Background Documents

Cooling for All

Cooling Solutions for Cold Chains

MARCH 2018

KIGALI
COOLING EFFICIENCY PROGRAM

SUSTAINABLE ENERGY FOR ALL

DISCLAIMER AND COPYRIGHT

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

This work is supporting information only and has not undergone a process of peer review. Therefore, the data and supporting evidence should be understood only as a vehicle upon which to build more robust analyses, and not as an academic publication. It is provided in this format to encourage the exchange of ideas and data on access to cooling, and to make these findings available to practitioners and researchers, even if the document is less than fully polished.

RIGHTS AND PERMISSIONS: The material in this work is subject to copyright. Because SEforALL encourages dissemination of their knowledge, this work may be reproduced, in whole or in part, for non-commercial purposes if full attribution to this work is given to Sustainable Energy for All (SEforALL).

ADDRESSING DATA LIMITATIONS

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

To support this publication, an extensive data gathering exercise and literature review was undertaken, including a call for data to organizations that may have access to enhanced levels of granularity. The data expressed herein draws on a model produced by SEforALL that is based on data received through that process and data which is publicly available, and given limitations is subject to assumptions and margins of error.

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

COOLING FOR COLD CHAINS SOLUTIONS

1. POTENTIAL TECHNOLOGICAL AND OTHER SOLUTIONS

Cold chains consist of several components, typically including at least pre-cooling, cold storage, and refrigerated transport. Within most countries, it is common to find at least three different types of fresh food value chains, involving cold chain components to a smaller or larger degree. These include individual producers, who sell surpluses on the local market; groups of producers producing for domestic markets, who may combine their products and pay for cooling for highly valued products; and export marketers, who produce for overseas markets and must follow international standards for packing, cooling and shipping.

Not every food producer requires all components of the cold chain for their produce to arrive in good condition at consumers, however for those components they do use, having an **uninterrupted cold chain** is vital to reduce food loss and wastage. Similarly, consumers pending on the produce and the time between purchase/harvesting and consumption will have greater or lesser needs for cooling, however in the absence of cooling, many are likely to experience a greater loss of precious fresh food that otherwise could have been consumed or may even experience food poisoning.

For temperature-sensitive medicines such as vaccines, the main components of the cold chain comprise cold storage and refrigerated transport. Both are usually handled by stakeholders such as medical staff and may only involve consumers where medicines are to be taken home and kept cool for ingestion over multiple days.

Pre-cooling

A number of (in part low-tech) measures can be applied to help improve cold chains in developing and emerging countries for food and medical products. Applying **pre-cooling** solutions before transport or storage for instance can be a very cost effective and efficient way of preserving produce quality, as most refrigerated trucks or storage rooms have neither the refrigeration capacity nor air movement capability needed to rapidly cool produce straight from harvest. Technologies include evaporative forced air pre-cooling, the use of ice, hydro-cooling, forced air pre-cooling, individually quick frozen (IQF) and blast freezing, all of which need a power source.[i]

Nonetheless, passive cooling techniques such as evaporative natural cooling and even just putting crops under shade immediately after harvest will help prevent moisture loss, lower the temperature and maintain quality for far longer than if such produce is left out in the sun. This is particularly important for crops with high respiration rates. [ii]

Food product	Storage potential			
	At optimum cold temperature	Optimum temperature + 10°C	Optimum temperature + 20°C	Optimum temperature + 30°C
Fresh fish	10 days at 0°C	4-5 days at 10°C	1-2 days at 20°C	A few hours at 30°C
Milk	2 weeks at 0°C	7 days at 10°C	2-3 days at 20°C	A few hours at 30°C
Fresh green vegetables	1 month at 0°C	2 weeks at 10°C	1 week at 20°C	Less than 2 days at 30°C
Potatoes	5-10 months at 4-12°C	Less than 2 months at 22°C	Less than 1 month at 32°C	Less than 2 weeks at 42°C
Mangoes	2-3 weeks at 13°C	1 week at 23°C	4 days at 33°C	2 days at 43°C
Apples	3-6 months at -1°C	2 months at 10°C	1 month at 20°C	A few weeks at 30°C

Table 1 Predicted loss of storage potential at different temperatures[iii]

Some developers are tapping into this. **Sunchill** for example is an off-grid refrigeration solution that helps remove field heat from crops immediately following harvest. It can transform 50°C solar thermal energy into 10°C refrigeration using water-based refrigerants and local, non-precision components, with no need for electricity, resulting in a low cost, low-maintenance system. Like phase-change cold packs, it leverages the solvation of salt to absorb heat and produce cooling. The system has not been commercialized yet and uses open source to further improve the concept, as well as to provide access to the concept to other who may want to commercialize it.[iv]

Cold storage

Cold storage allows food to be stored and sold days, weeks or even seasons after it was harvested. In areas with little access to electricity, **evaporative coolers** are an affordable, low-tech way of prolonging the shelf life of fruits and vegetables. They are constructed by placing a vessel containing the food inside a larger vessel, with water poured into the gap between the vessels which cools the inner vessel as the water evaporates. In Nigeria for instance, simple evaporative coolers using wet sand between two clay containers, can be constructed for less than US$2 and are able to prolong the shelf life from fruits and vegetables from as little of 2 days to as much as 20 days.

Many options are already available and promoted or marketed in various parts of the world to **keep crops cool without using electricity**, both for pre-cooling and for storage purposes. These range from ancient solutions - often variations of the pot-in-pot evaporative cooling method - to new innovations or adaptations, such as an evaporative cooler designed in the shape of a fridge rather than a storage pot (Mitticool) in order to appeal more to modern tastes. Many solutions also use locally available materials, like clay, bricks, bamboo, charcoal, sand, cane, and simple designs that allow for people to construct their own coolers.[v]

The **Zeer pot** for example provides a good example of a low-cost refrigeration device tested in Sudan, Nigeria and Gambia, using natural evaporative cooling. An earthenware pot with a lid on the top is fitted inside a larger pot with an insulating layer of sand in between. This layer can be kept cool by adding water at regular intervals, generally twice a day. Produce such as tomatoes and guaves, which would normally expire within days without cooling can last up to 20 days in a zeer pot. A larger version of this is the **zero energy cool chamber** (ZECC) in India, which has a much higher capacity than Zeer coolers (about 100kg vs. 12kg), and can be used at small community level. It consists of two brick walls, with the cavity between the two filled with wet sand, and a bamboo cover. The outer wall and the sand layer are re-wet twice daily while the chamber is in use, resulting in a temperature difference of 11°C compared to outside air temperatures in the hottest months of the year.

Commercial size ZEEC with a capacity of 6-8 tonnes have also been piloted, although they require a fan to draw air into the chamber.[vi]

In addition, **new innovations** such as the CoolFinity fridge are entering the market, which is a large fridge for storing produce or vaccines and able to handle long power outages - for those with access to electricity - for up to 24 hours due to its ice bank.[vii] SureChill also provides fridges, at various sizes ranging from vaccine to fresh produce refrigeration, that keeps contents cool at a steady 4ºC for days or even weeks without power by using an ice bank.[viii] Coolar on the other hand has developed an electricity-independent fridge for food or medical use, cooled by adsorption cycle technology and powered by solar-heated water.

Moving on to cooling boxes, the ChotuKool in India, a 45-liter insulated portable plastic container can cool food to around 8 to 10 degrees on a 12-volt battery, using a thermoelectric or solid state cooling system.[ix] Somewhat similarly, the Evaptainer system uses evaporative cooling (water and solar energy) to cool a 60 liter portable container, keeping produce cool for up to 12 hours. Both ChotuKool and Evaptainer are aimed at providing low-cost, low-to-no energy portable refrigeration solutions to those in the developing world, who cannot afford to own a fridge and/or have no cooling solution to transport their fresh produce to market.[x]

As shown, technical solutions – ancient or new - for pre-cooling and/or cold storage are relatively abundant. The main challenge to provide access to cooling in an affordable manner in areas with no or limited access to electricity isn't merely a technical matter, but rather one that also revolves around the **enabling environment** such as system wide collaboration, political alignment, and putting in place the right policies as well as business and financial models. Although there is a proliferation of available technologies, more efforts are required to find answers to aspects such as how to reach people in more challenging locations and/or with limited access to information; what solutions suit different segments of the population best; ways to aggregate demand; how to access financing, as well as to make products financially within people's reach; the level and type of training, pre- and after-'sales' services required; and other factors critically important to let such solutions truly take off.

Solar refrigeration

Despite the need for the right enabling environment being greater than the need for more technological solutions for cold storage, one technology deserves a separate mentioning. Developments such as the drive for off-grid, solar access to energy solutions in Sub-Saharan Africa and Asia, the rapidly falling cost of solar panels, and the social acceptability and desirability of solar solutions create opportunity for solar refrigeration to reach larger numbers of low-income households as well as SMEs with insufficient access to cold storage.

Solar refrigeration can be a solution for areas with limited or no access to grid electricity as well as an alternative to fossil fuel powered refrigeration systems, such as conventional absorption cooling units. Solar cooling can be achieved either with the **use of PV panels or by solar thermal refrigeration** where the refrigerant is directly heated by a solar collector, and can be of great benefit to both food and vaccine preservation. The advantage of using solar power is its relative reliability, with the sun in warmer climates almost never failing to shine for more than a few days. This reliability is very important in case of vaccine storage, where loss of temperature control can easily spoil the vaccines. Either through battery storage or by using solar power to produce ice, solar refrigerators can continue to deliver cold at night and on days when no sunshine is available.[xi]

Solar refrigeration can not only provide a **solution at the level of individual households or small stores, but also for farmer collectives**. In Kenya for instance 30-50% of harvested fruit goes to waste due to poor post-harvest handling. For mango growers a species of fruit fly is their main enemy, resulting in losses as high as 60% of harvested fruit, and the flies are on the rise as a result of global warming. A **refrigerated solar storehouse** built by foreign NGOs allows farmer collectives in some villages to now safely store their mango crop. Not only does this give them greater access to international export markets, which have strict standards regarding food quality, pest and pesticide control, but also on the local market farmers get a higher price for their mangoes – in addition to being able to sell a larger quantity of the fruit harvested - as there is no need to hastily sell them before they rot.[xii]

In India, on the other hand, the world's largest producer of milk, an unreliable electricity supply as well as inadequate cooling infrastructure, means large quantities of milk are lost every year. India's dairy industry is dominated by small farmers with only a few cows, depending on rickshaws, bikes, or their own feet to transport the milk on the first leg from farm to local village collection center before its being transported to the dairy plant. A **Rapid Milk Chiller** is now being deployed in several agricultural areas, which uses a thermal energy battery pack that charges on solar power or, when available, grid electricity to cool milk from 35°C down to 4°C. The battery powers the chiller regardless of unreliable access to electricity, cooling up to 500 liters of milk. It can close the cold-chain from small producers to the point of pick-up by the dairy truck, while the dairy plants can also extend their reach to more isolated villages. [xiii]

To provide cold storage at **local community markets**, start-up ColdHubs in Nigeria provides an easy-to-set-up, modular, walk-in cold room in different sizes for off-grid storage and preservation of perishable foods. The cold room is powered by solar panels that can be mounted on a roof or awning. With this solution, fruits and vegetables can be kept fresh for up to 21 days rather than merely a few days maximum, and local farmers' post-harvest loss is cut significantly.

For vaccines, a few **solar powered vaccine fridge solutions** are available, such as Dulas, which powers its fridges either by batteries recharged daily by solar panels, or by using solar panels to cool a phase change material that freezes and thaws at exactly 5ºC. The system guarantees that vaccines will not be damaged by accidental freezing.

Some solar solutions target the factors that cause harvested produce to perish without actually delivering refrigeration. **Wakati** provides a pop-up solar-driven solution for keeping vegetables and fruits fresh without actively cooling them. An airtight tent with a capacity of between 200 and 1000 kg creates a protective microclimate, while a 10 Watt solar powered ventilator and 1 liter of water a week per 200 kg of produce help creates a high humidity atmosphere, which helps keep the crop's cell structure intact. Research results show can extend produce freshness up to 10 days or longer.

Improving 'last mile' vaccine transport

When it comes to temperature-sensitive medicines such as vaccines to retain their potency, **transport is the component where most frequently the vaccine cold chain breaks down**. Often ice packs are used to transport vaccines to more remote locations, which can result in relatively large temperature fluctuations from vaccines close to the icepacks becoming partially frozen while others are kept too warm.

A few emerging technology examples exist that help to overcome this problem, one being **Isobar**, which was developed by a student using a long-forgotten 1906 invention by Einstein, called two-phase ammonia-water absorption refrigeration. The 1.6-liter cylindrical container can hold as many as 330 4ml vaccine units and is carried in a specially designed insulating backpack. Vaccines can be carried over 6-days without the need to recharge, while a full recharge only takes an hour using a 900w heating element for day-to-day use and an efficient propane burner that can be recharged on-the-go in case of emergency for up to 30-days.[xiv]

Whereas cold storage is essential to have these temperature-sensitive medicines retain their potency, the cooling for transport need can sometimes be taken out by innovative solutions that allow vaccines to be delivered more quickly at destination. An example is **Zipline** which operates a drone delivery system to send urgent medicines to patients, delivering in under 30 minutes from dedicated distribution centers, negating the need for refrigeration. Medical supplies can be ordered by text message, and cost roughly the same as vehicle delivery except that supplies are delivered in a fraction of the time. [xv]

Both for solar refrigeration and vaccine transport, there is scope for further refinement of the emerging technologies as mentioned, but most of all due attention is required for creating the right enabling environment in order to facilitate large-scale dissemination and uptake, resonating the comment on pre-cooling and cold storage solutions.

Cutting out the 'last mile' of the vaccine cold chain

Keeping vaccines within a narrow band of acceptable temperatures during transport and storage is challenging and expensive. The cold chain consumes as much as 80% of the total cost of vaccination programs.[xvi] Instead of improving the cold chain or accelerating components of it, such as delivery by drone, a rapidly emerging area of research looks into how to cut out the 'last mile' of the cold chain all together -both transport and storage - by using **Controlled Temperature Chains** (CTC) combined with the use of more temperature-stable vaccines.

In 2012 the WHO did its first mass vaccination campaign conducted in Africa with a new vaccine for meningitis, allowing the vaccine to be kept at ambient temperatures for up to 4 days before use. The 10-day campaign in Benin vaccinating 1555,000 people was successful in providing complete coverage, with no meningitis cases reported in 2013, while ensuring the vaccine stayed viable even in temperatures up to 39°C. As temperatures had to stay below 40°C, a special card with a heat-sensitive sticker in the vaccine carriers showed if temperatures reached this level.

Since then WHO has established criteria for a vaccine to be labelled for and used in Controlled Temperature Chains (CTC). This includes such an approach only to be used in a vaccination campaign or other specific setting, and not in case of routine delivery.

Eliminating the cold chain from the moment the vaccines leave district-level storage and replacing it by a CTC, which aims at keeping vaccines at ambient temperatures but out of direct sunlight for several days before administering them, can also significantly reduce the workloads of health workers. They often spend large amounts of time maintaining the vaccine cold chain, and trying to extend vaccines to remote areas with limited to no cold chain infrastructure. Even more, the cost of vaccination could drop by 50%, while the number of under-vaccinated children and adults in remote areas would significantly drop as well.

Health workers in Benin were also highly positive about the CTC approach since it allowed them to vaccinate more people per day, while they did not need to return from far-away villages to local health centers every night to freeze ice packs for keeping the vaccines cold.[xvii]

Liquid air or nitrogen for transport

To reduce the heavy reliance on or need for access to electricity or fossil fuels (for combustion) to run conventional cooling systems, solutions such as liquid air or liquid nitrogen cooling may hold considerable potential for certain, densely populated and rapidly developing countries such as India and China. They can be transported to dispersed locations and stored until needed, providing flexibility. In addition, they hold promise as alternative options to power **refrigerated or air-conditioned transport,** ranging from trucks for transporting fresh produce to public transport modes such as buses operating in warm climates.

In the majority of cases a cold chain, which effectively links farmers to markets, will require produce to be transported in actively refrigerated spaces. This is mainly done by means of refrigeration trucks and reefers, marine shipping containers and railway wagons, all three which currently rely mostly on diesel fueled refrigeration units. The common diesel-powered transport refrigeration unit (TRU) consumes as much 20% of the truck's fuel, and emit 29 times as much particulate matter (PM) and 6 times as much nitrogen oxide (NOx) as a modern propulsion engine, while leaks of the most commonly used HFC gases in TRUs exacerbates global warming, being almost 4,000 times more potent than CO_2.

The challenge with converting these trucks to electric power instead is on the one hand the relatively high power usage of the refrigeration unit,   significantly shortening the truck's range on one battery charge, and on the other the massive energy demand expected to come from the growth in air conditioner use in buildings, requiring countries such as India to very rapidly expand power supply just to meet AC demand while simultaneously improving the stability of the grid, with lengthy power cuts still a common occurrence.

Refrigerated transport may currently not even be available though. In India's highly agrarian economy, fruit and vegetables worth almost US$6 billion are discarded each year – and rising to US$13 billion if meat, fish and dairy are included – and with it all the physical and human resources used to produce them are also squandered.[xviii] And while the agrarian sector in India employs over half the workforce, it generates less than 14% of national income. Even though India is second only to China in fruit and vegetable production, producing for instance 11% of the world's vegetables, only 4% of the country's fresh produce is transported by cold chain, resulting in large pre-consumer losses and low export value of its perishable agricultural exports.

In 2015, India's National Centre for Cold-Chain Development, a government organization, even suggested that too much money is being spent on developing cold storages, while other critical components of the cold chain including refrigerated vehicles are almost entirely without funding. Meanwhile India is home to a quarter of the world's undernourished, a number that may go up if food loss and wastage are not tackled considering ongoing population growth.

At a global scale, the **refrigerated transport fleet** is expected to double from its current level of over 4 million to about 9.5 million vehicles by 2025, however to meet the entire demand from emerging markets, in particular India and China, it **may have to nearly quadruple to more than 18 million vehicles**. At the moment, an estimated 10,000 refrigerated vehicles or less can be found on India's roads, pointing towards a potentially 100-fold surge in demand for such vehicles by 2025. With both India and China already plagued by having some of the worst air quality in the world in its major urban areas, such an expansion under a Business As Usual (BAU) scenario would likely result in a further worsening of what are already dangerously high levels air pollution and its associated health impacts.[xix]

While there is a significant unmet demand for (better) cold chains to support smallholder farmers, large amounts of residual cold are left unused. The largest source of **waste cold is cold required to turn natural gas into compact Liquefied Natural Gas (LNG)** at -162°C for transport by ship, with global trade in LNG rapidly on the rise. This cold is often subsequently discarded when the LNG is re-gasified at the import terminal, although could have beneficial use for purposes such as cold chains as well as district cooling, with a large share of the world population living near the coast and thus within potential proximity of such terminals.[xx] With annual global trade of LNG projected to reach 500 million tonnes by 2030, LNG terminals would give off enough waste cold to in theory supply cooling for more than 4 million refrigerated trucks at current efficiencies.

Such a cooling source can come at an affordable cost as well, with (net of capital costs) estimates pointing towards **savings as much as 75% of operating costs versus a conventional diesel system**. In a country like India, fuel costs for a regular freight trucks are estimated at 42% to 56% of total trip expenses. This number is likely to be higher for refrigerated transport. Add to this that in many countries the trucking industry is highly fragmented, with a large number of owner-operators (less than five trucks) - making up 70% of the trucking industry in India -, and characterized by small margins.[xxi]

A significant reduction in operating costs could make it more attractive to increase the fleet of refrigerated trucks, helping to reduce food waste and deliver the many benefits this brings to low-income groups, particularly those in the agricultural sector, while doing so with significantly reduced carbon and ambient air emissions compared to diesel. A potential challenge to overcome will be the limited consideration for efficiency at the point of sale, with many truck operators buying on credit and basing their choice on initial purchase cost.

Liquid nitrogen as an alternative, which can be used in the same way as liquid air, is already widely available through regular industrial processes in many countries including India, with the industry having enough spare production capacity to fuel twice as many refrigeration trucks as currently on the road in the country. Through India's National Center for Cold Chain Development (NCCD), the government is looking at how to better align policy with the challenges to overcome in India's cold chain sector, including a number of incentives being extended for transport refrigeration.

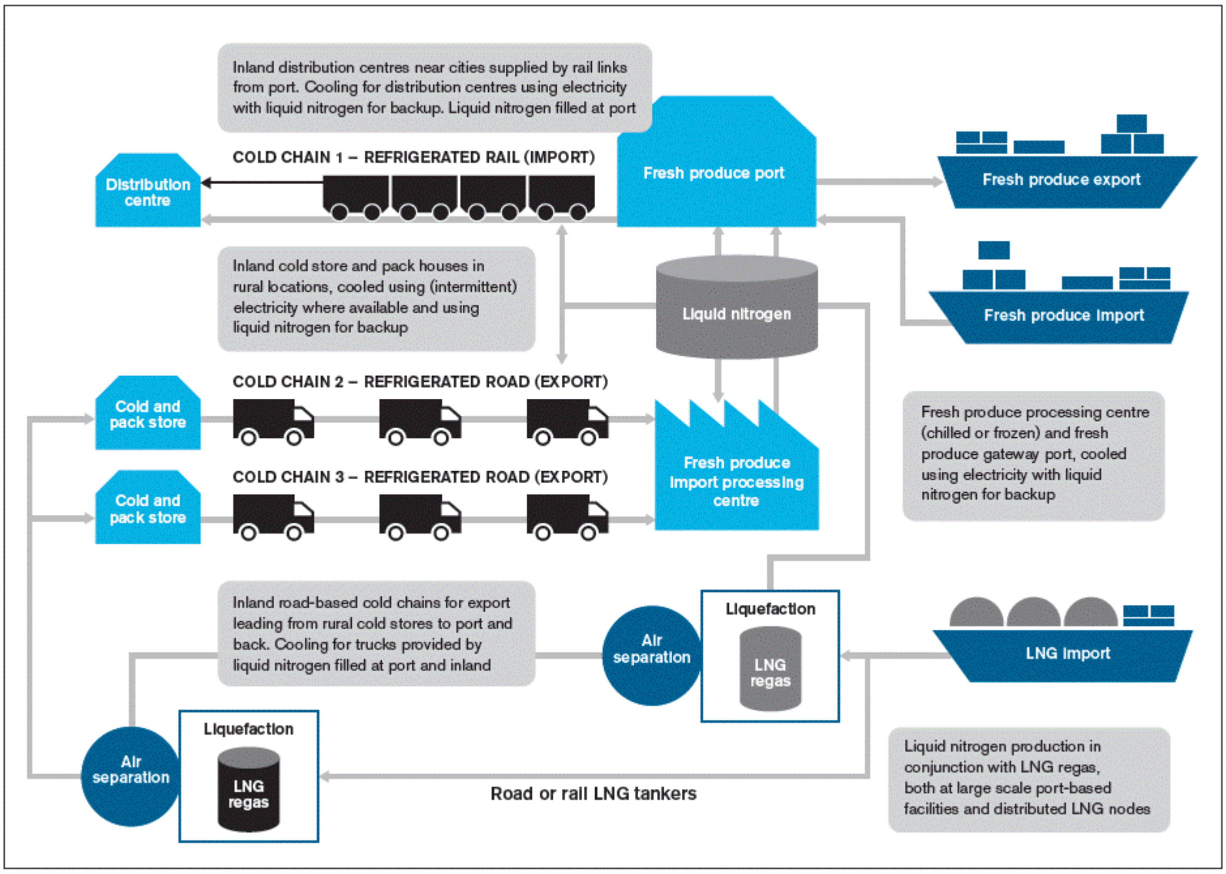

Figure 1 Flow chart for recycling LNG waste cold to provide cold chain cooling in India

With countries like India and China rapidly industrializing as well as expanding their LNG import capacity, opportunities exist to cheaply produce lower-carbon liquid air or nitrogen, which could allow them to leap-frog today's proven but outdated cooling technologies as they expand their cold chains.[xxii]

2. POTENTIAL POLICY AND BUSINESS MODEL SOLUTIONS

The challenge to provide low-cost, low-to-no energy cold chain solutions for stakeholders ranging from farmers to store holder to consumer in areas with no or limited access to electricity -whether a remote rural area or an urban slum -, is as pointed out not just a technical challenge as a proliferation of technologies shows. Instead, insufficient attention goes towards creating the right enabling environment to effectively reach and serve large numbers of people who otherwise are unlikely to gain access in significant numbers.

Annex E.2. provided examples of business models that might hold promise for cooling in buildings. Some of these models, such as PAYG and aggregated purchasing, may also hold promise for the availability or uptake of cold chain solutions.

Cold chain platforms and coordination

The **highly fragmented nature of cold chains** in many developing and emerging countries contributes considerably to food and vaccine losses. Fostering greater collaboration between stakeholders involved in the cold chain and creating a dedicated body to bring together and coordinate between the different players in the supply chain can greatly enhance the efficiency and responsiveness of local cold chains.

A good example is the **National Centre for Cold-chain Development (NCCD) in India**, which was established by the Indian government with an agenda to positively impact and promote the development of the country's cold chain sector. The center was born out of a National Task Force on Cold-chain which recommended that a dedicated institute be established to promote and coordinate various cold chain initiatives undertaken by different government organizations and the private industry.

The NCCD is overseen by a governing council, chaired by the secretary of the Ministry of Agriculture, and monitored by an inter-ministerial group. The center is overseen by a director from the public sector while being assisted by an established leader from the private sector, appointed to act as chief advisor. The center attracts participation from a wide variety of private and public stakeholders, ranging from research institutions, and regulatory authorities, to trade bodies, individual companies, and farmer associations. Each member group also gets to elect representation on the governing council. It also has various technical committees, ranging from strengthening the supply and logistics chain, to the application of non-conventional energy sources in cold chain Infrastructure.[xxiii]

As a non-governmental initiative, **GAVI[1] introduced the Cold Chain Equipment Optimization Platform** in 2015. It commits funding to jointly invest with countries to help upgrade them to high-performing and well-maintained cold chain technologies for vaccines. The main objective of the Platform is to get more equipment that is efficient, sustainable, and better performing deployed to every health facility where it is required and at an affordable price. GAVI uses a range of tested market approaches and tools adapted to the cold chain market, including the development of roadmaps; the improvement of product performance through the development of so-called target product profiles; strategic engagement with cold chain manufacturers and countries to enhance information sharing; and tailoring procurement tactics to the cold chain market.[xxiv]

Using policy to increase uptake of BoP solutions

A variety of policy instruments are available to local policy makers to help increase the successful **dissemination and uptake of either self-help solutions**, such as Do-It-Yourself evaporative coolers built from local materials, **or of solutions that require a purchase**, like the CoolFinity, ChotuKool and Evaptainer and other systems aimed at low-income consumers with limited cooling access. These policy instruments include for instance: [xxv]

- Organizing capacity building activities to raise awareness among farmers about alternative, affordable and sustainable low-to-no energy cooling options for their fresh produce;
- Coalitions of e.g. donors, NGOs, local authorities, and cold chain stakeholders such as farmers and shop keepers can jointly identify cold chain-related issues and come up with action plans to eliminate these breaks in the cold chain;
- Energy access programs, ranging from off-grid and minigrid solutions to extending electrification, can help assist stakeholders such as farmers and end consumers in purchasing suitable cold chain equipment like fridges or cooling boxes using solar or evaporative cooling;
- Capacity building programs can be used to create a pool of technicians to provide after-sales services for solutions that may require regular maintenance or which cannot easily be repaired without the right skills;
- Financial institutions can be encouraged to establish micro-crediting programs dedicated to cold chains and targeting individual smallholder farmers and farmer cooperatives;
- Local governments can help SMEs offering innovative cooling services take off by creating a stable and facilitating policy environment, including having light-touch regulatory conditions, extending incentives to them, creating knowledge and learning platforms, providing training and supporting critical elements of the wider enabling environment such as for example the mobile money sector.

Tailoring business models to reach low-income consumers

Business models generally consist of a number of key components, including the customer value proposition, a profit and revenue formula, key processes, and key resources the company must use to deliver the value proposition repeatedly and at scale. Creating competitive advantage lies in integrating these elements to produce value for both customer and company. For many incumbent

---

[1] The Global Alliance of Vaccines and Immunizations

(larger) companies, new offerings that come with altered business models requiring changes in overhead, margins, or resource velocity can be problematic, which is why **most of the solutions covered in the technology section are developed and offered by start-ups.**

Start-ups however are more likely to face challenges in terms of access to capital – especially where it concerns servitised offerings, with the company incurring the upfront capital costs, but receiving its customer revenues in small increments rather than having customers pay the full amount at point of sale -, logistics and distribution by not having an established network, and communication and marketing due to limited budgets and having little brand recognition amongst its target group. Which is where governments, NGOs, and public and private financers can help facilitate.

Tailoring offerings towards people's needs
At the same time, for business models targeting the so-called Base of the Pyramid population to succeed, extending current offerings and strip them down to make them more affordable, smaller, and/or low-tech may not suffice to appeal **to low-income consumers**, as their **needs may not align with those in higher income classes.**

This is what the ChotuKool team in India set off to investigate. They found out that the main needs of their target group was to stretch one meal into two by preserving small quantities of recently purchased food as well as leftovers and to keep drinks cooler than room temperature—a job quite different from the one high-end fridges have been designed to do, which is to keep a large supply of perishables on hand, cold or frozen, and paying (what for the target group would be) a considerable part of a month's salary on electricity fees just to power it.

This meant a cheaper conventional fridge wouldn't necessarily serve this groups need, pointing towards the opportunity to create a fundamentally new product for this underserved segment of the market. The Chotukool cooler not only provides a low-cost solution to preserving perishable foods, but also creates new income-generating opportunities, being used by small shops and kiosks which are now able to serve for example cold drinks. [xxvi]

Rather than creating sufficient customer demand, such **solutions can take over tasks people are already doing but do so more efficiently and conveniently**. This way existing demand can be redirected by offering a clear path from an unsatisfactory solution to a better one. Considering the technological solutions pointed out in previous Cold Chain sections, not all may pass this test.[xxvii]

Creating physical and financial access to the offering
In addition to meeting the target group's needs and providing an affordable solution, business models will also have to **ensure access to the solution, both in terms of physical access to the product and access to a finance network** that allow customers to pay for it. Mobile technology such as M-Pesa enables many PAYG Solar companies in Africa to function in a market where few have a bank account but may have access to a mobile phone. For the physical access to the PAYG Solar product, company M-Power in Tanzania for instance partners with little village roadside stores, delivering systems through local minibus and motortaxi drivers, with agents picking up the systems at the store to install them at customers' homes.[xxviii]

Chotukool in India on the other hand worked with India Post to deploy the Chotukool product to target communities, with its network being three or four times larger than the country's best logistic suppliers. For its marketing campaign, it mainly relies on word-of-mouth recommendations, including community self-help groups that it works with.

To address **'last mile delivery'**, the **ColaLife** organization initially aimed to use Coca Cola's supply chains to help deliver the Kit Yamoyo, which is an attractively designed small package, fitting into a Coca Cola crate between the bottles, and containing O.R.S.[2], zinc pills, a bar of soap, and an illustrated information packet, to help fight child diarrhea in Zambia. The product came about by the realization that a bottle or can of Coca Cola could be bought in the most remote locations, but children under the age of 5 in those same locations were still dying from diarrhea as simple measures to help reduce the severity of the illness, such as O.R.S. packets were often not available. Even in countries, such as Zambia and Cambodia, where O.R.S. is available for free, clinics in more remote locations

[2] Oral Rehydration Salts

would often be out of stock, as people in the middle of the supply chain had very little incentive beyond intrinsic motivations to ensure O.R.S. would be sufficient stocked in these hard to reach places.

ColaLife eventually did not end up using Coca Cola's supply chain, as transporting kits using Coca Cola crates was more limiting than it appeared. Demand for Coca Cola for example throughout the year for example might not match the demand for the Kit Yamoyo, which was likely to go up during the rainy season. Instead, ColaLife has focused on **emulating the Coca Cola model**. The many people who provide last mile delivery for Coca Cola have clear financial incentives to do so.

By paying great attention to the logistic chain, including developing relationships with and offering clear financial incentives to the people who can get the product to remote parts of Africa often, Kit Yamoyo has been able to achieve considerable reach in Zambia. The distribution model is a mixture of public and private systems, using the country's health system to transport Kit Yamoyo from a central warehouse to the district, and then handing the kits to the same people with whom Coca-Cola contracts and offering similar financial margins.

Nonetheless, ColaLife has difficulty moving to a profitable model, as the sales price of the kits is significantly subsidized relying on grants from external funders to do so. In addition, to stimulate initial demand it offered free vouchers, however now charges consumers one dollar, which has resulted in a drop-in sales by over 60%.[xxix]

Tailored business support to deliver public and SME outcomes

To address the issue of 'last mile delivery' in remote areas, **The Project Last Mile** (PLM) initiative began in 2010 with a mission to transform the delivery of medical supplies in Tanzania. Similar to ColaLife, the idea was to use Coca Cola's existing cold chain to transport vaccines and temperature-sensitive medicines to the most remote parts of the country in a controlled temperature chain that would radically cut spoilage of those vital products.

Instead of physically using Coca Cola crates to deliver medicines, the project now **works with countries to collaboratively help overcome severe challenges they face in the delivery of medicines and medical supplies**. In 2014 the project was expanded with a grant of more than US$21 million from supporting stakeholders and an ambition to help support 10 African countries by 2020.[xxx]

In participating countries, Project Last Mile partners with local Coca-Cola bottlers to build capability and share information with government agencies on everything from supply logistics and route to market, to planning and procurement, to marketing communications. Project Last Mile for example is helping rebuild Liberia's health systems, which were severely tested and strained by the 2014 Ebola outbreak in West Africa. Working closely with local partners and the local bottler Liberia Coca-Cola Bottling Company, Project Last Mile is using experienced Coca Cola managers to help share route-to-market and logistics expertise to help set up a more efficient and sustainable distribution network for medicines and medical supplies, with a particular focus on the distribution network into hard-to-reach communities.[xxxi]

Focused on SMEs rather than the public sector, NGO **PUM Netherlands** has been supporting entrepreneurs in developing and emerging markets for 39 years. It works with 150 representatives in 31 countries and 14 sectors including agriculture comprising e.g. dairy, flowers, and certain crops, and recruits Dutch senior experts between age 50 and 68 with in-depth knowledge of running a business in specific sectors. Entrepreneurs in the countries it works with can request specific support with optimizing or advancing their business and PUM will try to match this to an expert in their network. The expert is send out on a voluntary basis, for two weeks, with only his or her expenses covered. PUM pays for the airplane ticket, insurance and visa costs, while the local entrepreneur has to cover local board and lodging and local transportation costs.[xxxii]

Another option are **business incubators**, often offered by non-profit partners or through public-private partnerships, which provide practical support to SMEs in developing and emerging markets to help refine a business model, scrutinize a product's feasibility, help businesses grow, and match them to investors. An example is **BID Network**, which prepares emerging market entrepreneurs for investors and has been in existence for a decade, focusing on businesses that create social impact. BID also works with about 200 investors to give them access to a portfolio of high potential businesses. Many entrepreneurs are able to attract additional commercial and philanthropic funding as a result of the loans they received through the intervention of the BID Network. The program currently focuses on Uganda, with for example the company 'Village Energy, which provides PAYG Solar in rural communities, being successful in 2017 to attract private investment that can help grow the business.[xxxiii]

Another business incubator is the World Bank's new **XL Africa business accelerator program**, which in autumn 2017 out of 900 applications selected 20 promising African digital startups, include Power-As-You-Go company Rensource from Nigeria. These start-ups will attend a residency program in November 2017 in Cape Town, South Africa, where the selected entrepreneurs learn from mentors and peers, increase their regional visibility and get access to potential corporate partners and investors. Also recently established is the **Sustainability Accelerator**, launched in partnership between The Nature Conservancy and entrepreneurial network Techstars. The Accelerator challenges entrepreneurs to create technologies that can be rapidly scaled to tackle the major sustainability challenges of a growing world population, such as food, water, and climate change. The program will be mentorship driven, connecting a select group of 30 entrepreneurs, conservationists, corporate partners and investors to accelerate the pace of technological innovation for sustainable development.[xxxiv]

A different approach is used by the **Global Lighting Challenge**, a public-private collaborative campaign to deploy 10 billion LEDs worldwide, launched by the Clean Energy Ministerial (CEM). The challenge is designed as a race to reach cumulative global sales of 10 billion high-efficiency, high-quality, and affordable lighting products - such as LEDs - as quickly as possible. It brings together and helps elevates public sector efforts -from national governments to cities - to promote efficient lighting policies, while also creating a global platform for recognition of the efforts put in by private sector parties. Commitments made by the participants are reviewed on a yearly basis to assess progress and best practice is showcased on the Challenge platform.[xxxv]

Cooling as a service

With servitization rapidly on the rise as a business model and value proposition, it is worth briefly looking into the potential for providing cooling as a service in the cold chain. An example is **ColdHub**s, which helps farmers access cold storage for their produce, and was started by a Nigerian entrepreneur. It provides communal cold storage as a service, targeting farmers selling products to local markets who need access to the service (temporary refrigeration of products ready to sell) rather than the actual product.

The company installs solar PV powered cold storage solutions in villages and at public markets to support farmers with the temporary storage and preservation of their fruits and vegetables. They offer their customers a flexible pay-as-you-store subscription model. In preparation for storage, farmers transfer their perishable foods into reusable crates, which fit onto the cold room's shelves, with farmers paying a daily flat fee for each crate of food they store."[xxxvi]

Letting the provision of such services to the private sector can provide advantages in terms of acceptability and uptake, as experience from East Africa shows that public warehousing did not scale quickly due to repeated political interference in times of food insecurity, which distorted incentives for private banks, borrowers, and collateral managers to cooperate.[xxxvii]

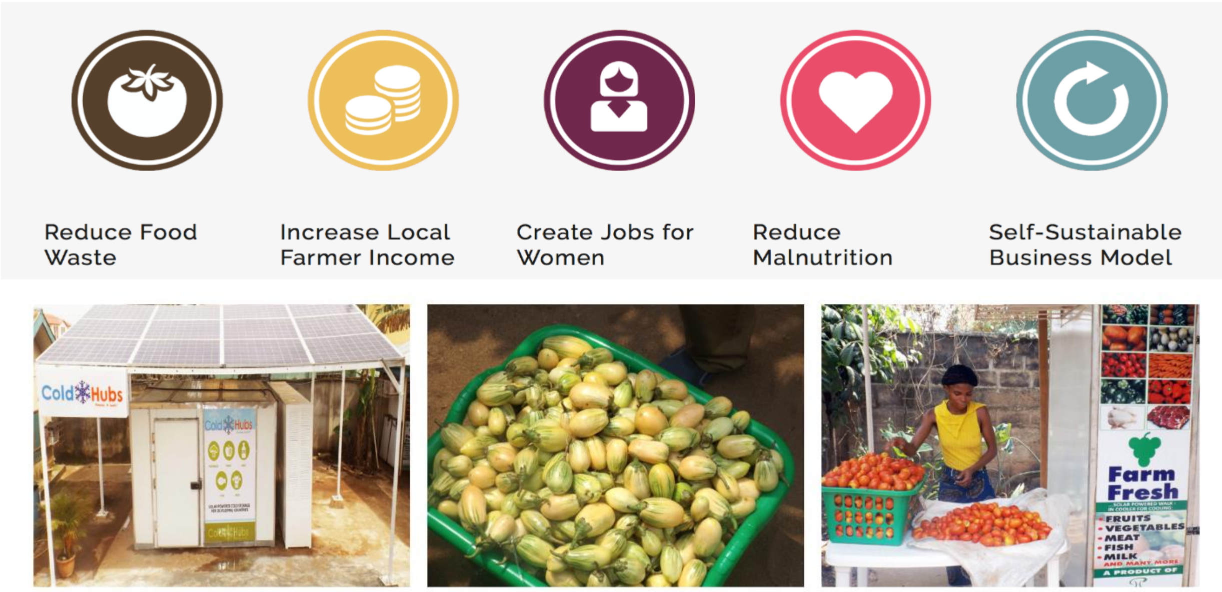

Figure 2 ColdHubs cold storage pay-as-you-go solution for Nigerian farmers

[i] Institute of Mechanical Engineers (2014). A tank of cold: Cleantech leapfrog to a more food secure world. Available at https://www.imeche.org/docs/default-source/reports/a-tank-of-cold-cleantech-leapfrog-to-a-more-food-secure-world.pdf?sfvrsn=0
[ii] University of Nottingham (2015). The impact of reducing food loss in the global cold chain. Available at http://naturalleader.com/wp-content/uploads/2016/04/UTC-Nottingham-Report_3-30_FINAL.pdf
[iii] University of Nottingham (2015). The impact of reducing food loss in the global cold chain. Available at http://naturalleader.com/wp-content/uploads/2016/04/UTC-Nottingham-Report_3-30_FINAL.pdf
[iv] Rebound (2016). Sunchill - Open Source Cooling. Available at http://rebound-tech.com/sunchill/
[v] Practical Action (2012). Evaporative cooling. Available at https://answers.practicalaction.org/our-resources/item/evaporative-cooling
[vi] Lipinski et al, (2013). On-farm storage technology can save energy and raise farm income. Available at http://ucce.ucdavis.edu/files/datastore/234-2143.pdf
[vii] Swain, T. (2016). Keep it cool during power outages with Coolfinity – the Ice bank Cooler. Available at http://www.designindaba.com/articles/creative-work/keep-it-cool-during-power-outages-coolfinity-%E2%80%93-icebank-cooler
[viii] Schieber, J. (2014). The Sure Chill Company Raises Gates Money To Store Vaccines. Available at https://techcrunch.com/2014/05/14/the-sure-chill-company-raises-gates-money-to-store-vaccines-anywhere/
[ix] WIPO (20013). Chotukool: Keeping things cool with frugal innovation. Available at http://www.wipo.int/wipo_magazine/en/2013/06/article_0003.html
[x] Markham, D.. (2015). Evaptainers uses old-school electricity-free technology for 21st century cooling. Available at https://www.treehugger.com/clean-technology/evaptainers-electricity-free-refrigeration.html
[xi] Practical Action (2012). Refrigeration for developing countries. Available at http://medbox.iiab.me/modules/en-practical_action/Crop%20processing/Crop%20storage%20and%20preservation/KnO-100162_Refrigeration%20for%20developing%20countries.pdf
[xii] Obi, L. (2017). Africa: As Solar Refrigerator Keeps Mangoes Cold, Farmers' Profits Heat Up. Available at http://allafrica.com/stories/201702210656.html
[xiii] Food and Agriculture Organization (2016). How access to energy can influence food losses. A brief overview, Available at http://www.fao.org/3/a-i6626e.pdf
[xiv] The James Dyson Foundation (2017). Isobar. Available at https://www.jamesdysonaward.org/en-GB/2016/project/isobar/
[xv] Walcutt, L. (2017). Zipline Is Launching The World's Largest Drone Delivery Network In Tanzania. Available at https://www.forbes.com/sites/leifwalcutt/2017/08/24/zipline-is-launching-the-worlds-largest-drone-delivery-network-in-tanzania/
[xvi] VBI Vaccines (2014). Thermostable Vaccines: Overview and Market Opportunity. Available at https://www.vbivaccines.com/wire/thermostable-vaccines-overview-and-market-opportunity/
[xvii] World Health Organization (2014). First mass campaign using a vaccine outside the cold chain is successful. Available at http://www.who.int/immunization/newsroom/press/19_02_2014_meningitis_vaccine_outside_cold_chain/en
[xviii] Moloney, C. (2016). India's major agricultural produce losses estimated at Rs 92,000 crore. Available at http://www.firstpost.com/business/indias-major-agricultural-produce-losses-estimated-at-rs-92000-cr-2949002.html
[xix] University of Birmingham (2014). The prospects for liquid air cold chains in India. Available at https://www.birmingham.ac.uk/Documents/news/The-prospects-for-liquid-air-cold-chains-in-India.pdf
[xx] Peters, T. (2015). (Powerpoint presentation) The Cold Economy – Doing Cold Smarter. Available at http://slideplayer.com/slide/10727993/
[xxi] Smart Freight Centre (2014). State of Play: Green Freight in Asia. Available at http://www.smartfreightcentre.org/news/new-sfc-report-state-of-play---green-freight-in-as
[xxii] The Carbon Trust (2015). The emerging Cold Economy Sustainable solutions for rapidly increasing cooling needs. Available at https://www.carbontrust.com/media/619349/the-emerging-cold-economy.pdf
[xxiii] Wikipedia (2017). National Centre for Cold-chain Development. Available at https://en.wikipedia.org/wiki/National_Centre_for_Cold-chain_Development
[xxiv] GAVI (2015). Cold Chain Equipment Optimization Platform Available at http://www.gavi.org/support/hss/cold-chain-equipment-optimisation-platform/
[xxv] Kefaliadou, A. (2016). Sustainable energy solutions to 'cold chain' food supply issues. Available at https://sustainabledevelopment.un.org/content/documents/968624_Kefalidou_Sustainable%20energy%20solutions%20to-cold%20chain-food%20supply%20issues.pdf
[xxvi] WIPO (20013). Chotukool: Keeping things cool with frugal innovation. Available at http://www.wipo.int/wipo_magazine/en/2013/06/article_0003.html
[xxvii] Eyring, M. et al (2011). New Business Models in Emerging Markets. Harvard Business Review. January–February 2011 Issue. Available at https://hbr.org/2011/01/new-business-models-in-emerging-markets
[xxviii] Galliot, L. (2015). Africa's quiet solar revolution. Available at http://www.csmonitor.com/World/Africa/2015/0125/Africa-s-quiet-solar-revolution
[xxix] Global Health Council (2017). Making a Medicine as Easy to Find as a Can of Coke. Available at http://globalhealth.org/making-a-medicine-as-easy-to-find-as-a-can-of-coke/
[xxx] Coca Cola Company (2017). Project Last Mile Expands to Strengthen Health Systems in Liberia and Swaziland. Available at http://www.coca-colacompany.com/stories/project-last-mile-2017
[xxxi] Coca Cola Company (2017). Project Last Mile Expands to Strengthen Health Systems in Liberia and Swaziland. Available at http://www.coca-colacompany.com/stories/project-last-mile-2017
[xxxii] PUM (2017). How we work. Available at https://www.pum.nl/
[xxxiii] BID Network (2017). Preparing emerging market entrepreneurs for investors. Available at http://www.bidnetwork.org/
[xxxiv] Sustainable Brands (2017). The Nature Conservancy, Techstars Team Up to Launch Sustainability Accelerator. Available at

http://www.sustainablebrands.com/news_and_views/product_service_design_innovation/sustainable_brands/nature_conservancy_techstars_tea

[xxxv] Global Lighting Challenge (n.d). The Climate Group Partners with the GLC. Available at http://www.globallightingchallenge.org/Latest/The%20Climate%20Group%20Partners%20with%20the%20GLC

[xxxvi] ColdHubs (2017). The Problem: In developing countries, 45% of food spoils mainly due to lack of cold storage. Available at http://www.coldhubs.com

[xxxvii] Rockefeller Foundation (2014). Waste and Spoilage in the Food Chain. Available at https://www.rockefellerfoundation.org/report/food-waste-and-spoilage/