable use of energy and water.[lxiii]

THE INTERNATIONAL FINANCE CORPORATION'S EDGE TOOL[LXIV] PROMOTES THERMAL COMFORT THROUGH GOOD DESIGN

The design of buildings for thermal comfort offers numerous opportunities—as well as challenges—taking into account user behavior. The IFC has found affordable housing designed with the benefit of its EDGE tool can be energy-efficient and cool.

The Waterfall Park project in South Africa focuses on passive cooling design and energy efficiency. It utilizes thermal insulation on the roof, low-E coated glass, natural ventilation, energy-saving lighting for internal and external spaces, lighting controls for common areas and outdoors, solar hot water collectors, and smart meters in each of their 232 EDGE-certified green homes. The homes save 21 percent lower energy compared to the building codes in South Africa that already have energy efficiency requirements.

The Via Verde project in the Philippines has gone a step further by also utilizing solar photovoltaic power and battery storage, with good design, resulting in houses that consume about 40 percent less energy, 25 percent less water, and up to 38 percent less energy in the making of building materials. Residents can power lights, TVs, and fans at the same time—a significant lifestyle benefit—while also receiving significant savings on their utility bills.[lxv]

Innovative technologies are also addressing other types of cooling needs. For example, an innovative solution to the need to transport blood and medicines is **Zipline**,[lxvi] launched in Rwanda in 2016, which operates a drone delivery system to send the urgent blood and medicines to patients, delivering in less than 30 minutes from dedicated distribution centers and negating the need for refrigeration. Medical supplies can be ordered by text message and cost roughly the same as vehicle delivery, except that supplies are delivered in a fraction of the time.

The World Health Organization has evaluated and qualified 16 designs for insulated containers with frozen water packs to transport vaccines short distances and 21 cold boxes for longer distances, but has found freezing can be a problem. Project Optimize was established to demonstrate and evaluate promising new technologies to address the needs more effectively.[lxvii]

Behavior change can be a powerful means of helping to curb energy demand from cooling and responding to climate change. The Ahmedabad Heat Action Plan, discussed below, uses a well-publicized color-coding system to warn citizens at risk of extreme heat to go to emergency cooling centers. The city provides people with heat warnings and information on shelters, but the effectiveness of the program depends on the public response.[17] [lxviii]

In Japan, a national energy-saving campaign by the Ministry of Environment called Cool Biz started in 2005 and runs from May until September or October. A highly visible awareness program with support from the prime minister successfully promoted behavioral changes. Offices and retailers are asked to keep thermostats at 28°C or above and to allow employees to come

---

[17] *Most of the research available on the public response to heat warnings is from developed countries, but the experience appears to be a reflection of issues common to human behavior in response to warnings. See Porter, R. E. (2013). Public Perception and Response to Extreme Heat Events. Available at https://scholarworks.iupui.edu/bitstream/handle/1805/3802/Thesis.pdf;sequence=1*

to work in less formal attire. Government buildings—including schools, community centers, and libraries—are mandated to lead by example. Although initially met with skepticism—and some resistance, including from the necktie business—Cool Biz has become one of Japan's most successful environmental initiatives.[lxix] China has a policy that the settings for air conditioners in summer be no lower than 26°C[lxx] and promotes a high-level of awareness with respect to the potential for reducing energy demand through measures that focus on lifestyle changes.[lxxi]

With India's household air conditioning market growing 10-15% annually, researchers at CEPT University developed the India Model for Adaptive Comfort (IMAC), intended to measure the ability of building occupants to adapt to their environment through means other than air conditioning. Through a survey of 6,330 occupants, the study found that Indians have a higher tolerance of warmer temperatures, with an acceptable range of 20.5-28.5°C in naturally ventilated buildings, depending on seasonal outdoor conditions. For fully air-conditioned buildings, the study also found the acceptable range to be 22-27°C, questioning the predominant trend of operating air-conditioned buildings at 22.5°C +/-1°C all year round in India.[lxxii]

A project undertaken by the Rocky Mountain Institute (RMI) to design and build a zero-energy office building in Colorado, USA, shows that perceptions of comfort must be balanced with design and technology when attempting to minimize energy requirements. Smaller approaches, including fans and temperature-controlled chairs, can allow greater individual satisfaction at lower cost than single temperature controls. While compromises—including back-up systems—were ultimately included to assure occupant comfort, the project was able to demonstrate the potential benefits of moving away from a single temperature-based design criterion. RMI's experience highlights the value of considering the multiple variables that influence perceptions of thermal comfort in buildings. According to RMI "This foundation can then drive a more integrated design that uses targeted systems to enable personal comfort approaches."[lxxiii]

Another behavioral consideration is the need to take into account unmet or "latent demand" for thermal comfort, such that improvements in energy efficiency from better equipment that may result in greater use of air conditioning and consequently less-than-expected reductions in electricity requirements. For example, a program in Mexico between 2009 and 2012 encouraged replacement of inefficient refrigerators and air conditioners more than 10 years old through rebates and consumer financing.[lxxiv] While the program successfully replaced 167,000 ACs, a rebound effect led to increased energy consumption and higher energy bills for people, as the lower hourly operating costs allowed for increased operating hours, reflecting unmet demand for comfort. Unintended consequences of programs like these will need to be anticipated and accurately assessed when considering costs and benefits.

7. THE FINANCING GAP

Financing for access to cooling—both public and private—is a key part of the challenge in developing solutions. Much can be learned from recent efforts to identify financing for energy access, as already noted an objective closely linked to cooling as the absence of reliable electricity is a key barrier. A recent review of financial flows for energy access from all sources undertaken by SEforAll, *Energizing Finance*, undertook a detailed look at 20 high-impact countries where energy access gaps are largest. The report found that:

> **Finance commitments for decentralized energy solutions are miniscule, accounting for roughly $200 million per year, or only one percent of total trackable finance for electricity committed in 2013/14 across the high-impact countries.**

There are many factors responsible for this very low number. One is the very limited support within the budgets of the countries with the greatest needs. Another is the concentration of external flows to a handful of countries, with relatively little going to Sub-Saharan African countries that collectively represent over half the global population living without electricity access. Financing for many disaggregated small purchases—as opposed to the much larger amounts required for power plants and other relatively large energy projects—is also a challenge, insofar as due diligence and collateral are lacking. Financing for very small forms of energy use, such as clean cooking, has therefore been particularly challenging, averaging just $32 million a year in 2013/14. As discussed below, innovative financial solutions and business models are being developed in response to this challenge. Financing therefore encompasses a range of challenges depending on the status of the market, status of the target consumer, and resources available within the distribution chain.

Because of the strong linkage between air conditioning, the rising demand for power, and climate change, it is not surprising that much of the focus of financing for cooling has been on improving the efficiency of room air conditioners and much less on access to cooling. However, there are some successful models of public and private investment in programs for off-grid energy that could provide possible models for access to cooling. The increasing sale of small, off-grid solar systems combined with fans and other productive uses is an outstanding example; beginning with modest donor support, the sale of these devices has achieved rapid market adoption in off-grid areas across Africa and South Asia.

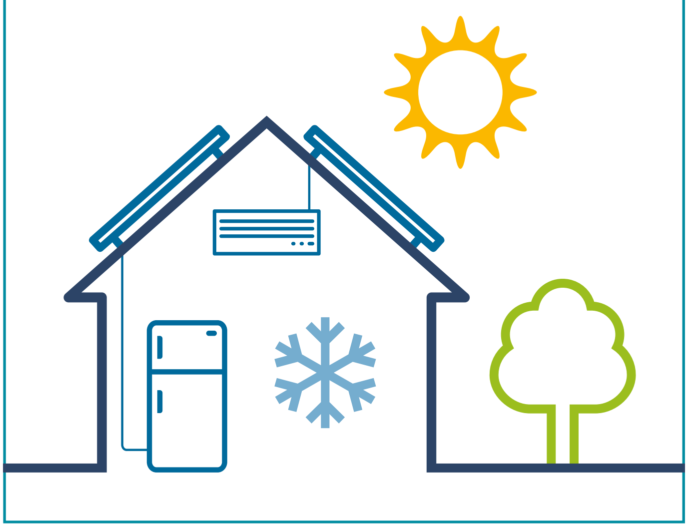
Consumer finance is a critical requirement for selling to the rural poor, even when the purchase saves money relatively quickly, as with solar lanterns replacing kerosene. A major development in the off-grid solar market in recent years has been the rapid growth of sales linked to pay-as-you-go, or PAYGO financing:

> **PAYGO refers to a business model that allows users to pay for their product via embedded consumer financing. A PAYGO company will typically offer a solar product (predominantly solar home systems and multi-light pico devices) for which a customer makes a down payment, followed by regular payments for a term ranging from six months to eight years. Payments are usually made via mobile money, though there are alternative methods that include scratch cards, mobile airtime, and cash.[lxxv] (OGS, p. XVI)**

PAYGO is particularly relevant for purchasers of appliances supported by solar systems, as the higher cost almost always requires some form of financing. Most PAYGO options are priced at levels comparable to or lower than a household's weekly cost for purchasing alternative energy, often kerosene, and can deliver a degree of payment flexibility to consumers that traditional financing options

MARKET UPTAKE OF OFF-GRID SOLAR SYSTEMS

Beginning with a small GEF-supported program supporting the sale of solar lanterns in 2007, Lighting Africa, has become the basis for much more ambitious efforts to support the sale of small solar power systems. As already noted, the programs in this space offer consumers with modest incomes (although not the very poorest) the possibility of acquiring a fan and small refrigerator through equipment designed for direct current, low-power applications and creative financing models, such as PAYGO, discussed below. The program has evolved to include a range of services supporting market development in addition to consumer financing, including quality standards and product testing, national policy development, and market intelligence. An independent evaluation of the project in 2014 concluded that the project had an economic rate of return plausibly as high as 2,000 percent, with a benefit cost ratio of 87:1. An annual trends report is a significant source of information on market trends and challenges, providing information that small entrepreneurs would otherwise not be able to obtain.



don't offer. The PAYGO business model has been a big driver of growth in demand by low-income consumers, a trend expected to continue.[lxxvi] The success of this model has in turn led to increased financing for companies offering this product; in East and West Africa, PAYGO companies raised about $263 million in capital—up 19% from 2016—and served more than 700,000 customers.[lxxvii]

As the Off-Grid Solar Report documents, the adoption of this financing model has been associated with increasing demand for a wider product set.[lxxviii] The specifics of this demand vary by location and market conditions, but fans and refrigerators for access to cooling are among the purchases most frequently linked to solar systems, along with TVs, radios, and mobile phone chargers. Some sellers of small appliances for this market are also designing more efficient equipment to reduce the power demand, and in the process reduce the overall cost to the customer and increase the number of potential buyers able to afford the combined product.

Public Bulk Procurement to Lower Cost and Improve Efficiency: A 2017 program in India administered by EESL, a joint venture company of the Government of India Ministry of Power and Public Service Undertakings (PSUs), used $68 million in public resources for a competitive procurement of 100,000 room air conditioners at efficiencies better than had generally been available in the market.[lxxix] Two companies—one Japanese (Panasonic) and one Indian (Godrej)—were awarded contracts. A similar approach was used previously for street lamp replacement, another application with significant opportunities for replication and scaling across public agencies. In May 2018, EESL was also awarded a loan by the World Bank to scale its business and to expand the product range to include efficient fans.

Enterprise financing: Fundraising in the off-grid sector (OGS) has doubled annually between 2012 and 2016, with annual investments touching $317 million in 2016. However, the sales slowdown in 2016-2017 may have caused some investors to take pause. Cumulatively, $922 million has been raised since 2012. Historical funding patterns have reflected growing enterprise financing needs, as well as increasing investor confidence in the sector. The number of transactions per year increased from 15 to 79 between 2012 and 2016 (a rise of over ~50% year-on-year), demonstrating the growing appetite of the funding market. Average transaction size has also broadly increased, reflecting growing needs as well as investor preferences for larger deal sizes, which reduce transaction costs—such as legal fees and due-diligence costs—on a per-dollar-raised basis.[lxxx]

Financing for mini-grids: Mini-grids that serve communities or villages offer numerous benefits as the basis for off-grid but larger-scale systems that are able to support a wider range of services, ranging from low-power fans and refrigerators to high-demand mobile phone chargers and TVs. Driven in large part by falling solar costs, private mini-grid developers are actively testing a range of business models and achieving greater success. In 2017, over 100 renewable energy-based mini-grid projects were completed in developing countries, primarily in Africa and South Asia.[lxxxi] However, such projects cannot be financed on the basis of short-term consumer loans. Their larger capital costs typically require long-term funding (10–15 years), with a low cost of capital to make economic sense; commercial lenders, though, are typically reluctant or unable to offer loans that meet the need. In the countries of greatest need, interest rates for commercial loans may exceed 15 percent and have high collateral requirements.[lxxxii]

DONOR FUNDING SOURCES FOR CONCESSIONAL FINANCING

The *Energizing Finance* and *Off-Grid Solar Market Trend* reports highlight the diversity and complexity of financing needs related to energy access, raising issues very comparable to those associated with access to cooling. Both reports highlight the importance of financing for locally based, small entrepreneurs highly responsive to market needs and conditions. Debt financing is particularly important and, in the early stage of business development, concessional support from development institutions less risk averse than commercial lenders. The most recent OGS report highlights that with recent market growth, capital flows have increased dramatically—but primarily to a handful of more established companies: "Commercially focused funders and crowdfunding have emerged, while local capital remains limited; social investors may refocus to maximize impact."[lxxxiii] The *Energizing Finance* report highlights the significance of differences in domestic financing. In Bangladesh, domestic finance accounted for 44 percent of total electricity financing, more than twice the percentage in Ethiopia, where China was a dominant funder and provided only 40 percent of its support on concessional terms.[lxxxiv]

A recent review of cooling efficiency financing case studies prepared by the UK Carbon Trust highlights some of the potential innovative financing models that might be used to promote access to cooling solutions.[lxxxv] While these examples are all based on promoting the purchase of air conditioning equipment and are not directly applicable to the challenges of financing access to cooling, they illustrate the potential for creative use of financial instruments to advance environmental objectives. One example is an energy-saving insurance program designed to assure investors of the expected return on investment. Insurance products might also be designed for lenders financing small fans and refrigerators. A World Bank project in Thailand provided banks with low-interest loans to finance consumer purchases of energy efficiency equipment, also potentially the basis for similar terms to promote purchases related to cooling access.

Given that products and markets for access to cooling are still poorly defined, grant and highly concessional financing is particularly important. Such funds are critical for multiple purposes, including technical assistance for country climate programs (NDCs) and enabling policies at the national and local level, e.g., appliance efficiency regulation, building code development, and implementation of cooler cities programs; support for research and development of innovative technologies; capital for small businesses offering cooling services; and financing for low-income consumers. Donor support for such activities is therefore crucial.

Donor funding targeted for climate change exists through multiple sources[18] and has been a source of grant and concessional funding for clean energy measures for more than two decades, beginning with the Global Environment Facility (GEF)[lxxxvi] and more recently the Green Climate Fund.[lxxxvii] However, these programs have provided very little funding for cooling, with the exception of projects promoting efficient appliances. Funding for the replacement of refrigerants to comply with requirements of the Montreal Protocol is available from the Multilateral Fund for the Implementation of the Montreal Protocol, separately from support for energy efficiency improvements.[19] Almost nothing from these funds has been for access to cooling.[lxxxviii] With the ratification of the Kigali Amendment, there are signs that funding for access to cooling may be increasing. For example, the International Climate Initiative, a funding program of the German Environment Ministry, included "climate friendly cooling technology in buildings, logistics, and industrial processes" as one of 10 topics for consideration in its 2018 solicitation.[20]

The Multilateral Fund for the Implementation of the Montreal Protocol provides technical and financial assistance to developing countries to enable their compliance with the control measures of the Montreal Protocol. Such assistance will also include compliance with the Kigali Amendment. In 2017, the Fund was replenished at a total budget of $540 million for the 2018-2020 triennium. The Executive Committee of the Multilateral Fund is in the process of developing the funding guidelines—including those related to energy efficiency—to address the phase-down of HFCs in accordance to the Kigali Amendment.[21] A group of public donors and private foundations is supporting the Efficiency for Access coalition to accelerate energy efficiency in clean energy access efforts, driving markets for super-efficient technologies, supporting innovation, and improving sector coordination. One initiative, the Low-Energy Inclusive Appliances (LEIA) program, funded by UK aid, is a research and innovation program to accelerate the global market for highly energy-efficient appliances needed for clean energy access. Under LEIA, UK aid will provide £18 million over five years to accelerate the availability, affordability, efficiency, and performance of a range of appliances and related technologies suited to developing country contexts.[lxxxix]

The modest level of financing now going to provide access to cooling products and programs is far from commensurate with their social, environmental, and developmental importance. As an initial response, the status of funding and investments in such efforts needs to be more clearly defined, tracked, and reported—a process that has evolved significantly for energy access as a product of SEforALL.

[18] Climate Funds Update (www.climatefundsupdate.org), a website maintained by the Heinrich Boll Stiftung and Overseas Development Institute, provides information on the major multilateral climate funds in operation, the scale of funding pledged and delivered, and the distribution of funds by region and sector/theme.

[19] Information on the Multilateral Fund for the Implementation of the Montreal Protocol is available from the Fund website: http://www.multilateralfund.org/default.aspx. A UNDP GEF climate project for Mauritius shows recognition of the need to coordinate funding from these different sources. See https://www.thegef.org/project/realising-energy-savings-and-climate-benefits-implementing-mandatory-energy-auditing. The project concept was approved but implementation is still to occur.

[20] Funding is intended to go to joint programs addressing national and regional needs, with a volume of 15-20 million euros in a target list of developing countries, and address needs "that have been particularly communicated to BMUB by partner countries."

[21] As background for consideration of this issue, the Montreal Protocol Technology and Economic Assessment Panel produced a report in May 2018, DECISION XXIX/10 TASK FORCE REPORT ON ISSUES RELATED TO ENERGY EFFICIENCY WHILE PHASING DOWN HYDROFLUOROCARBONS, available at http://conf.montreal-protocol.org/meeting/oewg/oewg-40/presession/Background-Documents/TEAP_DecisionXXIX-10_Task_Force_EE_May2018.pdf

8. RECOMMENDATIONS AND NEXT STEPS –

TOWARD NATIONAL ACCESS TO COOLING ACTION PLANS

The significance, urgency, and complexity of achieving access to cooling is only now becoming understood. This report identifies around 1.1 billion people most at risk from rising heat levels who need access to sustainable solutions, especially to fix or provide intact sustainable cold chains. Another 2.3 billion people need to be influenced to purchase higher rather than lower efficiency devices. All these people need to be provided with solutions they can afford. This report has provided a reference point but urgent, accelerated action is needed to clarify needs, identify priority areas and populations, engage governments and private sector partners, and propose and test solutions including business models.

The potential for solutions to the access to cooling gap are as diverse as the problems they need to address. The importance of expanding sources of funding—which includes a wide range of sources active in climate change, health, food security, and energy—has already been discussed. Equipment makers and distributors are another key set of partners although, as noted, products well-suited to the circumstances of lower-income consumers are now coming from smaller entrepreneurs serving this market, as well as from larger companies. While innovative technologies will help, measures with the potential for rapid scale-up are urgently needed today, including adapting today's best available, high efficiency technologies for use with renewable energy supplies. Partnerships will be needed at many levels—with equipment makers, building designers and the construction industry, city leaders, agricultural processors, the pharmaceutical industry and healthcare providers, the financial sector, the public health community, and civil society. Development institutions and energy organizations, including the IEA, are also key actors.

DEFINING TARGETS FOR THE CRITICAL NINE

Our analysis has identified nine priority countries drawn from the rankings of the "rural poor", "the slum dwellers", the "carbon captives" and the "middle class". These countries have been selected to take account of the number of the population at risk (which can be a proxy for potential market size for solutions), and the presence of the country in multiple lists (which can be a proxy for the attention that Government might pay to taking action). Available data in this report provide an initial quantification and baseline but the key next step is for each of these nine countries to set specific goals for reducing these gaps, both by sector, specific geographic location and with specific timelines. Countries that are already developing national plans for HFC reductions under the Kigali Amendment may have a head start. Both the Montreal Protocol and UNFCCC also support the development of national action plans as a focus for addressing their objectives.[22] There is a need to source human and financial resources to work with Governments on target setting and planning. Donor funding is often provided to support the **development of Nationally Determined Contributions and National Adaptation Plans**.[23]

[22] The Paris Agreement requires that each signatory country determine its own program to mitigate global warming and submit its plan, or "Nationally Determined Contribution." The UNFCCC maintains a registry of NDC submissions available online at https://unfccc.int/news/ndc-interim-registry

[23] See the website of the multi-donor National Adaptation Global Support Programme for examples of support for adaptation action plans: http://globalsupportprogramme.org/nap-gsp

As discussed in Chapter 3, available data allow for only very rough, initial quantification of the access to cooling gap—a critical baseline requirement for identifying the highest priority countries and populations and a foundation for developing solutions. One challenge is that the analysis had to draw on data from different sources covering different periods and sometimes defining populations differently. A high priority is a focused effort to create a data set specific to the access to cooling gap that will support the creation of cold chains for rural small farmers and vaccines, adoption of heat action plans by large cities in locations with many days above 30°C, development of national cooling plans, and assessment of the potential for district cooling.

Once the critical nine countries have data sets, targets and plans in place they can be used as models to move to the next group of 21 countries and ultimately to complete target setting for the top 52 countries at risk but the development community and industry must step up to get the right data and put it in the hands of those who need it.

COOLER CITIES

Among the potential partners, cities merit special attention. As sources of higher temperatures through the urban heat island effect, the importance of cities as partners in providing access to cooling has been noted. Fortunately, there is much that cities can and are doing to reduce the urban heat island effect and help provide access to cooling. Actions include promoting less reflective building designs and “green” rooftops; promoting tree planting; and using lighter-colored paving materials to reduce the local albedo. Some cities are already actively implementing some of these measures, as discussed below. There is also a critical need to accelerate the development and uptake of Minimum Energy Performance Standards for appliances, as well as the implementation of better building codes to reduce the heat island effect at source.

Heat Action Plans give guidance on what to do to provide short-term access to cooling in the event of an extreme heat wave. Ahmedabad, India, was the first city in South-Asia to formulate a Heat Action Plan after a devastating heat wave hit the city in 2010.[xc] The plan was developed in collaboration with external partners, such as the Natural Resource Defense Council (NRDC) and the Indian Institute of Public Health (IPH), with support from the Climate and Development Knowledge Network. Local authorities mapped areas with populations at high risk of heat stress—including slums—and developed an easy-to-understand, early-warning system, as well as a strategy for mobilizing the city in advance of impending heat waves. This includes color-coded heat warnings announced in the media, phone companies sending out SMS warnings, and social workers going into the slums to hand out rehydration packets and pamphlets on heat safety. The initial investment required was modest, about $60,000. The Ahmedabad program has evolved and expanded over time and is becoming a model for other cities.[xci] Evaluations between 2013 and 2015 offer proof the program is working; heat-related casualties in Ahmedabad were low during a major 2015 heat wave, while thousands died elsewhere across India. As of June 2017, 17 cities and 11 states across India had released or were developing heat action plans.[xcii]

Several cities in the U.S. have also adopted cooling plans in recent years. San Francisco mandates some combination of solar and living roofs on most new construction. New York City announced a $106 million “Cool Neighborhoods” initiative in June 2016 following a heat wave. Much of the funding will go for planting trees in selected neighborhoods and parks. Greenery and white paint will also be used to cool 2.7 million square feet of rooftops. Philadelphia and Denver have cool roof programs, while Seattle requires certain new developments to meet minimum requirements for vegetative cover.[xciii]

France adopted its own version of a heat action plan with strict guidelines, following the deadly heat wave of 2003. It includes requests that businesses reschedule the workday for outdoor labor, schools limit outdoor activities, and local governments check on the status of elderly residents.[xciv] Several international initiatives provide a platform for sharing city experiences, including the Global Cool Cities Alliance, the Rockefeller Foundation's 100 Resilient Cities, the C40 Cities Climate Leadership Group, and the ICLEI Network.

Cool Roofs are a specific area that has seen some success and there should be a significant scale up and replication of initiatives such as those of the Global Cool Cities Alliance. There is also a critical need to accelerate the development and uptake of Minimum Energy Performance Standards for appliances, as well as the implementation of better building codes to reduce the heat island effect.

COOLER AGRICULTURE

Having an uninterrupted cold chain is vital to reduce food loss and waste. Fresh fish kept at 0°C can be kept for 10 days but only a few hours at 30°C. Mangoes can be stored for 2-3 weeks at 13°C but only 2 days at 43°C. Cold chains consist of several components, typically including at least pre-cooling, cold storage, and refrigerated transport. For pre-cooling and cold storage, which we might think of as stationary needs, there are a number of emerging technologies and a growing group of entrepreneurs coming up with innovative solutions. Here, there is a need for greater commercialization of the technologies to improve designs, produce at scale and make the solutions affordable – being able to produce at volume and with a business model that makes technology affordable. Setting up a network of "Business Angels" that can provide expertise and support to entrepreneurs and start-ups could accelerate the development and deployment of these new technologies. Prizes and awards such as Ashden Awards that recognize leaders in sustainable technology can give recognition and broader awareness of achievements in the space.

A thornier problem is transportation. The use of refrigerated trucks to deliver produce between storage facilities or to retail outlets has its issues. In some countries there are simply not enough trucks, and if there were enough provided then the emissions associated with the engine units for the vehicles and the engines to drive the refrigeration would start to grow at rates reminiscent of the growth in air conditioners. Further research, such as that being carried out by the National Centre for Cold-chain Development (NCCD) in India, and collaboration between like-mandated institutions and agribusiness and cooling industries could focus on the development of integrated cold chains that are sustainable from farm to fork, that look at the efficiency of the trucks and refrigeration units, as well as looking at alternative cooling technologies.

> **Focus attention on fixing and de-carbonising agricultural cold chains through increased R&D and prizes for sustainable business solutions.**

BRING INDUSTRY TO THE FORE

It will be essential to partner and collaborate with industry. The Montreal Protocol has been widely acknowledged as perhaps the most successful environmental treaty, with a remarkably high degree of cooperation across developed and developing countries, a high degree of compliance with specific targets and timetables for production and consumption reductions, and donor provision of financial assistance for conversion of factories and equipment in developing countries.[xcv] One of the more notable reasons cited for this success was the early and extensive engagement with the affected industries in the design and implementation of the agreement. The refrigeration and air conditioning industries, along with many others, actively supported the conversion of equipment to new refrigerants, the evaluation of substitutes to limit exceptions for "essential" uses, and the transfer of technology on reasonable terms to developing countries.[xcvi]

In India, the Alliance for an Energy Efficient Economy illustrates the benefits of bringing together a broad coalition of public agencies, civil society organizations (both domestic and international), industry and academia around a shared interest in advocating for energy efficiency. The Alliance recently produced a focused report on cooling issues in India, with a detailed review of options for reducing heat buildup and providing cooling more efficiently, including policies as well as technologies.[xcvii] This history of cooperation provides a foundation for continued collaboration to address access to cooling needs, despite differences in technologies and markets.

And the challenges are considerable. The Off-Grid Solar Market Trends Report 2018 explains the importance of developing products specifically suited to serving low-income, off-grid populations: "It is clear the industry needs to help put money back in the pockets of consumers if it wants to move customers up the energy ladder. Several industry players have noted in interviews that they are likely to increase their R&D budget to develop and pilot productive use solutions such as agricultural implements and refrigerators for cold chain infrastructure. However, currently the collective market remains under-developed, fragmented, and in need of targeted support. An increase in investment levels (especially in research and development) above existing plans could catalyze the integration of productive use appliances. Importantly, significant potential exists for convergence between larger capacity solar players (mini-grids, captive plants) that are already experimenting with productive use applications, and PAYGO OGS players with know-how of product level financing and remote asset management."[xcviii]

The OGS report also emphasized the importance of consumer financing measures, including local debt financing and securitization as critical to enabling growth of the off-grid solar market and the sale of fans and refrigerators—among the products most desired in areas without access to the grid. The PAYGO approach is one promising solution but there is considerable room for further innovation and cooperation with the financial sector.[xcix] There are also some notable dedicated financing programs for promoting more energy efficient appliances, including the Global LEAP + RBF (results-based financing) facility, a partnership of European and U.S. donors.[c] The use of innovation prizes for vaccine storage has already been noted; there are also competitions for innovative ways to provide cold storage for fruits, vegetables, and dairy products.[ci]

One model that could be applied to access to cooling is the Global Lab for Climate Finance.[cii] Lab members include donor agencies, international financial institutions, and commercial banks with a shared interest in promoting sustainable financial solutions that address climate problems. The Lab operates through a competitive solicitation of ideas; the most promising are selected for further development and ultimately endorsement and pilot testing. In March 2018, the Lab announced a significant milestone: The 26 investment vehicles incubated and launched by the Lab have mobilized over $1 billion for action on climate change—including more than $220 million in funding from Lab members.[ciii] To date, the Lab has not funded projects addressing access to cooling, a potential way to engage with a significant cross-section of the financial community.

New programs must be co-created with industry and input from the financial community to stimulate their interest, harness their creativity, use their market presence and ensure buy-in from the start.

CAPACITY BUILDING AND SKILLS DEVELOPMENT

One of the four implementing agencies of the Montreal Protocol is UN Environment's OzonAction. OzonAction produces briefs on technical and policy subjects, organizes workshops on technical subjects at a regional level. In addition, with support from K-CEP, OzonAction and United for Efficiency are implementing a two-year "twinning" project to build the capacity of National Ozone Officers and national energy policymakers for linking energy efficiency with Montreal Protocol objectives in support of the Kigali Amendment.[civ]

Technical cooperation is also highly desirable to address quality assurance issues. The market for solar lamps has had problems due to low-cost, poor-quality products, which can undermine consumer confidence. In response, interested stakeholders created the Lighting Global Quality Assurance program,[cv] a model that could be adapted for small appliances. Similar efforts should be undertaken to support national policy and program development to support access to cooling.

Such efforts will need to be tailored to the vulnerable populations and national and local strategies. Some countries, for example, may want to assess the extent of the access to cooling gap in more detail, while others may be interested in technical training related to cold chains and opportunities for "thinking thermally." In still others, the priority may be assisting cities to develop and implement building codes more sensitive to cooling, as well as heat action plans. Developing countries dependent on imports for cooling equipment may want to train customs officials to ensure equipment is consistent with applicable standards and policies promoting energy-efficient appliances. High tariffs on imported solar equipment can also be a significant barrier, increasing prices by as much as 25 percent.[cvi] Training of service technicians is also a significant issue in the developing world, as some cooling equipment designed to be efficient depends on regular servicing and, if this is not available, leakage as well as reductions in efficiency can result. The main objectives of the NCCD, mentioned earlier, are to recommend standards and protocols for cold-chain infrastructure, suggest guidelines for human resource development, and recommend the appropriate policy framework for development of the cold chain. There are also many university programs and researchers working on cooling solutions in the developing world with the potential to network and share experiences.[cvii]

> **Similar centers for promoting focused work on access to cooling should be established in vulnerable countries, or even at the regional level, where more appropriate. These centers might also include elements of research and development of innovative approaches to cooling. Competitive grants and awards also should be developed, as has been done to promote innovative solutions for health care.[cviii]**

Much of this work on capacity building and skills development can be built into existing initiatives or incorporated into new associated initiatives at the design phase but the people designing these must be aware of the importance of cooling and its links to their programs.

> **With 9.5 billion appliances entering operation, training on installation and maintenance must increase rapidly and ahead of the demand curve if an environmentally friendly industry is to be maintained.[cix]**

RAISING AWARENESS

A final, crosscutting recommendation is that all the actions proposed respond to a larger need to raise awareness of the critical role of access to cooling in addressing poverty and achieving the Sustainable Development Goals. Thanks to the Kigali Amendment, the linkages between cooling and climate change have risen considerably on the international agenda. However, cooling is not an issue just for the cooling industry and climate scientists. We have shown that cooling is a development issue and we need to raise awareness much more broadly and integrate cooling into the development debate. Awareness raising activities must reach out to the climate adaptation community as well as those in infrastructure development, hospitals and public health, affordable housing, education departments. The donor community needs to consider clean and efficient cooling as a part of the design process for new initiatives across the spectrum of their interests.

For developed countries, there is an urgent need to transform the perception of cooling from luxury to human necessity and a development challenge.

A response to this need is to create a "Secretariat" with a mandate to: promote awareness and focused responses to this issue; coordinate the many potential partners among public agencies, businesses, and civil society organizations; work with industry, donors, international organizations to co-design pilot solutions; support technical assistance to governments; and track and report on progress. The Secretariat could also manage the network of Business Angels previously suggested. An urgent first task would be to initiate the further investigation of the "critical nine" to better identify vulnerable populations and to characterize the risks they face. Reporting would be a key function of the Secretariat with the publication of an annual "Outlook" report as well as the organization of an annual conference bringing together all the key stakeholders.

As with other recommendations, implementation details should be the subject of further dialogue among the wide range of international institutions—public-sector, private sector, and civil society organizations—with shared interests.

CONCLUSION

Demand for cooling is driven by people. If we are to provide "Cooling for All," we cannot deny 3 billion people access to thermal comfort, agricultural cold chains, provision of safe vaccines, and many other life-supporting services that require cooling to function.

This report shows that there is a need to think more holistically. We need to consider the simple solutions of whitewashing roofs or using solar power to drive fans to help make people feel more comfortable. We need to scale-up today's most efficient technologies, power them with renewables, and make them affordable for those at the Base of the Pyramid. We need to think of how to keep food safe and preserve its economic and nutritional value along its entire journey from farm to fork in a way that also minimizes energy consumption.

There are huge economic and social impacts to be gained by improving access to cooling: reducing the number of lost work hours, improving the productivity of the workforce, avoiding costs of healthcare for people with food poisoning or who are suffering because their vaccines weren't stored properly, increasing the incomes of farmers, and increasing the number of jobs available to service a new cool economy.

The HVAC and refrigeration industry has already shown its commitment and the ability to innovate in response to the Montreal Protocol and it has been a driving force behind the Protocol's Kigali Amendment. It now needs to stand up and solve the cooling conundrum for those at the base of the pyramid as well as those at the top.

Achieving Cooling for All means deploying the most efficient current technology as well as developing new, innovative, efficient solutions for those most in need. This will require new business models, the training of a new workforce, and collaboration across government, industry, finance, and civil society.

It also requires all of us to act now.

REFERENCES

i Im. E. et al (2017). Deadly heat waves projected in the densely populated agricultural regions of South Asia. Available at http://advances.sciencemag.org/content/3/8/e1603322.full

ii Kjellstrom, T. et al. (2014). Technical report 2014: 2 Threats to occupational health, labor productivity and the economy from increasing heat during climate change: ... an emerging global health risk and a challenge to sustainable development and social equity. Available at http://www.climatechip.org/sites/default/files/publications/Technical%20Report%202_Climate%20change%2C%20Workplace%20Heat%20exposure%2C%20Health%2C%20%20Labor%20Productivity%2C%20and%20the%20Economy.pdf

iii Ahmad, M. (2018). Looking for a Bit of Shade as Intense Heat Wave Hits Karachi. Available: https://www.nytimes.com/2018/05/29/world/asia/karachi-heat-ramadan.html

iv IPCC (2014). Fifth Assessment Report – Working Group II. Available at https://www.ipcc.ch/pdf/assessment-report/ar5/wg2/WGIIAR5-Chap10_FINAL.pdf

v International Energy Agency, (2018). Future of Cooling, Opportunities for Energy-Efficient Air conditioning. Available at http://www.iea.org/publications/freepublications/publication/The_Future_of_Cooling.pdf

vi Practical Action. (2003). Evaporative Cooling. Available at http://www.fao.org/climatechange/17850-0c63507f250b5a65147b7364492c4144d.pdf

vii WHO and PATH (2013). Innovative Passive Cooling Options for Vaccines. Available at http://www.who.int/immunization/programmes_systems/supply_chain/optimize/evidence_brief_passive_cooling.pdf

viii US Department of Energy (2015). History of Air Conditioning. Available at https://www.energy.gov/articles/history-air-conditioning https://www.energy.gov/articles/history-air-conditioning

ix US Department of Energy, History of Air Conditioning (2015), online: https://www.energy.gov/articles/history-air-conditioning https://www.energy.gov/articles/history-air-conditioning

x International Energy Agency, (2018). Future of Cooling, Opportunities for Energy-Efficient Air Conditioning. Available at http://www.iea.org/publications/freepublications/publication/The_Future_of_Cooling.pdf

xi Murphy, K. (2015). Enduring Summer's Deep Freeze. Available at https://www.nytimes.com/2015/07/05/sunday-review/enduring-summers-deep-freeze.html

xii UNICEF (2018). Millions of children are still not reached by potentially lifesaving vaccines. Available at https://data.unicef.org/topic/child-health/immunization/

xiii Schiermeier, Q. (2018). "Clear Signs of Global Warming Will Hit Poorer Countries First." Nature 556, 415-416.doi: 10.1038/d41586-018-04854-2

xiv U.S. National Oceanic and Atmospheric Administration (2015). India Heat Wave Kills Thousands. Available at https://www.climate.gov/news-features/event-tracker/india-heat-wave-kills-thousands

xv World Health Organization (2014). Quantitative Risk Assessment of the Effects of Climate Change on Selected Causes of Death, 2030s and 2050s. Available at http://apps.who.int/iris/bitstream/handle/10665/134014/9789241507691_eng.pdf?sequence=1&isAllowed=y

xvi Moira, C. et al. (2017). "Global Risk of Deadly Heat." Nature Climate Change volume 7, pages 501–506. doi:10.1038/nclimate3322

xvii World Health Organization (2013). Innovative Passive Cooling Options for Vaccines. Available at http://www.who.int/immunization/programmes_systems/supply_chain/optimize/evidence_brief_passive_cooling.pdf

xviii World Health Organization (2017). Food safety. Available at http://www.who.int/mediacentre/factsheets/fs399/en/ http://www.who.int/mediacentre/factsheets/fs399/en/

xix World Bank (2018). Oceans, Fisheries, and Coastal Economies. Available at http://www.worldbank.org/en/topic/environment/brief/oceans

xx Kruijssen, F. (2016). At a loss: The big impact of wasted fish on the poor. Available at: http://blog.worldfishcenter.org/2016/09/at-a-loss-the-big-impact-of-wasted-fish-on-the-poor/;
Kumolu-Johnson, C.A. and Ndimele, P.E. (2011). A Review on Post-Harvest Losses in Artisanal Fisheries of Some African Countries. Journal of Fisheries and Aquatic Science, 6: 365-378. Available at https://scialert.net/fulltextmobile/?doi=jfas.2011.365.378

xxi Klasa, A. (2018). Senegal's fishing small fry take on the sharks Available at https://www.ft.com/content/2406f368-2d3a-11e8-97ec-4bd3494d5f14

xxii Green Climate Fund (2018), Concept Note : Climate Resilient Fishery Initiative for Livelihood Improvement, Available at: https://www.greenclimate.fund/documents/20182/893456/19130_-_Climate_Resilient_Fishery_Initiative_for_Livelihood_Improvement.pdf/269fab05-1eee-5b11-0e3e-11b8594d5c76 FAO. (2018) Food Loss and Food Waste. Available at http://www.fao.org/food-loss-and-food-waste/en/

xxiii FAO. (2018) Food Loss and Food Waste. Available at http://www.fao.org/food-loss-and-food-waste/en/

xxiv World Food Programme (2017). Zero Hunger. Available at http://www1.wfp.org/zero-hunger.

xxv FAO. n.d. SAVEFOOD: Global Initiative on Food Loss and Waste Reduction. Available at http://www.fao.org/save-food/resources/keyfindings/infographics/fruit/en/

xxvi Kummu, et al (2012). Lost Food, Wasted Resources: Global Food Supply Chain Losses and their Impacts on Freshwater, Cropland, and Fertilizer Use, Science of the Total Environment, Volume 438.

xxvii University of Birmingham Energy Institute (2017), Clean Cold and the Global Goals. Available at https://www.birmingham.ac.uk/Documents/college-eps/energy/Publications/Clean-Cold-and-the-Global-Goals.pdf
Intergovernmental Organization for the Development of Refrigeration (2009). The Role of Refrigeration in Worldwide Nutrition, 5th Informatory Note on Refrigeration and Food. Available at http://www.iifiir.org/userfiles/file/publications/notes/NoteFood_05_EN.pdf

xxviii World Food Programme (2017). Zero Hunger. Available at http://www1.wfp.org/zero-hunger

xxix World Economic Forum (2016). Global Risks Report, 11th Edition. Available at https://www.mercer.com/content/dam/mercer/attachments/global/wef-global-risks-report-2016-mercer.pdf

xxx Peters, T. (2015). Lots of hot air about heat, but why is no one talking about sustainable cooling? Available at https://birminghamenergyinstitute.org/2015/03/16/lots-of-hot-air-about-heat-but-why-is-no-one-talking-about- sustainable-cooling/

xxxi Institute of Mechanical Engineers (2014). A tank of cold: Cleantech leapfrog to a more food secure world. Available at http://www.imeche.org/policy-and-press/reports/detail/a-tank-of-cold-cleantech-leapfrog-to-a-more-food-secure-world

xxxii Waisnawa, I.N.G.S. et al. (2018). "Model Development of Cold Chains for Fresh Fruits and Vegetables Distribution: A Case Study in Bali Province." Journal of Physics: Conference Series. Volume 953, Conference 1. doi :10.1088/1742-6596/953/1/012109

xxxiii National Centre for Cold-chain Development. N.d. Available at https://nccd.gov.in/

xxxiv University of Birmingham Energy Institute (2017). Clean Cold and the Global Goals. Available at https://www.birmingham.ac.uk/Documents/college-eps/energy/Publications/Clean-Cold-and-the-Global-Goals.pdf

xxxv Kjellstrom, T., Lemke, B., Otto, M. (2013). Mapping occupational heat exposure and effects in South-East Asia: ongoing time trends 1980-2011 and future estimates to 2050. Industrial Health, 51, 56–67. https://www.jniosh.go.jp/en/indu_hel/doc/IH_51_1_56.pdf

xxxvi Kjellstrom, T. et al. (2014). Technical report 2014: 2 Threats to occupational health, labor productivity and the economy from increasing heat during climate change: ... an emerging global health risk and a challenge to sustainable development and social equity. Available at http://www.climatechip.org/sites/default/files/publications/Technical%20Report%202_Climate%20change%2C%20Workplace%20Heat%20exposure%2C%20Health%2C%20%20Labor%20Productivity%2C%20and%20the%20Economy.pdf

xxxvii UN DESA Population Division, World Urbanization Prospects (2018). Available at https://www.un.org/development/desa/en/news/population/2018-world-urbanization-prospects.html

xxxviii Zielinski, S. (2014). Why the city is (usually) hotter than the countryside. Available at https://www.smithsonianmag.com/science-nature/city-hotter-countryside-urban-heat-island-science-180951985/#PlkJHDkD0EJoxsgO.99

xxxix International Energy Agency (2018). Future of Cooling, Opportunities for Energy-Efficient Air conditioning. Available at http://www.iea.org/publications/freepublications/publication/The_Future_of_Cooling.pdf

xl Araujo et al. (2015). "São Paulo urban heat islands have a higher incidence of dengue than other urban areas." The Brazilian Journal of Infectious Diseases. Volume 19. Issue 2, pp 146 – 155. http://dx.doi.org/10.1016/j.bjid.2014.10.004

xli World Bank Group et al. (2018). Tracking SDG 7: The Energy Progress Report. Available at https://trackingsdg7.esmap.org/data/files/download-documents/tracking_sdg7-the_energy_progress_report_full_report.pdf

xlii McKibben, B. (2017). The Race to Solar-Power Africa. Available at https://www.newyorker.com/magazine/2017/06/26/the-race-to-solar-power-africa

xliii UN Habitat (2016). Slum Almanac 2015-2016: Tracking Improvements in the Lives of Slum Dwellers. Available at https://unhabitat.org/wp-content/uploads/2016/02-old/Slum%20Almanac%202015-2016_EN.pdf

xliv World Bank, Climate Change Knowledge Portal. n.d. Nigeria RCP 8.5 Scenario, CMIP 5 Model. Available at http://sdwebx.worldbank.org/climateportal/index.cfm?page=country_future_climate&ThisRegion=Africa&ThisCcode=NGA

xlv Henley, J. (2015). World Set to Use More Energy for Cooling than Heating. Available at https://www.theguardian.com/environment/2015/oct/26/cold-economy-cop21-global-warming-carbon-emissions

xlvi University of Birmingham Energy Institute (2017). Clean Cold and the Global Goals. Available at https://www.birmingham.ac.uk/Documents/college-eps/energy/Publications/Clean-Cold-and-the-Global-Goals.pdf

xlvii University of Birmingham Energy Institute (2017). Clean Cold and the Global Goals. Available at https://www.birmingham.ac.uk/Documents/college-eps/energy/Publications/Clean-Cold-and-the-Global-Goals.pdf

xlviii Barry, E. and Davenport, C. (2016). Emerging Climate Accord Could Push A/C Out of Sweltering India's Reach. Available at https://www.nytimes.com/2016/10/13/world/asia/india-air-conditioning.html

xlix US Environmental Protection Agency, Understanding Global Warming Potentials, available at https://www.epa.gov/ghgemissions/understanding-global-warming-potentials

l UNFCCC. n.d. Nationally Determined Contributions. Available at https://unfccc.int/process-and-meetings/the-paris-agreement/nationally-determined-contributions-ndcs

li Berwyn, B. (2017). Global CO2 Emissions to Hit Record High in 2017. Available at https://insideclimatenews.org/news/12112017/climate-change-carbon-co2-emissions-record-high-2017-cop23

lii Grubler, A. et al. (2018). "A low energy demand scenario for meeting the 1.5°C target and sustainable development goals without negative emission technologies" Nature Energy, Volume 3, 515–527. Available at https://www.nature.com/articles/s41560-018-0172-6

liii American Council for an Energy Efficiency Economy (2013). Overcoming Market Barriers and Using Market Forces to Advance Energy Efficiency. Available at https://aceee.org/files/pdf/summary/e136-summary.pdf

liv Montreal Protocol (2018). Report Of The Technology And Economic Assessment Panel. Challenges for the uptake of energy efficient technologies. May 2018. Volume 5. Available at http://conf.montreal-protocol.org/meeting/oewg/oewg-40/presession/Background-Documents/TEAP_DecisionXXIX-10_Task_Force_EE_May2018.pdf lv Isaac M. & Van Vuuren D. P. (2009) HYPERLINK http://www.sciencedirect.com/science/article/pii/S0301421508005168" Modeling global residential sector energy demand for heating and air conditioning in the context of climate change, Energy Policy 37:507–521.

lvi Montreal Protocol (2018). Report Of The Technology And Economic Assessment Panel. Challenges for the uptake of energy efficient technologies. May 2018. Volume 5. Available at http://conf.montreal-protocol.org/meeting/oewg/oewg-40/presession/Background-Documents/TEAP_DecisionXXIX-10_Task_Force_EE_May2018.pdf

lvii Institute of Mechanical Engineers (2014). A Tank of Cold: Cleantech Leapfrog to a More Food Secure World. Available at https://www.imeche.org/docs/default-source/reports/a-tank-ofcoldcleantech-leapfrog-to-a-more-food-secure-world.pdf?sfvrsn=0

lviii GOGLA (2018). Off-Grid Solar Market Trends Report. Available at https://www.lightingglobal.org/2018-global-off-grid-solar-markettrends-report/

lix Energy4Impact (2018). Off-Grid Refrigerator Competition – Lessons and Achievements So Far. Available at https://www.energy4impact.org/news/grid-refrigerator-competition-%E2%80%93-lessons-and-achievements-so-far

lx Practical Action (2003). Evaporative Cooling. Available at http://www.fao.org/climatechange/17850-0c63507f250b5a65147b7364492c4144d.pdf

lxi Green Passive Solar Magazine (2010). Mesa Verde Cliff Dwellings. Available at https://greenpassivesolar.com/2010/04/mesa-verde-cliff-dwellings/

lxii National Renewable Energy Laboratory (1994). Cooling Your Home Naturally. Available at https://www.nrel.gov/docs/legosti/old/15771.pdf

lxiii Mahanta, V. and Babar, K. (2018). IFC, PNB Housing plan $800m platform for affordable homes. Available at https://economictimes.indiatimes.com/industry/services/property-/-cstruction/ifc-pnb-housing-plan-800m-platform-for-affordable-homes/articleshow/62953449.cms

lxiv www.edgebuildings.com

lxv International Finance Cooperation (2018). In the Philippines, a Blueprint for Low Income Housing Goes Green. Available at https://www.ifc.org/wps/wcm/connect/news_ext_content/ifc_external_corporate_site/news+and+events/news/impact-stories/philippines-green-buildings.

lxvi Zipline (2018). Available at http://www.flyzipline.com/uploads/Zipline%20Fastest%20Drone%20Press%20Release.pdf

lxvii WHO and PATH (2013). Innovative Passive Cooling Options for Vaccines. Available at http://www.who.int/immunization/programmes_systems/supply_chain/optimize/evidence_brief_passive_cooling.pdf

lxviii Porter, R. E. (2013). Public Perception and Response to Extreme Heat Events. Available at https://scholarworks.iupui.edu/bitstream/handle/1805/3802/Thesis.pdf;sequence=1

lxix Smart, R. (2015). Ditch the tie and reduce the AC—Japan's Cool Biz gets summer hell just about right. Available at https://qz.com/465327/ditch-the-tie-and-reduce-the-ac-japans-cool-biz-gets-summer-hell-just-about-right/;

Takagi, K. (2015). The Japanese Cool Biz Campaign: Increasing Comfort in the Workplace. Available at http://www.eesi.org/articles/view/the-japanese-cool-biz-campaign-increasing-comfort-in-the-workplace

lxx Li, B. et al. (2012). Proceedings of 7th Windsor Conference: The changing context of comfort in an unpredictable world - The Chinese Evaluation Standard for the Indoor Thermal Environment in Free-Running Buildings. Available at https://pdfs.semanticscholar.org/bd39/fe92c6db7cbb4365c089dd5ef9346bffd903.pdf

lxxi Tsinghua University Building Energy Research Center (2016). China Building Energy Use 2016. Available at https://www.researchgate.net/publication/318106589_China_Building_Energy_Use_2016.

Amecke, H. (2013). Buildings Energy Efficiency in China, Germany, and the United States. Available at https://climatepolicyinitiative.org/wp-content/uploads/2013/04/Buildings-Energy-Efficiency-in-China-Germany-and-the-United-States.pdf

lxxii Manu, S. et al (2014). An Introduction to the India Model for Adaptive (Thermal) Comfort. Centre for Advanced Research in Building Science and Energy, CEPET University, Ahmedabad, India. Available at: http://shaktifoundation.in/wp-content/uploads/2014/09/Brochure_IMAC.pdf

lxxiii McClurg, C. (2016). Rocky Mountain Institute Insight Brief, Redefining and Delivering Thermal Comfort in Buildings. Available at https://d231jw5ce53gcq.cloudfront.net/wp-content/uploads/2017/03/Insight-brief_Thermal-Comfort-V7_FINAL-FOR-RELEASE.pdf

lxxiv Kigali Cooling Efficiency Program and the Carbon Trust (2018). Cooling Efficiency finance case studies. Available at https://www.k-cep.org/wp-content/uploads/2018/04/Cooling-efficiency-financing-case-studies_final-edited03.pdf

lxxv GOGLA (2018). Off-Grid Solar Market Trends Report. Available at https://www.lightingglobal.org/2018-global-off-grid-solar-market-trends-report/

lxxvi GOGLA (2018). Off-Grid Solar Market Trends Report. Available at https://www.lightingglobal.org/2018-global-off-grid-solarmarket-trends-report/

lxxvii REN21, Global Status Report 2018 (highlights), available at http://www.ren21.net/gsr-2018/pages/highlights/highlights/

lxxviii GOGLA (2018). Off-Grid Solar Market Trends Report. Available at https://www.lightingglobal.org/2018-global-off-grid-solar-market-trends-report/

lxxix Kigali Cooling Efficiency Program and the Carbon Trust (2018). Cooling Efficiency finance case studies. Available at https://www.k-cep.org/wp-content/uploads/2018/04/Cooling-efficiency-financing-case-studies_final-edited03.pdf

lxxx GOGLA (2018). Off-Grid Solar Market Trends Report. Available at https://www.lightingglobal.org/2018-global-off-grid-solar-market-trends-report/

lxxxi REN21 (2018). Global Status Report. Available at http://www.ren21.net/gsr-2018/pages/summary/summary/

lxxxii US AID (2018). Challenges and Needs in Financing Mini-Grids. Available at https://www.usaid.gov/energy/mini-grids/financing https://www.usaid.gov/energy/mini-grids/financing

lxxxiii GOGLA (2018). Off-Grid Solar Market Trends Report. Available at https://www.lightingglobal.org/2018-global-off-grid-solar-market-trends-report/

lxxxiv SEforALL (2017). Energizing Finance. Scaling and Refining Finance in Countries with Large Energy Access Gaps. Available at https://www.seforall.org/sites/default/files/2017_SEforALL_FR4P.pdf lxxxv Kigali Cooling Efficiency Program and Carbon Trust (2018). Cooling Efficiency Financing Case Studies. Available at https://www.k-cep.org/wp-content/uploads/2018/04/Cooling-efficiency-financing-case-studies_final-edited03.pdf

Global Environment Facility (2014). Investing in Energy Efficiency. Available at https://www.thegef.org/publications/investing-energy-efficiency

lxxxvi Green Climate Fund. N.d. How We Work. Available at https://www.greenclimate.fund/how-we-work/funding-projects

lxxxvii Global Environment Facility. N.d. Market Transformation of Energy Efficient Appliances in Turkey. Available at https://www.thegef.org/project/market-transformation-energy-efficient-appliances-turkey

lxxxviii Global Environment Facility. N.d. Lighting and Appliances Efficiency Project (Mexico). Available at https://www.thegef.org/project/lighting-and-appliances-efficiency-project

lxxxix CLASP (2018). Efficiency for Access – A New Phase of Cooperation to Accelerate Energy Access Through Affordable, Efficient Appliances. Available at https://clasp.ngo/updates/2018/efficiency-for-access-a-new-phase-of-cooperation-to-accelerate-energy-access-through-affordable-efficient-appliances

xc Ahmedabad Heat Action Plan 2017. Available at http://www.thehindu.com/news/national/other-states/sixth-edition-of-heat-action-plan-hap-launched-in-ahmedabad/article23509706.ece

xci Jaiswal, A. (2018). Climate Leadership: Ahmedabad's 6th Heat Action Plan. Available at https://www.nrdc.org/experts/anjali-jaiswal/climate-leadership-ahmedabads-6th-heat-action-plan

xcii CDKN (2017). Heat Action Plans - Scaling Up India's Ambition to Protect the Climate-Vulnerable. Available at https://cdkn.org/resource/heat-action-plans/?loclang=en_gb

xciii Kirn, J. (2018). "Mitigation of Urban Heat Islands: Greening Cities with Mandates versus Incentives," American Bar Association, Natural Resources & Environment section. Vol. 32, No.3, pp. 40-43.

xciv France24 (2015). France takes steps to avoid deadly 2003 heat wave. Available at http://www.france24.com/en/20150701-france-paris-heat-wave-alert-deadly-2003-summer-guidelines

xcv Andersen, S. and Madhava Sarma, K. (2002). Protecting the Ozone Layer: The United Nations History. New York United Nations Publications.

xcvi Andersen, S. and Madhava Sarma, K. (2002). Protecting the Ozone Layer: The United Nations History. New York United Nations Publications.

xcvii Alliance for an Energy Efficient Economy (2017). Thermal Comfort for All – Sustainable and Smart Space Cooling, available at http://www.aeee.in/buildings/sustainable-and-smart-space-cooling-coalition/

xcviii GOGLA (2018). Off-Grid Solar Market Trends Report. Available at https://www.lightingglobal.org/2018-global-off-grid-solar-market-trends-report/

xcix GOGLA (2018). Off-Grid Solar Market Trends Report. Available at https://www.lightingglobal.org/2018-global-off-grid-solar-market-trends-report/

c Global Leap. n.d. Off-Grid Appliance Procurement Incentives. Available at http://globalleap.org/incentives/

ci Global Leap. n.d. The Global Leap Off-Grid Cold Chain Challenge. Available at http://globalleap.org/coldchain/

cii The Lab. Driving Sustainable Investment. n.d. Available at www.climatefinancelab.org

ciii The Lab (2018). Press release, The Lab reaches $1 billion milestone in sustainable investment. Available at https://www.climatefinancelab.org/news/1-billion-milestone/

civ UN Environment and Kigali Cooling Efficiency Program (2017). Twinning of National Ozone Officers and Energy Policymakers. Available at http://www.unep.fr/ozonaction/information/mmcfiles/7935-e-K-CEP-factsheet-Twinning.pdf

cv Lighting Global (2016). Lighting Global Quality Assurance Framework Past, Present, and Future Support for the Off-Grid Energy Market. Available at https://www.lightingglobal.org/wp-content/uploads/2015/07/LG_QualityAssurance-Roadmap_Sept_2016_v4.pdf

cvi Information provided by CLASP

cvii Vorster, J. and Dobson, R. (2011). Sustainable Cooling Alternatives for Buildings. University of Stellenbosch, South Africa, Journal of Energy in Southern Africa. Vol 22 No 4. Available at http://www.scielo.org.za/pdf/jesa/v22n4/05.pdf

cviii Government of New South Wales, Australia (2017). Awards for Greatest Ideas in Health Care. Available at http://www.health.nsw.gov.au/news/Pages/20171026_00.aspx

cix Kigali Cooling Efficiency Program (2018). Knowledge Brief, Optimization, Monitoring, and Maintenance of Cooling Technology." Available at http://k-cep.org/wp-content/uploads/2018/03/Optimization-Monitoring-Maintenance-of-Cooling-Technology-v2-subhead....pdf

cx SEforALL (2018). Background Papers Supporting the Preparation of Chilling Prospects: Providing Sustainable Cooling for All. Available at https://www.seforall.org/coolingforall

DISCLAIMER AND COPYRIGHT

Headquarters
Andromeda Tower 15th floor
Donau City Strasse 6
1220, Vienna, Austria

Satellite Office
1750 Pennsylvania Ave NW, Suite 300
Washington, DC 20006,
USA

This work is a product of Sustainable Energy for All (SEforALL). The findings, interpretations, and conclusions expressed in this work do not necessarily reflect the views of SEforALL, its Administrative Board or its donors. SEforALL does not guarantee the accuracy of the data included in this work. The boundaries, colors, denominations and other information shown on any map in this work do not imply any judgment on the part of SEforALL concerning the legal status of any territory or the endorsement or acceptance of such boundaries. This document has been produced with the financial assistance of the Kigali Cooling Efficiency Program (K-CEP). The views expressed herein can in no way be taken to reflect the official opinion of the K-CEP.

ADDRESSING DATA LIMITATIONS

Access to cooling is a new area of investigation and, inevitably, when piloting a new approach not all the data one would wish to examine is neatly lined up, especially when it comes to looking for disaggregated data on vulnerability based on gender, health, and education level.

To support this publication, an extensive data gathering exercise and literature review was undertaken, including a call for data to organizations that may have access to enhanced levels of granularity. The data expressed herein draws on a model produced by SEforALL that is based on data received through that process and data which is publicly available and, given limitations, is subject to assumptions and margins of error. The data and evidence gathered also served to support the production of background documents prepared by SEforALL which are available online.[cx]

In a nascent field such as access to cooling, it is crucial that organizations be empowered to put concerted efforts in the collection of a more extensive set of granular and verified data at the country level, as well encouraging organizations with significant non-public datasets to make them available to K-CEP and selected partners. This would allow for more detailed access gap quantifications with a lower error margin, in order to inform both discussions with key stakeholders as well as future policy and program design. Organizations that may have the knowledge and capacity to undertake such an effort include: GIZ,CLASP,GAVI,Global Cold Chain Alliance, the Global Food Cold Chain Council, UN Habitat, and the IEA.

CONTACTS

Headquarters
Andromeda Tower 15th floor, Donau City Strasse 6
1220, Vienna, Austria

Satelite Office
1750 Pennsylvania Avenue NW, Suite 300
Washington, DC 20006, USA

Email: Coolingforall@seforall.org
Website: www.SEforALL.org
Twitter: https://twitter.com/SEforALLorg