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A REPORT FROM ENERGY CATALYST

Learning from innovative businesses in the sustainable cooling sector

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About Energy Catalyst and this report

This research presents an overview of the challenges and opportunities within the sustainable cooling market, and highlights a selection of innovation projects, supported by Energy Catalyst, with the potential to address these challenges. It will also draw out relevant learnings and insights from these case studies.

Energy Catalyst is an Innovate UK programme funded by the Foreign, Commonwealth and Development Office (FCDO) and the Department for Science, Innovation and Technology (DSIT) under the Ayrton Fund, part of the UK's International Climate Finance commitment. Through financial and advisory support, and by building strategic partnerships and uncovering new insights, Energy Catalyst accelerates the innovation needed to realise a just and inclusive clean energy transition across communities in Africa, Asia, and the Indo-Pacific region.

Energy Catalyst aims to accelerate progress on Sustainable Development Goal (SDG) 7 to ensure access to affordable, reliable, sustainable, and modern energy for all. Sustainable cooling and cold chain solutions support Energy Catalyst's mission through accelerating innovation for a just and inclusive clean energy transition. By developing energy-efficient and renewable-powered cooling solutions, these initiatives reduce emissions and improve energy access in underserved regions. This directly supports Energy Catalyst's goal of addressing energy poverty and promoting sustainable development in Africa, Asia, and the Indo-Pacific region.

Additionally, sustainable cooling technologies can enhance food security, healthcare, and economic growth by preserving perishable goods and medicines, thereby improving the quality of life and fostering resilience in vulnerable communities.

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Executive summary

As global temperatures rise and the impacts of climate change intensify, access to sustainable cooling products has never been more critical, particularly for vulnerable and energy-underserved communities. Sustainable cooling solutions not only improve quality of life for these communities, but also play a vital role in supporting small businesses and uplifting standards of living. Access to cooling is critical in reducing food waste and strengthens health services by enabling the safe storage of vaccines, medication, and blood. Access to cooling can also contribute significantly to productive use and income generation for a wide range of existing and potential end-users.

Despite the vast potential market for cooling technologies—both for productive applications and space cooling—adoption remains low in off-grid and weak-grid areas. Recent reports highlight a significant gap between the current sales of cooling products and their estimated potential serviceable market. Although these technologies offer many advantages, their adoption is hindered by barriers related to affordability, reliability, and accessibility. Upfront cost is the most significant barrier to uptake because sustainable cooling technologies are often expensive, particularly for communities in off-grid areas, where income levels are lower and access to financing is difficult.

However, innovation in technologies and business models is reshaping the market, making sustainable cooling solutions more affordable and reliable. Companies supported by the Energy Catalyst are helping to drive this transformation, spearheading projects that address key barriers and challenges to unlock new opportunities. This report highlights the following groundbreaking projects:

Cooling as a Service by Oxford University allows small enterprises and communities to access cooling solutions without upfront costs. Users pay a subscription fee that covers installation, maintenance, and energy, making sustainable cooling more accessible.

Inclusive Energy's use of Cloud Solar charge controllers with real-time monitoring showcases how data can optimise energy consumption and improve system efficiency while its pay-as-you-go model integrates carbon financing to enable more affordable cooling.

PyroGenesys' technology utilises a pyrolysis plant using locally available waste sources, such as rice straw and husks, to produce electricity for cooling and biochar for fertiliser use, allowing for additional revenue streams alongside the provision of cooling to keep costs low.

Portable cooling pods by Hubl Logistics use phase change materials (PCM) to provide efficient cooling for perishable goods, showcasing sustainable cooling's role in enhancing productivity in agriculture and logistics.

Innovative mobile solar-powered cooling systems developed by Akreon improve healthcare delivery in remote areas with affordable and reliable vaccine storage moving to health centres when it is needed.

SureChill's ice storage keeps stable temperatures for health and agricultural products, while its innovative energy harvesting controller allows surplus energy to be used for other uses, so supporting energy access.

These innovations have enormous potential to enable local farmers and other businesses to increase productivity, create jobs, and drive economic development. By making sustainable cooling more accessible and affordable, these technologies offer a promising pathway to addressing climate challenges while supporting the requirements of several key sectors across off- and weak-grid areas.

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Introduction

Photo: A man transporting a freezer with a wheelbarrow on the road in Kibogora, Rwanda (istockphotos.com)

Photo: Sokofresh, Kenya - 2023

This report explores the critical role of sustainable cooling products and productive use of renewable energy (PURE) solutions in fostering energy access, income generation, waste reduction and a just transition, particularly in off-grid and weak-grid areas. It examines key challenges hindering the uptake, implementation, and demand for these cooling technologies. Featured in this report are a selection of Energy Catalyst-supported companies showcasing how their innovations are breaking down barriers to accessible cooling.

Sustainable or clean cooling refers to cooling methods that utilise climate-friendly refrigerants and minimise environmental harm, including impacts on climate change, in alignment with the goals of the Paris Agreement and the Montreal Protocol[1]. This approach encompasses a variety of practices, such as deploying energy-efficient appliances, implementing passive cooling techniques, and harnessing renewable energy sources. The aim of sustainable cooling and cold chain implementation is to deliver effective cooling solutions for off-grid or weak-grid communities through renewable energy sources.

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As global temperatures rise and the impacts of climate change intensify, the need for sustainable cooling products has never been more critical, especially for the most vulnerable and energy-limited communities. These solutions have the potential to not only help improve the quality of life for these communities through disease reduction and efficacy improvement of temperature-sensitive pharmaceuticals and medicines, but they play a vital role in supporting small businesses, creating economic opportunities and uplifting overall standards of living through reduction in food spoilage, higher farmer yields and improved profitability and job creation.

Tackling spoilage and wastage

Amid escalating global food insecurity and price volatility driven by rising populations, supply chain disruptions and declining agricultural yields due to climate change, the urgency to reduce food waste has never been greater. About 17% of the total global food produced is wasted[2] on average, partly due to a lack of adequate or accessible cooling solutions, and the rate of wastage is particularly high in off-grid areas. It is estimated that unlocking sustainable cold chains in agriculture could enable low and middle-income countries to boost their food supply by 15% by extending the shelf life of perishables[2]. Additionally, reducing food wastage could potentially save communities up to $400 billion per year globally[3], providing a significant economic opportunity for off-grid households.

Economic development

Cooling can contribute significantly to productive use and income generation and is relevant to a wide range of existing and potential end-users, including households, small retail shops, hotels, restaurants, small-scale farmers and fisherfolk. There is a need for cold chain systems, including refrigerators, freezers, cold storage units and cold rooms, by farmer cooperatives, aggregators and customers of vegetables, fruits, fish, dairy, and meat, as well as municipal authorities managing local markets[4]. It is estimated that the lack of reliable cold chains reduces the income of approximately 470 million farmers worldwide by up to 15 per cent[19]. In addition to reducing these losses and increasing incomes, there is scope for income generation from the new services available from cold chains. For example, in a study carried out in Uganda, Kenya and Tanzania, 72% of off-grid refrigerator customers interviewed had increased income and business growth as a result of their refrigerator[20].

The shift towards sustainable cooling technologies can also create extra jobs in the installation, maintenance, and operation of these systems. The International Renewable Energy Agency (IRENA) estimates that the renewable energy sector could create up to 40 million jobs worldwide by 2050[6], many of which could be in off-grid communities focusing on sustainable technologies such as cooling.

Photo: Inclusive Energy (Nigeria) - 2023/4

Health implications

The use of cooling also extends to health services, where it is critical. The World Health Organisation (WHO) estimates that approximately 50% of vaccines are wasted globally[5], contributing to over four million deaths annually[2]. Discontinuities of the cold chain in low-income settings where electricity is scarce contribute greatly to this wastage. Whilst essential for storing vaccines and other temperature-sensitive medications and improving health outcomes, reliable cooling is often scarce in off-grid communities. Effective cooling also helps prevent the growth of pathogens in food and medicines, reducing disease transmission and improving overall health. With its capacity to reduce harm and save lives, adequate refrigeration plays a critical role in the wellbeing and future of these communities. It also has far-reaching economic impacts: WHO estimates that the return on investment in every immunisation programme is US$44 per dollar invested, a figure that can only rise with less vaccine wastage.

Emission reduction

Sustainable cooling solutions, such as solar-powered refrigeration systems and the use of climate friendly refrigerants, also reduce direct emissions and reliance on fossil fuels, which are often used in off-grid settings to power equipment and generators. This transition is crucial in achieving global Sustainable Development Goals aimed at directly and indirectly reducing CO_2 emissions. The UN Environment Programme (UNEP) estimate that if future cooling needs (particularly space cooling, as well as cold chain) can be done sustainably, potential greenhouse gas emissions could be reduced by as much as 60% by 2050[4].

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The sustainable cooling market

Photo: Fresh fish frozen in ice red snapper crocker and tilapia fish in cold storage (istockphotos.com)

Overview of cooling technologies and their market use segmentation

Three key refrigeration or freezing technologies are deployed to address the needs of off-grid and weak-grid markets[2]:

Compression refrigeration is the most common method, employing electrical energy to compress a refrigerant gas. Options include:

- Conventional alternating current (AC) refrigeration powered by the grid, a generator, or a solar system with an inverter.
- Solar direct drive (SDD) refrigeration connects directly to a PV panel and includes a thermal or electrical battery to allow cooling during the night or on cloudy days.
- Direct current (DC) refrigeration works with solar systems and batteries and includes more efficient design features such as highly efficient compressors or thicker insulation. Advancements in energy-efficient designs and solar-powered options have enhanced its viability for small commercial and domestic applications.

Absorption refrigeration utilises heat from sources such as natural gas, propane, solar thermal energy or waste heat, allowing it to operate independently of electrical power, which makes it ideal for areas with unreliable electricity.

Evaporative refrigeration, or swamp coolers, use the natural process of water evaporation to cool air, proving highly efficient in dry climates with lower operational costs, although there is a limit to its cooling potential.

These technologies are used within cooling appliances or products, which can be categorised into three key product types: freezers, refrigerators, and variable temperature units; walk-in cold storage or cold rooms; and portable solutions. See Figure 1 for an overview of the appliances and their target markets.

Photo: A CoolRun pod being loaded with PCM, Hubl; UK - 2024

	Cold storage or cold room	Freezer or refrigerator	Portable cooling solutions
Health and wellbeing		Ice-Lined Refrigerators (ILRS) and vaccine storage Blood storage and other medical samples Household and micro, small and medium-sized enterprises (MSMEs) refrigeration	Active and passive vaccines and other medical sample carriers
Livelihoods			
Agriculture	Cold storage for storing aggregation and processing of perishable produce	Retail shops (including value-added cut fruits and vegetables, juice, etc)	Transportation of fruits and vegetables
Animal husbandry	Cold storage for meat and processed food	Milk chillers and coolers Retail shops	Transportation of milk and dairy products, meats, etc
Micro businesses	Shared cold storage units in markets (flower, meat, fish, vegetables, and fruits)	Restaurants, retail, mobile vendors, delivery agents	

Figure 1: Cooling technologies and their applications; Source: SELCO Foundation 2023

The product types target three main market segmentations: domestic and small commercial demand, agricultural applications, and health applications.

Technologies for domestic and light commercial refrigeration used in homes and small shops, and by small agricultural producers. These are mostly refrigeration and freezer units, typically with volumes ranging from 50 to 400 litres that are available across various markets, but their high cost remains a significant barrier to widespread adoption. A consumer impact study of solar DC refrigerator owners revealed a preference for models between 150 and 250 litres. However, due to their prohibitive costs, many consumers opt for AC refrigerators with inverters instead[7]. Additionally, freezers and multi-temperature units are gaining popularity among small businesses as they offer strong potential for boosting revenue.

Technologies for agricultural applications. This is an emerging segment that includes technologies such as solar-powered walk-in cold rooms, milk chillers, ice makers and electric chiller vehicles designed for producer cooperatives, retailers and wholesalers of agricultural produce, transporters, and brokers and collectors of agricultural produce. While promising, these technologies are still new in many markets. Innovations such as SDDs and PCMs are enhancing energy efficiency and reducing operational costs, enabling better cold chain solutions for these actors.

Technologies for healthcare refrigeration: Solar refrigerators have been widely used in areas with no or unreliable electricity since 2014[2] and the sector has gained considerable attention in recent years due to the roll-out of the COVID-19 vaccine. It focuses on maintaining strict temperature controls for vaccines, drugs, and medical supplies. Advancements in areas such as insulation, and efficient compressors and controllers, are improving cost-effectiveness and performance, while technologies like PCMs and variable-speed compressors are reducing energy needs and costs.

Photo: KoolBoks, Nigeria - 2023

Potential market for cooling technologies

When market segments are combined, it becomes clear that the total potential market for cooling technologies, including space cooling, is vast. The scale of the market is also apparent from estimates around the need for cooling. According to SEforALL's Chilling Prospects report[8], around 1.1 billion people in the 52 most vulnerable countries face risks related to cooling access. This includes approximately 470 million people in rural areas without electricity or cold chains for food and medicine, as well as 630 million living in informal settlements in hot urban areas where electricity services are either unavailable, unreliable, or too costly.

The recent sales reports carried out by the Global Off-Grid Lighting Association (GOGLA), *Lighting Global and Efficiency for Access* indicate that, cumulatively, only about 68,000 refrigerators for off-grid and weak-grid use have been sold in low and middle income countries between 2019 and 2023[7] (see Figure 2). This number of units is vastly lower than the estimated potential serviceable market which has varying estimates. The Lighting Global report[17] suggests that the largest market for cooling will be farmers and that 12% of farmers with perishable goods in sub-Saharan Africa (SSA) are able to afford cold storage services (approximately 0.89 million out of a potential market of 7.4 million).

In India, the report estimates that about 30% of farmers could afford participation in cold storage facilities, approximately 15.8 million out of a potential market of 52.5 million. That means, in SSA and India, there is a current market of about 16.7 million farmers for individual or shared cooling units. In contrast to the Lighting Global report, Efficiency for Access and GOGLA estimate a more conservative serviceable market at 4.8 million individual refrigerators/freezers out of a potential of more than 32 million units in off-grid areas. The estimate is likely to be larger if weak grid areas are included, particularly in Southern Asia, and if shared cold storage facilities are added.

The large gaps between existing sales and the serviceable market, as well as between the serviceable and potential market, present significant opportunities. This underscores the critical need for innovations in technologies and business models to make them more affordable and accessible, aligning with the SDG's commitment to "leave no-one behind." Current slow market growth is largely attributed to affordability issues, low access to finance, supply chain challenges and low consumer awareness.

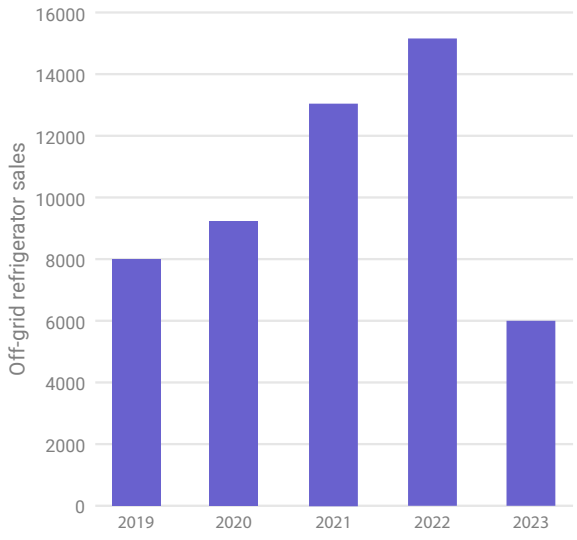

Figure 2: Estimated off-grid refrigerator sales data; Source: Efficiency for Access 2024

However, awareness around the importance of cooling solutions is increasing amongst populations living in off-grid areas, particularly in terms of income generation, food preservation, health services and medicine accessibility. Building upon this awareness is critical to driving demand for sustainable cooling options.

With more players getting into this space, there are now some successful pilot projects and case studies highlighting the implementation of sustainable cooling in off-grid settings. These initiatives demonstrate the tangible mutual benefits for both electricity providers and the communities they serve and often entail investment in local community engagement and customised solutions that meet specific local needs.

Recognising the potential of sustainable cooling to enhance community resilience, contribute to economic growth and improve quality of life, some governments and organisations are establishing policies, regulations, and support frameworks to promote sustainable cooling in off-grid areas and reduce inequalities in access. Currently, around 20 governments have policies or programmes that support off-grid cooling[1].

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Towards the widespread adoption of cooling technologies

Photo: Sokofresh, Kenya - 2023

Current challenges

Despite the potential advantages, the adoption of sustainable cooling technologies, particularly in off-grid and weak-grid areas, faces several significant barriers.

Affordability barriers

High cost: Price is the most significant barrier to the uptake of sustainable cooling technologies which are often expensive compared to conventional cooling solutions[3]. This often proves prohibitive, especially for communities in off-grid areas, where income levels are lower and financing difficult to access.

Factors that contribute to affordability barriers include high production costs, particularly when expensive components such as batteries are needed and in places where there are not sufficient economies of scale for producers to bring down costs. Access to finance is an issue for the producer and the distributor too, particularly in the wake of global financial shocks in recent years, which have made many financiers more risk-averse[7].

Another issue relating to accessing finance is the capital-intensive nature of the cooling industry, particularly when it comes to cold rooms; financial institutions perceive this as a high-risk sector and thus charge high interest rates. Furthermore, the lack of specialised financing mechanisms to make these technologies affordable for end-users suppresses demand and acts as a brake on company growth.

The **inadequacy of accessible customer financing** options also means of course that affordability issues for end-users are not sufficiently addressed. Many households and SMEs in off-grid areas do not have access to credit or financial institutions that offer loans tailored to purchasing sustainable technologies. Without viable financing, even low-cost sustainable solutions may remain out of reach to many households and businesses that need them.

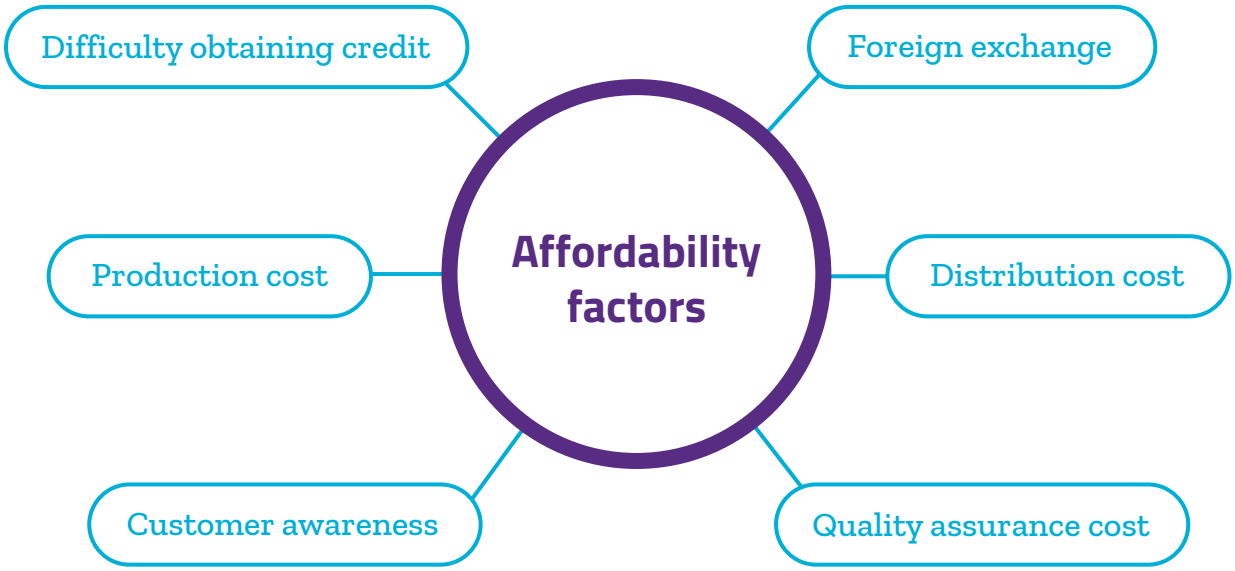

Figure 3: Factors that affect the affordability of cooling appliances and products; Source: Efficiency for Access

Reliability barriers

The reliability of cooling appliances is critical, particularly for productive uses such as health applications, agricultural produce storage and income generation. Any interruption to cooling can have significant impacts, resulting in lost revenues to users and companies operating service models, and potential risks to health or life when it comes to food supply or healthcare provision.

However, the reliability of off-grid sustainable cooling technologies, which require renewable energy sources such as solar power, is often affected by a complex range of factors. Some of these solutions lack adequate energy storage capacity, and sometimes inconsistent sunlight or seasonal variations can affect their cooling performance, particularly during periods of peak heat. High variability in fridge or freezer temperatures can also lead to a deterioration of agricultural produce or result in a reduction in the potency of vaccines. In cases where refrigeration technologies do not monitor or display precise temperature measurements from inside the cooling unit, health workers often do not know if the vaccines they are administering will work. This can undermine the uptake of these healthcare technologies and overall trust in vaccination programmes amongst the populace.

The reliable operation of sustainable cooling technologies often requires regular maintenance and technical support. In off-grid areas, the lack of skilled technicians or service centres can hinder the long-term reliability of these cooling solutions. Without proper maintenance, systems may fail or operate inefficiently, reducing their intended economic or efficiency gains. Improving technical support and aligning products with quality assurance programmes can enhance the long-term reliability and durability of these products, ensuring more high-performing products reach the market and potentially encouraging competitors to follow suit.

Access and awareness barriers

Many rural and off-grid areas in low and middle-income countries lack the necessary infrastructure, such as accessible roads, markets, and logistics, which inhibits the development of distribution networks that could make sustainable cooling technologies more readily available. Where they are available, the cost is inflated to consider the cost of distribution to typically rural, remote, or otherwise hard-to-reach areas, which dampens adoption. Transportation challenges mean that people living in remote locations may not have easy access to the suppliers or service technicians needed to build, install, and maintain these solutions, which again undermines demand. Limited distribution networks also mean that even when the cooling technology is affordable to potential end-users and there is significant potential demand within a given location, it may not be practically accessible.

In remote and off-grid communities, there is often lack of awareness about the benefits and availability of sustainable cooling technologies. Awareness-raising initiatives are often needed to inform small business owners and householders about the advantages of these products, and how they can improve their business or quality of life, which adds to the cost of the product. Additionally, residents and businesses may have preconceived notions about the performance of cooling solutions based on their experiences with conventional systems. If sustainable cooling options do not meet these expectations, it can lead to a reluctance to adopt them. Companies must undertake targeted marketing efforts to address and overcome these expectations.

Looking ahead

Addressing these challenges requires a comprehensive and multi-faceted approach. Below are some of the trends and innovations currently promoted by cooling companies, such as the companies featured in this report, to address them. Innovation in technology and business models is increasing the affordability as well as improving the reliability of cooling.

However, more can be done to accelerate uptake of cooling for productive uses as well as domestic use, including efforts by acceleration programmes such as Energy Catalyst to support the demonstration of new technologies and business models in clean cooling. Figure 4 summarises some of the solutions.

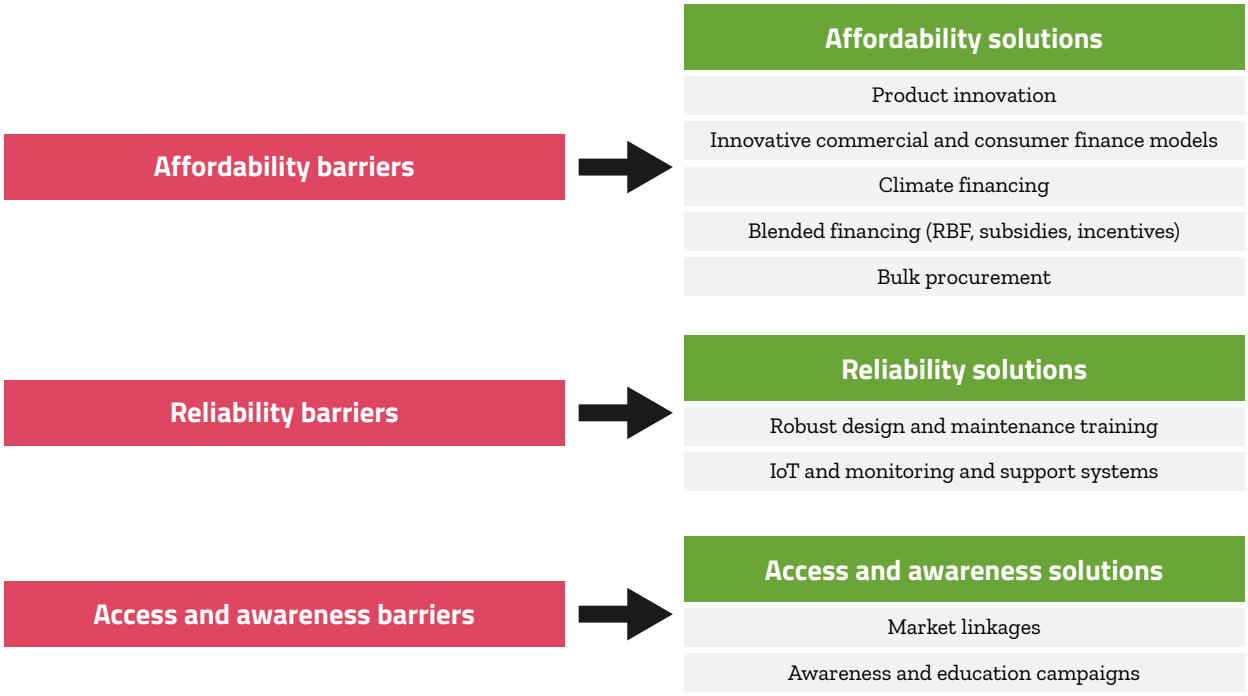

Figure 4: A summary of proposed solutions to affordability, accessibility, and reliability barriers

Addressing affordability

Reducing costs through product innovation

One of the major developments in refrigeration technology, used by an increasing number of solar refrigerator manufacturers, is the incorporation of thermal energy storage, or thermal batteries, which reduce reliance on costly electrical batteries. The technology not only cuts down the expense of the solar setup required to power the refrigerator, but also enhances the system's durability and resilience, especially in off-grid and weak-grid regions. Thermal batteries use PCM to store the cold and so allow low temperatures to be maintained even when there is no power. Where PCM is included as part of an SDD technology it can eliminate the need for electrical batteries completely, reducing product cost, because PCM is less costly to produce and integrate, reducing energy usage and operating costs. Examples of these are provided by Energy Catalyst-supported organisations, SureChill, University of Oxford and Hubl, described in further detail in the case study section of this report.

Another trend related to energy storage is the reduction in the cost of lithium-ion batteries over the past ten years, due to continued progress in R&D, economies of scale and technological innovation[15]. Battery costs are expected to decline further,[16] which will contribute to a reduction in sustainable cooling costs.

In addition, there have been improvements in refrigeration efficiency by an average of 5% between 2019 and 2022 as measured by Verasol. Improvements come from insulation, compressor, evaporate and condenser performance. There is also a growing interest in absorption cooling technologies, which could reduce costs if low-cost heat is available whilst also eliminating the need for high Global Warming Potential (GWP) refrigerants, thus reducing environmental impact. Furthermore, evaporative cooling techniques could offer a low-energy and low-cost solution for maintaining low temperatures in storage, further reducing operational costs.

Photo: Heifer International – Solar for Sustainable Income in Dairy project, Uganda – 2023

Innovative end-user commercial and consumer financing models

A number of innovative end-user commercial financing approaches, such as service-based models and pay-as-you-go (PAYGO) business models, improve the accessibility and affordability of cooling technologies.

Service-based models

Cooling-as-a-Service (CaaS) has emerged as a promising model, especially for large cold storage hubs users (farmers, fisherfolk, traders) who can store their produce as needed and pay less due to their variable use. The model usually involves a subscription or pay-per-use format allowing users to access cooling products and services without incurring significant upfront costs. However, CaaS can be challenging for the cooling companies to finance if their customer base does not generate sufficient revenues.

PAYGO models

PAYGO systems allow users to pay for cooling products and services in small, manageable instalments over time, reducing the financial burden of upfront costs. PAYGO can be delivered through various approaches depending on the market, mobile network, and technology level. It is quite common in Kenya and East Africa, and gaining traction in West Africa, particularly in Nigeria.

Both CaaS and PAYGO can be challenging for the cooling company in manage in terms of assessing credit risk and collecting payments. Some companies outsource consumer finance to address these challenges. However, extending credit or services without sufficient due diligence can lead to the end-users becoming overburdened with debt, and refrigeration services being withdrawn when payments are not made, incurring costs for the company.

Other financing models

In South Asia, PAYGO is less common, and finance is more likely to be provided by established microfinance institutions (MFIs). In this case, cooling technology companies partner with local MFIs to offer low-interest loans specifically designed for purchasing sustainable cooling products.

Other promising end-user business models, such as on-wage financing, on-bill financing, renting, and leasing, also exist. However, many of these business model innovations have only been demonstrated in well-established, higher-income markets. Many have not yet been widely deployed in low-income rural areas, where cooling access gaps are most acute, due to the low commercial attractiveness of these markets. Therefore, their applicability to such markets remains largely unproven.

Use of climate finance and carbon credits to enhance affordability

The rise of carbon finance offers a promising opportunity to monetise the emission reduction benefits of sustainable cooling technologies, attracting private investment and making these solutions more affordable. This is made possible through the integration of Internet of Things (IoT) into appliances allowing for monitoring and calculation of carbon emissions savings. While carbon markets are well-established for clean cooking, the costs of developing the carbon projects can be high compared to the early benefits. Nevertheless, this is a promising area that Inclusive Energy and PryoGenesys are currently exploring, amongst others.

Additionally, major funding initiatives, such as the Green Climate Fund's commitment of $157 million for the World Bank's Cooling Facility, along with $722 million[9] in leveraged co-finance, significantly promote the development of low-carbon cooling solutions across various countries. Climate finance sources like the Global Environment Facility and the Climate Investment Fund also work together to create synergies that amplify the impact of funding for sustainable cooling, particularly in rural contexts.

Additional revenue streams

In addition to carbon credits, some technologies or products offer opportunities for additional revenue streams. For example, SureChill's system allows for surplus generation of power, which can be used to generate additional revenue streams. PryoGenesys' pyrolysis technology generates biochar, which can be sold for fertiliser, in addition to energy for cooling. These revenue streams can bring down the cost of cooling for the end-user, making it more affordable.

Photo: Heifer International – Solar for Sustainable Income in Dairy project, Uganda – 2023

Addressing reliability

Internet of Things and monitoring

Increasingly the Internet of Things (IoT) is allowing remote monitoring solutions to be implemented that allow for real-time performance tracking and troubleshooting, enabling timely maintenance and support. Monitoring and support systems development plays a crucial role in enhancing the reliability of cooling solutions in underdeveloped markets. By enabling real-time data collection on temperature, humidity and equipment performance, these systems help identify potential issues before they escalate into failures, allowing for predictive maintenance. Predictive maintenance minimises downtime by forecasting when equipment may need servicing, which is vital in regions with limited access to replacement parts. Additionally, optimising energy consumption through data insights helps reduce operational costs, making cooling solutions more efficient and sustainable.

Reduced reliance on external support

As these systems provide the data to effectively troubleshoot and maintain equipment, they empower local technicians and reduce reliance on external support. With their scalability and adaptability, monitoring systems can be tailored to various contexts, and remote support capabilities enable expert assistance without the challenges of on-site visits. Overall, these developments ensure that cooling solutions are more reliable, sustainable, and better equipped to address the unique challenges in underdeveloped markets.

Interoperability

Progress has also been made to address concerns related to the interoperability between solar systems, appliances and controllers which can result in higher costs in adapting communication protocols to different hardware providers. More still needs to be done to ensure the many practical and economic benefits of interoperable systems are realised.

Training

To improve maintenance, companies provide training programmes for local technicians to ensure they can effectively maintain and service sustainable cooling technologies, there is also an opportunity to establish local technical support groups or networks. Comprehensive training can equip end-users with troubleshooting and maintenance skills, fostering a sense of community ownership and knowledge sharing.

Designing to suit the market conditions improves reliability

Technologies specifically designed for off-grid or weak-grid conditions, which can withstand local environmental challenges and meet local market needs, are likely to be more reliable than those not tailored to specific demographics and locations. For example, vaccines or medical product refrigerators require higher standards in temperature consistency and back-up energy storage to prevent spoilage. As environmental conditions (particularly temperature and humidity) vary by location, the size of solar panels must be adjusted to deliver the same level of cooling. Integrating user feedback allows for continuous improvement and customisation of solutions to meet local needs. Adherence to quality standards for specific regions also supports product reliability and durability.

Photo: A shopkeeper loads a SureChill fridge with soft drinks and water bottles (image: SureChill)

Addressing access and awareness

Collaboration with local businesses, microfinance institutions, cooperatives and NGOs can create improved distribution networks that ensure sustainable cooling technologies are available in off-grid areas as well as contribute to more effective consumer awareness activities[4]. Companies are making market linkages directly with those in agriculture value chains, such as aggregators or with fast moving consumer goods (FMCG) companies, to reach a wider market whilst also boosting the incomes of the customers, whether farmers, fisherfolk, or small businesses. SureChill, an Energy Catalyst-supported company featured in this report, has demonstrated this approach with Highland Soft Drinks.

Additional education and business training for customers can help them to maximise their cooling technology and boost sales. Suppliers can also assist customers in refining their business models. For instance, a small retailer using a solar fridge or freezer for ice sales might have low sales volume because ice is cheap, takes time to freeze and occupies a lot of space. A more profitable product, like refrigerated drinks, takes up less space, sells at a higher price and can be readily available. The more that cooling companies can enhance profitability for their end-users, the more popular their units are likely to become.

Photo: Heifer International – Solar for Sustainable Income in Dairy project, Uganda – 2023

Other enabling environment and financing support

In addition to technological and business model innovations, there are also external factors that can increase the affordability of cooling technologies. These include governments taking steps to create an enabling environment, particularly around including supportive policy, building awareness, and developing quality assurance frameworks for cooling products. The availability of financing options can enhance affordability and support the development of new products, such as:

Subsidies, grants, concessional finance, and public-private partnerships: Government concessional finance, subsidies, as well as public-private partnerships for low-income households and SMEs, all encourage the adoption of sustainable cooling technologies. These subsidies and incentives are required to promote innovation and support the needs of the most economically excluded populations until the costs of cooling solutions come down and access to finance increases significantly. Sellers and distributors may also need to be offered concessional financing to support the development of nascent commercial markets. For example, it is important for equipment suppliers in the early stages of introducing new technologies, to help them establish product lines and provide financing options to customers, thereby increasing the affordability of new products. NGOs and multi-lateral development banks can also provide funding or grants to offset some of these costs.

Results-based financing (RBF): RBF has emerged as an effective tool for enhancing access to, and affordability of, off-grid appliances. This mechanism offers payments based on pre-agreed results, requiring verification to ensure benefits reach end-users. Although not extensively tested at scale in the sustainable cooling sector, RBF has gained traction as a grant-based approach to boost market penetration. By promoting affordability of sustainable cooling solutions, RBF plays a crucial role in expanding access in underserved communities.

Other emerging financial instruments and business models for sustainable cooling include cooling bonds, energy service companies (ESCOs) and revolving funds. These have potential in low and middle-income markets but have yet to be widely used, and their applicability will depend on the characteristics of the markets, cooling providers and consumers[10].

Bulk procurement programmes: Bulk procurement is one of the proven ways to lower the price[3] of cooling products and appliances by reducing costs through economies of scale. This strategy can be implemented by public agencies, private entities, or public-private partnerships and involves aggregating the demand for cooling devices (such as refrigerators, cold rooms, and cold trucks) and placing a bulk order. A large, guaranteed order enables investment and production at volumes that achieve economies of scale. It also encourages the scaling of operations, service, and maintenance, making it more attractive for suppliers and supporting their commercial viability.

Photo: Inclusive Energy (Nigeria) - 2023/4

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Energy Catalyst funding and portfolio analysis

Photo: Heifer International – Solar for Sustainable Income in Dairy project, Uganda – 2023

The Energy Catalyst programme has made considerable progress over 10 funding rounds in promoting sustainable cooling solutions, focusing on the productive use of energy to accelerate the energy transition and benefit local economies. In funding innovative sustainable cooling projects, it aligns with global initiatives like CLASP, the Clean Cooling Collaborative, Efficiency for Access, the IFC's Sustainable Cooling Initiative and Cool Coalition. In the last four rounds of investment (Rounds 7, 8, 9, and 10), Energy Catalyst has provided approximately £114 million to innovative companies across Africa and Asia. This funding spans seven broad energy and related technology areas, as seen in the figure below. Cooling technologies represent about 7% of the Round 9 and Round 10 portfolios. As more innovators enter the sector and the potential of sustainable cooling becomes increasingly evident, Energy Catalyst aims to highlight and disseminate insights emerging from supported projects to inform other initiatives.

Energy Catalyst provides financial and advisory support to innovators developing new business models and technologies as demonstrated in the following case studies. Each of their innovations aim to address specific challenges limiting the uptake of clean cooling technologies. The cooling-related projects supported by the Energy Catalyst Rounds 9 and 10 are distributed across seven countries, with Nigeria hosting the most projects, as shown in Figure 6 below.

CaaS business models, such as the one pioneered by Oxford University, allow businesses and communities to access cooling solutions without upfront costs. Users pay a subscription fee that covers installation, maintenance, and energy making sustainable cooling more accessible for small enterprises and households. Similarly, Inclusive Energy's PAYGO model integrates with carbon financing to enable affordable and incremental payments for energy-efficient cooling, thus promoting financial inclusion. PyroGenysis' technology including a pyrolysis plant using locally available wastes, such as rice straw and husks, to produce electricity for cooling and biochar for fertilizer use, allows for additional revenue streams alongside the provision of cooling to keep costs low.

Innovative solutions, like the portable cooling pods by Hubl Logistics that use PCM to provide efficient cooling for perishable goods, showcase sustainable cooling's role in enhancing productivity in agriculture and logistics. Mobile solar-powered cooling systems by Akreon improve healthcare delivery in remote areas. SureChill's ice storage keeps stable temperatures while their energy harvesting controller redirects surplus energy so supporting energy access by optimising energy usage.

These innovations have the potential to significantly galvanise local economic development, enabling farmers and businesses to increase output and create jobs.

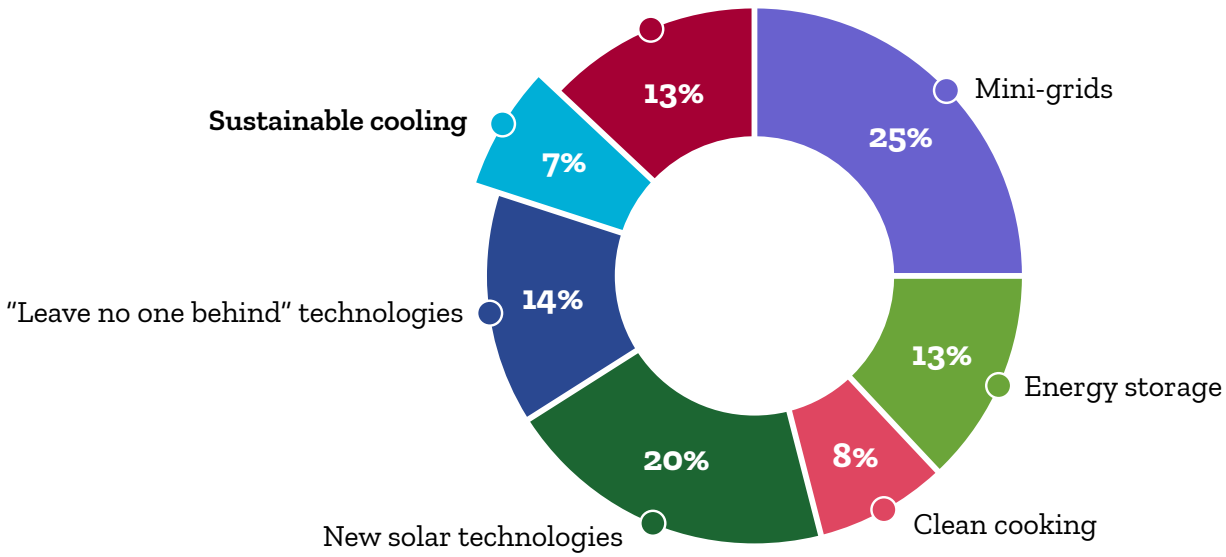

Figure 5: Share of individual thematic areas supported through Energy Catalyst for Round 9 and 10 portfolios

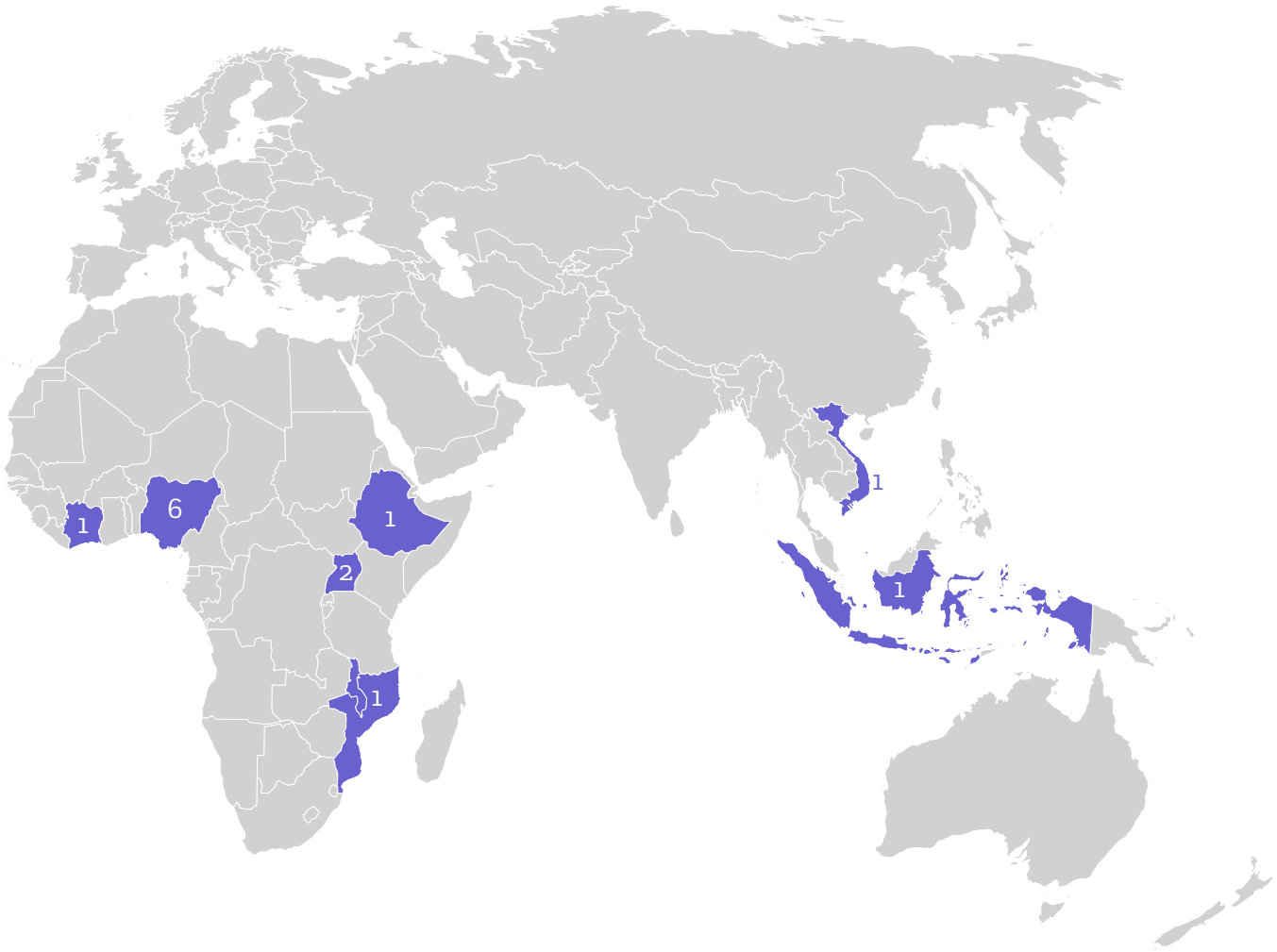

Figure 6: Countries, and number of projects, where Energy Catalyst has supported sustainable cooling innovations in Rounds 9 and 10

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Energy Catalyst companies addressing challenges in cooling

Photo: PyroGenesys UK pilot, UK - 2024

Hubl Logistics

Innovating last-mile delivery in cold chains to address affordability and reliability in Malawi

Hubl Logistics is focused on transforming the middle-mile and last-mile delivery processes, particularly in multi-temperature freight logistics, by providing efficient, cost-effective, and environmentally friendly solutions. A key objective is to reduce emissions and congestion in urban areas by addressing inefficiencies in multiple delivery drops through consolidation. To enable a more efficient means of consolidation and cross-docking[i], their innovative solution, CoolRun, a roll-cage scale transport container, has been developed for this chilled and frozen food transportation market, aiming to enhance cold chain delivery in the UK, plus tackle logistics challenges in Africa where food waste is a significant issue.

Photo (top): A CoolRun pod with side rendered transparent to allow view of interior, UK (image: Hubl) Photo (left): A CoolRun pod in use and filled with bottles of chilled water, UK (image: Hubl) - 2024

i Cross-docking is a logistics technique that transfers goods from inbound to outbound vehicles without warehouse storage

Traditional temperature-controlled vehicles used in food transportation contribute significantly to emissions, including CO_2, methane, and nitrogen oxides (NOx), due to the added weight of insulation and cooling systems. This makes transport refrigeration units (TRUs) a major source of pollution and operational inefficiency. Additionally, producers in rural areas face high transportation costs, leading to underutilised capacity and limited market access when loads are not optimised. Hubl Logistics addresses these challenges with the CoolRun pod, a passively cooled, emissions-free transport container that integrates into ambient temperature vehicle fleets. Resembling a large high-tech cooler, the pod can maintain frozen temperatures for up to 15 hours and chilled temperatures for up to 30 hours, utilising PCM thermal batteries for cooling without traditional TRUs, thus significantly reducing emissions.

The CoolRun pods not only cut operational costs through shipping consolidation and reduced fuel consumption, but also improve market access for small producers in remote areas, enabling the efficient transport of chilled goods and opening new market opportunities. This approach is particularly transformative in Africa, where cold chain infrastructure is undeveloped or underutilised. The CoolRun solution offers a scalable alternative that does not require substantial infrastructure investments, making it accessible and flexible for producers looking to transport temperature-sensitive products without incurring high costs.

One of the significant advantages of the CoolRun pod is its potential to mitigate food waste, a pressing issue in many African countries. By preserving the quality of perishable goods during transportation, the pod can extend shelf life and reduce spoilage, thereby enhancing food security and increasing farmers' incomes. Supported by Round 9 of the Energy Catalyst, Hubl Logistics is piloting the CoolRun solution in Malawi, collaborating with local partners such as the Malawi Fruit and Vegetable Farming Collective. This pilot aims to test 15 pods under local conditions, focusing on road quality, temperature fluctuations, and market demands while refining the pod's features, including solar-powered blast freezers; this technology enables the emissions-free charging of the PCM plates, which act as thermal batteries used within the pods making the whole cooling process emissions-free and cost-effective.

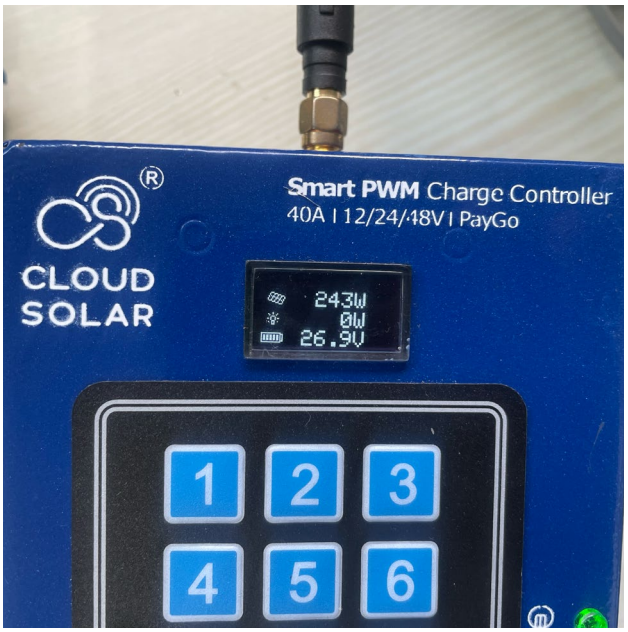
Hubl Logistics is also developing a commercial model for Africa, potentially incorporating leasing or rental options to lessen upfront costs for small producers. Environmentally, the CoolRun pods can reduce transport emissions by up to 67%, a critical factor in regions like Malawi, where transportation-related air pollution is a growing concern. Moreover, reducing food waste aligns with Hubl's sustainability goals, as food waste represents a loss of energy and resources.

Commercialising innovations like the CoolRun pod in Africa presents challenges, particularly regarding cost sensitivity in rural areas. The price point must be affordable for local producers and consumers, and the success of the CoolRun pod will depend on its ability to deliver sufficient value to justify the product's cost. Hubl's Malawi-based project partners are keen to improve product quality, widen their market reach, and improve producers' revenues.

The outcome of the Malawi pilot will be crucial for determining the scalability of the CoolRun solution across other African markets. While Malawi poses economic challenges, larger markets, such as South Africa, Nigeria, Kenya, and Ethiopia, present more opportunities due to their developed logistics networks and demand for temperature-sensitive products. Overall, the CoolRun pod represents a scalable, cost-effective solution for chilled and frozen food delivery, with the potential for significant expansion across Africa, driven by partnerships, technological innovation, and a commitment to sustainability.

Inclusive Energy

Improving cooling reliability and affordability through enhanced monitoring, PAYGO and carbon accounting



Inclusive Energy, a UK-based company established in 2018, has developed innovative smart solutions for solar home systems (SHS) and biogas technologies. Its work in Nigeria with Koolboks, a solar-powered refrigeration company, has highlighted the potential of using smart energy management systems to address key challenges in off-grid cooling, specifically for solar-powered freezers and refrigerators.

While solar refrigeration systems provide a sustainable alternative to conventional energy-intensive methods, they encounter issues related to performance and maintenance. Efficient energy management is crucial due to the varying energy requirements for different cooling needs, such as freezing meat or preserving vaccines. Without proper monitoring tools, it becomes challenging to track energy consumption, battery health, solar panel efficiency, and temperature regulation.

Photo (top): A Koolboks fridge with an integrated Cloud Solar charge controller (image: Inclusive Energy) Photo (left): A smart Cloud Solar charge controller in close-up (image: Inclusive Energy) Nigeria, 2023/4

To enhance the performance of Koolboks' solar refrigeration units, Inclusive Energy has integrated its Cloud Solar charge controller product, which monitors battery health, regulates energy usage, and optimises overall system efficiency. This monitoring system gathers data on energy consumption, solar power input, and internal temperatures, allowing Koolboks to offer personalised customer support and ensure efficient operation under varying conditions. The charge controller provides critical troubleshooting assistance by alerting users to issues like dirty solar panels or degrading batteries, thus minimising maintenance trips and reducing operational costs. Additionally, Inclusive Energy has implemented a PAYGO system within its charge controller, enabling users in off-grid areas to access refrigeration services through remote token payments, alleviating the burden of large upfront investments.

The integration of detailed energy consumption data has also enabled Koolboks to engage in carbon accounting, quantifying the carbon emission reductions achieved through their solar refrigeration units, which may facilitate trading these credits in online carbon markets. With support from Energy Catalyst, Inclusive Energy has enhanced data analytics related to battery degradation and freezer performance, developing a more efficient Maximum Power Point Tracking (MPPT) version of the charge controller to boost energy efficiency.

Between mid-2023 and the end of 2024, Inclusive Energy monitored 20-30 solar-powered fridges in Nigeria. Now, it is poised to supply charge controllers for an additional 2,000 units as Koolboks expands its reach. The company aims to fully commercialise its product by the end of the Energy Catalyst project, supported by a business model that generates revenue through hardware sales and data usage charges.

Looking ahead, Inclusive Energy sees considerable potential for scaling its technology, with plans to expand into markets for additional solar equipment, such as inverters and lower-cost AC refrigerators, while increasing the capacity of its charge controllers. The company also intends to incorporate more sensors targeting specific markets like agriculture. Inclusive Energy's technology is designed to be battery and solar panel agnostic, making it adaptable to various off-grid applications across different regions. With a growing presence in Nigeria, the Democratic Republic of the Congo (DRC), and East Africa, Inclusive Energy plans to explore new market partnerships over the next two years.

In summary, Inclusive Energy's collaboration with Koolboks exemplifies the transformative impact of integrating smart solar technologies with off-grid refrigeration solutions. Real-time monitoring, efficient energy management, and PAYGO integration, can be combined to address critical challenges, while collecting data for carbon accounting opens up significant opportunities for future growth.

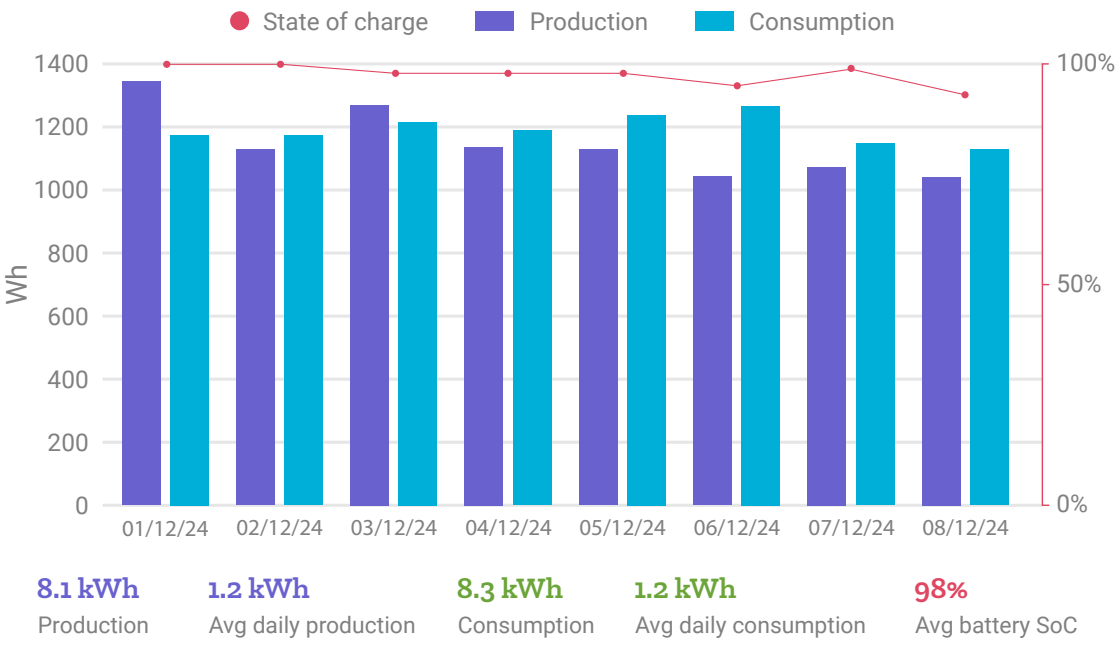


Figure 7: Screenshot of energy usage © Inclusive Energy

Akreon

Mobile PV-powered chilled storage for health products provides better performance and reduced costs in Nigeria

A UK-Nigerian company established in 2021, Akreon is tackling the critical challenges of vaccine storage and transportation in Africa, especially in Nigeria. The widespread reliance on diesel generators for vaccine cooling in Africa has led to high operational costs, inconsistent temperature regulation, and harmful emissions. Moreover, last-mile delivery often involves basic cooling boxes that fail to maintain the necessary temperatures, resulting in significant vaccine wastage—Nigeria lost an estimated 37% of its vaccines in 2022 due to inadequate storage conditions.

To address these issues, Akreon has developed EcoCool, a bespoke solar-powered off-grid refrigeration system. The EcoCool unit features a trailer with a 200 litre freezer and a 200 litre refrigerator, capable of storing vaccines at temperatures ranging from -20°C to +8°C, along with space for a pop-up office. A fold-out solar canopy with 8 kW of photovoltaic capacity powers the system, supported by batteries that provide up to 20 hours of storage during poor weather conditions.

Photo (top): An EcoCool refrigeration system in situ at a hospital in Nigeria (image: Akreon) - 2024. Photo (left): Vaccines in cold storage (image: Akreon)

EcoCool incorporates advanced features for safe vaccine storage and transport, including internal temperature probes for external monitoring, hybrid inverters for efficient power management, and internet modems that offer real-time updates on storage conditions and locations. With support from Energy Catalyst, two EcoCool units were trialled across three states and four health centres in Nigeria, successfully storing vaccines for 5-10 days in each location. Feedback was largely positive, though the team identified areas for improvement, such as enhancing efficiency and reducing the size of the trailers, which posed logistical challenges.

The next phase of development aims to redesign EcoCool for greater efficiency, potentially using compressors instead of electric chillers, and extending storage time during adverse weather. The team is also considering switching from trailers to hybrid vans for easier transportation and deployment. Plans include scaling refrigeration capacity up to 600 litres and integrating AI-based monitoring for traditional cooling methods to reduce vaccine wastage.

Akreon is exploring localising manufacturing in Nigeria to reduce costs and create jobs while collaborating with UK engineering and refrigeration firms to enhance the design and assembly process. The goal is to introduce the use of repurposed batteries in EcoCool, thereby supporting circularity and reducing overall costs of production.

While initially designed for vaccine storage, EcoCool's capabilities could expand to include blood storage and the transport of medical supplies, ensuring proper temperature management even in remote areas. The company is also considering applications for storing and transporting biological waste without diesel, which could foster partnerships with health systems like the NHS in the UK for waste management initiatives.

Currently in the pre-commercialisation phase, Akreon plans to refine and scale EcoCool by 2025. Their commercialisation strategy targets non-governmental organisations involved in vaccine distribution and government health agencies, such as the Nigeria Centre for Disease Control (NCDC). Akreon is also exploring revenue models beyond Nigeria, including direct sales, leasing, or franchise options, particularly in areas affected by natural disasters needing temporary cold storage solutions.

With ongoing improvements and redesigns, EcoCool aims to provide a versatile and scalable solution to address critical healthcare challenges in Africa and beyond. The next steps involve securing additional funding and forming commercial partnerships to bring the system to market and enhance its impact.

Photo: An EcoCool refrigeration system in situ at a hospital in Nigeria (image: Akreon)

PyroGenesys

Business model innovation with additional income streams improves affordability

Established in 2017, PyroGenesys specialises in pyrolysis technology that transforms locally available agricultural and agri-processor wastes into renewable heat, electricity, and biochar. The company's innovative PYROCHEMY solutions aim to address challenges related to energy access and food spoilage, significantly improving post-harvest storage conditions. With a team of 10 staff members based in the UK, PyroGenesys is focused on creating sustainable energy solutions tailored to local needs.

PyroGenesys identifies several barriers to the widespread adoption of cooling technologies including the high upfront costs and the lack of reliable energy. There is also a demand for specific skill sets for the operation and maintenance of these technologies, which are often scarce in the locations where they are needed most, especially in places like Nigeria. This expertise gap creates a culture of dependency whenever expensive imported technologies are deployed to provide much needed capabilities, hindering long-term sustainability.

Photo (top): A PYROCHEMY pyrolysis unit located alongside commercial operations (image: PyroGenesys) Photo (left): Pyrogenesys, UK - 2024

To overcome these challenges, PyroGenesys is committed to developing localised solutions that empower communities and reduce reliance on external specialists. Its approach includes partnering with local stakeholders, leveraging local expertise, and ensuring that their PYROCHEMY systems are robust, repairable, and maintainable by locally trained technicians. A key initiative is the development of a PYROCHEMY plant in Northern Nigeria, supported by Energy Catalyst, which aims to provide cold storage for onions, thereby reducing post-harvest losses that can reach 50%. In addition, the collaboration with Lavender Fields, a local agro-tech company, will establish a cool chain from harvest to cold room by facilitating efficient transport and storage of onions using a mobile cooling unit.

The pilot project, set to take place in Kano, will feature a 500 kg/hour PYROCHEMY pyrolysis plant utilising locally available waste streams, such as rice straw and husks, to produce and convert process heat to 60 kWe of renewable, island-mode electricity, generated by an Organic Rankine Cycle (ORC) engine, which will power a specialised onion chilled storage unit. Currently, the pyrolysis unit is being designed to meet the demands of the ORC engine, scaling up from an earlier successful pilot demonstrator in Scotland funded by the UK government's Department of Energy Security and Net Zero, while the cooling unit which has been installed in Kano, was sourced from the Netherlands.

To assist the cash-flow of customers requiring only a single PYROCHEMY installation, PyroGenesys operates a build, own, and operate (BOO) model, selling energy as a service via a 10-year power purchase agreement. Due to the challenges of selling energy affordably while remaining commercially viable, the company also generates additional revenue from biochar production. European Biochar Certification (EBC)-certified biochar, a byproduct of the PYROCHEMY pyrolysis process, serves as the substrate for a sustainable bio-fertiliser alternative called NUTRICHAR, which qualifies for carbon credits, with potential earnings of $166 per tonne of carbon removed. This revenue stream underpins the sustainability of the PyroGenesys BOO business model as it continues to scale.

Looking ahead, PyroGenesys is exploring opportunities to expand its technology into other markets, including regions in Africa with high demand for sustainable cooling and energy solutions, as well as Asian markets utilising rice waste. They also see potential in southern Europe, particularly in the dairy sector where waste slurry and cooling energy demands are significant. Additionally, the aid sector presents opportunities for applications in vaccine storage and food distribution in areas with poor infrastructure. By demonstrating the effectiveness of its technology in Nigeria, PyroGenesys aims to unlock new markets for perishable goods.

Through their unique approach to addressing food preservation and energy access, PyroGenesys offers scalable solutions that reduce waste, generate clean energy, and create valuable byproducts like biochar. As the company continues to pilot and expand its initiatives, it has the potential to transform how rural communities access energy and cooling, ultimately reducing post-harvest losses and fostering more resilient value chains.

University of Oxford

Improving cooling affordability and accessibility for Vietnamese fisherfolk with solar-powered cold storage and a CaaS business model

The University of Oxford, in collaboration with partners Chat Truc Technology And Trading Company, Institute For Circular Economy Development and Vietnam Solar Power EPC Corporation, is tackling critical issues in cold storage within Vietnam's seafood industry, particularly for small-scale fisherfolk and underserved communities. Its innovative approach aims to diminish the environmental impact while enhancing the affordability and accessibility of cold storage solutions.

Currently, only 35% of the cold storage demand in Vietnam is met, with the seafood sector experiencing the most severe shortages. High operational costs associated with diesel-powered storage solutions hinder smaller operators' access, while reliance on fossil fuels contributes to significant carbon emissions. Additionally, frequent power outages in Vietnam's electricity grid make traditional cold storage methods unreliable, and inefficient chilled transportation exacerbates product quality issues.

Photo (top): Field team installing solar PV panels at a pilot project in Vietnam (image: University of Oxford) Photo (left): Fish in cold storage at a pilot project in Vietnam (image: University of Oxford) - 2023

With funding from Round 9 of the Energy Catalyst Accelerator Programme, a pilot project has developed a hybrid cold storage system that integrates PCMs with solar photovoltaic (PV) technology. This system aims to replace traditional batteries with PCM, thereby reducing both capital expenditures and environmental impacts. The PCMs function by absorbing and releasing energy during phase changes, providing effective thermal storage. The pilot system includes a 20ft reefer container as cold storage capable of holding 20-30 tonnes of seafood at -18°C, supported by a 17 kWp PV system and a 5 kWh battery for energy management during night hours. Initial tests with 500 kg of fish have allowed for system optimisation, leading to reductions in PV system size and highlighting PCM's sustainability potential despite its slower charging speed due to low thermal conductivity.

Future phases of the project aim to scale up the cold storage system while reducing costs for PCM and PV components through design optimisation. Key strategies include refining thermal controls with potential AI integration for better temperature management, enhancing PCM conductivity to expedite charging, and incorporating remote monitoring for real-time system oversight. The partnership with a local operator to provide CaaS has received positive feedback from farmers, who appreciate the system's ability to maintain product freshness without freezing. However, collaboration with seafood collectors is crucial since small farmers often depend on them for financing and distribution.

Looking ahead, the project aims to expand beyond Vietnam, targeting off-grid communities and customers aiming to lower energy costs and carbon emissions. Plans include local manufacturing of cold storage systems to reduce dependence on imports and enhance sustainability. To facilitate widespread commercialisation, raising awareness of the system's benefits and demonstrating its potential to cut capital and operating costs while preserving product quality will be essential. Despite challenges regarding technology adoption and awareness, the pilot has shown promise in significantly reducing food loss, lowering emissions, and improving farmers' livelihoods. Continued refinement and scaling of the hybrid cold storage system could transform cold chain logistics in Vietnam and potentially other markets.

SureChill

Innovation in product design ensuring reliability and energy harvesting optimising energy use and affordability

SureChill was founded fourteen years ago with a focus on creating medical refrigeration products for the WHO. From the outset, the company aimed to extend its innovations beyond medical applications to develop cooling technologies that could benefit various sectors requiring stable temperature solutions, including agriculture and commercial industries. Advantages of their products include the ability to maintain stable temperatures during power outages, thus sustaining cooling for up to 12 days without the need for batteries or generator back up, plus the versatility to operate across different power contexts, from urban areas to remote rural settings. The fridges also require significantly less power than standard fridges. All these features are crucial for the safe and effective storage of vaccines, agricultural products, and perishable goods.

Photo (top): Local children gather around a newly installed SureChill fridge at a community shop in Malawi (image: SureChill) Photo (left) - A SureChill fridge used to store vaccines at a health facility (image: SureChill)

Following their success with WHO-approved products, SureChill expanded into the domestic and the small commercial refrigeration markets, targeting off-grid and weak-grid regions. They quickly recognised a demand for productive use applications, particularly for shopkeepers, farmers, and pharmacies. To address this, SureChill developed a new product specifically tailored for the currently underserved pharmaceutical and private medical markets, ensuring that the unique needs of such facilities were met and they no longer needed to rely on domestic fridges for medical purposes.

In tandem with their market and product expansion, SureChill launched a CaaS offering, allowing small businesses to access reliable refrigeration on a pay-per-use basis. This model addresses affordability challenges while fostering sustainable growth. The integrated payment technology enables customers to manage payments through mobile money, with alerts notifying them a few days before payment is due to ensure uninterrupted service. SureChill envisions incorporating further smart technologies for remote temperature monitoring and fault detection, technologies which advance upon their current systems of recording temperatures locally with a month's worth of data available for download.

SureChill has forged partnerships with distributors to promote PAYGO models and explore CaaS applications that yield measurable impacts for clients. In Kenya, for instance, it collaborated with Highlands Soft Drinks, providing SureChill fridges to sales outlets under a rent-to-own CaaS model, which boosted sales and reduced energy costs. The company is also piloting refrigeration solutions in the dairy sector with cooperatives to improve milk preservation and reduce operational costs, viewing this cooperative model as a means to reduce waste and costs for small-scale farmers. Additionally, they are exploring applications in the fishing sector and developing cold chain solutions for larger enterprises.

SureChill's fridges are designed to consume up to 60% less energy than other fridges, functioning effectively on just 4-6 hours of daily energy input. This innovative design can be used to employ a "time-shift energy" model using an energy harvesting controller which priorities energy distribution to maintain optimal cooling, while allowing excess power to be used for other applications, like solar home systems. This versatility positions its product as a potential "business in a box" solution for medical facilities and retailers needing consistent cooling. Supported by Energy Catalyst, SureChill is validating this concept alongside an Energy Management System Control Hub, which will provide users with real-time control over energy consumption and flexible payment options.

Looking ahead, SureChill is excited about commercialisation opportunities, exploring partnerships to refine their energy harvesting system, which has already attracted considerable media attention. It aims to ensure compatibility between their energy systems and both solar and mains-powered fridges, potentially increasing product uptake in various markets. Research and development remain a cornerstone of SureChill's approach, with their headquarters in Cardiff housing testing facilities for diverse climatic conditions. With growing teams in Kenya, and Nigeria, and a manufacturing presence in China, the company is well-positioned to continue expanding into underserved regions, backed by a diverse team of 40 members across multiple markets, including Côte d'Ivoire, Senegal, and Uganda.

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Learnings

Photo: Sokofresh, Kenya – 2022

Whilst the sustainable cooling sector has huge growth potential, learnings from companies in this field highlight the complex local variables which are critical to scaling and accelerating the adoption of sustainable cooling solutions, especially those aimed at productive energy use in low and middle-income markets. Yet by understanding the unique challenges and opportunities within these regions and devising strategies that take them into account, innovators can create impactful solutions that not only enhance energy efficiency but also contribute to local economic development and food security.

The insights from cooling companies contained in this report can equip other organisations and enterprises in the cooling space with the knowledge necessary to navigate such complexities, enabling them to roll out effective solutions on a greater scale.

Leverage smart technologies and data analytics

The integration of smart technologies and data analytics can enhance the performance and reliability of cooling solutions. Inclusive Energy's use of Cloud Solar charge controllers with real-time monitoring showcases how data can optimise energy consumption and improve system efficiency. This capability not only boosts operational performance but also facilitates preventive maintenance, thereby reducing downtime and repair costs. Cooling companies can harness such technologies to create more resilient and efficient cooling systems, ultimately providing greater value to users.

Embrace innovative business models

The critical role of innovative business models cannot be overstated in enhancing affordability and accessibility for underserved communities. Both the University of Oxford and SureChill employ CaaS models to provide reliable cold storage solutions without substantial capital expenditures. These models address significant gaps in the market while ensuring that users maintain product quality. By focusing on innovative financing and service delivery pathways, economically viable solutions, which promote sustainability without sacrificing financial feasibility, can be made more accessible.

Implement innovative financial models

Adopting innovative financial models, such as PAYGO systems, can significantly improve access to sustainable technologies in cost-sensitive markets. Inclusive Energy's PAYGO model allows users to pay for refrigeration services in manageable increments, alleviating the burden of upfront investments. This strategy enhances adoption rates among small producers and consumers in off-grid areas, ensuring that sustainable solutions are economically viable. Similar models can be explored to broaden their market reach and make their technologies more accessible to underserved communities.

Diversify revenue streams

Diversifying revenue streams can enhance the affordability and accessibility of cooling technologies. For example, PyroGenesys generates additional income from biochar production, a byproduct of their pyrolysis process. This innovative model allows them to offer energy services at lower cost while also qualifying for carbon credits, supporting the long-term sustainability of their business. Akreon is exploring various revenue models, including leasing and franchise options, to expand its market reach and ensure the financial viability of its EcoCool system for governmental and non-governmental organisations. By creating multiple income avenues, companies can better navigate financial challenges and improve accessibility for underserved communities.

Integrate advanced technologies for performance and sustainability

Integrating advanced technologies is a way to improve the performance and sustainability of cooling solutions. SureChill's use of ice storage and smart technologies enables real-time monitoring and energy management results in significantly lower energy consumption. Meanwhile, the University of Oxford's pilot project combines PCM with solar PV systems to enhance energy efficiency and reduce reliance on traditional power sources. Such technological advancements can improve product efficiency, lower operational costs, and minimise environmental impacts, ultimately aligning their solutions with broader sustainability goals.

Develop scalable, adaptable, and cost-effective solutions

Building scalable and cost-effective cooling that seamlessly integrates with existing frameworks can enhance the reach and impact of cooling while catering to local market needs. For instance, Hubl Logistics' CoolRun pod exemplifies this approach by offering a passively cooled transport container that operates efficiently within ambient temperature vehicle fleets. This innovation mitigates the need for substantial investments in traditional refrigeration systems, making it particularly accessible for small producers in regions with underdeveloped cold chain infrastructure.

By adopting these lessons, cooling companies can position themselves effectively in the off-grid and weak-grid sustainable cooling market, driving innovation and improving outcomes for communities in need.

Photo: Heifer International - Solar for Sustainable Income in Dairy project, Uganda

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