CHILLING PROSPECTS:

PROVIDING SUSTAINABLE COOLING FOR ALL

EXECUTIVE SUMMARY

SUSTAINABLE ENERGY FOR ALL

KIGALI COOLING EFFICIENCY PROGRAM

FOREWORD

RACHEL KYTE

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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.

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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.

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.

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.

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 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. 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,

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

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

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.

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 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.

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 of prolonging the shelf life of fruits and vegetables.

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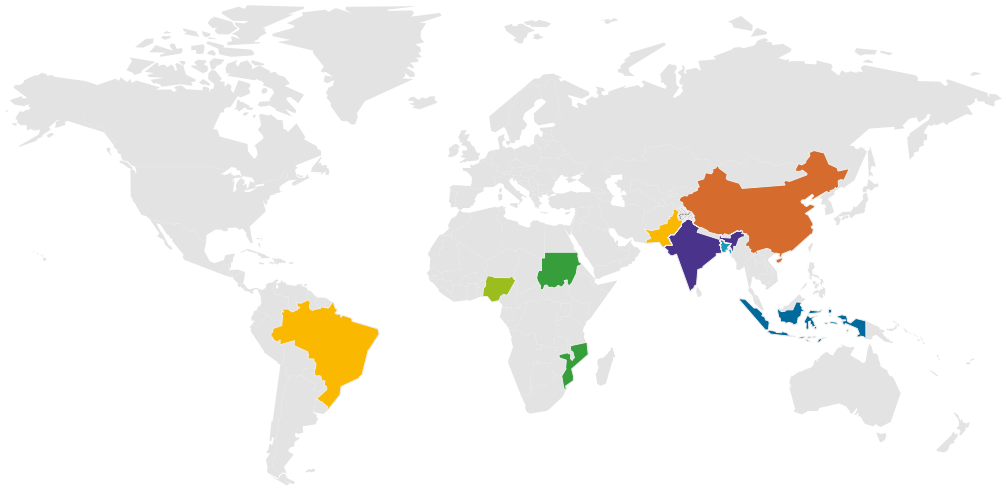
[2] Scientists use climate models to estimate the warming expected to result from current trends in human activities including the choice of refrigerants and the fuel mix used to generate electricity. By using scenarios that include lower emissions—lower GWP refrigerants, less use of fossil fuels—they 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.

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.

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.

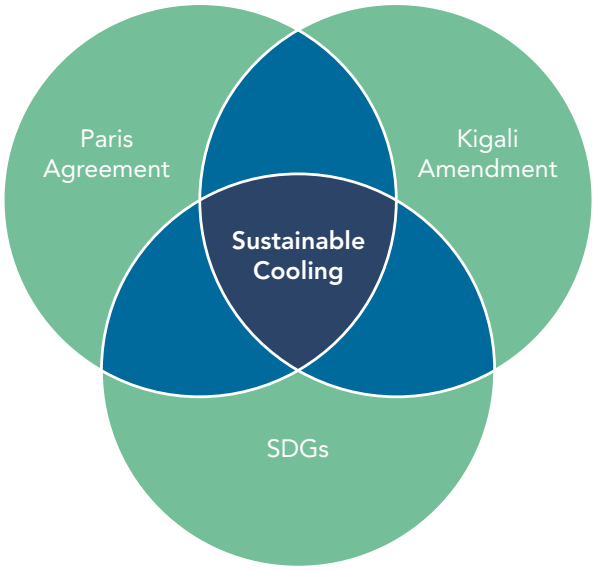
Preventing the degradation of vaccines and medicines also requires integrated, innovative, and affordable systems for temperature control in rural areas and sometimes over long distances. The World Health Organization has evaluated and qualified 16 designs for insulated containers with frozen water packs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

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

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



(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.

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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.

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.


PLEASE NOTE
THE CENTRIFUGE SHOULD
ALWAYS BE AT ZERO
SPEED BEFORE
SWITCHING ON/OFF

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