TECH EMERGE COOLING

AN INNOVATION OF IFC International Finance Corporation WORLD BANK GROUP

UK Government

Report

TechEmerge Sustainable Cooling Innovation Program

Results and Lessons Learned

DECEMBER 2025

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IFC — a member of the World Bank Group — is the largest global development institution focused on the private sector in emerging markets. We work in more than 100 countries, using our capital, expertise, and influence to create markets and opportunities in developing countries. In fiscal year 2024, IFC committed a record $56 billion to private companies and financial institutions in developing countries, leveraging private sector solutions and mobilizing private capital to create a world free of poverty on a livable planet. For more information, visit www.ifc.org.

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Acknowledgement

On behalf of the IFC team who led the implementation of the TechEmerge Sustainable Cooling Innovation Program, I would like to express my sincere gratitude to everyone who has contributed to the success of this initiative. The achievements documented in this report are a testament to the dedication and collaborative spirit of our global community.

Our deepest appreciation goes to the United Kingdom Department for Energy Security and Net Zero, whose generous contribution, strategic support and commitment to climate innovation made this program possible. We are also grateful to the innovators and corporate adopters across Africa, Asia, and Latin America. Their adoption of new technologies and business models in diverse settings across the globe showcased the potential for scalable solutions.

The TechEmerge program has helped innovators scale their operations across countries and regions. Some new technologies enabled smallholder farmers to have access to affordable cooling for the first time, for example. Other technologies, meanwhile, allowed large multinational corporations to use sustainable cooling to achieve their climate targets towards reducing their carbon footprint.

Special thanks are to our technical advisors, local delivery partners, industry associations, and academic institutions, who provided expertise and guidance for our innovators and adopters to successfully implement pilot projects. The program's investors, including development organizations, helped strengthen the ecosystem for sustainable cooling and mobilize resources to support measures such as IFC's Sustainable Cooling Initiative, which aims to accelerate investment in this sector.

Thank you for your commitment and for partnering with us toward our shared vision for a more sustainable future.

Selcuk Tanatar
IFC Disruptive Technologies and Funds
International Finance Corporation

Foreword

As global temperatures rise and urbanization intensifies, the demand for cooling is expected to quadruple during the next few decades. Conventional cooling technologies, while essential, require significant energy consumption and lead to more greenhouse gas emissions, highlighting the urgent need for innovative, sustainable cooling solutions across emerging economies.

During 2019 – 2024 the TechEmerge Sustainable Cooling Innovation program, led by the International Finance Corporation (IFC) in partnership with the United Kingdom Department for Energy Security and Net Zero, has promoted the adoption of climate-smart cooling technologies for space cooling, cold chains and industrial cooling across Latin America, Africa and Asia.

Through strategic collaboration among innovators, corporates, academia, industry associations, and innovative financing, the initiative supported more than 100 pilot projects of which about two thirds demonstrated significant benefits, with up to 85% cost savings, reduction in energy use and GHG emissions, improved operational efficiency and conservation of water resources.

The TechEmerge program has already inspired new initiatives exploring accessible, efficient, and climate-smart cooling solutions such as IFC's Cooler Finance[1] report, which identifies and quantifies sustainable cooling needs and financing gaps; and IFC's new Sustainable Cooling Initiative[2], which seeks to boost investments in sustainable cooling across emerging markets.

This report presents the results and lessons learned from the TechEmerge program, provides insights and recommendations across a range of topics, including the need for robust validation systems, new business models, and local adaptation. It includes case studies spanning multiple regions and sectors, highlighting how partnerships and capacity building help advance sustainable cooling efforts.

Policymakers, investors, and practitioners should actively collaborate to pilot, fund, and scale climate-smart cooling technologies—using the report's lessons to implement robust validation systems, develop new business models, and adapt solutions locally—so that sustainable cooling becomes standard practice in emerging markets.

Farid Fezoua
Global Director for Disruptive Technologies, Services, and Funds
International Finance Corporation

1. https://www.ifc.org/en/insights-reports/2024/mobilizing-investment-for-the-developing-world-s-sustainable-cooling-needs

2. https://www.ifc.org/en/what-we-do/programs-projects/sustainable-cooling#:~:text=Sustainable%20Cooling%20is%20a%20new,costs%20of%20products%20and%20services.

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Executive Summary

Over the past century, access to cooling has become essential for human health, food security, and economic development, and in a warming world demand for cooling is growing rapidly, especially in emerging economies.

While cooling is vital, this increase in cooling demand is fueling energy consumption and is currently contributing an estimated 7 percent of global greenhouse gas emissions (GHGs) each year. If business-as-usual continues, cooling-related emissions could constitute about 16 percent of global emissions by 2050.[3] Although the international community has sought to address this challenge through various climate agreements, existing technologies and practices remain insufficient to drive meaningful departures from the status quo. Acknowledging the need for innovations and to meet the challenge of providing energy-efficient, affordable, climate-smart cooling where it is needed most, IFC conducted the TechEmerge Sustainable Cooling Innovation (TE-SCI) program in partnership with the United Kingdom Department for Energy Security and Net Zero (UK DESNZ).

Launched in 2019, the TE-SCI program connected innovators worldwide with leading companies in emerging markets to pilot sustainable cooling technologies and business models, de-risk investment, and provide a demonstration effect to accelerate the adoption of new, sustainable cooling solutions. The program focused on key themes in Africa, Asia, and Latin America, including cooling in cities, retail cold chains, temperature-controlled logistics, space cooling, and cooling-as-a-service (CaaS) business models.

Results

By its conclusion in September 2024, TechEmerge had received more than 380 applications to join the program. Experts in cooling, innovation, and climate helped TechEmerge to select innovations with the highest potential. Innovators from across the globe and leading emerging market companies then attended match-making events in person and online. Ultimately, 40 cooling innovators partnered with 51 corporates who served as adopters to field-test 82 climate-smart, energy-efficient technologies. Backed by TechEmerge technical and market expertise, these partners conducted 100 pilots on the ground in real world conditions in Colombia, Mexico, Ecuador, Nigeria, Kenya, Rwanda, India, Bangladesh, Türkiye, and Vietnam. In total, over 500 entities, including industry associations and local delivery partners, were engaged during the course of the program.

To respond to client-specific needs, the pilots tested these innovations in existing cooling systems or as part of new systems that combined multiple commercially available technologies. As of March 2025, nearly two-thirds of the completed pilot projects reported reductions in energy consumption and greenhouse gas emissions ranging from 15 to 100 percent. In addition to these environmental benefits,

3. IFC. 2024. Cooler Finance: Mobilizing Investment for the Developing World's Sustainable Cooling Needs.

approximately three-quarters of the pilots achieved cost savings of similar magnitudes. The pilots also demonstrated that sustainable cooling offers broader advantages, such as reduced water and chemical use, and decreased maintenance costs.

The pilots also re-confirmed the importance of field-testing innovations to advance their technology readiness levels (TRLs).[4] TRLs provide a global benchmark to assess the technological maturity of an innovation. Despite challenges in tracking these advancements, TE-SCI teams reported that about 60 percent of the piloted solutions recorded at least one level progression in their TRL. As of the end of April 2025, innovators reported that in addition to TRL progression, the technical and financial assistance TE-SCI provided were key factors enabling them to raise $113 million in financing, sign 42 contracts with adopters, and establish multiple collaborations between innovators and adopters for commercialization of the piloted technologies worldwide.

Sharing knowledge was central to the TE-SCI program. For example, TE-SCI provided funding for each innovator to deliver on-site training for its partner adopter, while social media campaigns, feature stories, and videos built broader awareness of the need and opportunities for sustainable cooling innovation. TE-SCI also staged a wide range of events targeting corporates, innovators, and other key stakeholders. This culminated in a three-day summit held in Birmingham in partnership with the United Kingdom Department for Energy Security and Net Zero. This capstone event resulted in a commitment by the UK government and IFC to build on TechEmerge's work through a new, expanded IFC Sustainable Cooling Initiative to accelerate innovation and scale investments across emerging and frontier markets.

Key Lessons Learned

TechEmerge pilots generated solid results, impact, and lessons on sustainable cooling innovations and the ecosystems in which they operate, but they also encountered unique challenges that required creative solutions and generated important learnings. The following lessons learned can be leveraged to facilitate the scaling of sustainable cooling solutions in emerging economies.

1. **While the private sector and other key stake-holders recognize that cooling is essential to development and to achieve multiple sustainable development goals (SDGs), demonstrating the business case for the adoption of sustainable cooling is critical to meeting global climate objectives.** Awareness of the climate impacts of cooling is more advanced in countries that have adopted national cooling plans, such as India. However, even in the most sophisticated emerging markets, more needs to be done to raise awareness about the business benefits of adopting innovations that provide cooling for all who need it while also actively mitigating greenhouse gas emissions and reducing energy consumption.

   TechEmerge deliberately sought out market-leading corporates to act as adopters in pilot projects. For example, the highly respected Indian Hotels Company Limited (IHCL) conducted pilots that resulted in energy savings of up to 33 percent compared to conventional systems. The participation of industry leaders significantly enhanced the outreach of the TE-SCI program while sending a strong message about the business case for adopting sustainable cooling solutions to the broader private sector. It also raised the bar for competitors and encouraged them to minimize their carbon footprints.

4. See Annex 2 – Technology Readiness Levels.

2. **Stronger incubation and verification systems for innovators, with better connections to investors and adopters, are vital to overcome early-stage risks associated with sustainable cooling technologies and business models.** Early-stage ecosystems—where game-changing technologies are incubated and paths to minimum viable products and solutions are established—are often poorly connected to academia. Links to the private sector are also underdeveloped, even though these are vital to grow and scale new technologies. This problem is particularly severe in the global cooling ecosystem, where a small group of well-established companies dominate the market while younger innovators of sustainable cooling technologies struggle to prove their commercial readiness. Innovators and cooling entrepreneurs also need more holistic support to grow their businesses.

   To mobilize investment and support sustainable cooling innovation and entrepreneurship, TechEmerge supported the creation of the Cooling Innovation Lab at the Indian Institute of Technology in Jammu. The lab subjects sustainable cooling innovations to rigorous testing and evaluation to ensure they are deployable in real-world contexts. TechEmerge also supported four of its most promising innovators to join the inaugural intake of the Africa Centre of Excellence for Sustainable Cooling and Cold-Chains. Along with research, awareness-raising, and technical capacity building, the Centre aims to develop, test, demonstrate, and deploy fit-for-market pathways to net zero cold chains and accelerate cooling at scale in Africa.

3. **New blended funding models are needed to shorten the timeframe between successive rounds of growth funding for sustainable cooling innovators.** While the market tends to view cooling innovators through a traditional venture capital lens, most investment opportunities in cooling businesses do not conform with the typical return profile of the venture capital asset class. Cooling innovators are predominantly assets and CAPEX-heavy businesses with relatively long gestation periods. This often extends the duration between funding rounds for cooling innovators and stunts their growth prospects. It also delays the launch of mass market-ready cooling innovations that are critical to meet climate commitments at all levels, from individual firms to national cooling action plans to global pledges by the Conference of Parties (COP).

   TechEmerge leveraged grants, combined with commercial and in-kind contributions from adopters and innovators, to help mitigate risks and overcome cost barriers. The calibrated blending of commercial and non-commercial capital was critical to balance risk and reward, helping adopters and innovators gain confidence to pilot innovative cooling technologies.

   New instruments should be developed and deployed across the debt-to-equity spectrum to meet the funding needs of cooling innovators with varied growth trajectories. Cooling innovators with relatively higher growth potential may require patient equity injections early in their development cycles to prove their business models. Others may require access to working capital in the form of guarantees or asset-backed loans to fulfill pending orders.

4. **Technical advice and independent monitoring and evaluation of cooling innovations can help to overcome 'business-as-usual' constraints.** The TE-SCI team found that real sector adopters tended to rely on a handful of well-established heating, ventilation, and cooling (HVAC) vendors and can be reluctant to engage younger, more innovative companies that may not have comparable references and documentation.
To change the risk-averse mindsets of adopters, the program mobilized seasoned HVAC experts to help participants design test beds and maximize the potential for successful pilot outcomes. TechEmerge also facilitated third-party monitoring and evaluation to independently report on savings and climate benefits, thereby building confidence among adopters considering investments in new cooling solutions. Replicating this approach holds significant potential to drive cooling innovation.

5. **New business models are essential to address ongoing challenges such as neglect, split incentives, and skills shortages, while also driving innovation forward.** Cooling is vital for many companies. However, most often their core business lies elsewhere, such as in health or retail, and the pursuit of greater cooling efficiency is rarely a top priority. In other sectors where cooling is mission critical, such as hospitality or data centers, adopters are highly risk-averse to testing new technologies.

   In addition, the issue of 'split incentives' is common when cooling large built environments. For example, a property developer may build a hotel or a large retail space, but another company may ultimately manage the day-to-day operations of these buildings. In such cases, the potential for higher upfront costs may give developers less incentive to integrate innovative, energy-efficient, climate-smart cooling infrastructure into their building designs, and require additional approvals or negotiations among the parties. Furthermore, adopters often lack in-house expertise and technical capacity to evaluate and maximize the benefits of integrating sustainable cooling technologies into their existing systems.

   To tackle these challenges, TechEmerge explored cooling-as-a-service business models (CaaS). CaaS is a pay-as-you-go model that seeks to eliminate high upfront investment costs for cooling consumers, and reduce risks associated with adopting innovative cooling solutions. End-customers only pay for the cooling they consume, while supply of equipment, operations, and maintenance are delivered by the CaaS provider for a fixed fee.

   TechEmerge partnered with district cooling company Tabreed to explore CaaS business models in India, one of the world's fastest growing cooling markets. In Africa, the program supported innovators such as Eja-Ice and Koolboks to scale the adoption of their technologies through the CaaS business model. While further investigation is needed, TE-SCI observed growing market interest in potentially outsourcing cooling operations to CaaS providers, especially among companies with sizeable cooling footprints.

6. **Transformational shifts in how cooling is produced, consumed, managed, and evaluated are overdue.** The TE-SCI team noted a clear tendency among adopters to evaluate the potential of innovations only in terms of identifying more efficient technologies to deliver the same amount of cooling as their existing equipment. Other factors that could affect technology selection, such as the potential for reducing the need for cooling and long-term operational, financial, and climate benefits were almost never taken into consideration.

Similarly, when evaluating the financial feasibility of new cooling technologies, most adopters required a pay-back period for investment of less than two or three years. However, it was observed that only the purchase, installation, and energy savings from the specific equipment were considered, while the savings from reduced waste, water, and chemical use, and other operational benefits such as reliability and availability, were almost never taken into account.

7. **Cooling innovation is not only about the underlying technology.** Innovators often assumed that their solution would work 'off the shelf' in all markets, even though adopters' needs, geographic and economic conditions, and local business practices and regulations varied dramatically. Even language barriers could lead to sub-optimal outcomes if left unaddressed.

   Understanding the totality of the adopter's business, establishing strategic ties with an effective local delivery partner, and possessing the flexibility to modify, integrate, and enhance their technology enabled innovators to better navigate entry into new markets. Innovators with strong local relationships also garnered greater confidence among adopters who rely on specialized technical expertise and dependable after-sales support.

   Several innovators leveraged the TechEmerge process to trial local partnerships and evaluate the feasibility of licensing the manufacturing and distribution of their sustainable cooling innovations. For example, a TechEmerge adopter in India passed on adopting a promising chemical-free water treatment because of concerns about the lack of a reliable local partner. In contrast, in Mexico, a well-regarded local engineering firm was responsible for importing the same technology, installing it at the adopter's test site, servicing the equipment, and collecting and evaluating results. That pilot was a success, and its results have already convinced other Mexican companies to adopt the solution.

New Frontiers In Sustainable Cooling

Both innovators and established companies often build upon existing cooling solutions, making incremental improvements in energy-efficiency, affordability, and greenhouse gas emissions. Entirely new and unique technologies are few and far between. Greater focus is needed on the research and development of 'leapfrog' technologies that bypass existing systems and enable emerging markets to adopt radically new solutions that meet their specific needs at commercially scalable price points. A more holistic approach is also key to expanding the frontiers of sustainable cooling innovation. For example, energy, water, and the Internet-of-Things (IoT) all play a critical role, and innovators, adopters, and other stakeholders need to consider how these intersect and impact the piloting and scaling of sustainable cooling solutions.

During the course of the program, TE-SCI saw new challenges emerge, along with a need to re-think the ways in which cooling is produced, consumed, and managed. For example, the agribusiness sector has already recorded a decrease in agriculture yields and production and increased storage, processing, and distribution costs due to rising temperatures. Without new technologies to cool crops and livestock, as well as preserve food, access to affordable nutrition may be negatively affected, especially in emerging markets. Rising temperatures could also impact worker productivity and academic achievement and impede long-term growth of human capital.

Rather than adapting lives and businesses according to what cooling equipment can deliver, a needs-driven approach is required to guide the development of new sustainable cooling technologies. To do so, shortages in cooling engineers and other skilled workers must be addressed, and they must be equipped with an understanding of how to evaluate and meet needs, in addition to technical knowledge.

These learnings and proposals to scale sustainable cooling are explored in more detail in the body of this report, along with the goals, methods, pilots, and results of the TE-SCI program. Stories from the field provide additional insight into the challenges and opportunities presented by new cooling technologies and business models. **It is hoped this report will be leveraged to further expand on the impact of TechEmerge and support efforts to provide cooling for all who need it while mitigating greenhouse gas emissions and building resilience to climate change.**

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1.

Pathways to Sustainable Cooling & the Need for Innovation

Cooling in Context

Since the invention of artificial cooling in the mid-1750s, its commercialization in the late 1800s, and its introduction into homes starting in the 1920s, cooling has become one of the key enablers of economic growth. With gradual improvement and adaptation, cooling technologies have become essential for protecting vaccines and medicines from spoilage, safely distributing and preserving food, and maintaining productivity in workplaces. Although not always visible or recognized, cooling keeps data centers running, improves the efficiency of power generation, and dissipates the heat generated as a by-product of many industrial processes.

For more than a century, the developed world has reaped the benefits of cooling, but it has also come at a great price. It is estimated the energy load for space or stationary cooling already accounts for somewhere between 17 to 19 percent of global energy consumption.[5,6] This makes cooling a major contributor to climate change, accounting for 7 percent of global greenhouse gas emissions and fueling a vicious cycle that warms the world even further.[7]

Furthermore, population growth, urbanization, and a warming climate are all increasing the need for cooling. Improved access to energy and better incomes, especially in emerging markets, are also driving cooling demand. If business-as-usual continues, cooling-related emissions are estimated to increase to nine billion tons by 2050, and could constitute about 16 percent of global emissions.[8]

However, all people need access to cooling, especially the most vulnerable. Cooling is also essential to meet 16 of the 17 sustainable development goals (SDGs), as shown in Figure 1. Research estimates that more than 1.2 billion people are already at high risk due to a lack of access to cooling, which impacts their nutrition and thermal comfort, spoils vaccines and agricultural produce, and restricts their ability to engage in economically-productive activities.[9] Insufficient access to sustainable cooling would also have a major impact on the private sector through power outages, increased energy costs, decreased worker productivity, and lower quality goods and services, among other issues, and constrain its ability to contribute to the SDGs.

Since the late 1980s, the international community has sought to address these challenges by phasing out ozone-depleting chemicals used in air-conditioning and refrigeration through agreements such as the Montreal Protocol, Kigali Protocol, and Climate Change Framework. There have also been significant efforts to enforce stronger energy efficiency policies and standards and to promote the adoption of the best available cooling technologies.

However, these efforts will not be sufficient to sustainably meet rapid growth in demand for cooling. One significant challenge is that much of today's cooling equipment has only marginally improved on technology that was commercialized in the late 19th century, and even the best available technologies only deliver about 14 percent of maximum theoretical efficiency.[10,11] In fact, according to the International Energy Agency (IEA), the efficiency of air conditioners has only improved by roughly 1.7 percent per year since 1990[12].

One of the reasons for the slow pace of innovation is that, until recently, cooling was a 'blind spot' in the climate change agenda. While billions of dollars have gone to support research and adoption of renewable energy and electric energy storage technologies, for example, very little has been allocated to accelerate research, development, and commercialization of novel cooling solutions. Investors have also not looked for opportunities in cooling as part of their climate investment agenda.

According to IFC research, the global market for cooling equipment market was $270 billion in 2023, and 80 percent of the market is dominated by a handful of large corporations.[13] Cooling companies that make up the remaining 20 percent are considered too small, and the segment too fragmented,

5. IEA. 2018. *The Future of Cooling: Opportunities for Energy Efficient Air Conditioning.*
6. UNEP. 2023. *Global Cooling Watch, Keeping it Chill.*
7. Estimate based on CO_2e (CO_2 equivalent).
8. IFC. 2024. *Cooler Finance: Mobilizing Investment for the Developing World's Sustainable Cooling Needs.*
9. Sustainable Energy for All. 2023. Chilling Prospects: Global Access to Cooling Gaps 2023
10. Rocky Mountain Institute. 2018. *Global Cooling Prize - Solving the Global Cooling Challenge.*
11. Deduced by Nicolas Leonard Sadi Carnot in 1796 and still used today to determine efficiency of thermal systems, the Carnot efficient sets an absolute limit on the efficiency with which heat energy can be turned into useful work.
12. International Energy Agency. 2018. *The Future of Cooling - Opportunities for Energy-efficient Air Conditioning.*
13. IFC. 2024. *Cooler Finance: Mobilizing Investment for the Developing World's Sustainable Cooling Needs.*

FIG 1.

Links between Access to Cooling and the Sustainable Development Goals

Source: "The Cooling Imperative - Forecasting The Size and Source Of Future Cooling Demand" by The Economist Intelligence Unit (2019) and "Clean Cooling Landscape Assessment" by Professor Toby Peters (Heriot-Watt University, University of Birmingham), (2018).

to attract the investment needed for them to scale. The large players also control a well-structured manufacturing, distribution, and servicing network, and this creates significant competitive barriers for startups and smaller companies seeking to enter the cooling market.

However, opportunities lie in the growing market for sustainable cooling in emerging economies, which is expected to more than double to at least $600 billion in annual demand by 2050.[14]

Supported by increased awareness of the adverse climate effects of conventional cooling technology, this market could help achieve the SDGs while also enabling emerging economies to reap the benefits of cooling through more sustainable pathways.

Achieving these outcomes will require access to estimated funding of $400 billion to $800 billion. It will also require holistic support for disruptive, technology-driven cooling startups throughout their corporate journeys.

14. IFC. 2024. *Cooler Finance: Mobilizing Investment for the Developing World's Sustainable Cooling Needs.*

TechEmerge Sustainable Cooling Innovation Program

Acknowledging these cooling challenges and the need for innovation, in 2019, IFC partnered with the United Kingdom's Department for Energy Security and Net Zero (UK DESNZ) to create the TechEmerge Sustainable Cooling Innovation (TE-SCI) program with an aim to accelerate the adoption of energy-efficient, affordable, and climate-smart cooling innovation in emerging markets—where demand for cooling is growing most rapidly.

The key objectives were to:

1. Accelerate the adoption and technology readiness levels (TRLs) of promising new sustainable cooling technologies, business models, and services that can mitigate climate change and provide wider development benefits in emerging economies.[15]
2. Support technical assistance activities in emerging markets to demonstrate the business case for innovative, energy-efficient, cost-effective, climate-smart cooling solutions.
3. Encourage knowledge-sharing and cooperation in innovation for sustainable cooling.

IFC's TechEmerge Platform

Initially conceived in 2016 as a program to close the technology adoption gap in emerging markets, TechEmerge brings together a wide range of stakeholders interested in adoption of innovative technologies in a specific sector. It does this by facilitating and supporting their collaboration through a structured and curated process for identifying, evaluating, piloting and scaling adoption of new technologies.

Over time, TechEmerge evolved into a ro-bust platform that has to date supported 94 innovators through 167 pilots in health, resilience and cooling. To date it has partnered with 96 adopters across 15 countries and facilitated innovators raising more than $400 million in financing and investment. See Annex 1 for details.

TE-SCI was implemented in three distinct phases, each benefiting from feedback that informed the program's successive components.

15. TRLs provide a global benchmark to assess the technological maturity of an innovation. Refer to Annex 2 for the TRL scale used in the TE-SCI program.

Phase 1: Understanding Supply and Demand for Innovative Cooling Technologies

During this initial phase, the TE-SCI team conducted activities to assess the funding needs, existing opportunities, and potential market for sustainable cooling innovations. **This was guided by two key questions:**

1. Whether there was sufficient interest and demand from existing and future users/adopters of innovative cooling technologies in emerging markets, and
2. How many cooling technology companies/innovators had commercially viable solutions across different technology readiness levels.

While these initial activities informed the strategy and overall approach to TE-SCI pilots, the team continued mapping the global cooling market throughout the program.

Phase 2: Addressing the Most Critical Needs

Based on the learnings and outcomes from Phase 1, IFC launched four TE-SCI projects in areas identified as having the highest need or demand and potential for development impact:

Cooling Cities: This project conducted pilots on the ground in Mexico and Colombia. It aimed to address growing cooling needs and the challenges of urbanization and urban heat islands.

Making Temperature-Controlled Logistics (TCL) Work: This project partnered innovators with adopter companies in Nigeria. It aimed to find affordable cooling solutions for countries with poor infrastructure and ultimately spur the development of viable TCL sector in Africa's largest economy.[16]

The 'Missing Link' in Retail Cold Chains: Pilots in India and Bangladesh aimed to find solutions that enable retailers to off-take and distribute low value produce, like fresh fruit and vegetables, and/or 'high risk' food products, such as meats, while minimizing food loss and waste.

Sustainable Recovery of the Hospitality Sector: Field tests in India aimed to reduce the cost and climate impacts of the hospitality sector and support its sustainable recovery in the wake of the COVID-19 pandemic.

This phase also included a comprehensive study to explore the potential for capturing and redirecting cold energy usually wasted during the regasification of liquefied natural gas (LNG). See Annex 3 for a summary of its findings.

16. TCL, also known as cold chain logistics, refers to the handling of products within a low temperature environment in an unbroken chain at all stages following harvest or production, including collection, packing, processing, storage, transport and distribution.

Phase 3: Replicate, Scale, Innovate

After accumulating significant learnings and experience from Phase 2 projects, **TechEmerge focused this third phase on three priorities:**

- Supporting the replication of the most promising technologies in new environments with substantial supply gaps.
- Scaling the most promising technologies in markets and sectors with the highest demand, while progressing innovations' technology readiness levels.
- Initiatives to support the innovation ecosystem and develop new business models for the long-term commercial viability of sustainable cooling solutions.

With these focus areas in mind, IFC expanded the scope of the TE-SCI program to include:

Making Temperature-Controlled Logistics Work Across Africa: This project aimed to help innovators progress their TRLs and replicate and scale cold-chain technologies with the greatest potential to benefit agriculture and food value chains. It also enabled the transfer of technology and knowledge to the newly established African Centre of Excellence for Sustainable Cooling and Cold-Chain in Rwanda.

Scaling & Replicating Cold Chain Technologies: This project in Colombia, Ecuador, Peru, and Mexico aimed to transfer and scale technologies with the greatest demonstrated need and a focus on temperature-controlled logistics and industrial cooling for agribusiness.

Cooling-as-a-Service and Ecosystem: This project aimed to introduce state-of-the-art technologies in district cooling and innovative cooling-as-a-service (CaaS) business models in India and create a Cooling Innovation Lab to sustain and enhance the cooling innovation ecosystem across the country.

Innovative Cooling Technology Push: This global project created a repository of technologies that had either established or demonstrated high potential to attain techno-commercial feasibility. IFC clients and broader networks in targeted sectors will have access to this repository.

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2.

Six Steps: From Innovation to Scale

This section examines how the TE-SCI program refined its six-step process to accelerate the adoption of innovative cooling technologies and deepen its impact.

1 ASSESS

TechEmerge identified both innovations and innovation gaps in emerging markets and worked closely with local companies to understand the unique needs of potential adopters/buyers.

Mapping the Innovation Landscape

In 2019, the TechEmerge team undertook six months of research to understand the cooling innovation ecosystem, map innovators, and gauge the technology readiness levels of their solutions. In this limited timeframe, desk research identified about 300 companies offering new cooling solutions, and the team estimated that in total there could potentially be up to 1,500 cooling innovators globally. This is a modest number compared to sectors such as healthcare or renewable energy. Of the innovators mapped by TechEmerge, 75 percent were domiciled in the USA and Europe and 25 percent in Asia, particularly in China and India.

This research revealed that about 87 percent of innovators were focused on space cooling technologies, while the remaining 13 percent targeted mobile cooling. Mobile cooling (AC in vehicles and refrigerated transport) accounts for an estimated 25 percent of total energy consumption for cooling[17] indicating significant room for growth and innovation in this segment.

Innovations were identified across all cooling technology areas, with 36 percent concentrated in alternate[18] cooling. These technologies offer the highest potential energy savings – over 50 percent – but are largely at early technology readiness levels.[19] The next largest category was cooling management or control and demand reduction (25 percent), followed by advancement in traditional technologies such as vapor-compression cycles (21 percent), and thermal storage solutions (18 percent).

> *"Sometimes it's hard for you to find customers that are willing to trust you with a new technology because there's no precedent. That's where a facilitator like IFC comes into play."*
>
> Rahul Bhalla, Co-founder & CEO, Zenatix. India.

The research team also examined barriers to commercialization. Challenges reported by innovators included (i) limited access to long-term financing, specifically for those working on alternative cooling technologies; (ii) a lack of access to testing facilities and field-testing opportunities under real-world conditions; and (iii) an inability to seamlessly integrate newer technologies with existing conventional or legacy cooling systems.

Mapping continued throughout the duration of TE-SCI and over 450 cooling companies had been identified by the end

17. Green Cooling Initiative. 2018. *Non-state Action Towards Climate-friendly and Energy-efficient Cooling.*

18. In this document, alternate (or alternative) cooling is used interchangeably for all cooling technologies other than those based on the vapor-compression cycle.
19. TRL of 4-6.

of the program. Most of the companies identified were in later stages of their TRLs (7-8) but their distribution remained largely in-line with previously established patterns across the technology landscape and target application areas.

Needs & Demand

The TechEmerge team leveraged IFC's existing business relationships with portfolio and pipeline clients, industry associations, and policy makers across Latin America, Africa, and Asia to gauge adopters' cooling needs and challenges, and their interest in innovative technologies. This enabled TechEmerge to pinpoint areas of greatest need and opportunity, and to tailor the focus of the program for maximum impact.

During this stage, and contrary to expectations, stakeholders expressed high levels of interest in testing and piloting innovative solutions, even those with early TRLs. The top three motivations driving this interest were (i) potential reductions in operating expenses and lower climate impact; (ii) improved reliability, efficiency, and mitigation of cooling-related losses; and (iii) the opportunity not only to trial new technologies but also to explore efficient and sustainable business models that fuel economic growth across value chains.

Needs, demands, and challenges varied by region and country. For instance, Latin America—characterized by the world's highest urbanization rate and a warm climate—is projected to see a five- to six-fold increase in urban cooling demand over the next 30 years. In Mexico and Colombia, TechEmerge initially focused on addressing the cooling challenges of businesses and organizations in these urban areas, such as property developers, retailers and food and pharmaceutical distributors. The program later expanded to cover the supply, processing, and distribution of food into cities, extending the reach of the TE-SCI program to Ecuador and Peru.

In Nigeria, it is estimated that over 40% of food is lost at the farm gate, with significant additional losses occurring during distribution for both producers and retailers. These dynamics are representative of other Sub-Saharan Africa markets and presented TechEmerge with an opportunity to tackle challenges that are common across the region. Accordingly, the team focused on identifying affordable, energy-efficient, scalable technologies that could make temperature-controlled logistics work for the agriculture and food sectors.

> *"Existing technologies do not suffice to make a significant impact in meeting our needs and sustainable cooling goals. By engaging with innovators at earlier stages we hope to shape the technology to our needs and achieve significant impact that will justify replacement of what we already have."*
>
> Technical Director of major retail chain, Mexico.

In India and across Asia, TechEmerge observed significant efforts and incentives aimed at enabling affordable farm-gate storage and aggregation. However, a critical 'missing link' was identified in the retail segment of the cold chain, where effective storage and distribution capabilities for perishable items like fresh produce and meat are vital. TechEmerge also discovered significant opportunities to work with the fast-growing hospitality sector in India. **In general, hotels have the highest average energy intensity compared to any other built environment and in countries with warm climates like India, cooling represents almost 50 percent of their total energy consumption.**

2 SOURCE

TechEmerge encouraged leading emerging market corporates and high-potential cooling innovators worldwide with locally-relevant solutions to apply to the TE-SCI program.

During the TE-SCI program, the TechEmerge team engaged with more than 500 entities in sectors where cooling innovation was most needed. This included emerging market corporates that expressed interest in testing and potentially adopting innovative solutions as well as cooling innovators from across the world. Of these potential adopters, approximately one-third signed up to field-test the most promising cooling technologies relevant to their needs and operating environments.

In June 2020, TE-SCI launched its first global call for innovators to submit proposals with cooling technologies specifically aimed at enhancing energy efficiency in Latin American cities, with a particular focus on Mexico and Colombia. The 'Cooling Cities' open call received 112 solutions from 80 innovators across 20 countries. While most solutions focused on tackling challenges in space cooling in commercial and residential buildings, TechEmerge also received applications addressing the water-cooling nexus, indoor air quality, Internet-of-Things (IoT), and passive cooling.

A second call for proposals ran from December 2020 to February 2021 targeting solutions for cold chains and temperature-controlled logistics in Nigeria. The 'TCL Nigeria' call received 70 applications from 59 innovators across 19 countries. Most of the solutions were cold storage equipment using renewable energy and phase change materials (PCMs), and medium and short haul TCL applications. The call did not receive any applications with solutions for long haul transport or innovations that could significantly reduce the cost of cooling at the farm gate.

> *"The idea of the TechEmerge program, which is to bring together innovators and adopters, is a really good one as we adopters sometimes are focused on our side of the lane and are not aware of what is happening on the innovators' side. TechEmerge helps us discover the new things that are happening and try them in the real world."*
>
> Michelle Cabrera Beruete, Chief Financial Officer, Refrigeración Starr, Mexico.

The third and fourth open calls were launched in October 2021 and focused on cooling technologies for the missing link in retail cold chains in India and Bangladesh and the hospitality industry in India. The 'Missing Link' call received 41 applications from 26 innovators in eight countries. The applications primarily focused on hybrid renewable energy, PCM-based cold storage equipment, medium and short-haul temperature-controlled transport, and last-mile delivery solutions. The 'Hospitality' call received 41 applications from 35 innovators in 11 countries for solutions in high-side equipment optimization, low-side optimization and indoor environmental quality, IoT-enabled systems, and passive cooling solutions.

A final global call was launched in 2023 and covered all focus areas, sectors, and geographies where TechEmerge was active. This call received 132 applications from 85 innovators in 30 countries, of which 62 were new applicants. In total, the open calls received more than 380 applications.

The open calls were carried out through direct outreach to relevant companies identified during the mapping and assessment phase, social media campaigns, and webinars. **TechEmerge consultations with IFC investment and advisory staff also resulted in more than 20 introductions to cooling and cooling-related innovators.** This created a foundational repository of cooling innovators that expanded over time and allowed for more targeted sourcing in response to adopters' needs.

3 SELECT

Supported by expert advisors, TechEmerge selected high-performing innovators with proven technologies that could meet the needs of participating local adopters.

The TechEmerge team carefully evaluated all applications, and this process was supported by more than 50 advisors from within and outside IFC, all of whom were leaders in industry, technology, and investment. The advisors brought decades of expertise in key sectors and insight into cooling, climate change, early-stage financing, and much more to the TechEmerge selection process. In addition to deep cross-cutting knowledge, the pool of advisors provided valuable, independent third-party perspectives, which helped shape long lists of innovative cooling solutions to align with adopters' needs.

Each application was assessed on:

+ **Viability and technology readiness levels,** to ensure that the innovation was based on proven scientific norms and standards, and that the innovator's stated TRLs were sound.

"This is a truly impactful technology - in the face of the global need for energy diversification."

+ **Relevance, ability, and potential** of the technology to address adopters' needs and challenges as detailed in the call for proposals, while also avoiding energy use and greenhouse gas emissions.

"…their expertise in development of a new product in mobile category is doubtful."

+ **Organizational capacity and proposed business model,** to determine the ability of the innovator to deliver a pilot on time and within budget, and its potential to scale in the target market.

"Good idea, but the business part of the venture has to be thoroughly thought through."

Of more than 380 applications received, over 160 solutions were shortlisted and presented to potential adopters.

Most of the proposed solutions had self-declared TRLs of six or greater and offered adaptation of improved known technologies to specific use cases. However, almost all the piloted technologies had their TRLs downgraded due to shortcomings identified during field testing. Over 80 percent of the innovators that applied to the program were earlier-stage

startups with limited international exposure or knowledge of the markets for which they had proposed solutions.

A few innovators proposed alternate cooling technologies with substantial impact potential. However, most of them withdrew their applications due to inadequate organizational capacity, financial weaknesses, and uncertainty about global travel and costs stemming from the COVID-19 pandemic.

4 MATCH

Through a carefully curated process, TechEmerge arranged events and meetings for shortlisted innovators to meet top local companies, demonstrate their products, and discuss potential pilots.

After the TechEmerge team compiled a shortlist of solutions that met sustainable cooling needs identified during the assessment stage, it shared this information with potential adopters. TechEmerge provided opportunities for innovators to pitch their solutions and for adopters to ask questions and learn more about sustainable cooling. Due to COVID-19 health and safety considerations, most of these activities were conducted through virtual summits and webinars.

The team then facilitated one-on-one meetings between adopters and innovators to discuss the potential to jointly pilot sustainable cooling innovations on the ground in emerging markets. Where needed, TechEmerge provided translation services and technical expertise.

Often, multiple conversations were required to build trust as well as technical understanding of the underlying cooling solutions and potential applications in adopters' operating environments. Most meetings resulted in a consensus on pilot designs and cost-sharing among the adopter, innovator, and TechEmerge, but even engagements that did not result in a match yielded learnings that informed successive open calls and the selection process. Innovators and adopters jointly developed more than 120 pilot proposals.

> ***"Matchmaking is crucial and the TechEmerge program provided an important platform to bring all the relevant parties together to discuss sustainable cooling solutions and how they can be deployed commercially."***
>
> Chuma Maduekwe, Managing Director,
> Tak Logistics, Nigeria.

5 PILOT

With support from TechEmerge, selected innovators and participating adopters partnered to field test technologies in local settings.

In total, the program facilitated 100 pilots on the ground in Colombia, Mexico, Ecuador, Nigeria, Kenya, Rwanda, India, Bangladesh, Turkey, and Vietnam. These pilots field-tested 82 unique cooling solutions from 40 high-potential cooling innovators in partnership with 51 market-leading corporate adopters.

These pilots came about after TechEmerge advisors helped matched innovators and local corporates to evaluate their

joint pilot proposals for design quality, technical and financial feasibility, and potential for impact. Almost all pilot proposals went through multiple iterations to arrive at pilot designs that had the highest probability of success.

Key observations from these conversations include:

- Innovators often had weak understanding and knowledge of local delivery mechanisms, export and import regulations, transport, and logistics. They also lacked knowledge about the quality of local technical expertise and the challenges of integrating their solutions with adopters' existing or legacy cooling systems.
- Adopters took a conservative approach to testing new technologies. This was reflected in their disproportionate requirements for guarantees on operational continuity, maintenance, servicing, and cost coverage by innovators.
- Both innovators and adopters lacked knowledge about key performance indicators needed to monitor pilot implementation, or how to set realistic targets to evaluate and verify the technical and financial feasibility of the underlying technologies.
- The TechEmerge team, together with subject matter experts, worked with both the innovators and adopters and provided hands-on support to address these issues during pilot design.

Once the proposals were finalized, Memorandums of Understanding were signed between innovators and adopters to ensure the parties were aligned on critical aspects such as pilot milestones, roles and responsibilities, and reporting requirements. Based on this, TechEmerge then signed separate agreements with participating innovators and adopters covering financial and technical support.

In a departure from previous iterations of TechEmerge where innovators and adopters were responsible for identifying local delivery partners to assist with pilot implementation, TE-SCI took an active role in facilitating these relationships. This approach aimed to counter the adverse effects of COVID-19 travel restrictions and increase the likelihood of successful pilot implementation and scale-up in local markets—particularly when pilots involved cross-border technology transfers. Over the course of TE-SCI, more than 14 local delivery partners teamed up with innovators to implement pilots, of which five continued their cooperation post-pilot.

> ***"Teaming up with innovators worldwide is a win-win proposition that will lower our energy consumption and greenhouse gas emissions, create value for our customers, and ensure the sustainability of our business moving forward."***
>
> Ishaan Gupta, Director, Snowman Logistics, India.

In most cases, TechEmerge also introduced independent third-party monitoring and evaluation consultants to help pilot partners establish baselines and reconfirm data collection protocols. Monitoring of pilots included monthly status check-ins, quarterly progress reports from consultants, and targeted feedback from TechEmerge experts to help resolve technical challenges, when relevant. Learnings during this period were used to further refine pilot designs and implementation. This proved critical to pilot performance, as did the cross-pollination of knowledge among TechEmerge teams on potential challenges and solutions across regions. These recurring conversations helped anticipate and resolve challenges more efficiently.

6 SCALE

In most cases where pilots established techno-commercial feasibility, the relevant adopter and innovator independently negotiated commercial contracts.

The final stage of the TechEmerge process involved reviewing results reported by innovators and adopters. In most cases, these results were supplemented by reports from independent monitoring and evaluation consultants.

In regard to techno-commercial feasibility, the success of a pilot was measured by realized savings in energy consumption and operating expenses, and reductions in greenhouse gas emissions. With the help of TechEmerge technical experts, innovators conducted this analysis using baseline data established at the beginning of each pilot. These baselines helped innovators understand how their solutions performed in real-world settings and how they compared to traditional cooling alternatives.

Return-on-investment analyses were conducted by adopters, and decisions on whether to scale the piloted solutions were made and executed independent of TechEmerge. Innovators and adopters typically conducted additional tests and pilots before entering into a full-scale commercial contract. As detailed in the next section on results, this led to 10 commercial agreements between TechEmerge adopters and innovators. Innovators also leveraged the results of their pilots to sign more than 30 additional contracts with adopters outside the TechEmerge program.

"Two things that came from participation in the TechEmerge program are, one, the support in helping us better measure our CO_2 emission reduction, and two, thinking about our business model, such as exploring cooling-as-a service."

Natalie Casey, Chief Business Officer, Koolboks, Nigeria/ France.

"IFC's support in assessing our technology in Mexico and Colombia was crucial for Elgressy's local presence. In Mexico, Sigma installed an EST system in their Chihuahua plant and plans to expand to five more plants in 2025. In Colombia, the success at Ernesto Cortissoz Airport led to a new project at Hyatt Grand Bogota."

Sagi Feldman, Business Development Director, Elgressy, Israel.

"TECAM and A.T.E. share common values and are committed to successfully commercializing the product jointly developed under this IFC project and extending the benefits of energy savings to the larger audience in Latin America."

Sunil Tiwari, former Vice President, Global Sales & Marketing, A.T.E., India.

Image © Gorondenkoff/Shutterstock. Used with permission.

3.

Technology Focus, Results, and Impact

During the 4-year implementation period, the TE-SCI program received more than 380 applications from 180 companies worldwide, offering different solutions across a wide range of technology classes. Although most proposed solutions were interesting, the evaluation of TechEmerge advisory teams excluded many due to following key reasons:

- The proposed solutions were at a very early stage (less than TRL 5) often lacking sufficient evidence of validation of the underlying scientific claims, and it would therefore not be possible to pilot/field test the technology within a reasonable time.
- Piloting/field testing of the technology would require significant financing, require construction of costly infrastructure, or need more than 3 years to reach decisive results.[20]
- Innovation in technology or business model was lacking or insignificant and was purely seeking to replicate or scale known and commercially proven technologies/solutions.
- Insufficient interest or demand from adopters for field testing the technology due to lack of sufficient technical and/or financial evidence for the viability of the solution.

Post-evaluation, the TE-SCI program narrowed down to supporting 40 innovators for testing their solutions in 100 pilots covering key technologies classes shown in dark blue in Figure 2. Almost all technologies, except 4, were tested as part of an entire cooling system that would meet the cooling needs of the adopters. About half of the technologies were tested by integration into existing cooling systems, such as embedding IoT into a hotels HVAC system for space cooling and retrofitting existing reefer trucks with phase change materials (PCMs) for cold energy storage.

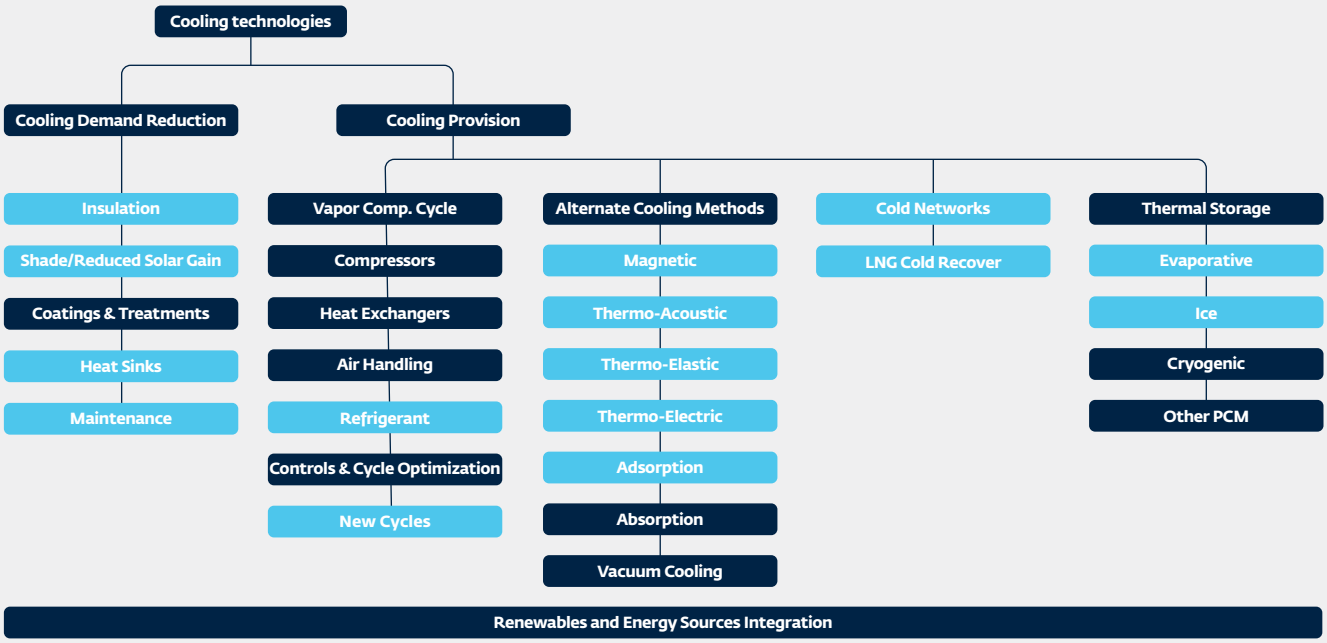
Where no existing cooling system existed, the innovators were tasked to deliver an entire cooling system that combined multiple technology classes to demonstrate the effectiveness of their specific technology to meet adopter needs. For example, innovator Pluss, who is specialized in PCMs needed to deliver a complete solution combining compressors, insulation, and solar PV to meet an adopter's cold storage need.

Where possible, the technology performance was evaluated isolated from the rest of the system. However, as this was not possible in most cases, the technology was evaluated based on its effect on the complete system.

20. These types of solutions were mainly in the insulation, retrofitting, waste cold/heat recovery from industrial plants and district cooling.

FIG 2.

Technologies piloted under TE- SCI program (shown in dark blue boxes) classified according to "Clean Cooling Technology Families Overview"



Credit: Professor Toby Peters, University of Birmingham

Overall, of the 100 pilots,

- **80 pilots** were completed successfully producing sufficient evidence for their ability, or inability, to achieve energy/GHG emissions avoidance[21] and costs savings,
- **7 pilots** are ongoing, as producing sufficient evidence will require operation over multiple seasons and/or use-case scenarios, and
- **13 pilots** were either dropped before starting or was terminated during implementation due to various reasons as outlined in Box 1.

21. IFC uses the term "avoidance" (rather than "savings") to also account for increases in energy consumption and GHG emission that result from intervention aimed at unlocking or improving a specific business or sector (eg. enabling first-time access to cold chains in rural communities). In such cases, energy use and emissions may rise where there was previously none, but the intervention still avoids higher emissions that would result from less efficient alternatives.

Box 1.

Why do pilots and/or technologies fail?

TechEmerge defines "success" as a pilot that has produced sufficient evidence for their ability, or inability, to deliver anticipated results and outcomes as agreed between the innovator and adopter. Despite the diligent process TechEmerge deploys to evaluate the technologies proposed by the innovators, pilots sometimes fail due to a wide range of reasons such as export/import challenges, adaptation of technology to new use case or user needs, damage due to wrong installation, and/or unreliable operation of the technology. Whereas these may be viable reasons, **TechEmerge observes that the failure stems from following key root causes:**

- **Weak organizational capacity of the innovator** who are typically early stage and young startups that have not yet developed their general business skills beyond technology (eg. organizing export, aftersales support).
- **Weak technical capacity of adopters** who are not able to provide sufficient guidance and knowledge to the innovator of the pilot environment.
- **Weak pilot design capability of both innovator and adopter,** including insufficient scoping, planning, and lack of measurement systems needed to validate performance claims.
- **Mission creep,** partly resulting from poor pilot design, but mostly from increasing requests and demand from adopters during implementation.

Energy Use and Greenhouse Gas Emissions

Of the completed pilots, about 70 percent yielded reliable data on key performance indicators related to costs, energy use, and greenhouse gas emissions. This data indicated a strong correlation between energy savings and the avoidance of greenhouse gas emissions.

About 9 percent of pilots reported that they avoided 85 to 100 percent of greenhouse gas emissions, as shown in Figure 3. These results were largely attributed to specific applications that allowed cooling systems to operate almost entirely off-grid or provided access to cooling in use cases where baselines could not be established (i.e., the baselines were zero).

About 53 percent of the pilots reported greenhouse gas emissions avoidance ranging from 15 to 85 percent. The piloted technologies either: (i) used phase change materials for thermal storage, (ii) improved heat exchange capabilities, or (iii) integrated multiple technologies – such as combining phase change materials with solar energy and better compression.

About 33 percent of pilots reported greenhouse gas emission avoidance of less than 15 percent. The technologies tested in these pilots were either innovations that marginally improved existing or known technologies or improved peripheral aspects of cooling systems, such as lowering chemical use or improving air quality, or they enabled better control and optimization of legacy cooling systems.

In regard to CO_2 equivalent emissions avoidance, TechEmerge observed a range of results from a few hundred kilograms to as high as 750 tons. This range is due to (i) the inclusion of only the emissions avoided during the pilot period, which varied from eight weeks to ten months; (ii) insufficient baseline data to annualize pilot results; and (iii) the inclusion of indirect emissions avoided, such as emissions avoided as a result of reductions in food losses.

FIG 3.

Pilot Results: Energy Avoidance

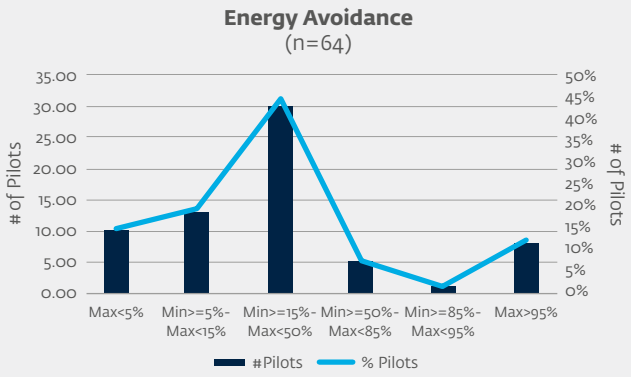
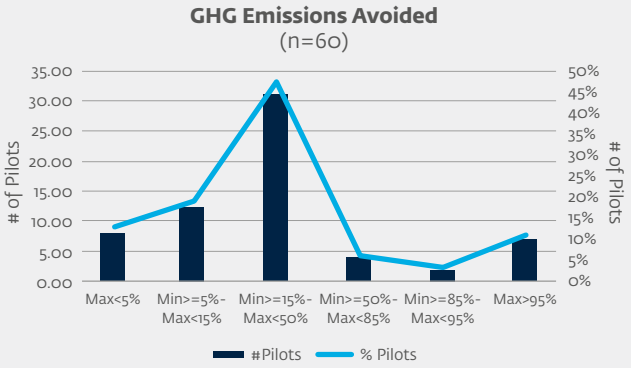


FIG 4.

Pilot Results: GHG Emissions Avoided



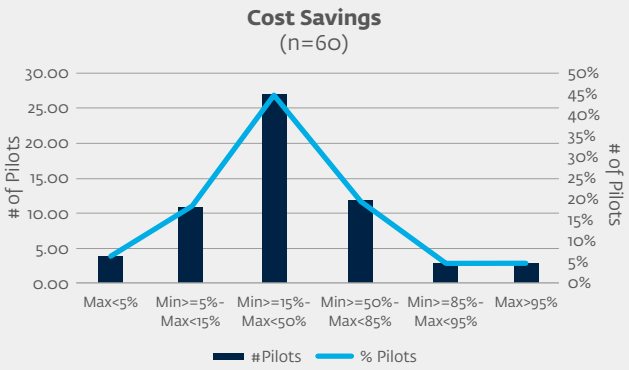
Cost Savings

About 65 percent of completed pilots reported cost savings from 15 to 85 percent, as shown in Figure 5. These calculations only include savings in operational expenses directly related to cooling systems, such as energy, water, and chemical use. They do not cover indirect savings, such as reduced maintenance costs or product losses, and other non-financial benefits such as enhanced reliability, reduced environmental impact, increased operational efficiency, and in many cases, improved comfort or safety.

The vast majority of adopters were only interested in technologies with payback periods of less than five years—which typically translates to a minimum 30 percent in energy saving. However, the results of the TE-SCI pilots clearly indicate an economic case for also considering these broader benefits when calculating payback thresholds.

FIG 5.

Pilot Results: Cost Savings



Box 2.

Outliers

A few pilots reported extraordinary cost savings or cost increases that were subsequently rationalized by revisiting the pilot conditions and data collection methods. The results of these outliers were excluded from the overall program evaluation.

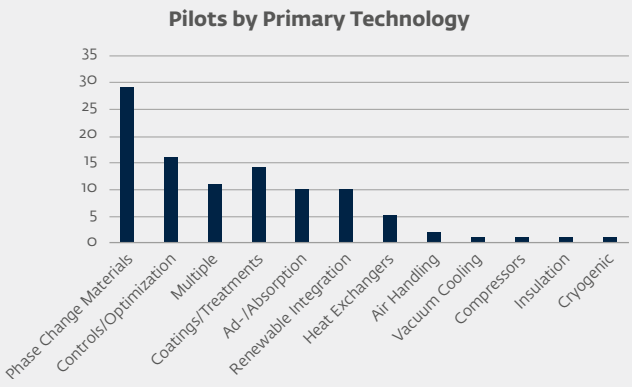
For example, one pilot reported 100 percent cost savings. However, this was because the savings were calculated on an assumption that the new solar-powered system would operate year-round, and did not consider the fact that a back-up generator would be required during prolonged cloudy or rainy periods. Similarly, a pilot for testing PCM boxes for last-mile delivery reported a 37 percent cost increase where the cost of cooling the PCM inserts was added on top of regular non-refrigerated transportation costs.

Technology Performance and Potential

Almost all of the piloted technologies were either tested as a part of pre-existing systems or as part of new systems that combined multiple commercially-available technologies. TE-SCI's financial and technical support aimed to empower adopters to set ambitious targets. However, specifically at the engineering level, adopters indicated a strong preference for less risky, plug-and-play technologies that would only provide incremental improvements to the performance of existing systems.

FIG 6.

Piloted Technologies



As shown in Figure 6, pre-existing or improved technologies such as phase change materials and IoT-enabled building management systems, accounted for almost half of the pilots, even though they promised only moderate results of less than 40 percent in energy and greenhouse gas avoidance. Lesser-known technologies, such as ad/absorption cooling

Table 1.

Results by Technology Category

		Energy Avoidance			GHG Avoidance			Cost Savings (OPEX)		
	# of Pilots	Min	Max	Average	Min	Max	Average	Min	Max	Average
Phase Change Materials	29	17%	74%	38%	21%	89%	34%	13%	69%	34%
Controls/Optimization	16	0%	29%	14%	0%	29%	14%	0%	29%	14%
Multiple	11	12%	100%	59%	16%	100%	60%	12%	97%	72%
Coatings/Treatments	14	-1%	16%	8%	-1%	16%	8%	5%	75%	36%
Ad/Absorption	10	Inconclusive results								
Renewable Integration	9	4%	100%	52%	17%	100%	53%	22%	78%	49%
Heat Exchangers	5	1%	35%	16%	1%	35%	16%	1%	35%	16%
Air Handling	2	13%	13%	13%	13%	13%	13%	13%	13%	13%
Vacuum Cooling	1	Inconclusive results								
Compressors	1		39%			39%			54%	
Insulation	1		0%			0%			30%	
Cryogenic	1	Pilot ongoing								

and vacuum cooling, were not as attractive for adopters, even though they offered the potential for greater energy and greenhouse gas avoidance of more than 40 percent. However, after the first cohort of pilots were successfully completed, adopters gained more confidence and the TechEmerge team recorded a significant increase in interest for lesser-known technologies and pilots that integrated multiple technologies.

The TE-SCI team also observed significant variation in the performance of technologies in the same category, as shown in Table 1. For example, energy savings delivered by phase change material (PCM) technologies ranged from 17 to 74 percent. It was acknowledged that the performance of innovative technologies would, to a certain degree, be influenced by the performance of other technologies in the system. However, the variation indicated that other factors, such as the specific use case, the quality of the solution, and technical knowledge, were equally as important.

Phase change materials (PCMs) from seven different innovators were tested in mobile or transport solutions and in stationary or cold storage applications. These 29 pilots delivered energy and greenhouse gas emission avoidance of 34 percent and cost savings of 38 percent. In most cases, pilots that exceeded these averages combined PCMs with renewable energy or additional e-battery energy sources. None of the pilots delivered less than 17 percent energy and greenhouse gas emissions avoidance. This indicates that PCM applications could potentially produce savings of 40 to 50 percent when other technologies in the cooling system are better optimized.

Controls/Optimization technologies from eight different innovators were tested in 16 pilots of IoT and advanced software systems. Of these, only one technology was designed for transportation, while the rest were tested in stationary applications in hospitality, retail, and industrial settings. Even though the technologies did not deliver substantial energy or greenhouse gas avoidance or cost savings above a maximum of 29 percent, adopters appreciated the deep insights generated about their cooling systems, including preventive maintenance and opportunities for further improvement.

Multiple technologies in combination were tested in eleven pilots. Technologies from three innovators combined PCMs, optimized compressors, and solar photo-voltaic and batteries to deliver 100 percent off-grid cold storage, while also reducing greenhouse gas emissions to zero. Another two innovators used similar combinations in solutions for long- and medium-haul transport, leading to a 30 percent reduction in total energy use and greenhouse gas emissions and cost reductions of almost 90 percent.

Coatings/Treatments, such as electrolytic cooling water treatments, heat-reflecting films, and ecofriendly additives that improve heat transfer in cooling systems were tested in 14 pilots. Although these technologies did not deliver more than 16 percent of energy or greenhouse gas emission avoidance, they had the least variance and were the most cost-effective and easily deployable solutions.

Ad/Absorption technologies were selected for 11 pilots across regions and different use cases, due to their potential to deliver energy and greenhouse gas emission avoidance and cost savings of over 80 percent. However, except for New Leaf's Greenchill pilots in India and Kenya, nine pilots failed to complete testing, or did not produce conclusive results. Despite this, TechEmerge believes these technologies have the potential to generate highly impactful outcomes.

Renewable integration pilots deployed renewable solar PV energy to power high-grade, commercially available cooling technologies. While one innovator focused on transport applications with e-batteries, the other sought to reduce solar PV energy source losses, optimize the efficiency of air

conditioning, and improve air quality. All nine pilots were completed successfully and delivered energy and greenhouse gas emission avoidance and cost savings of around 50 percent.

Heat exchanger pilots covered testing of improved low-approach cooling towers used in HVAC systems for commercial space cooling. Three out of the five pilots did not deliver noteworthy improvements or efficiency gains. However, two pilots demonstrated improvements in energy and greenhouse gas emissions avoidance, indicating that these technologies are highly dependent on local climatic conditions.

Air handling technologies from two innovators were tested in two pilots. One pilot that sought to transfer and adapt a highly efficient technology from India to the Latin American market demonstrated about 13 percent energy and greenhouse gas emissions avoidance and cost savings, and significant potential to scale. The other pilot explored the nexus between air quality, cooling, and perceived comfort. This pilot clearly demonstrated that better air quality reduced the cooling needs of occupants in common spaces, thereby reducing energy consumption.

Vacuum cooling technology was piloted as a transport application that could be recharged in less than 20 minutes, reduce weight, and provide significant prolonged transit time. Although the technology had proven success in stationary applications, its adaptation for mobile conditions encountered significant challenges and failed to deliver conclusive results. Despite this outcome, TechEmerge believes these types of ground-breaking technologies have potential for high impact.

Compressor technology was tested in an electric reefer unit for short and medium haul transport in Nigeria. Although the product was commercially available from a brand name vendor in developed markets, this pilot assessed its application in African markets and established a benchmark for testing other technologies. As the product was designed for developed markets, substantial modifications were required to adapt the vehicle for implementation. After the modifications, it reported almost 50 percent energy and greenhouse gas emissions avoidance and cooling-related cost savings.

Insulation in the form of affordable, locally made compressed earth blocks was piloted as part of a 150 square meter cold storage facility designed to meet the needs of low-income farmers. The pilot demonstrated that, with further improvement, CAPEX for cold storage facilities could be reduced by two thirds and deliver almost the same insulating properties as those built with conventional sandwich panels.

A cryogenic solution was piloted using innovative carbon dioxide-based cooling technology for cooling at the farm gate. The pilot is still ongoing and will generate data across multiple seasons and crop varieties. So far, indicative results suggest this solution has significantly increased the shelf life of produce, reduced losses, and enhanced affordability, and has the potential to be scaled across a wide range of sectors.

Technology Readiness Level (TRL) Progression

To apply to join the TE-SCI program, innovators were required to self-declare the technology readiness level (TRL) of their solution. This data point was intended for use as a baseline for monitoring technology progression during the pilot process. See Annex 2 for a description of each TRL level.

Sixty percent of the technology solutions progressed at least one TRL level during the TE-SCI implementation period. The remaining solutions did not record any

progression in their TRL levels and were either rated above TRL-8 or the innovators lacked the financial or technical capacity to progress the technology.

During pilot implementation, when TechEmerge technical experts were able to evaluate each solution, it became apparent that almost two thirds of TRLs were overrated by at least one level, and in some cases up to three levels. This was not unexpected, as TRLs are often overrated due to innovators' optimism or limited knowledge of TRL systems. Readiness achieved or demonstrated for a specific use case may also have differed from the use case in the pilot. Although the TRLs were re-rated by TE-SCI experts based on field observations, evaluating and measuring progression was very challenging and, in some cases, caused controversy and dissenting views on rating among stakeholders.

For example, the innovator Purix proposed an air-conditioning solution with solar thermal absorption to cool an adopter's convenience stores. Purix's proposed solution promised 85 percent energy savings, was already commercially available as a substitute for traditional room air-conditioning and had a TRL of nine. For the pilot, multiple units were combined in a daisy-chain to increase cooling capacity, but a range of challenges forced Purix back to the drawing board and lowered the field-based readiness level to TRL-6. Through the pilot process, Purix technology progressed to TRL-7. Although the pilot failed to produce conclusive results in that instance, Purix developed and filed a patent application for a completely new thermal storage technology, starting at TRL-3, that was later deployed in other TE-SCI pilots at TRL-6.

The team did not find a correlation between TRL progression and the success of TE-SCI pilots, as progressions were recorded in both successful and unsuccessful pilots.

Financing

Sustainable cooling innovations have the potential to deliver long term savings in energy consumption as well as climate benefits. However, the technical risks associated with adoption of new technologies and potentially greater upfront costs compared to conventional solutions can deter some adopters. To level the playing field, TechEmerge leveraged grants, combined with commercial and in-kind contributions from adopters and innovators, to help mitigate risks and overcome the cost barriers of piloting new cooling technologies.

On average, grants from TechEmerge met 57 percent of pilot costs across the global program. In Latin America, this figure was 58 percent, while in Africa and Asia grants amounted to 49 percent and 46 percent of total costs respectively. This blended financing approach was used, for example, to pilot low-approach cooling towers, with TechEmerge covering the incremental cost of these innovations versus traditional cooling towers.

This approach proved to be effective in leveraging private sector financing for the adoption of new cooling technologies. **During implementation of the TE-SCI program, the team recorded $113.3 million in private sector financing** in the form of (i) adopter investments to scale the adoption of technology solutions; (ii) financing raised by innovators to scale their technologies in new regions; and (iii) financing raised by innovators to spin off new solutions or improve existing technologies. See Box 3 for an example.

Box 3.

Innovator Secures Financing for Growth

India-based innovator Ecozen participated in a TE-SCI pilot in Nigeria with Agvest Limited and engineering company Lange & Grant to field test a portable solar-powered cold room for fruits, vegetables, and other agricultural commodities. In April 2024, Ecozen raised $30 million from Nuveen Global Fund and other equity investors, with debt support from InCred Credit Fund and the International Development Finance Corporation. Ecozen says the financing will enable it to accelerate its plans to expand its offerings and extend its market reach in Africa and Southeast Asia.

Building an Inclusive, Skilled Workforce, and New Opportunities for the Cooling Industry

During the pilots, innovators typically conducted on average two site visits to install their solutions and address any issues. These site visits, often accompanied by TechEmerge local technical experts, included training to build the capacity of adopters and local delivery partners to operate, monitor, and maintain innovative cooling technologies. In some cases, COVID-19 constraints necessitated virtual interactions. To date, it is estimated that more than 400 staff have received the training, thereby helping to build a pool of skilled workers who can support the growth of sustainable cooling across sectors.

In addition, in 2023, TechEmerge collaborated with the Colombian HVAC industry association, ACAIRE, on a study into the challenges and opportunities for increasing female participation in the cooling sector. The study found that women comprise only 5 to 8 percent of the workforce in the cooling sectors in Mexico and Colombia. They also face discrimination and earn less than their male counterparts, while under-representations in higher-level roles and innovation stifles sectoral growth. Women also make up less than 3 percent of students in cooling-related science, technology, engineering, and mathematics (STEM) technical and vocational programs, making it difficult for companies to meet demand for skilled workers.

Addressing gender gaps with targeted incentives could help build a more diverse and skilled workforce, benefiting companies and the sector in the long term. The study provided a detailed set of recommendations for companies, education and training institutes, and national agencies.

TechEmerge also explored valuable new opportunities for the cooling industry. In 2021, TechEmerge conducted an exploratory study on the potential and viability of harnessing waste cold from liquefied natural gas regasification through a case study of a plant in Kochi, India. A webinar series disseminated its recommendations and practical considerations for project developers and financiers to tap into 84,000 GWh of cold energy, with an investment potential of more than $50 billion. See Annex 3 for more information.

Raising awareness about the benefits of sustainable cooling innovation is also critical to accelerate the adoption of new technologies and business models that improve energy efficiency, lower costs, and reduce climate impacts. See Annex 6 for more detail on how TechEmerge supported knowledge sharing across sectors and regions, and enabled networking and connections to support the growth of the sustainable cooling industry.

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4.

Key Learnings

While TechEmerge generated solid results and impact, even pilots that encountered challenges provided important learnings. The following lessons learned can be leveraged to facilitate the scaling of sustainable cooling solutions in emerging economies.

1. Leverage industry leaders to raise awareness and engage the private sector.

While the private sector and other key stakeholders recognize that cooling is essential to development and to achieve multiple sustainable development goals (SDGs), even in the most sophisticated emerging markets, more needs to be done to raise awareness about the business benefits of adopting innovations. With this in mind, TechEmerge deliberately sought out prominent, well-respected organizations in key target markets and sectors to participate as adopters in pilot projects.

In Latin America, the Colombian Industry Association of Heating, Ventilation, Cooling, and Refrigeration (ACAIRE) played a major role throughout, from assessing local needs, to recruiting adopters, implementing the program on the ground, and raising awareness of the business benefits offered by sustainable cooling innovations. In India, Indian Hotels Company Limited (IHCL) was a key collaborator. Known for its luxury Taj Hotels brand, it is recognized as one of the most progressive top hotel chains in Asia. IFC client, Tabreed India, a leader in district cooling, joined TechEmerge in 2022 to anchor and implement a later phase of the program focused on supporting the development of cooling-as-a-service business models. In Nigeria and Bangladesh, Kobo360 and Chaldal—two IFC equity clients in the e-logistics and e-commerce sectors serving thousands of merchants—also came onboard to anchor the TechEmerge process in their respective countries.

The participation of these industry leaders significantly enhanced the outreach of the TE-SCI program while sending a strong message about the business case for adopting sustainable cooling solutions to the wider sector. It also raised the bar for competitors and encouraged them to minimize their carbon footprints. For a story from the field that illustrates this learning, see Box 4.

Box 4.

Proving the Business Case: Leveraging the Power of Market Leaders

When guests check in to one of the 200-plus properties operated by Indian Hotels Company Limited (IHCL), they are instantly enveloped in a serene environment that seems a world away from the hustle and bustle outside. But in the back rooms, space cooling and refrigeration systems are churning away, enabling hundreds and sometimes thousands of guests to stay comfortable and fed.

Of all building types, hotels have the highest average energy intensity—which means that they consume more energy per built area than office complexes, hospitals, residential buildings, and other developments. In India, for example, 50 percent of energy used by hotels, malls, and large commercial spaces goes to cooling.

"Cooling as a cost head in the hospitality sector is the second largest expense that we have," said Gaurav Pokhriyal, IHCL's Chief Human Resources Officer. ***"It goes without saying that it has a tremendous amount of impact as far as climate is concerned, and not only from an operating efficiency point of view, but also on sustainability."***

Part of the powerful Tata Group, IHCL is a leader in the hospitality sector in India and beyond. IHCL's influence and ability to inspire competitors to lift their game made it a perfect match for the TechEmerge program. IHCL took part in nine pilot projects. Different property types in a variety of climatic conditions were deliberately chosen as field test sites to demonstrate that the business benefits of sustainable cooling apply to the widest possible range of players in the market.

The pilots resulted in median savings of 15 percent in energy use, cooling costs, and greenhouse gas emissions. They also lowered risks for IHCL in adopting new technologies while simultaneously enabling innovators to test and fine-tune their cooling solutions in real world conditions. IHCL's partnership with TechEmerge succeeded in firmly embedding cooling in the company's sustainability goals. Seasoned technical expertise provided by TechEmerge also strengthened the motivation, capacity, and confidence of IHCL engineering teams to search out and adopt sustainable cooling solutions.

"This experimental phase we have undertaken with IFC will genuinely in the long run provide a tremendous amount of benefit and learning not only for Indian Hotels Company but also for the sector at large," said Gaurav Pokhriyal.

IHCL's participation in TechEmerge inspired others in the sector to seek out cooling innovations and to launch their own sustainability initiatives. India is one of the world's fastest growing cooling markets, and by leveraging the power of local market leaders, TechEmerge accelerated the adoption of energy-efficient, climate-smart cooling where it is needed most.

Box 4.

Proving the Business Case: Leveraging the Power of Market Leaders (continued)

The climate-smart cooling tower from Paharpur is part of a TechEmerge pilot at the Taj Palace Hotel in New Delhi, India. Photo by Chirag Patnaik/IFC.

2. Stronger incubation, verification, and market-validation systems that better connect innovators, investors, and adopters are vital to overcome early-stage risks associated with sustainable cooling technologies and business models.

A small group of well-established multinational companies currently dominate the global cooling ecosystem, securing them a strong advantage over early-stage innovators trying to break into the market. For example, young innovators often lack connections with private sector clients that would enable them to demonstrate the commercial readiness or suitability of their product in new target markets. Moreover, early-stage innovators of sustainable cooling technologies are often poorly linked to academia—where game-changing technologies are incubated and paths to minimum viable products and solutions are established. Without these connections, it can be hard for new

innovators to properly test and validate their solutions, or to provide clients with sufficient impartially verified evidence that their technology works.

To address these ecosystem challenges, TechEmerge supported the creation of the Cooling Innovation Lab at the Indian Institute of Technology in Jammu. The lab offers to rigorously test and evaluate sustainable cooling innovations to ensure they are deployable in a real-world context. In doing so, the lab acts as a much-needed catalyst to bridge early financing and technical gaps in the cooling market and cements links between cooling innovators, private sector adopters, and the academia. It also mobilizes investment by providing an early opportunity for innovators to connect with adopters and local delivery partners, along with verified performance data to enhance potential partners' confidence and understanding of the solution's technical details.

TechEmerge also contributed to stronger incubation and verification systems in Africa. During COP26, TechEmerge facilitated the signing of an agreement between IFC, the UK Department for Environment, Food and Rural Affairs (DEFRA), and the Rwanda Environment Management Authority to support the Africa Centre of Excellence for Sustainable Cooling and Cold-Chains (ACES). This is expected to help innovators establish a foothold in the region, provide growth opportunities, enhance investment in sustainable cooling businesses and solutions, while also transferring much-needed technical skills. See Box 5 for more details.

On other occasions where innovators needed support to address challenges in delivering pilots or improving their solutions, TechEmerge encouraged them to connect with academic institutions. For example, in Nigeria, TechEmerge facilitated a collaboration between TAK Logistics, the International Institute of Tropical Agriculture in Nigeria, the country's National Yam Farmers Processors Marketers Association, the engineering company Penuel Integrated Concepts and a cooling technology company KSR Power & Engineering Limited. Together with TechEmerge, they designed and built an innovative cold store that extended the shelf life of yams by four months compared to traditional storage sheds. Scaling this innovation has strong potential to provide affordable cooling to farmers while significantly reducing their losses which is currently more than 40 percent. See Annex 4 for this story from the field.

Innovators also need more holistic support to grow their businesses. Cross-border or international expansion is a primary area where targeted support for high-potential cooling solution providers has generated encouraging results. For example, Indian companies like TESSOL and Ecozen have leveraged TechEmerge to pilot their solutions in Nigeria. Danish innovator Purix has conducted pilots in Kenya, Vietnam, Mexico, and Nigeria. Israeli company Elgressy has worked with TechEmerge in Mexico, Colombia, and India. Access to new markets—and verified capacity to execute expansion strategies with support from TechEmerge—can be a compelling data point for potential investors, who can access pilot outcomes and factor them into their decision-making.

Box 5.

Creating Ongoing Impact with the Africa Centre of Excellence for Sustainable Cooling and Cold-Chains

As part of TechEmerge's strategy to accelerate the adoption of sustainable cooling innovations, the program partnered with the Africa Centre of Excellence for Sustainable Cooling and Cold-Chains (ACES) in Rwanda. The partnership supports the ongoing development, testing, demonstration, and uptake of energy-efficient, affordable, climate-smart innovations in the region.

ACES focuses on solutions that meet growing demand for cooling in the health and agriculture sectors, while also ensuring access to cooling for all who need it. These include innovations that provide reliable and consistent cooling for vital temperature-sensitive vaccines. Solutions to store and transport perishable produce are also needed, with food loss and waste currently accounting for a 12 percent reduction in Rwanda's gross domestic product.[22]

"Equitably turning food loss into nutritionally available food is essential for Africa's sustainable development, as well as building the food systems that are used to feed people in times of uncertainty," said Professor Toby Peters, advisor and Director of the Centre for Sustainable Cooling at the University of Birmingham and TechEmerge Technical Advisor.

TechEmerge provided grant funding for high-potential TechEmerge innovators to ship their technology to ACES' facility, where they are tested under local conditions and showcased to potential adopters. The pilots also include the training of ACES staff in use and maintenance of sustainable cooling equipment.

The selected technologies include:

- **A five-kilowatt off-grid solar-powered cooling system** developed by Danish designer Purix, with thermal storage and power backup from a photovoltaic system for an insulated cold store, as well as a 2.5 kilowatt solar-powered cooling system for air-conditioning and storage applications.

- **Two solar-powered chest freezers** with Li-ion batteries, phase change material (PCM) backups. and IoT-enabled remote monitoring to enable reliable cooling in off-grid settings, developed by French Nigerian innovator Koolboks.

- **A six-meter refrigerated box for long-haul transport** of more than 48 hours, lined with PCM-filled plate and aided by solar panels mounted on top of the truck and Li-ion batteries under the chassis, developed by Turkish innovator ATC.

22. https://www.unep.org/topics/energy/cooling/africa-centre-excellence-sustainable-cooling-and-cold-chains-aces

Box 5.

Creating Ongoing Impact with the Africa Centre of Excellence for Sustainable Cooling and Cold-Chains (continued)

- **Insulated boxes and phase change material inserts** from Indian innovator Tessol that provide passive, emission-free cooling for autonomous refrigerated transport of chilled and frozen products for short and medium distances, along with a blast freezer for the PCMs.

In addition to enabling sustainable cooling innovators to enter and grow their business in this important market, it also transferred knowledge gained during the TechEmerge program and created pathways to ensure ongoing impact.

ACES, which also conducts research, awareness-raising, and technical capacity-building, was established by the governments of Rwanda and the United Kingdom, the United Nations Environment Program, the Centre for Sustainable Cooling in the United Kingdom, and the University of Rwanda. ACES is currently developing specialized outreach and knowledge establishments (SPOKEs) to demonstrate solutions in rural communities and accelerate the adoption of sustainable cooling innovations in local markets.

Tessol staff working with the ACES team in Rwanda. Photo by ACES.

3. New blended funding models are needed to shorten the timeframe between successive rounds of growth funding for sustainable cooling innovators.

Early scoping missions conducted by TechEmerge indicated that there were only modest numbers of cooling innovators globally. A lack of access to stage-appropriate financial instruments may be contributing to this. In addition, sustainable cooling is not a well-defined asset class within the larger umbrella of climate investing. While the market tends to view cooling innovators through a traditional venture capital lens, most investment opportunities in cooling businesses do not conform with the typical return profile of the venture capital asset class.

Cooling innovators are predominantly asset and capital expenditure (CAPEX) heavy businesses with relatively long gestation periods. This often extends the duration between funding rounds for cooling innovators and delays the launch of mass market-ready cooling innovations. At this stage, innovators often lack funding to demonstrate the performance of their innovation to the market or to convince investors that these new solutions are as reliable as conventional technologies. This stunts growth prospects even further, as do adopters' CAPEX budget cycles and their risk aversion to new technologies.

To level the playing field, TechEmerge leveraged grants, combined with commercial and in-kind contributions from adopters and innovators, to help mitigate the risks and overcome the cost barriers of piloting new cooling technologies. On average, grants from TechEmerge met 57 percent of pilot costs across the global program. Similar approaches could be used to determine the right amount of blended capital to support the growth and sustainability of novel cooling technologies and business models.

New instruments should be developed and deployed across the debt-to-equity spectrum to meet the funding needs of cooling innovators with varied growth trajectories. Cooling innovators with relatively higher growth potential may require patient equity injections early in their development cycles to prove their business models. Others may require access to working capital in the form of guarantees or asset-backed loans to fulfill pending orders. Given the nature of the risks involved, different amounts of subordinated capital and varied blended finance structures are needed to help meet the financing needs of cooling innovators. For more insights from an innovator's perspective, see Box 6.

When looking at climate financing in general, the market does not fully factor in the costs of traditional cooling technologies, which results in so-called negative externalities. Negative externalities occur when one party imposes indirect costs onto another. For example, a company may make decisions based only on the direct costs and profit opportunities from production, while passing on the indirect costs of its greenhouse gas emissions to others. Addressing externalities requires a coordinated mix of policy interventions and pools of sub-to-non-commercial capital to identify, test, and—once techno-commercial feasibility is established—to scale the adoption of more sustainable cooling technologies and business models.

Box 6.

Return-on-Investment: Scaling Sustainable Cooling Innovation

How do you turn a great idea into a profitable, sustainable venture? For climate-smart cooling innovators like Pluss Advanced Technologies, securing growth capital is a make-or-break factor with implications not only for the business itself, but also for global efforts to achieve climate goals.

Pluss, which is headquartered in India, conducted seven TechEmerge pilots in Latin America and Nigeria with a wide range of companies, including leading local dairy, pork, and poultry operations, a cold chain logistics company, and a manufacturer of ambulances, medical units, and rescue equipment.

"Taking part in TechEmerge helped us to expand our business networks and ensure our sustainable cooling innovations meet the needs of the widest possible array of companies and sectors," said Pluss Managing Director, Samit Jain.

The pilots used solar power and advanced phase change materials for temperature-controlled storage as well as short and long-haul transport. The results enabled Pluss's partners to meet their cooling needs while reaping fuel savings of 20 to 100 percent. Greenhouse gas emissions also fell by similar amounts.

In 2021, Pluss was acquired by Carborundum Universal Limited (CUMI), one of India's leading business conglomerates, in a deal worth approximately $13 million. However, sustainable cooling businesses often come with high upfront asset and capital expenditure costs, while the benefits delivered by their innovations—for example lower energy consumption and operating costs, as well as a reduced carbon footprint—take longer to realize. This short-term outlook can hamper growth prospects.

"We need to change the metrics for return on investment," said Jain. ***"Many investors ask, can I get my payback within one or two years? That is a challenge with any new technology because it takes time for scaling up to happen, for mass production, and this is directly linked to how efficient one can become. Also, what about the cost of climate change? We cannot put a number on that."***

Jain said several European governments have successfully used policies and tax incentives to increase appetite for investment in sustainable cooling technologies, and emerging market governments should follow this lead. He says development finance institutions like IFC also have a role to play.

"When they fund businesses to conduct sustainable cooling pilots, like TechEmerge did for example, they could include a clause that requires adopters to scale up their use of these solutions if the pilot proves successful," said Jain. ***"Organizations like IFC could also take on a little more risk by leading funding rounds and investing earlier in climate-smart innovators."***

Box 6.

Return-on-Investment: Scaling Sustainable Cooling Innovation (continued)

"When you are a brick-and-mortar innovator not a digital company, trials are needed and adopters need convincing, so the gestation period to achieve large, steady sales numbers is fairly long," said Jain. ***"Perhaps we need new solutions, such as funding pools in the investment community that could be used for smaller companies, rather than investing only in those that will become billion-dollar companies."***

Jain says innovators also need to consider whether potential investors share the same goals and values, and in CUMI's case, its expertise in material science and its global footprint have enabled Pluss to expand while also bringing together two companies that put people and the planet first.

An adopter's staff member working with Pluss' equipment during pilot implementation. Photo by IFC.

4. Technical advice and independent monitoring and evaluation of cooling innovations can help to overcome 'business-as-usual' constraints and risk-adverse mindsets.

As noted earlier, private sector adopters often tend to rely on a handful of well-established heating, ventilation, and cooling (HVAC) vendors with ample documentation to prove the performance of their technologies. Adopters may view young cooling companies as risky—especially in cases where uninterrupted cooling is mission critical—and harbor doubts about innovators' abilities to install and integrate new solutions into pre-existing cooling systems or offer reliable after-sales service.

To shift risk-adverse mindsets, TechEmerge invested significant time and resources in encouraging sustainability managers at leading emerging market corporates to pilot new climate-smart cooling technologies. TechEmerge mobilized seasoned HVAC experts to help program participants design test beds and supported adopters' site engineers and building managers when integrating new solutions into their existing cooling systems. The technical support and expertise provided by TechEmerge was especially effective to bridge different opinions and build consensus between innovators and adopters on a wide range of issues during pilot implementation.

TechEmerge also supported innovators and local delivery partners, such as engineering firms, with access to technical experts in specialized fields, such as HVAC for built environments, cold chains, cooling-as-a-service business models, and more. This enabled the innovators to enhance their understanding of how their solutions would likely perform in real-world conditions, effectively resolve implementation challenges, and adapt their cooling solutions to local conditions.

TechEmerge also facilitated third-party monitoring and evaluation to independently report on savings and climate benefits, thereby building confidence among adopters considering investments in new cooling solutions. In some pilots, this approach proved critical in building mutual trust between innovators and adopters, and it holds significant potential to accelerate the adoption of cooling innovations. See Box 7 for more details.

Box 7.

Scaling Cooling Innovation through Independent Monitoring and Evaluation

For many companies, the uncertainties associated with adopting an innovative climate-smart technology or business model can be daunting, especially for those that need uninterrupted cooling. The TechEmerge team found that many adopters lacked confidence in the technical performance reported by cooling technology vendors. Nor were they able to validate these results themselves.

To address this barrier, TechEmerge offered financial and technical support to de-risk investment and accelerate the adoption of innovative cooling solutions. To build trust, TechEmerge also encouraged innovators and adopters to work with third party engineering companies and monitoring and evaluation firms to independently verify the benefits of sustainable cooling technologies.

Box 7.

Scaling Cooling Innovation through Independent Monitoring and Evaluation (continued)

In Mexico, local engineering company Graco Mexicana field tested an electrochemical water treatment solution, known as EST, from Israeli innovator Elgressy and found it significantly improved the performance and environmental sustainability of cooling towers. Graco Mexicana was keen to move forward as Elgressy's local distribution partner, but it ran into problems convincing clients to invest in the technology.

"Despite our well-documented results on water, energy, and chemical savings, our clients still did not trust it due to the significant number of variables we were not able to control," said Carlos Gracida, Director of Graco Mexicana. ***"We found ourselves locked in endless unproductive discussions with our clients that prevented us from moving to real commercial negotiations."*** So Graco engaged independent monitoring and evaluation company SETRI to evaluate and document the results of Elgressy's innovative solution.

"This changed the game," said Gracida. ***"The strong methodological approach and in-depth expertise SETRI used produced even better results than what we initially documented, and this was key in convincing our clients that the technology truly delivered what it promised."***

In India, TechEmerge worked with New Delhi-based Environmental Design Solutions (EDS) to independently monitor and evaluate the benefits of the technologies being tested.

"Vendors can make promises about the technical potential of their solution, but whether that is borne out in the field is another matter," said EDS Director Tanmay Tathagat. ***"At EDS, we assess technologies in a very scientific and objective way, including how they are selected and sized, where they are positioned, how to integrate them into larger systems, and how to operate and maintain them."***

"Rather than just doing an analysis on paper, it is essential to look at technologies in a real-world situation, like TechEmerge has done through its pilots," said Tathagat. ***"The same goes for innovation providers—they have to understand the operations, do pilots on client premises, and get independent measurement and verification."***

"Often anything that's over two to three years of simple payback is not seen as a viable investment, and definitely climate benefits are not factored into financial decision making," said Tathagat. ***"So, we do a proper accounting of savings, quantified with specific baselines, that anyone can scrutinize and confirm. That builds the confidence of owners and operators to move forward."***

Box 7.

Scaling Cooling Innovation through Independent Monitoring and Evaluation (continued)

Tathagat says partnering with TechEmerge has reinforced the importance of taking an integrated approach to measurement and verification among the EDS team too.

"Rather than coming towards the end of a process, TechEmerge engaged us at the beginning, from selection of the site and technologies, vetting the design, reviewing installation and commissioning and integration with larger building systems and operations," said Tathagat. ***"Our team now sees itself as integral to this holistic process of change."***

EDS team taking measurements when evaluating a TechEmerge pilot. Photo by EDS.

5. New business models are needed to fuel innovation and overcome the persistent challenges of neglect, split incentives, and skills shortages.

Although cooling is essential and widely used across various sectors, it is typically a enabling function rather than a core focus for most companies. For instance, in the health sector, the primary goal is to save lives and enhance well-being—not to manage cooling systems. However, reliable cooling is still critical for preserving medicines and ensuring patient comfort. Because cooling serves as an enabler rather than a central priority, efforts to improve its efficiency are often overlooked. In sectors where cooling is mission critical, such as hospitality or data centers, adopters are highly risk averse and often lack the in-house expertise and technical capacity to evaluate, integrate, and maximize the benefits of new sustainable cooling technologies, and therefore opt for older and proven technologies. Adopters also tend to invest very little in developing the skills of their engineers and technicians, exacerbating skills shortages.

In such sectors, the issue of 'split incentives' is a common challenge for adopting innovative, energy-efficient technologies that may have higher upfront costs. For example, a property developer may build a hotel or a large retail space, but another company may ultimately manage the day-to-day operations of these buildings. In such cases, the developers will have less incentive to integrate these technologies into their building designs as they may not benefit from the savings. In contrast, the operators will not have an incentive to finance an asset that they cannot transfer to another location at the end of their operation contract.

TechEmerge sought to address these challenges through multiple cooling-as-a-service (CaaS) initiatives. CaaS is a pay-as-you-go model that seeks to eliminate high upfront investment costs and reduce risks associated with adopting innovative cooling solutions. End customers pay only for the cooling they consume, while supply and maintenance are delivered by the CaaS provider for a fixed fee.

TechEmerge partnered with IFC client Tabreed India to explore an aggregation mechanism for the CaaS business model. A total of 17 pre-feasibility studies investigated the viability of this model in India through small and medium sized companies specialized in cooling and energy efficiency. While this model needs further investigation, TE-SCI observed growing market interest in CaaS and a desire among companies with sizeable cooling footprints to outsource their HVAC plant operations to CaaS providers.

In Africa, TechEmerge also supported innovators such as Eja-Ice and Koolboks to scale the adoption of their technologies through the CaaS business model. See Box 8 for a relevant story from the field. In Latin America, Graco Mexicana successfully promoted a similar 'equipment-as-a-service' model which lowered adopters' up-front costs and maintenance and ultimately accelerated the adoption of Elgressy's solution for cooling towers.

For CaaS providers to realize the commercial benefits of owning and operating a cooling technology or facility, they must optimize operations. Whether integrating new but tested cooling technologies into brownfield environments or introducing these technologies during the design phase of greenfield projects, CaaS models are inherently better at driving cooling innovation relative to traditional business models.

Box 8.

Affordable Solar-powered Cooling Keeps Nigerian Businesses Running

In the town of Ikeja in Nigeria, Adeola Mojodi works as an agent for Fan Milk, storing a range of ice cream and yogurt for local pushcart operators and other last-mile vendors. However, power outages of more than eight hours per day are common in Mojodi's neighborhood, and to keep his freezers running, he often relies on back-up generators powered by expensive and polluting diesel.

To tackle this cooling challenge, Fan Milk, a subsidiary of Danone, teamed up with TechEmerge and cooling innovator Koolboks to pilot an affordable solar-powered freezer. The technology also uses Li-ion batteries and phase change materials to maintain constant temperatures, and is equipped with IoT monitoring of temperature, battery life, and humidity. During a recent power outage, Mojodi says Koolboks' freezer "saved the day". No stock was spoiled and local supply and delivery continued as normal.

Koolboks is headquartered in Paris and Lagos. The innovator says sustainable cooling technologies are key to tackling food waste and loss—a major problem in Nigeria and across the world.

"Up to 40 percent of their food is spoiled before it reaches the market," said Co-founder Ayoola Dominic. ***"Some people work all day and night to put their savings together to buy food stocks only for them to lose it the next day due to lack of refrigeration"***

Koolboks also conducted TechEmerge pilots with Nigerian poultry company Amo Farm, testing a solar-powered freezer for poultry products, as well as a refrigerator for vaccines, to gauge opportunities for Amo Farm to diversify its operations.

During the pilots, the freezers ran without the need for grid power or generators, resulting in 100 percent savings in fuel consumption and greenhouse gas emissions. The ability to consistently maintain desired temperatures also ensured high product quality, which in turn improved sales.

The pilots were not without challenges. Koolboks' products were originally designed for individuals and small and micro retailers, but in Nigeria, it needed to cater for large emerging market corporates. During field tests, the freezers were also opened much more frequently than expected, and cloudy conditions presented difficulties too.

The Koolboks team was not discouraged. Instead, it went back to the drawing board and came up with solutions that delivered a more robust and cost-effective design. The company also adapted its business model to include pay-as-you-go options for small businesses and cooling-as-a-service for large corporates.

Box 8.

Affordable Solar-powered Cooling Keeps Nigerian Businesses Running (continued)

Fan Milk subsequently ordered an additional 300 Koolboks freezers, a first step towards a supply agreement for 20,000 units across West Africa. Koolboks will also supply 8,000 vaccine refrigerators for the Association of Community Pharmacists in Nigeria.

Koolboks has gone on to secure new investment to fuel its expansion. It won the 2022 Startup the Future Award sponsored by the multinational energy corporation Galp and was selected as a finalist in several climate and innovation awards. It now plans to set up a production facility in Nigeria with an annual capacity of 72,000 units to meet growing demand for cost-effective, climate-smart cooling.

Koolboks' freezer stores frozen poultry for delivery to last-mile customers in Nigeria. Photo by IFC/Freya PR Agency.

6. Transformational shifts in how cooling is produced, consumed, managed, and evaluated are overdue.

Over the 4-year program, the TechEmerge team noted the need to transform current approaches to how sustainable cooling is produced, consumed, managed, and, importantly, evaluated. Adopters tended to assess the potential of new technology only in terms of whether it could replace or upgrade existing equipment and maintain the status quo. Other potential advantages, such as reducing the need for cooling, and long-term operational, financial, and climate benefits were rarely considered.

For example, for space cooling, the adopters evaluated the technologies by their ability to produce the tons of refrigeration (TR) that was currently produced by existing equipment, and their financial feasibility. While working closely with adopters and assessing their existing technologies and practices, it became clear that little attention had been given to exploring passive cooling solutions to reduce thermal

refrigeration demand, or to adopting improved measurement, data collection, and thermal storage technologies to better manage and optimize the cooling process. After working with adopters to understand their needs, the TechEmerge team often found that the combination of lower-grade, more affordable cooling technologies and improved business practices provided a more sustainable solution. See Annex 4 for a story from the field on a low-cost solution to improve food security and grow incomes for yam farmers.

Similarly, adopters in all sectors usually set a pay-back period of two to three years when assessing the financial feasibility of new cooling technologies. However, their calculations only considered the costs of purchase, installation, and energy savings—while savings from lower water and chemical consumption, reduced waste, other operational benefits such as reliability and availability were almost never factored in.

7. Cooling innovators often need to develop their business and entrepreneurial skills.

Innovators, including those in sustainable cooling, can suffer from tunnel vision by focusing solely on their technology, while neglecting the skills needed to secure clients and scale their business. For example, innovators often assumed their solution would work 'off the shelf' in all markets and for all clients. However, specific user needs and capacity, pre-existing equipment, local economic and environmental conditions, and business practices and regulations can vary dramatically. For these reasons, innovators need to be prepared to modify, integrate and enhance their offerings to meet local contexts and unique client needs. See Annex 4 for a story on how innovator Tessol adapted its technology for Nigerian conditions.

TechEmerge observed that business skills such as sales and marketing, technical support, measurement and analytics, logistics, reporting, and project management, are as important as technology and technical skills. Even language barriers can lead to sub-optimal outcomes if left unaddressed and jeopardize attempts to scale.

For example, a Latin American innovator's pilot in Nigeria using insulation and active and passive cooling technologies. produced strong results and garnered very positive adopter feedback. However, in South Asia, the company was unable to provide sufficient customer support in local languages or meet challenging import and export requirements.

TechEmerge found that local delivery partners, for example engineering firms, could help innovators overcome barriers by providing on-the-ground knowledge, contacts, and expertise. See Box 9 for a story from the field on how local delivery partners can make or break innovators' efforts to enter and thrive in new markets.

As noted, while adopters need cooling, most often this is not their core business and innovators may need to support their clients in understanding the benefits innovative cooling technologies brings to their cooling practices. For example, although ice cream is normally transported at -18°C to -25°C range, a manufacturer was deploying a practice of cooling their reefer trucks to -35°C to safeguard and gain a few more hours to save their products in case of breakdown of refrigeration equipment during transportation. This practice was abolished when the Turkish innovator ATC developed a fully electric refrigerated truck-box quipped with phase change materials, solar photo voltaic panels and e-batteries. They demonstrated the new truck-box would maintain -18°C for at least 6 hours even if critical cooling equipment should break down. The new technology enabled the manufacturer to reduce transportation costs, enhance safeguards to preserve the quality and safety of their ice cream, and reduce losses.

Box 9.

Local Partnerships Lower Barriers to Cooling Innovation

To accelerate the adoption of vital sustainable cooling solutions, IFC's TechEmerge program carefully matched high-potential innovators across the world with leading corporates in emerging markets—but sometimes additional connections were needed. Local delivery partners, such as engineering companies, manufacturing firms, and distributors, participated in several TechEmerge pilots in Latin America, Africa, and South Asia, and provided specialized expertise and knowledge that can make or break entry into new markets.

At two sites in Mexico, Israeli innovator Elgressy partnered with local engineering firm Graco Mexicana to field test a unique plug-and-play electrochemical solution, known as EST, that improves the performance and sustainability of cooling towers.

"In Israel, we do the research and development, manufacturing, and sell and implement the systems ourselves," said Sagi Feldman, Business Development Director at Elgressy. ***"But internationally we need local delivery partners for sales and servicing."***

The pilots improved the energy efficiency of the water towers and largely eliminated the use of expensive and environmentally unfriendly chemicals, including salt. The automated system also lowered water consumption by up to 35 percent, and to add to the benefits, all of the water recycled from the cooling tower was suitable for irrigation.

"Return on investment for the EST system can be very short depending on the price of water, which makes it very sensible and feasible where water is costly," said Feldman.

However, despite strong technical results and operational savings of 40 percent, a similar pilot in India did not gain traction due to the lack of a reliable local partner.

"In India the pilot was structured as a direct relationship between us and the client," said Feldman. ***"From our experience, it's important to have a strong local partner taking responsibility for pilot execution and data collection."***

In Mexico, Elgressy's local partner, Graco Mexicana, imported the EST equipment, installed and operated the technology, provided technical support, and in some cases, monitored and evaluated the results. Graco Mexicana's involvement also helped to overcome differences in language, culture, local business practices, and regulations that can pose challenges when entering new markets.

Box 9.

Local Partnerships Lower Barriers to Cooling Innovation (continued)

"In Mexico, the market for solutions to save water and energy is high and there is a lot of room for innovation," said Carlos Gracida, Director of Graco Mexicana. ***"We want to be part of this chain offering sustainable cooling for the industry."***

The successful pilot has already generated a strong pipeline of clients for Elgressy, and local partners will continue to help it meet growing demand for sustainable cooling in Mexico and beyond.

Representatives from Graco and Elgressy discussed their pilot experience at the TechEmerge Sustainable Cooling Summit. Photo by IFC/Creative Media.

Image © Snowman Logistics.

5.

The Future of Sustainable Cooling

While the technologies piloted under the TE-SCI program have shown benefits in energy efficiency, affordability, and greenhouse gas emissions avoidance, they largely represent incremental improvements to established solutions. To truly advance the state of the art and anticipate future challenges, entirely new and transformative technologies and practices are essential.

Blind Spots

In designing and planning the TechEmerge Sustainable Cooling Innovation program, the team used a wide range of studies, conducted its own research, and held consultations with adopters and innovators to shape priorities and narrow down the sectors and regions where cooling was needed the most. However, during the program's implementation, several 'blind spots' emerged, revealing cooling needs that had not been previously considered in forecasts of future demand. If these needs are not addressed sustainably, they could lead to significant economic and social consequences.

Chill hours: Agrifood companies producing flowers, fruits, and nuts have recorded a 10 to 20 percent decrease in yields because rising global temperatures are depriving plants of 'chill hours'. Chill hours reflect the amount of time that certain plants require to flower or fruit. Some producers are deploying passive cooling to partially compensate for this, and they are now also seeking active cooling technologies to address this issue.

Animal produce: The productivity of livestock and yields of dairy, meat, and poultry are highly dependent on ambient temperatures. As global temperatures rise, producers expect yields and productivity to fall. Although rudimentary technologies such as fans or misting are used to keep animals cool, producers are seeking more effective active cooling technologies.

Academic achievement: Studies indicate that heatwaves and other extreme temperatures can negatively affect student performance. During TechEmerge pilots, two universities in Mexico made it clear they wanted sustainable cooling technologies not only to reduce their carbon footprint, but also to support their students. See Annex 4 for a story from the field on how innovative TechEmerge pilots kept students cool and productive in Mexico.

To address what we know, but also to respond to needs and challenges that are not yet visible, greater focus is needed on research and development of "leapfrog" technologies.

Needs-driven Approach

The TechEmerge team observed that many adopters had not invested in properly assessing their cooling needs. This resulted in oversized or undersized coo-ling systems and operational inefficiencies. Indian innovators Zenatix and IoTomation, Nigeria's Tunasha, and Konverter from Mexico all piloted control and cycle optimization solutions that monitor many parameters and determine real-time demand for cooling. Backed by advances in artificial intelligence and machine learning, these innovations have the potential to greatly reduce energy use and greenhouse gas emissions and deliver cost savings.

The needs-driven approach also demonstrated its benefits across other pilots. For example, Indian e-grocer BigBasket

suffered cold losses from its last-mile refrigerated warehouses where they stored products in various temperature ranges. In collaboration with their vendors, they designed a solution that divided these cold stores into smaller, reach-in compartments cooled with phase change material inserts. This not only saved energy but also improved working temperatures for employees. Similarly, by focusing on the need of farmers to get access to cooling they could afford, TechEmerge turned to locally made adobe bricks to build a cold store for yams in Nigeria. Although this innovative cold store does not provide the ideal cooling, it cost less than one-third of similar modern storage facilities, enabling farmers to extend the shelf life of yams by four months, reducing losses by 40 percent and almost doubling their incomes. Both pilots are detailed in stories from the field in Annex 4.

"In order to achieve sustainable cooling that is affordable, financially sustainable, and accessible to all who need it, a new needs-driven integrated system-level approach is required that incorporates 'thinking thermally' into energy strategies."

TechEmerge advisor Professor Toby Peters, University of Birmingham, UK.

In contrast to current practices where cooling systems are designed by cooling technology professionals, these examples underline the importance of adopters getting much more involved in assessing and determining their specific needs to ensure that their systems meet exactly what is needed, not more, not less.

Reduce the Need for Active Cooling

As part of understanding cooling needs, it is as important to explore how to reduce demand for active cooling. Starting this exploration at the design stage can produce impressive results. Best example of this approach is Orlar, a vegetable producer in Vietnam, who developed a root-zone cooling technology for hydroponic farming. By effectively controlling temperatures at the plant's roots, Orlar eliminated the need to cool an entire enclosed space, which is usually a necessity in hydroponic farming. To further reduce energy consumption, Orlar partnered with Danish innovator Purix to pilot a solar-thermal cooling system that would enable production of temperate-climate vegetables in regions where it has not been possible before.

Similarly, passive cooling approaches as in IFC's Excellence in Design for Greater Efficiencies (EDGE) certification program have proven that smart design and material selection can achieve savings of more than 40 percent in energy consumption and 25 percent in water use, along with 45 percent less embodied energy in construction materials.

TechEmerge innovators with solutions suitable for retrofit also demonstrated impressive results. For example, innovator Heat Inverse applied an ultra-thin, easy-to-install film on a temperature-controlled truck in Mexico. Its CoolFilm successfully reflected sunlight and heat emitted from inside the truck, ultimately delivering 29 percent savings in fuel consumption and greenhouse gas emissions. With no moving parts, no ongoing energy requirements, and easy application, this passive solution reduces capital expenditure and operational costs in cooling systems.

The results from these examples clearly demonstrate that much more can be achieved through continued innovation in material and process science aimed at reducing the need for cooling.

Leapfrog Technologies

Even though cooling demand can be significantly reduced through a needs-driven approach, global requirements for active cooling will continue to increase. As noted, over the past 100 years technologies for producing cold, such as vapor-compression, have only recorded marginal improvements, and TechEmerge pilots found that even the best available solutions remain far from their theoretical limits. While efforts to improve the vapor-compression cycle are important, more resources should be invested in developing and refining ad/absorption, magnetic, solid state, and other innovative technologies to produce and/or consume cold more sustainably. Academic institutions are well placed to collaborate in these endeavors.

At the TechEmerge Sustainable Cooling Innovation Summit in Birmingham, U.S. innovator Phononics explained how it developed and patented an innovative solid state cooling technology that not only saves energy and eliminates the use of hydroflurocarbons but also enables e-grocery companies to reduce cooling space by up to 50 percent.

Another TechEmerge innovator, Natural Offset Farming (NOF), developed a technology that harnesses liquid carbon dioxide for post-harvest cooling. It can be used in water or hydroponic environments, or for air or ground applications in the field or at the farm gate. The low-cost solution is extremely easy to transport, requires no electricity, and increases the shelf life of fresh produce, thereby helping to reduce food waste and its related greenhouse gas emissions. In a pilot in Mexico with berry farmers, NOF technology doubled shelf life from 10 to 20 days, while largely maintaining the sugar content of the stored berries.

The modular nature of these technologies is hi-ghly scalable and can be adapted for use in data centers, transport, and even space cooling for built environments. However, in order for these leapfrog technologies to scale, multiple factors must first be addressed, such as establishing new supply chains and distribution and service networks and potentially adopting CaaS business models.

Cooling as a Business

In addition to innovative technologies, new business models are essential to secure a sustainable cooling future. As noted previously in this report, one such model is pay-as-you-go cooling-as-a-service. With their specialized cooling and technical expertise, CaaS providers will be able to integrate multiple technologies and expand the frontiers of innovation. They can also promote a more holistic approach in which energy, water, and the Internet-of-Things (IOT) all play a critical role. Innovators, adopters, and other stakeholders should also consider how these factors intersect and impact the piloting and scaling of sustainable cooling solutions.

A Legacy of Continuous Innovation

IFC has launched several initiatives to build on the achievements of the TechEmerge Sustainable Cooling Innovation Program. As detailed earlier in this report, TechEmerge supported the establishment of the Cooling Innovation Lab in India in partnership with Tabreed India and the Indian Institute of Technology. The lab provides state-of-the-art reusable environments to pilot and verify new energy-efficient, cost-effective cooling technologies that lower greenhouse gas emissions, such as IOT-solutions, nanotechnologies, and solar and renewable energy solutions for hotels, shopping malls, data centers, cold chains, transport, and more. Similarly, TechEmerge's legacy of cooling innovation continues through its partnership with the Africa Centre of Excellence for Sustainable Cooling and Cold-Chains (ACES).

In addition, IFC and the UK Department for Energy Security and Net Zero have launched a new $12.7 million sustainable cooling initiative. Leveraging knowledge and expertise generated by more than five years of TechEmerge sustainable cooling operations, the new initiative will help countries and their private sectors to lower emissions from cooling and to take action to adapt to extreme heat. With an expanded scope, it will focus not only on innovative technologies but also on transformative cooling systems for district cooling, space cooling, manufacturing and innovation, cold chains and temperature-controlled logistics, and finance for consumers and small and medium enterprises. It is a global initiative, but will initially focus on Bangladesh, India, Indonesia, Philippines, Thailand, Vietnam, Brazil, Colombia, Mexico, Egypt, Nigeria, Rwanda, South Africa, Pakistan, and Turkiye.

It is hoped that the results, lessons learned, and stories from the field in this publication will be leveraged to further expand on the impact of TechEmerge. We encourage all stakeholders—innovators, adopters, investors, development organizations, and others in the climate, cooling and innovation space—to support even greater efforts to provide cooling for all who need it while mitigating greenhouse gas emissions and building resilience to climate change.

Annex 1 – TechEmerge Overview

IFC's TechEmerge platform is designed to accelerate the adoption of innovative technologies in emerging markets by bringing together a diverse range of stakeholders within a specific sector. Through a structured and curated process, the platform facilitates collaboration between technology providers and local adopters to conduct pilots, build commercial relationships, de-risk investment, and scale solutions that tackle critical development challenges.

TechEmerge stakeholders include:

ADOPTERS – EXISTING OR POTENTIAL USERS OF TECHNOLOGY

Ranging from corporates, NGOs and governmental agencies who are interested in exploring adoption of state-of-the-art technology to improve their operation.

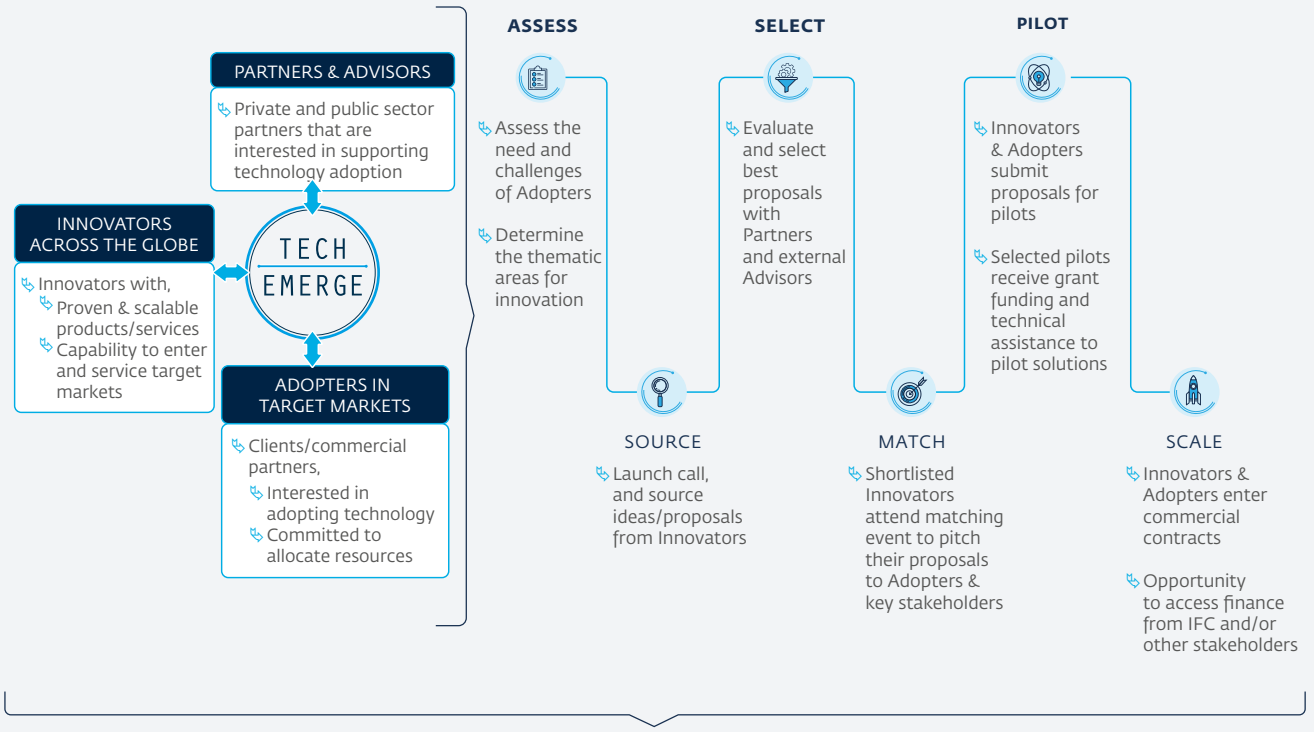
INNOVATORS

Across the world, including homegrown solutions and local delivery partners from the region/country TechEmerge is targeting.

PARTNERS AND ADVISORS

Who are contributing financially or in-kind and working closely with IFC to deliver the TechEmerge process.

TechEmerge stakeholders include:



- Needs driven: Technologies are screened and selected based on existing and future challenges and needs of the future users (corporates)
- Fair and impartial: The technologies are pre-screened and evaluated by a wide network of experts to minimize bias and conflict of interest
- Confidence and risk mitigation: Curation and the follow-through support enables both the innovators and the adopters to increase confidence and minimize risks
- Leadership and support: IFC's involvement as a convener, curator, matchmaker, financier and advisor delivers results and increases potential for business

TechEmerge programs are delivered in close collaboration and coordination with these stakeholders through a *6-step process*:

1 ASSESS

Leveraging IFC's 50+ years of expertise, we identify innovation gaps in emerging markets, and work closely with local companies to understand the challenges and specific needs of potential adopters/buyers.

2 SOURCE

Based on the identified challenges and needs, TechEmerge leverages its global network and reach (e.g. IFC clients, development partners, VC firms, accelerators) to identify innovators with the most suitable and proven technologies.

3 SELECT

Leveraging a global network of advisors, TechEmerge evaluates and selects the technologies in terms of technical validity, business model and best fit for the target markets.

4 MATCH

Through a carefully curated process, we arrange events and meetings for shortlisted innovators to meet top local companies and demo their products and discuss the potential to pilot projects together.

5 PILOT

The matched innovators and adopters are supported to test and validate the technology in the local environment. Innovators and adopters are provided financial support to offset incremental cost of piloting the technology and technical assistance to resolve administrative and technical issues.

6 SCALE

Innovators and adopters that reach a commercial ground may receive additional support to scale the technology in the country/region (e.g. establishing distribution network, local manufacturing/servicing, adoption, etc.). IFC also evaluates financing needs and may invest in companies to scale game-changing innovations.

Global Footprint in Key Sectors

HEALTH
2016 - 2023

Technologies that improved patient outcomes and service delivery at multi-specialty hospitals, primary care clinics, lab chains, pharmaceutical retailers, health insurers, and more.

- Point of Care Diagnostics
- Patient Engagement
- Quality Management
- Operational Efficiency
- Maternal & Child Health

Pilot & Test India

Validate & Replicate Brazil

Scale: East Africa

IN PARTNERSHIP WITH

Ministry of Economic Affairs and Employment of Finland

RESILIENCE
2019 - 2020

Innovations to make disaster risk management smarter, more efficient, affordable, and accurate in the time of COVID-19, while building long-term disaster & climate resilience.

- Remote Solutions
- Warning Systems
- Resilience Analytics

Implemented in partnership with the World Bank and Indian National & State Disaster Management Authorities

IN PARTNERSHIP WITH

THE WORLD BANK · nasscom · IBM · GFDRR · CES · UK Government

SUSTAINABLE COOLING
2020 - 2024

Energy-efficient, cost-effective, and climate-smart cooling technologies applicable in space cooling, transport & logistics, and industrial and commercial applications.

- Space Cooling
- Transport & Logistics
- Industrial & Commercial
- Cooling as a Service

Latin America · **Africa** · **Asia**

IN PARTNERSHIP WITH

UKaid from the British people

Annex 2 – Technology Readiness Levels

The Technology Readiness Levels used in the TE-SCI Program were adapted from the valuable work conducted by TechEmerge advisor, Professor Toby Peters, and his team at Birmingham University.

Level	Level status	Description
TRL 1	Basic Research	Principles postulated and observed but no experimental proof is available. Scientific research has started to be translated into applied research and development.
TRL 2	Applied Research	Basic physical principles are observed/identified. Practical applications of those characteristics are being 'invented' or developed. Technology/Application is still speculative: there is not experimental proof or detailed analysis to support the conjecture.
TRL 3	Proof of Technical Concept	Critical technical functions are proved through experiments and feasibility for application is validated. Active research and development are initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology.
TRL 4	Lab and Test Bench Demonstrations	Lab and Test Bench Demos of sub-systems and key components are underway. Modelling and experimentation with parameters representing future conditions are defined. Application proof-of-concept completed.
TRL 5	Development Prototypes	The system, sub-system, components, or sub-scale units are integrated with reasonably realistic supporting elements ready to be tested in a simulated or representative environment. Critical cost assumptions are carefully investigated, and the feasibility of the proposed manufacturing process is being tested.
TRL 6	Engineering or Demonstration Prototype	Engineering prototype/full-scale system developed and tested in representative/relevant conditions. Proof-of-application is demonstrated.
TRL 7	Operational Prototype (Alpha Product)	Near or at planned operational system, requiring demonstration of an actual system prototype in an operational environment. Prototype can be used for prolonged use at "representative" client or user site. Developer is in control of all planned functions, and interfaces are integrated for monitored trials.

Level	Level status	Description
TRL 8	Production Prototype (Saleable Beta product)	Development is complete, final design and features are set. The product/ technology has been released to a limited appropriate number of clients. All fulfilment procedures under client/users' control and operation are trialed and documented. Technology is proven to work-technology design for production or roll-out is completed and qualified through test and demonstration.
TRL 9	Marketable/ Commercial Product	Technology proven through successful operations in repeated use and being sold in market. Actual application of technology is in its final form and scaling up sales volumes.

Annex 3 – Harnessing Cold Energy from Liquefied Natural Gas

Natural gas is a key component in the global energy mix and accounts for more than 20 percent of total energy supply.[23] When put in context, its contribution is approximately twice that of renewables and more than four times greater than that of nuclear energy. Natural gas is typically delivered to its consumption point in one of two ways: through pipelines in its gaseous form, or—when pipelines are impractical—by cooling it to -162°C and transporting it by ship as liquefied natural gas (LNG). Cooling natural gas to such low temperatures is an energy intensive process, requiring 250-380 kWh of work input per ton of LNG depending on process and operating scale.[24]

When LNG is subsequently re-gasified for consumption, about 200kWh-th/ton of usable cold energy is released. Currently, this cold energy is mostly wasted—typically dumped into the sea—with less than one percent recovered globally. This is partly due to a lack of awareness of the benefits and the costs of harnessing this resource for industrial gas production, power generation, cold chains, space cooling, and more.[25]

Innovative technologies and business models could increase the efficiency of waste cold recovery during LNG regasification processes. Estimates indicate that this could generate more than $50 a ton in economic and social benefits. By 2030, this could offer the potential of 168,000 GWh in zero-emission cooling, opening up an investment opportunity of approximately $50+ billion. In most cases, the use of recovered cold would avoid the need for mechanical cooling, significantly reducing electricity consumption and associated economic and environmental costs.

The Scale of the Opportunity

In 2020, about 12 percent of global gas demand was met by LNG, and about 356.1 million tons were shipped worldwide.[26] If all these cargoes had been regasified and the cold captured, this would have provided 71,224 GWh-th of cooling. LNG consumption is expected to almost double by 2040.[27] At a simple Co-efficient of Performance (CoP) of four, this could generate electricity savings of 17,806 GWh-e per year—which is greater than the annual output of two 1.0 GWe capacity nuclear power stations.[28, 29]

These savings would also help to address the LNG sector's carbon footprint. At a global average carbon intensity of generation of 463gCO_2/kWh-e, annual saving from the application of waste cold would be equivalent to approximately 8.2 million tons of CO_2e.[30]

23. International Energy Agency (2021), World Energy Outlook 2021, IEA.
24. J. Zhang, H Meerman, R Benders and A Fair (2020), Comprehensive review of current natural gas liquefaction process on technical and economic performance, Applied Thermal Engineering.
25. Energies (2017), LNG Regasification Terminals: The Role of Geography and Meteorology on Technology Choices, Agarwal et al.
26. International Gas Union (2021), 2021 World LNG Report, International Gas Union.
27. Shell (2021), Shell LNG Outlook 2021, Royal Dutch Shell.
28. This is used as a simplifying average efficiency of the cooling devices that this waste resource is displacing.
29. 1GWe output x 8760 hours x 80% load factor.
30. IEA (2020), Tracking Power 2020, IEA, Paris https://www.iea.org/reports/global-energy-review-2020

Cold Resource Opportunities

The cold energy of LNG during the regassification process is available in differing quantities over a range of temperatures. The distribution of cold availability in relation to temperature varies with pressure driven by changes in the boiling point. Generally, higher pressure LNG has a higher boiling point.

The chart below summarizes cold availability from methane to illustrate this variation for a range of send out pressures appropriate to local, intermediate, and high-pressure transmission. Methane constitutes 96.5 percent of LNG.[31] This means in practice that 200 kWh-th/ton LNG is a reasonable assumption for cold availability, allowing for differing operating pressures and variations in LNG composition.

This cold energy has the potential to be used in a wide range of applications such as for air separation, cryogenic CO_2 capture and comminution, butane liquification, temperature-controlled warehousing and transport, desalination, district cooling, data center cooling, etc. Some of these applications have been demonstrated at several regasification terminals around the world and new applications are emerging.

Despite the significant economic, social, and climate benefit potential cold energy recovery, it does not scale due to following key barriers:

- As the core business of LNG terminal operators is receiving, storing and dispatching natural gas, they are not aware of, or are simply not interested in embedding cold energy recovery equipment at the design stage.
- Retrofitting existing terminals with cold energy recovery equipment for single use applications are in most cases not financially feasible.
- Time synchronization of cold energy recovery (when LNG is received) with cold energy demand can be difficult and may result in recovered energy being wasted.
- Terminals are often located some distance from demand for cooling. This requires intermediate energy vectors, including cold stores like water-glycol, ice, or industrial gases to store and transport the cold through space and time from production site to consumption site.

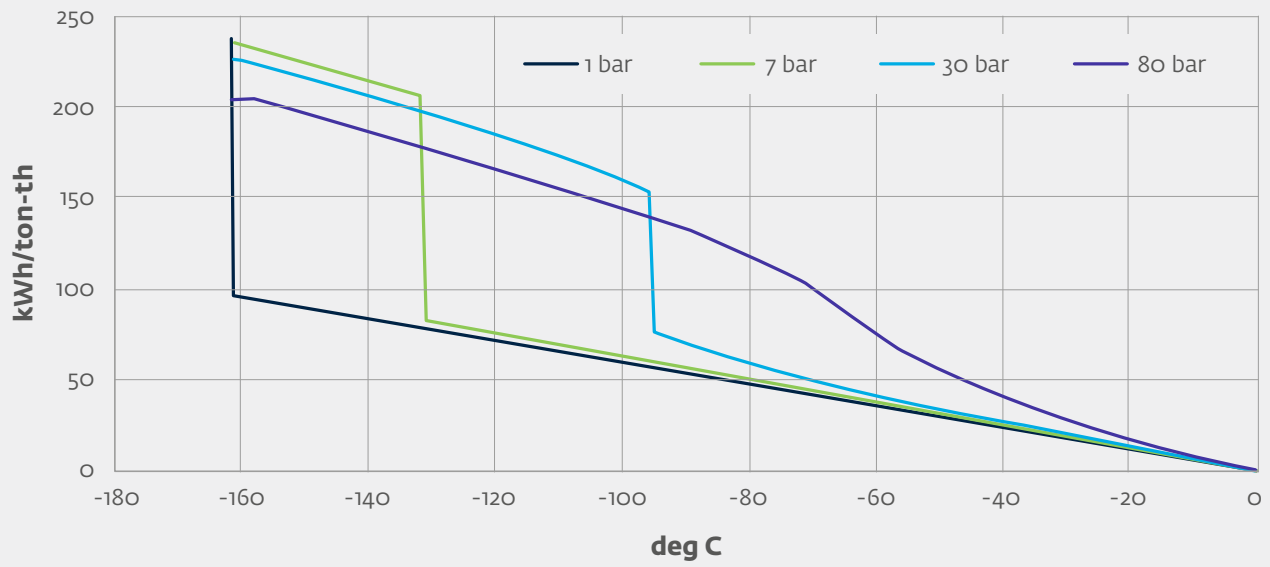
These barriers can be overcome by stacking applications that make cascading use of recovered cold energy across different grades of cooling. This approach can maximize use of available cold and distribute integration costs across multiple customers, and better balance supply and demand for cooling in space and time. In addition, monetization of carbon credits can further enhance project economics.

With the emerging innovative technologies and increase in the demand for cooling, specialist project joint venture partners are beginning to enter the market and taking on the challenges of application and integration design, end user recruitment, and project and asset management.

31. Gas Processors Suppliers Association (GPSA) (2004), Engineering data book, 12th ed.Tulsa: GPSA.

FIG 1A.

Cumulative Cooling vs Flow Pressure per ton LNG



Kochi Case Study

As part of this research, IFC conducted a six-month study of the LNG import terminal operated by Petronet LNG Limited in Kochi, in India's Kerala state. The terminal has a name plate capacity of 5 MTPA, but as pipeline construction had not been fully completed, it was running at 40 percent capacity and importing app $668 million worth of gas per year.[32]

It was found that that harnessing waste cold released during regasification would produce $15.6 million in economic benefits per year for the Kochi terminal operators, while voluntary carbon offsets could save another $4.9 million. In addition, application of the recovered cold would avoid 86,000 tons of greenhouse gas emissions per annum, which is equivalent to the emissions from burning 43 million kilograms of coal.[33]

32. Energies (2017), LNG Regasification Terminals: The Role of Geography and Meteorology on Technology Choices, Agarwal et al.

33. https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

Annex 4 – Stories from the Field

1. Open for Innovation: Indian Hotels Company Limited

Sireesha Chandana is Vice President of Sustainability at Indian Hotels Company Limited (IHCL). She sat down with TechEmerge to explore the challenges and opportunities in adopting new climate-smart cooling solutions.

Sireesha Chandana at the IFC-UK TechEmerge Summit. Photo by IFC.

Q IHCL was strongly committed to sustainability before it partnered with TechEmerge, but is cooling now playing a more prominent role in your sustainability strategy?

A TechEmerge opened a window of opportunity for us to be able to see how much more could be done in the space of cooling. When we started to slice and dice data, this helped us see that heat, light and power-related costs are due to cooling, and it created awareness not just in the hotels where we had pilots, but it has become mandatory for everyone at our hotels to look at cooling efficiencies. It created a great culture for the whole company.

When we look at adopting innovative technologies, sometimes these come with higher upfront costs—do the long-term benefits compensate for this?

A The first concern for our engineers was not the cost, but that we were doing something dramatically different. But TechEmerge de-risked the entire process of trying new technology. It opened the minds of the engineers and now they know exactly the kind of conversations to have with innovators—what to ask for, what to seek, how to engage. So, while these technologies may come with certain costs because they have not scaled yet, when one sees the benefits that can be derived, yes, it is worth it for us. These pilots helped shape the mindset on the associated costs, the risks, and how to navigate these from a long-term sustainability perspective.

Some of the pilots you participated in were more successful than others – did you find any patterns or factors in your dealing with innovators that seemed to influence the likelihood of success?

A I think there was a pattern where local innovators understood the ecosystem in which the business operates, and they had the cultural nuance, the proximity, and the accessibility to make things work. However, if innovators have a strong team in India to partner with, the implementation are seamless. I also feel that innovators have to balance their passion for technology with a passion for entrepreneurship and business. These two very dramatically different qualities might not be always possible in one person. In that case, an extended team, a board, or mentors can help them in navigating businesses, understanding how and where to make the inroads, and what kind of tradeoffs you're ready to make. If they look at the larger picture this creates greater opportunities for success.

Do you have any advice for others in your position who are seeking to reduce the climate footprint of their own companies and organizations?

A The number one thing is to demonstrate actionable commitment—is the organization ready to set aside a certain amount of money to try something new? I know it's not possible everywhere, but organizations should set aside certain amounts of money for testing, even knowing that it might not give you the ROI that you want. This is critical. Also, as corporates, we need not work in silos. We need to work as an industry and come together to try, for example, three, four, or five different technologies. It's a mindset change that is required internally as well as externally for success both ways.

IHCL is a leader in the industry and you can influence change in the sector, not only in India but internationally. During the course of the program, have you seen any shifts in the larger hospitality industry in terms of attitudes and investment in sustainable cooling and sustainability in general?

A One fantastic step forward is that when it comes to sustainability, people don't think competition, they think collaboration, and now cooling innovation is something we can share with other businesses. We don't limit this to the hospitality sector—we share our learnings across the entire Tata Group. Tata Realty, for example, might benefit out of the innovations and pilots that we have worked with. Creating awareness and sharing the excitement of this experience is important, because when others see this, they want to be part of it too.

Q **What's next for IHCL? Do you see the company embracing more sustainable cooling innovations?**

A About 60 percent of our portfolio sits in water-stressed areas, so our teams are looking at how they can customize and build in greater efficiencies through water-related technologies. Waste is also a very big focus, especially the elimination of plastic. While we've had regulation eliminating single use plastic in India, I think IHCL is way ahead of the curve, and we want to set an example of how to reduce this waste going into landfill. And just recently we started some great work around biodiversity. As I mentioned, TechEmerge has changed the way our engineers and key stakeholders actually think and feel about innovation so they are independently having conversations across geographies with different innovators about what they can bring to the table. We definitely think this mindset is key and we hold a responsibility to make change happen.

2. TechEmerge Partners Overcome Challenges and Exceed Expectations

In Nigeria, Aisha Bashir, founder and CEO of Câm Dairy Foods (Câm), has long been determined to reduce local dependency on powdered milk and make fresh milk more accessible for consumers.

A Câm aggregator picks up milk from a farmer in northern Nigeria. Photo by IFC/Freya PR Agency.

However, she quickly realized that a lack of investment in primary production, processing, and logistics made it easier to import dairy products than produce them locally.

It typically takes many hours on poorly surfaced roads to travel from dairy farms to collection centers and then to Câm's factory in the capital of Abuja and preserving milk at the required temperature was costly and difficult. In search of solutions, Câm joined the TechEmerge Sustainable Cooling Innovation program, and was matched with Indian innovator Tessol.

Tessol had developed insulated boxes equipped with phase change material (PCM) cartridges, and during the pilot these were installed on two milk trucks equipped with PCM plates. For Tessol, the partnership provided a valuable opportunity to gain feedback from a potential adopter as well as solid data on its solution's energy savings and environmental impact in real-world conditions.

"You are rarely able to get third-party data to actually support your claims," said Rajat Gupta, co-founder and CEO of Tessol. ***"That is where the TechEmerge program comes in very handy, because they absorb the financial risk and give the opportunity to both the innovator as well as to the adopter."***

However, the two companies soon realized this was only half the battle. Initially, the local delivery partner did not adhere to Tessol's instructions and incorrectly installed the solutions. Additionally, the global pandemic disrupted shipping, logistics, and the availability of testing sites.

Despite these obstacles, clear communication and a willingness to collaborate kept the pilot on track. Tessol modified its products based on feedback from Câm , enlisted a new local delivery partner with the help of the TechEmerge team, and successfully completed the pilot.

The pilot showed that Tessol's solution was able to maintain the desired temperature for Câm's milk for up to 18 hours, even when the boxes were opened multiple times during delivery. This result surpassed Câm's hopes for 12-hours of uninterrupted cooling.

Bashir's dream of expanding access to fresh milk across Nigeria is now a step closer and Tessol has provided Câm with a reliable, climate-smart refrigerated transport option.

"It's a no-brainer. We're saving money," Bashir said.

With the support of TechEmerge, Câm is now poised to strengthen the dairy sector in Nigeria, making fresh milk more accessible and affordable for consumers.

3. Innovative Cooling Pilot Brings Fresh Air—and Big Savings—to Colombia's Building Sector

In Cali, Colombia—a city known for its warmth and vibrant energy—demand for air conditioning is rising fast. But as temperatures rise due to climate change and urbanization, so does the urgent need for energy-efficient cooling solutions. That's where the TechEmerge program stepped in.

The prototype of the IEC-based AHU at TECAM's factory in Cali, Colombia. Photo by TECAM.

Colombia's building sector is expanding quickly. But with energy costs expected to rise nearly 50 percent by 2030 and carbon emissions from cooling projected to rise fivefold by 2050, building owners and manufacturers alike are searching for smarter, greener ways to keep spaces cool.

For A.T.E. Enterprises, an Indian engineering firm with over 80 years of experience, the challenge was clear—and so was the opportunity. The company's innovative arm, HMX, developed a sustainable cooling solution based on indirect evaporative cooling (IEC), which uses significantly less energy than traditional air conditioning and brings in 100 percent fresh air. But breaking into a new market is not easy.

"I've been to many international trade shows looking for partners, but many times companies may not want to talk to us because there's no way to establish our credibility," said Anuj Bhagwati, Managing Director and Chief Executive Office of A.T.E. Group, ***"I can tell people I've done 90 million cubic feet per minute of installations, but nobody in Latin America is going to fly to India to see those. For us, to get into a new market like Colombia, it would not have been on our roadmap as early, if it wasn't for the opportunity that came up because of TechEmerge."***

Through the TechEmerge matchmaking process, HMX found a like-minded partner in TECAM, a Colombian HVAC manufacturer with six decades of experience and reach across Latin America. TECAM saw the potential to integrate HMX's innovation into its air handling units, reducing energy costs for clients while maintaining high indoor air quality—something increasingly important in a post-pandemic world.

Together, they launched a pilot project to test how HMX's indirect evaporative cooling modules could be adapted to the Colombian climate and TECAM's existing systems. With support from TechEmerge and its partner the Colombian HVAC industry association, ACAIRE, the two companies co-developed a prototype air handling unit that included HMX's technology, traditional direct-expansion cooling, and other critical components.

Shipping the innovative units from India during COVID-19 disruptions was no small feat. Yet the prototype arrived safely at TECAM's factory, where it was assembled and tested under real-world conditions.

The results were promising. In Cali's humid, tropical climate, the IEC-enhanced system delivered energy savings between 8 and 22 percent, depending on specific conditions. Outdoor air was cooled by 5–7°C before entering the system, reducing the load on mechanical compressors.

The pilot wasn't without its hurdles. Selecting a suitable end-user for a second round of real-world testing proved difficult, and pandemic-related delays slowed progress. **But the experience offered rich insights for both companies:**

Thorough documentation is essential: When physical travel wasn't possible, having detailed manuals, test procedures, and design specifications helped keep the project on track.

Adaptability is critical: TECAM engineers had to adjust to unfamiliar materials and configurations—an opportunity to build capacity for future innovations.

Strong partnerships matter: IFC and ACAIRE provided not only funding but also critical technical support, local knowledge, and regular review cycles to keep the project moving forward.

Logistics planning pays off: Air shipping revealed the need for more modular and compact designs to ease future transport and scale-up efforts.

Most importantly, both companies walked away with more than just a working prototype.

For HMX, the pilot opened a pathway to the Latin American market much sooner than expected, validated its technology in a new climate, and informed product adjustments for other regions like the Middle East and South Asia. For TECAM, the pilot marked a major step toward launching a next-generation product line that blends cutting-edge cooling technology with energy efficiency and environmental responsibility. With support from TechEmerge, the company was able to reduce risk and gain the confidence to explore new solutions—resulting in a scalable product with strong market potential not only in Colombia, but also in neighboring countries like Peru and Ecuador.

4. Collaboration Fuels Affordable Cooling Innovations for Food Security

Nigeria produces almost 70 percent of the global yam crop, and the tuber is both a staple food and an important source of income for millions of people.

Wholesale yam traders and prospective buyers make their purchases at the Zuba market in Abuja, Nigeria.
Photo by IFC/Freya PR Agency.

Yams are harvested once a year and need to be consumed within four to six weeks, but a lack of affordable and effective cold storage for farmers in the region means 40 to 50 percent of production is lost or wasted each year.

When TechEmerge launched its Sustainable Cooling Innovation Program in Nigeria, the team evaluated several cold storage solutions that would extend the shelf life of yams for up to six months. However, these technologies were too expensive for local farmers, both in term of upfront investment and operational costs. So the team embarked on an ambitious project to develop a low-cost solution for emerging markets, including in Sub-Saharan Africa, where profit margins for fresh produce are razor thin.

Yam storage built by adobe bricks. Photo by IFC.

TechEmerge, together with the Nigerian companies Tak Logistics, KSR Power and Engineering, and Penuel Integrated Concepts, devised a first-of-its-kind cold storage facility using locally made adobe bricks rather than expensive imported materials. To keep the pilot simple, the system uses grid-powered, highly efficient mechanical refrigeration.

TechEmerge connected the three companies with the International Institute of Tropical Agriculture in Nigeria and the National Yam Farmers, Processors, and Marketers Association to help design, construct and test the solution. This resulted in the construction of an innovative cold store near the Nigerian capital of Abuja. Moreover, it costs only one-third of similar facilities made from modern materials—addressing the key challenge of affordability for farmers and agri-companies in emerging markets.

Next the team conducted field tests in real world conditions. A control group of 50 yam tubers of different varieties were stored in crates in a traditional storage shed constructed of raffia, while about 9,000 yam tubers were placed in crates in the new adobe storage facility.

Results showed that the innovative cold store extended the shelf life of yams by four months compared to the traditional storage shed, and wastage rates fell by more than 42 percent. During this period, yam price increased by 80 to 110 percent, making the payback period on investment just two to three years.

"Around 25 million metric tons of yams are wasted yearly in Nigeria, and if you can reduce that, the money you are putting back into farmers' pocket is going to significantly improve their livelihoods," said Abdulrazak Gashash, Project Manager at Tak Logistics. ***"The TechEmerge Sustainable Cooling Innovation Program allowed us to explore technologies with enormous potential benefits."***

To further improve affordability and sustainability and enable off-grid operation in rural areas, TechEmerge recommends the cold store be fitted with climate-smart cooling such as solar photovoltaic or solar thermal systems paired with absorption-based cooling technology, instead of relying solely on grid power. This would enable each storage facility to potentially avoid an estimated 19 metric tons of greenhouse gas emission annually. TAK Logistics will continue to develop the project with the aim of offering a commercially-viable solution to farmers and traders in Nigeria and beyond.

5. Cutting Costs and Climate Impacts of Getting Food from Farm to Fork in India

At a bustling warehouse in New Delhi, employees of India's largest online grocer, BigBasket, are packing fresh cauliflowers, tomatoes, limes, and leafy greens for speedy dispatch to customers.

Staff packing fruits at BigBasket distribution center in Hoskote. Photo by IFC/Jdot Productions.

Keeping these perishable fruits and vegetables fresh requires enormous amounts of energy. Furthermore, in India and many emerging economies, unreliable grid power often forces companies like BigBasket to turn to expensive, highly polluting fossil fuel back-ups, primarily diesel generators.

"In a typical grocery store, almost 50 percent of energy consumption goes to the cold chain," said Ganapathi Subramanyam,

Head of Innovation at BigBasket. ***"Demand for perishable produce is rising, and for us, customer satisfaction is paramount, so we absolutely have to innovate to grow the business."***

Typically, workers at these warehouses, also known as 'dark stores', enter and leave cold rooms frequently, causing cold losses from the system, increasing energy use, and hurting product quality.

"On an average day, our staff pick 75,000 separate items for customers. Every time staff go in and out of a large conventional cold room, energy consumption rises to keep temperatures stable," said Subramanyam. ***"We also wanted to reduce our workers' exposure to sub-zero temperatures."***

To meet this challenge, BigBasket teamed up with TechEmerge to find a sustainable way to reduce its cooling expenditure and greenhouse gas emissions.

BigBasket and TechEmerge also wanted to solve a common problem throughout the retail cold chain—the inability to compartmentalize a single space for multiple uses by desired temperature range and demand.

With grant funding and technical support from TechEmerge, BigBasket took on the role of both adopter and innovator for a unique pilot that divided a large walk-in cold room into multiple modular cold racks utilizing widely available phase change material (PCM) inserts.
This plug-and-play solution is easy to install, demount, and transport to new sites, and uses standardized factory-fabricated products.

"Now workers simply open a clearly labelled door, reach in, and retrieve the item they need, minimizing cold losses from the system," said Subramanyam. ***"Productivity is higher because no time is lost getting in and out of thermal jackets, and workers always have instantaneous Wi-Fi access to customer orders, something that's not possible in a standard cold room."***

The system can maintain desired temperatures for up to six hours – reducing the need for back-up fossil-fuel generators during power outages. In addition, different PCMs can be used to achieve different temperatures, enabling stacking and picking of produce to be isolated to specific zones.

The pilot found the use of modular cold racks reduced electricity consumption by 14 percent. Savings are likely to increase because racks in a particular dark store can be controlled dynamically, in response to predicted or real-time demand. In comparison, a conventional cold room must function continuously.

BigBasket is now scaling up use of the modular cold racks with the goal of increasing efficiency, lowering costs and climate impacts, and reducing food wastage along the entire retail cold chain – keeping farmers' produce fresh, helping businesses grow, and delivering tasty food to kitchens and dining tables.

6. Smart Thinking: Innovation Keeps Students Cool and Productive in Mexico

At the University of Guadalajara in Mexico students often take a break from the heat and sun beneath mature trees dotted around this historic campus.

OT Services team installing a hybrid air conditioner at the University of Guadalajara. Photo by IFC.

In the classrooms and lecture halls, however, air-conditioning is vital, with studies showing hot and humid environments can impact productivity at schools and at work by as much as 12 percent.

But cooling already accounts for ten percent of global energy consumption and seven percent of greenhouse gas emissions, and demand is rising sharply, particularly in emerging markets like Mexico. So, when the university decided to renovate some of its buildings, it turned to TechEmerge for help to ensure its cooling and ventilation systems were energy-efficient, cost-effective, and climate-smart.

"We did a study, and it showed that 20 percent of our electricity use went to air-conditioning," said Melva Herrera, sustainability coordinator at the university's Center for Health Sciences. ***"We realized that finding a technology that could help us reduce electricity consumption for space cooling could be a key element in moving towards sustainability."***

TechEmerge matched the university with Colombian cooling innovator OT Services. With grant funding and technical advice from TechEmerge, the two partners piloted a unique solar-powered air-conditioning and bipolar ionization system.

The project achieved impressive results—reducing energy consumption of space cooling systems by almost 53 percent under pilot conditions.

"Climate-smart cooling is key to meeting the sustainable development goals," said Juan Portilla, Chief Executive Officer and Co-founder of OT services. ***"IFC is bridging the gap between users who need cooling and technology providers by providing opportunities through TechEmerge for users and customers to try out new solutions."***

The solution not only provides space cooling, it purifies the air as well. This ensures the university's laboratories meet international standards while also addressing ongoing health and wellbeing concerns in the wake of the COVID-19 pandemic.

"We want the whole university community to join the transition to sustainability," said Melva Herrera. The university plans to further reduce its carbon footprint by scaling OT Services innovative system throughout its campuses.

Annex 5 – Pilots

Cooling Cities (1 of 5)

Completed | Cancelled | Ongoing

INNOVATOR:
A.T.E. Private Limited

ADOPTER:
TECAM S.A.

Indian Innovator and manufacturer A.T.E/HMX partnered with Colombian HVAC manufacturer TECAM to pilot technical integration of ATE indirect evaporative cooling solutions into TECAM air handling units. The new range of industrial cooling equipment is providing efficient HVAC and improved air quality for hotels, malls, schools, offices, and healthcare facilities.

INNOVATOR:
Biofreshtech Private Limited Company

ADOPTER:
New Transport Applications S.A. de C.V. (NTA)

Mexican transport and logistics company NTA which serves exclusively pharmaceutical clients and delivers temperature sensitive products was looking for a solution that will enable stable cooling during transportation for 72 hours in volumes that are too small for a refrigerated truck and too large for passive cooling measures. It collaborated with Spanish innovator BiofreshTech to pilot an integrated solution utilizing proprietary phase change material (PCM). This technology requires only a minimal initial charge to maintain cooling for up to six days, operates autonomously without continuous electricity, and offers real-time control.

INNOVATOR:
Biofreshtech Private Limited Company

ADOPTER:
Refrigeración Starr S.A. de C.V.

In this pilot, Spanish innovator BiofreshTech and Mexican industrial and commercial HVAC and refrigeration distributor, Refrigeration Starr, retrofitted and field tested an innovative, just-in-time technology to safely deliver vaccines and other pharmaceuticals for Refrigeration Starr's client, Walmart. The piloted solution requires only a small initial charge to cool or heat any space to the desired temperature for up to six days and operates autonomously, without an ongoing need for electricity.

Cooling Cities (2 of 5)

INNOVATOR:
Biofreshtech Private Limited Company

ADOPTER:
Refrigeración Starr S.A. de C.V.

Micro, small, and medium enterprises (MSMEs) are vital sources of jobs and economic growth in emerging markets. Mexican HVAC and refrigeration distributor, Refrigeration Starr partnered with innovator BiofreshTech to conduct field tests at a range of MSMEs, including a butcher's shop, a liquor retailer, a restaurant, and a fishmonger. They piloted BiofreshTech's integrated technology that needs only a small initial charge to cool or heat any space to the desired temperature for up to six days without the ongoing need for electricity.

INNOVATOR:
Biofreshtech Private Limited Company

ADOPTER:
Helado Popsy

The largest Colombia ice-cream retailer Helado Popsy has over 220 outlets across Colombia. It partnered with Spain's BiofreshTech to field test its integrated PCM based technology as a solution for its display cabinets with a main objective to reduce energy costs while maintaining stable temperature for its products, specifically in regions that experience energy supply outages.

INNOVATOR:
CMT-Technik, S. de RL de CV

ADOPTER:
7-Eleven Mexico

Convenience chain 7-Eleven partnered with Mexican innovator CMT Technik to pilot an IoT-based energy management system. This initiative aims to reduce energy costs and minimize climate impact while ensuring high performance and lowering breakdown rates of refrigeration and HVAC systems in its retail outlets across Mexico.

INNOVATOR:
Elgressy Engineering Services Ltd.

ADOPTER:
Fermic S.A. de C.V.

Fermic operates one of the largest fermentation plants in Latin America. It partnered with local engineering delivery partner Graco Mexicana and Israeli innovator Elgressy to pilot an automated, plug-and-play, chemical-free electrochemical system that prevents scaling, corrosion and algae in cooling towers while reducing water consumption and providing recycled wastewater for irrigation.

INNOVATOR:
Elgressy Engineering Services Ltd.

ADOPTER:
Tecnológico de Monterrey

Mexican university Tecnológico de Monterrey partnered with Israeli innovator Elgressy to pilot a unique plug-and-play electrochemical solution to improve the performance and sustainability of its cooling tower by preventing scaling, corrosion and algae in the towers, reducing water consumption, and providing recycled wastewater for irrigation.

Cooling Cities (3 of 5)

INNOVATOR:
Elgressy Engineering Services Ltd.

ADOPTER:
Serviparamo S.A.S.

In Colombia, Serviparamo, a leading company providing HVAC, refrigeration, and energy solutions, partnered with Israeli innovator Elgressy to pilot a chemical-free plug-and-play system for water and wastewater treatment in cooling towers. In addition to reducing energy, water, and chemical usage, as well as operational and maintenance costs, the technology also facilitates the recycling of blowdown water for irrigation purposes.

INNOVATOR:
Flair.Co

ADOPTER:
Serviparamo S.A.S.

Latin American company Serviparamo, a provider of HVAC, refrigeration, and energy solutions, partnered with U.S. innovator Flair to pilot remote management, monitoring, and control of thermostats and mini-splits. They tested Flair's innovative 'Puck' technology in conjunction with Serviparamo's platform on 200 thermostats in Colombia, introducing a new business model called condition-based maintenance.

INNOVATOR:
Heat Inverse, LLC

ADOPTER:
New Transport Applications S.A. de C.V. (NTA)

U.S. innovator Heat Inverse has developed a passive cooling film designed for application on the exterior of refrigerated trailers, trucking units, and other surfaces. This thin film requires no energy supply, generates no waste heat, and is maintenance-free after installation, effectively reducing fuel costs and easing the load on existing cooling systems. Heat Inverse partnered with Mexican transport and logistics company NTA to pilot this technology, aiming to achieve fuel savings and efficient temperature control for the distribution of pharmaceuticals and perishable goods by truck.

INNOVATOR:
Konverter Engineering Group

ADOPTER:
La Fazenda/ Aliar S.A.

Mexican innovator Konverter partnered with Aliar, a Colombian agro-industrial company, to pilot a user-friendly, real-time, cloud-based system to monitor energy consumption throughout Aliar's farm-to-fork value chain. The pilot aimed to reduce energy use in refrigeration and HVAC systems.

Cooling Cities (4 of 5)

INNOVATOR:
OT Services S.A.S.

ADOPTER:
Procaps Group, S.A.

Colombian pharmaceutical company Procaps partnered with local innovator OT Services to field test solar-based air conditioning and bipolar ionization technology at its plants. This initiative aims to significantly reduce energy consumption not only during sunlit hours but also under cloudy conditions and at night. The bipolar ionization technology also improves air filtration and significantly increases the life cycle of industrial filters while reducing maintenance costs.

INNOVATOR:
OT Services S.A.S.

ADOPTER:
SEI Soluciones

Colombian HVAC company and a main partner for housing developers SEI Soluciones teamed up with local innovator OT Services to pilot an energy-efficient solar air conditioning solution in a display home on the country's north coast, where HVAC costs can account for up to 80 percent of residential energy consumption.

INNOVATOR:
OT Services S.A.S.

ADOPTER:
University of Guadalajara

Mexico's University of Guadalajara partnered with Colombian innovator OT Services to field test innovative solar air conditioning and bipolar ionization technology with the aim of reducing energy consumption of air-cooling systems during sunlit hours, cloudy conditions, and at night. The bipolar ionization technology also improves air filtration and air quality, a key concern during the post COVID-19 era.

INNOVATOR:
PackID by SYOS

ADOPTER:
Norcul S.A. de C.V.

Brazilian innovator PackID piloted its real-time temperature and humidity monitoring system for perishable products with Norcul, a Mexican provider of refrigeration equipment and services. They field tested hardware and software that leverage IoT and cloud solutions as well as new business models to prevent product losses, protect product quality, and minimize energy use and operating costs throughout the distribution chain.

INNOVATOR:
PackID by SYOS

ADOPTER:
Refrimarket Colombia S.A.S.

Brazilian innovator PackID piloted its real-time temperature and humidity monitoring system for perishable products with Refrimarket, a Colombian provider of refrigeration equipment and services. Pilot included testing of the solution along with analysis of the commercial viability for the innovator to enter the Colombian market.

Cooling Cities (5 of 5)

INNOVATOR:
Pluss Advanced Technologies Private Limited

ADOPTER:
Carrocerías el Sol

Carrocerías el Sol, a manufacturer of ambulances, medical units, and rescue equipment for export across Latin America, partnered with Indian innovator Pluss to enhance polymer properties and PCMs. Together, they piloted Pluss's passive cooling solution for refrigeration in two settings: CeS's offices and last-mile delivery in small, refrigerated trucks. The goal was to reduce electricity and fuel usage, greenhouse gas emissions, and operation and maintenance costs.

INNOVATOR:
Pluss Advanced Technologies Private Limited

ADOPTER:
La Fazenda/ Aliar S.A.

Indian innovator PLUSS had developed a solution that enhances polymer properties and phase change materials. Aliar is a Colombian agri-industrial company that produces pork and beef, from early stages through processing and retailing under the La Fazenda brand. Their joint pilot project used refrigeration with passive cooling via PCMs to tackle the challenges of affordability, quality, and energy efficiency when delivering small quantities of frozen and fresh meat products by truck and motorcycle.

INNOVATOR:
Promethean Power Systems

ADOPTER:
Sigma Alimentos

Promethean Power Systems designs and manufactures refrigeration systems for cold storage and chilling in off-grid and partially electrified locations. Global food company, Sigma, manages a fleet of over 4,000 vehicles that service 210 distribution centers and 640,000 points of sale in 18 countries. Together, they piloted a solution that converts electrical energy into cold energy, without the need to mount a condensing unit on a refrigerated vehicle/reefer truck, with the aim of reducing diesel fuel consumption, as well as food losses from poor temperature control.

INNOVATOR:
Purix ApS

ADOPTER:
Oxxo

Global convenience chain OXXO partnered with Danish innovator Purix to pilot a solar-powered cooling system for air conditioners in its retail stores in Mexico. Purix's solar-powered absorption cooling technology does not require environmentally damaging F-gases and aims to reduce annual air-conditioning costs and related greenhouse gas emissions.

Making Temperature-Controlled Logistics Work in Nigeria (1 of 7)

INNOVATOR:
ATC International LLC

ADOPTER:
Fan Milk PLC

Turkish engineering, R&D and manufacturing company ATC partnered with Fan Milk, a subsidiary of Danone and a leading manufacturer and distributor of ice cream products in Nigeria, in a pilot that aimed to find an affordable, climate-smart solution for long-haul refrigerated transport – a sector with limited solutions in Nigeria. The pilot tested a first-of-its-kind 13-meter refrigerated trailer lined with PCM-filled plates, supported by solar panels mounted on top of the trailer and Li-ion batteries under the chassis.

INNOVATOR:
ChillTechnologies Ltd.

ADOPTER:
TAK Logistics Ltd.

IMPLEMENTING PARTNERS:
Lange and Grant Commodities Limited

UK-based innovator ChillTechnologies piloted an absorption chiller that runs on waste heat in partnership with Nigerian agro logistics provider TAK Logistics and Nigerian engineering company Lange and Grant. Together they tested the use of these chillers to maintain different temperatures for a range of produces stored in cold rooms. This pilot aimed to find cold storage solutions for highly perishable produce such as tomatoes and ginger at zero operational cost, using waste heat from adjacent grain silo operations.

INNOVATOR:
ChillTechnologies Ltd.

ADOPTER:
TAK Logistics Ltd.

UK innovator ChillTechnologies partnered with Nigerian agro logistics provider TAK Logistics to pilot a chiller that uses exhaust gas of a truck engine to cool the insulated container of a 40-foot trailer during the long-haul transport of temperature-sensitive products. This pilot is among the first in the world to use an absorption cooling technology for mobile application, which, if successful, has the potential to provide refrigerated transport at zero operational cost and zero emission.

Making Temperature-Controlled Logistics Work in Nigeria (2 of 7)

INNOVATOR:
Ecozen Solutions Private Limited

ADOPTER:
Agvest Limited

IMPLEMENTING PARTNER:
Lange and Grant Commodities Limited

India's Ecozen, a manufacturer of energy-efficient cold storage solutions, partnered with Agvest, an agri-financing and advisory company in Nigeria, and Nigerian engineering company Lange and Grant to field test a containerized, mobile, solar-powered cold room at the farm gate. This pilot aimed to support farmers growing fresh vegetables by addressing the challenges they face in preserving the shelf life of their harvested produce due to inadequate cold storage solutions.

INNOVATOR:
Eja-Ice Nigeria Ltd.

ADOPTER:
L&Z Integrated Farms Nigeria Ltd.

Nigerian innovator Eja-Ice, who provides end-to-end solar powered cold chain solutions, collaborated with one of Nigeria's top dairy producers, L&Z Integrated Farms, to pilot the use of a solar-powered cooling unit mounted on a tricycle for last-mile dairy distribution. The pilot aimed to assess the performance and viability of the solar-powered cold transport solution for last-mile delivery, which often relies on non-refrigerated equipment given energy scarcity and poor infrastructure.

INNOVATOR:
Eja-Ice Nigeria Ltd.

ADOPTER:
Fan Milk PLC

Nigerian cold chain solutions company Eja-Ice partnered with Fan Milk, a subsidiary of Danone that manufactures ice cream and yogurt in Nigeria and Ghana, to test Eja-Ice's solar-powered tricycle equipped with a cooling unit for transporting Fan Milk's dairy products between its depots and retailers. Fan Milk wished to seek a viable solution for its last-mile delivery which is more cost effective and energy sufficient.

INNOVATOR:
Eja-Ice Nigeria Ltd.

ADOPTER:
Food Concepts PLC

Nigerian cold chain solutions innovator Eja-Ice was matched with Food Concepts, a multi-brand quick service restaurant group, to field test Eja-Ice's solar-powered cooling unit mounted on a tricycle for delivering frozen pies from Food Concepts' central kitchen to their Pie-Express Outlets. The pilot aimed to help Food Concepts evaluate the performance and applicability of using solar-powered tricycles in its last-mile delivery.

Making Temperature-Controlled Logistics Work in Nigeria (3 of 7)

INNOVATOR:
Eja-Ice Nigeria Ltd.

ADOPTER:
Worldbay Technologies Ltd. (Grocedy)

Nigerian innovator Eja-Ice piloted end-to-end solar-powered cold chain solutions, including cold rooms, chest freezers, and a refrigerated van with Worldbay Technologies, which owns the e-commerce retailer Grocedy in Nigeria. The pilots at Grocedy's aggregation center, in its distribution chains, and at its last-mile delivery center aimed to solve refrigeration challenges without relying on fossil fuels and minimizing the use of grid power.

INNOVATOR:
Enersion Inc.

ADOPTER:
Anthorad Nigeria Ltd.

Canadian innovator Enersion, an engineering and manufacturing company that develops storage and transportation solutions based on absorption cooling technology, teamed up with Nigerian logistic company Anthorad to pilot the use of an insulated box backed by thermal batteries lid that can be charged using waste heat for the last-mile delivery of chilled meat. The pilot aimed to test the viability of a solution that can be suitable for long, medium, short and last-mile delivery of small quantities of temperature-sensitive products, without relying on fossil fuels or electricity.

INNOVATOR:
Indafre S.A.S.

ADOPTER:
Anthorad Nigeria Ltd., Câm Dairy Foods Ltd., GlaxoSmithKline (GSK) Nigeria, Artee Group Limited

Colombian innovator Indafre produces a wide range of passive and active refrigerated boxes. Indafre partnered with four adopters – Anthorad, Câm Dairy, GSK, and Artee – to utilize Indafre's PCM-based cooling boxes for various applications. These included last-mile delivery of fish and meat to retailers, long and medium-distance delivery of fresh milk and yogurt to customers, distribution of chilled meat from manufacturing facility to stores, and lab testing for pharmaceutical products. The tests aimed to explore cost-effective solutions that can enable frequent small lot deliveries of temperature-sensitive products while preventing wastage or spoilage.

INNOVATOR:
Koolboks Ltd.

ADOPTER:
Amo Farm Sieberer Hatchery Limited

French innovator Koolboks has developed chest freezers and coolers for the retail sector in Africa that operates 24/7 completely off-grid. In this pilot, Koolboks partnered with Nigerian integrated poultry company Amo Farm to test its solar-powered freezers and coolers, equipped with IoT technology, for storing frozen chicken and vaccines, with the goal of evaluating the performance of the devices in commercial settings.

Making Temperature-Controlled Logistics Work in Nigeria (4 of 7)

INNOVATOR:
Koolboks Ltd.

ADOPTER:
Fan Milk PLC

French solar cold storage provider Koolboks partnered with Nigeria's ice cream and yogurt manufacturer Fan Milk to pilot Koolboks' IoT-enabled solar chest freezers for storing ice cream and yogurt in retail stores. The pilot aimed to test the freezers' potential for large-scale commercial operations with strict temperature and autonomy requirements.

INNOVATOR:
KSR Power and Engineering Ltd.,
Penuel Integrated Concepts Ltd.

ADOPTER:
TAK Logistics Ltd.

KSR, a Nigerian company that develops turn-key refrigeration solutions, collaborated with Penuel Integrated Concepts, a local Nigerian construction company, to build a low-cost cold storage facility for storing perishable produce. The proposed cold store would be constructed using locally produced adobe bricks and equipped with a cooling system that utilizes a low greenhouse gas emission refrigerant. The pilot aimed to extend the shelf life of yams, a staple food in Nigeria, by using this cost-effective cold storage solution. The project would demonstrate that such facilities, built with affordable materials, can be easily replicated by farmers or traders to provide an accessible storage option.

INNOVATOR:
Mandilas Group Limited

ADOPTER:
JustFood West Africa

Nigerian company Mandilas Group, an official distributor for US-headquartered Carrier Transicold, conducted a pilot with JustFood, a Nigerian food equipment distributor and dairy processor. Mandilas installed a full-electric refrigeration unit on one of JustFoods' trucks to measure energy use and operational costs for continuous multi-drop deliveries of ice cream and ice cubes. This pilot sought to compare the performance of the all-electric system with traditional mechanical refrigeration units in the areas of cost of refrigeration and temperature stability. The pilot results would serve as a baseline for other pilots involving innovative technology.

Making Temperature-Controlled Logistics Work in Nigeria (5 of 7)

INNOVATOR:
Pluss Advanced Technologies Private Limited

ADOPTER:
L&Z Integrated Farms Nigeria Ltd.

IMPLEMENTING PARTNER:
Lange and Grant Commodities Limited

Indian Innovator PLUSS, a materials research and manufacturing company specializing in PCM, has developed a complete range of PCMs for various cooling and heating applications. PLUSS partnered with Nigerian dairy producer L&Z Integrated Farms and Nigerian engineering company Lange & Grant to test a hybrid cold store that operates on grid power and PCM-backed thermal energy batteries for storing processed milk and yogurt prior to distribution. This pilot aimed to assess the performance and applicability of an off-fossil fuel solution for cold storage, reducing reliance on generators.

INNOVATOR:
Pluss Advanced Technologies Private Limited

ADOPTER:
Amo Farm Sieberer Hatchery Limited

Indian PCM innovator PLUSS collaborated with Nigerian poultry company Amo Farm to test a truck fitted with a refrigeration system working on PLUSS's PCM-filled plates. The objective was to evaluate an off-grid, fossil fuel-free solution for temperature-controlled delivery operations. The truck was used to transport frozen meat with various retail stores and distributors, facilitating multi-drop deliveries.

INNOVATOR:
Pluss Advanced Technologies Private Limited

ADOPTER:
Artee Group Limited

Indian Innovator PLUSS partnered with Artee Group's SPAR, a leading retail company in Nigeria, to pilot two trucks with two PCM-lined chambers, one for frozen products and the other for chilled products for last-mile intra-city distribution. In addition, they also piloted two trucks that carry frozen goods in a single PCM-equipped chamber alongside insulated boxes for chilled products. The pilot aimed to implement a sustainable refrigeration solution that significantly reduces greenhouse gas emissions and operational expenses for refrigeration services.

Making Temperature-Controlled Logistics Work in Nigeria (6 of 7)

INNOVATOR:
Pluss Advanced Technologies Private Limited

ADOPTER:
Kennie-O Cold Chain Logistics Ltd. (KCCL)

IMPLEMENTING PARTNER:
Integrated Motors Industries (IMI)/KSR Power and Engineering Ltd. (KSR)

Indian PCM innovator PLUSS partnered with Nigerian logistics company KCCL to pilot a reefer truck with a refrigeration system that utilizes PCM-filled metal plates for intercity transport of various frozen food products. Additionally, they tested a solar cold room equipped with PCM plates for storing chilled food items. The pilot focused on testing passive cooling solutions to reduce electricity and fuel consumption, as well as operation and maintenance costs. Nigerian refrigerated motor service company IMI and Nigerian engineering company KSR were tasked with installing PLUSS's solutions.

INNOVATOR:
Purix ApS

ADOPTER:
Alyx Limited

Alyx, an aggregator of fresh tomatoes and other vegetables and an agri-transportation company, currently relies on second-hand imported trailers and trucks with inefficient HFC-based refrigeration systems. In order to find a scalable and affordable cooling solution for produces at the farm gate, Alyx partnered with Danish innovator Purix to test a low-cost storage facility constructed with adobe bricks and cooled by Purix's solar thermal absorption cooling system.

INNOVATOR:
Sonnenschein Engineering & Infra LLP

ADOPTER:
Integrated Motors Industries (IMI)

IMPLEMENTING PARTNER:
Iron Product Industries Ltd. (IPI)

Indian specialty paint innovator Sonnenschein teamed up with Nigerian refrigerated motor service company IMI and a leading Nigerian steel fabrication company IPI to field test a heat-reflective paint on the surface of vehicles, warehouses, and local storage sheds, with the aim of achieving desired temperature with minimal energy consumption and costs.

Making Temperature-Controlled Logistics Work in Nigeria (7 of 7)

INNOVATOR:
Thermal Energy Service Solutions Private Limited (TESSOL)

ADOPTER:
Câm Dairy Foods Ltd.

IMPLEMENTING PARTNER:
Lange and Grant Commodities Limited, Gricd Integrated Services Ltd.

Nigerian dairy company Câm collaborated with Indian innovator TESSOL to test TESSOL's insulated boxes equipped with PCM cartridges, aimed at maintaining the temperature of milk and yogurt during Câm's interstate and intrastate deliveries. TESSOL's solutions were installed on two trucks by a local delivery partner Lange and Grant and the trucks were fitted with IoT enabled temperature monitoring devices from GRICD.

INNOVATOR:
Thermal Energy Service Solutions Private Limited (TESSOL)

ADOPTER:
L&Z Integrated Farm Nigeria Ltd.

IMPLEMENTING PARTNER:
Lange and Grant Commodities Limited, Gricd Integrated Services Ltd.

Nigerian adopter L&Z Integrated Farms, a vertically integrated dairy company, teamed up with Indian innovator TESSOL to test a truck equipped with TESSOL's PCM-enabled solutions in making yogurt deliveries to multiple destinations while maintaining the desired product temperatures. The solution was installed by local engineering firm Lange and Grant, while the IoT device for temperature monitoring was provided by GRICD.

INNOVATOR:
Tunasha Technologies Ltd.

ADOPTER:
Amo Farm Sieberer Hatchery Limited

Two Nigerian companies IoT solutions innovator Tunasha and integrated poultry company Amo Farm, piloted temperature and humidity data logging devices. These devices enabled live monitoring, analytics, and alert systems for Amo's egg hatchery, cold stores, and trucks. This pilot aimed to dramatically reduce energy wastage associated with unnecessary cooling, give early warning of system failures, and provide information to further reduce energy consumption.

The 'Missing Link' in Retail Cold Chains (1 of 2)

INNOVATOR AND ADOPTER:
Supermarket Grocery Supplies Pvt. Ltd. (BigBasket)

In this pilot, India's largest online grocer, BigBasket, piloted its own plug-and-play modular cold rack system using widely available PCM inserts. The pilot aimed to compartmentalize a large walk-in cold room for multiple uses by desired temperature range and demand – tackling one of the biggest design issues that make cold rooms so inefficient and costly to run.

INNOVATOR:
Indafre S.A.S.

ADOPTER:
Chaldal Inc.

Colombian innovator Indafre teamed up with Bangladesh's largest online grocer, Chaldal, in a pilot that aimed to provide stationary and mobile cooling in areas where the electricity grid is weak, replacing the need for diesel power. This included field-testing passively cooled boxes for inter-city, intra-city, and last-mile deliveries of chilled and frozen groceries.

INNOVATOR:
Indafre S.A.S.

ADOPTER:
Snowman Logistics Ltd.

This pilot aimed to test the performance of PCM-based high-capacity passive cold boxes in maintaining temperatures while lowering energy use and greenhouse gas emissions under different environmental and operational conditions in India.

INNOVATOR:
Machphy

ADOPTER:
Chaldal Inc.

Indian innovator Machphy partnered with Chaldal—the largest online grocery company in Bangladesh—for a pilot project that used Chaldal's fleet of motorbikes and vans to field-test insulated containers passively cooled by low-cost phase change materials for delivering frozen goods directly from warehouses to customers' homes. The pilot aimed to reduce fuel consumption and greenhouse gas emissions, while providing reliable and affordable cooling for the last-mile transport of small amounts of frozen produce.

The 'Missing Link' in Retail Cold Chains (2 of 2)

INNOVATOR:
New Leaf Dynamic Technologies Private Limited

ADOPTER:
Supermarket Grocery Supplies Pvt. Ltd. (BigBasket)

In this pilot, Indian innovator New Leaf partnered with India's largest online grocery, BigBasket, to field test a GreenCHILL refrigeration system that uses a natural refrigerant with zero greenhouse gas emissions. Pelletized cashew nut shells and waste husks from a BigBasket coconut processing factory provided biomass fuel for the GreenCHILL unit.

INNOVATOR:
Thermal Energy Service Solutions Private Limited (TESSOL)

ADOPTER:
Chaldal Inc.

Indian innovator TESSOL partnered with Bangladesh e-grocer Chaldal to improve the reliability and affordability of mid-mile and last-mile delivery of perishable products, while reducing fuel consumption and greenhouse gas emissions. This pilot aimed to use passive cooling from emission-free PCMs in insulated boxes and bags rather than large, refrigerated reefer trucks for part-load deliveries of frozen and chilled items.

INNOVATOR:
Thermal Energy Service Solutions Private Limited (TESSOL)

ADOPTER:
Snowman Logistics Ltd.

Indian innovator TESSOL teamed up with Snowman, one of India's biggest logistics providers, to pilot its Ultracool 1400 plug-and-chill solution in a range of climatic conditions. The pilot aimed to maintain temperature control without the need for active refrigeration during intercity and last-mile deliveries, while reducing costs, energy consumption, and greenhouse gas emissions.

Sustainable Recovery of the Hospitality Sector in India (1 of 3)

INNOVATOR:
Desiccant Rotors International Pvt. Ltd. (DRI)

ADOPTER:
Indian Hotels Company Ltd. (IHCL)

Haryana-based innovator Desiccant Rotors International field-tested an air filtration system in the lobby at Indian Hotels Company Limited's Taj Palace in New Delhi that captures particulate and gaseous pollutants, while also maintaining positive pressure to address infiltration issues.

INNOVATOR:
Elgressy Engineering Services

ADOPTER:
Indian Hotels Company Ltd. (IHCL)

IHCL and Israeli innovator Elgressy piloted an automated, chemical-free, plug-and-play system at the Taj Holiday Village in Goa that aimed to prevent scaling, corrosion and algae in cooling towers while also reducing water consumption by up to 20 percent and providing wastewater for irrigation.

INNOVATOR:
Green Efficient Solutions Pvt. Ltd. (GREFFISOL)

ADOPTER:
Chalet Hotels Ltd.

With Mumbai-based innovator Green Efficient Solutions, Chalet Hotels Group piloted a low approach cooling tower at the Taj Jai Mahal Palace in Jaipur. The pilot aimed to increase the energy efficiency of the chiller and the HVAC plant room and decrease water consumption, with a payback period of less than one year.

INNOVATOR:
Green Efficient Solutions Pvt. Ltd. (GREFFISOL)

ADOPTER:
Chalet Hotels Ltd.

Indian innovator Green Efficient Solutions partnered with India's Chalet Hotels Group to pilot a cooling tower solution that met height restrictions from a major airport adjacent to the Marriot Sahar hotel. The forced-draft cooling tower was produced by Evapco, a US-headquartered company with global operations, and features energy-efficient centrifugal fans with custom-made louvers, guiding vanes, and distribution planes that aimed to reduce the cooling tower approach from 4.5 to 2.7 Celsius, and lower energy use, greenhouse gas emissions, and operating costs.

Sustainable Recovery of the Hospitality Sector in India (2 of 3)

INNOVATOR:
Green Efficient Solutions Pvt. Ltd. (GREFFISOL)

ADOPTER:
Indian Hotels Company Ltd. (IHCL)

Mumbai-based innovator Green Efficient Solutions and IHCL piloted a low approach cooling tower at the Taj Jai Mahal Palace in Jaipur with the aim of increasing the energy efficiency of the chiller and the HVAC plant room and decreasing water consumption, with a payback period of less than one year.

INNOVATOR:
Iotomation Ecotech Pvt. Ltd.

ADOPTER:
Indian Hotels Company Ltd. (IHCL)

IHCL and New Delhi-based innovator IoTomation piloted an IoT platform for health, safety, and sustainable built environments, called Be–IoT, at the Taj Jai Mahal Hotel in Jaipur and the Taj Palace in New Delhi. The solution provides an integrated dashboard for all hotel equipment and systems and makes them communicable. The resulting AI-driven data analytics aimed to improve energy efficiency, predictive and preventive maintenance, and operational efficiency.

INNOVATOR:
Zenatix Solutions Pvt. Ltd.

ADOPTER:
Chalet Hotels Ltd.

Indian innovator Zenatix and India's Chalet Hotels Group piloted ZenConnect—an automated IoT solution that connects physical assets over the internet, collects real-time data, and administers intelligent controls, thereby improving temperature management and energy efficiency, while reducing greenhouse gases as well as equipment and asset breakdowns. The partners conducted field tests at two properties, the Westin Powai and the Marriot Bangalore, to evaluate performance in different physical and climatic conditions.

INNOVATOR:
Paharpur Cooling Towers Limited

ADOPTER:
Indian Hotels Company Ltd. (IHCL)

IHCL and Paharpur Cooling Towers trialed an energy-efficient, low approach cooling tower at the Taj Palace in New Delhi and the Taj Exotica in Goa, to test performance in both dry and humid conditions, with the aim of lowering energy consumption for cooling, especially during peak times. Furthermore, 45 percent of materials used in the tower were recyclable, which reduced its environmental footprint.

Sustainable Recovery of the Hospitality Sector in India (3 of 3)

INNOVATOR:
Zenatix Solutions Pvt. Ltd.

ADOPTER:
Indian Hotels Company Ltd. (IHCL)

New Delhi-based innovator Zenatix partnered with IHCL to field-test an IoT-based energy and asset management solution called ZenConnect at two IHCL properties—the Taj Connemara in Chennai and the Taj Exotica in Goa. The solution aimed to monitor the existing electrical system, lower costs and energy consumption, and improve the planning and implementation of preventive maintenance to extend the life and performance of assets, while reducing breakdowns.

Innovative Cooling Technology Push (1 of 3)

INNOVATOR:
ATC International LLC

ADOPTER:
Africa Centre of Excellence for Sustainable Cooling and Cold Chain (ACES)

ATC will deliver a hybrid refrigerated body comprised of an insulated container built with polyurethane sandwich panels, a PCM with a cooling system, together with solar panels on top of the container and an Li-Ion battery pack for recharging the PCM system on the go.

INNOVATOR:
ATC International LLC

ADOPTER:
Natura Gida SAN. ve TİC. A.Ş.

Turkish innovator ATC has developed a refrigerated container that can be fitted on a truck to transport fresh and frozen products on long journeys of up to 50 hours. In collaboration with Turkish ice cream company Natura Gida, ATC aimed to conduct a pilot to test its refrigeration solution as an alternative to the traditional fossil fuel-based systems for long-distance and multi-drop transportation. The pilot would demonstrate significant reduction in fuel consumption and maintenance cost by utilizing ATC's innovative solution.

INNOVATOR:
Koolboks Ltd.

ADOPTER:
Africa Centre of Excellence for Sustainable Cooling and Cold Chain (ACES)

Koolboks will supply ACES with two of its solar-powered chest freezers, equipped with Li-ion batteries, PCM backup, and IoT-enabled remote monitoring devices. These features will ensure reliable cooling in off-grid settings.

Innovative Cooling Technology Push (2 of 3)

INNOVATOR:
New Leaf Dynamic Technologies Private Limited

ADOPTER:
Persea Oils & Orchards Ltd.

Indian innovator New Leaf and Kenyan adopter Persea have partnered to field test New Leaf's GreenCHILL refrigeration system that uses a natural refrigerant with zero greenhouse gas emissions. The solution, powered by biomass in the form of post-harvest waste, aims to provide a cost-effective and environmentally friendly method for cold storage and ripening of avocadoes and other produce at Persea's site.

INNOVATOR:
Natural Offset Farming Limited

ADOPTER:
Aneberries A.C.

Israeli innovator NOF partnered with Mexican berry-growing cooperative Aneberries to pilot a low-cost post-harvest cooling solution based on CO_2 in 20 fields with the aim of reducing costs and improving shelf life and fruit yields.

INNOVATOR:
Purix ApS

ADOPTER:
Africa Centre of Excellence for Sustainable Cooling and Cold Chain (ACES)

Danish innovator Purix will deliver its off-grid solar-powered cooling system, which includes thermal storage and a photovoltaic power backup, to ACES. This system is designed for use in insulated cold storage facilities. Additionally, the company will provide a 2.5-kilowatt solar-powered cooling system tailored for air-conditioning and storage applications.

INNOVATOR:
Purix ApS, Eja-Ice Nigeria Ltd., Greentech Refrigeration Solutions Ltd.

ADOPTER:
Farm to Feed Ltd.

Kenya's Farm to Feed is a digitally enabled aggregator that sources imperfect and surplus produce from farmers. In this pilot, Farm to Feed partnered with three innovators. It tested Greentech's medium and short-haul solar-powered transport solution to collect produce from farmers, a cold store running on Purix's absorption cooling system for warehousing of the produce, and Eja-ice's last-mile cooling van powered by solar panels. Collectively, this pilot aimed to increase produce shelf-life and reduce losses throughout the supply chain.

Innovative Cooling Technology Push (3 of 3)

INNOVATOR:
Purix ApS

ADOPTER:
Orlar Vietnam Joint Stock Company

Orlar, a vegetable producer in Vietnam, partnered with Danish innovator Purix to pilot a solar-powered cooling and heating system that aimed to test the possibility of producing temperate vegetables at affordable prices in Vietnam's lowland through root zone chilling technology, while reducing the need for conventional chillers.

INNOVATOR:
Thermal Energy Service Solutions Private Limited (TESSOL)

ADOPTER:
Africa Centre of Excellence for Sustainable Cooling and Cold Chain (ACES)

Insulated boxes and PCM inserts from Indian innovator Tessol aims to provide passive, emission-free cooling for autonomous refrigerated transportation of chilled and frozen products for short and medium distances, along with a blast freezer for the PCMs. It will be trialed and demonstrated at ACES.

Cooling-as-a-Service (1 of 3)

INNOVATOR:
CET Enviro Private Limited

ADOPTER:
Chalet Hotels Ltd.

This pilot tested two of CET's Scale and Bio-Removal (SBR) systems at Chalet Hotel's Westin Hotel in Hyderabad and its Westin Powai Hotel property in Mumbai. The solution offers comprehensive chemical-free treatment for cooling towers, prevents corrosion, algae formation, and scaling in cooling systems, and saves water. It is a fully automatic online technology that continuously cleans cooling tower water and augments cooling performance without any chemicals. The overall objective of this pilot is to help Chalet Hotels test the innovation under different operating conditions.

INNOVATOR:
Ecomax Solutions Pvt. Ltd.

ADOPTER:
India Habitat Center

Indian innovator ECOMAX partnered with the India Habitat Center to pilot a chemical-free, electrolytic water treatment system for cooling towers and an automatic tube cleaning solution for condensers, with the aim of reducing water use, environmental impacts, and costs.

Cooling-as-a-Service (2 of 3)

INNOVATOR:
Ekniti India Private Limited

ADOPTER:
Plaksha University

Tabreed tested Ekniti's Cryogel solution as part of a thermal energy storage (TES) setup, which served as an innovative component in a limited Cooling-as-a-Service demonstration project. This project involved Tabreed investing in the capital expenditure required to set up and operate the plant room and enhanced metering equipment to generate cooling for a hostel block at Plaksha University. Given the space constraints at the hostel plant room, a PCM-based system supplied by PLUSS and integrated into the system design by Ekniti was identified as the most effective way to test the TES solution. The TES system will be partially charged by solar PV during the day and will discharge at night when cooling loads increase. Enhanced metering will help align incentives around HVAC usage by enabling precise attribution. TE-SCI's support for this pilot was limited to testing the TES solution and the hardware/software required to monitor the hostel block's energy consumption patterns.

INNOVATOR:
Endo Enterprises (UK) Ltd.

ADOPTER:
Sofitel Mumbai BKC

UK innovator Endo Enterprises piloted an environmentally friendly, energy-efficient water treatment solution at a Sofitel hotel in Mumbai, India, using an organic chemical heat transfer fluid additive engineered to enhance the performance of HVAC systems.

INNOVATOR:
HT Materials Science

ADOPTER:
Tabreed India Pvt. Ltd.

The aim of this pilot was to explore the thermal conductivity qualities of HTMS's Maxwell™ product in a district cooling system in the Unted Arab Emirates, and to assess the potential for reduced energy consumption in future applications in India and other parts of Asia. Tabreed partnered with HTMS to pilot the solution at an HVAC plant in a technical college in Abu Dhabi. The Solution was tested on the chilled water system of a 2500TR HVAC plant at the pilot site.

INNOVATOR:
Iotomation Ecotech Pvt. Ltd.

ADOPTER:
Indian Hotels Company Ltd. (IHCL)

IoTomation designs and develops innovative and intelligent building management solutions that reduce the costs of energy, commissioning, and maintenance. The pilot aimed to build on a previous successful pilot and test IoTomation's BE-IoT solution at scale, covering the entire HVAC system at Taj Mahal by integrating with electro-mechanical systems, water pumps, chillers/heat exchangers, cooling towers, and more. This pilot aimed to provide additional evidence for BE-IoT to be adopted and scaled across all 250+ hotels owned or operated by IHCL.

Cooling-as-a-Service (3 of 3)

INNOVATOR:
Multiple

ADOPTER:
Indian Institute of Technology Jammu (IIT Jammu)

IIT Jammu is partnering with TechEmerge and Tabreed to enhance the capabilities of its dedicated 'Cooling Innovation Lab' on campus. The lab aims to incubate and accelerate the testing and pre-market validation of various sustainable cooling solutions and business models, with a strong focus on the Indian market and beyond. Over the course of this project, the lab will concentrate on cooling technologies within four distinct sub-domains. This initiative will help establish reusable test beds, pilot processes, and post-pilot results verification processes, thereby increasing the number and variety of sustainable cooling technologies that achieve pre-market commercial validation.

Scaling/Replicating Cold Chain Technologies

INNOVATOR:
Control de Variables S.A.S.

ADOPTER:
Koba International Group S.A. (D1)

Colombian innovator Control de Variables (operating under the trademark iMometrics) partnered with D1, the country's largest low-cost retailer to pilot integrated solutions for monitoring and managing cooling and refrigeration equipment. The pilot aimed to improve energy efficiency and reduce costs and food waste.

INNOVATOR:
Konverter Engineering Group

ADOPTER:
Procesadora Nacional de Alimentos C.A. (Pronaca)

Mexican innovator Konverter and Ecuador's largest food processor, Pronaca, piloted an IoT and platform-based energy management solution that aimed to establish an energy management system to measure, monitor, and record energy consumption, voltage, and power parameters at a granular level and support the company's sustainability strategy.

Annex 6 – Knowledge Sharing

Raising awareness and sharing knowledge about the benefits of sustainable cooling innovation is critical to accelerate the adoption of new technologies and business models that improve energy efficiency, lower costs, and reduce climate impacts. TechEmerge produced numerous social media campaigns, feature stories, and videos that raised broader awareness of the importance of sustainable cooling innovation and held a wide range of online and in-person events targeting corporates, innovators, and other key stakeholders.

For example, In October 2021, more than 60 participants joined a webinar that examined the current state of play and key levers required to catalyze the adoption of cold chain innovations throughout India. Meanwhile, in September 2022, TechEmerge participated in ExpoAcaire 2022, the biggest cooling expo in Latin America. In partnership with Colombian Association of Air Conditioning and Refrigeration, TechEmerge supported over 30 cooling innovators to present their pilot results and promoted partnership opportunities with more than 270 ACAIRE members.

A TechEmerge innovator presents their technology at ExpoAcaire 2022. Photo by IFC.

In May 2023, during the Developing Economies Conference in Mumbai, India, over 100 companies—including Indian Hotels Company Ltd, Chalet Hotels Group, Tata Realty, and others—took part in a half-day industry event organized by TechEmerge that showcased successful pilots and explored financing mechanisms to scale up climate-smart solutions. The conference was organized by the American Society of Heating, Refrigeration, and Air Conditioning Engineers. In addition, in August 2023, over 140 participants tuned in for a webinar hosted by TechEmerge and the Organization for Technology Advancement of Cold Chains in West Africa, where innovators conducted lightning demos of sustainable cold chain technologies and TechEmerge experts provided insights into opportunities and challenges in this vital sector.

In October 2023, TechEmerge held a Sustainable Cooling Innovation Summit in partnership with the UK Department for Energy Security & Net Zero. Over three days, more than 100 innovators, adopters, and experts in cooling and finance gathered at the University of Birmingham to share cutting-edge innovations and mechanisms to scale up financing for sustainable cooling.

TechEmerge also organized a virtual workshop during the World Bank's flagship Innovate4Climate conference in 2022. The team presented recommen-dations for cooling innovation at the Meeting of the Parties (MOP) in 2022 and 2024 organized by UNEP Ozone Secretariate, at the 2023 Sustainable Cooling as a Climate Solution event hosted by the Global Adaptation & Resilient Investment Group), and at the 2023 Green Cooling Summit organized by GIZ.

A panel discussion at the TechEmerge Sustainable Cooling Birmingham Summit, Photo by IFC/Creative Media.

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