Net zero cold chains for food

CARBON TRUST

KIGALI COOLING EFFICIENCY PROGRAM

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Cool Coalition

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A discussion document on the case for philanthropic action

The Carbon Trust's mission is to accelerate the move to a sustainable, low carbon economy. It is a world leading expert on carbon reduction and clean technology. As a not-for-dividend group, it advises governments and leading companies around the world, reinvesting profits into its low carbon mission.

The Kigali Cooling Efficiency Program (K-CEP) is a philanthropic collaboration launched in 2017 to support the Kigali Amendment to the Montreal Protocol and the transition to efficient, climate-friendly cooling solutions for all. K-CEP works in over 50 countries in support of ambitious action by governments, businesses, and civil society. K-CEP's program office, the Efficiency Cooling Office, is housed at the ClimateWorks Foundation in San Francisco.

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The Cool Coalition is a global network connecting over 100 partners from governments, the private sector, cities, international organizations, finance, academia and civil society to facilitate knowledge exchange, advocacy and joint action towards a rapid transition to efficient and climate-friendly cooling. Cool Coalition members collaborate on science, policy, finance and technology to support governments and industry meet their growing cooling demand through a comprehensive – "avoid-shift-improve-protect" approach.

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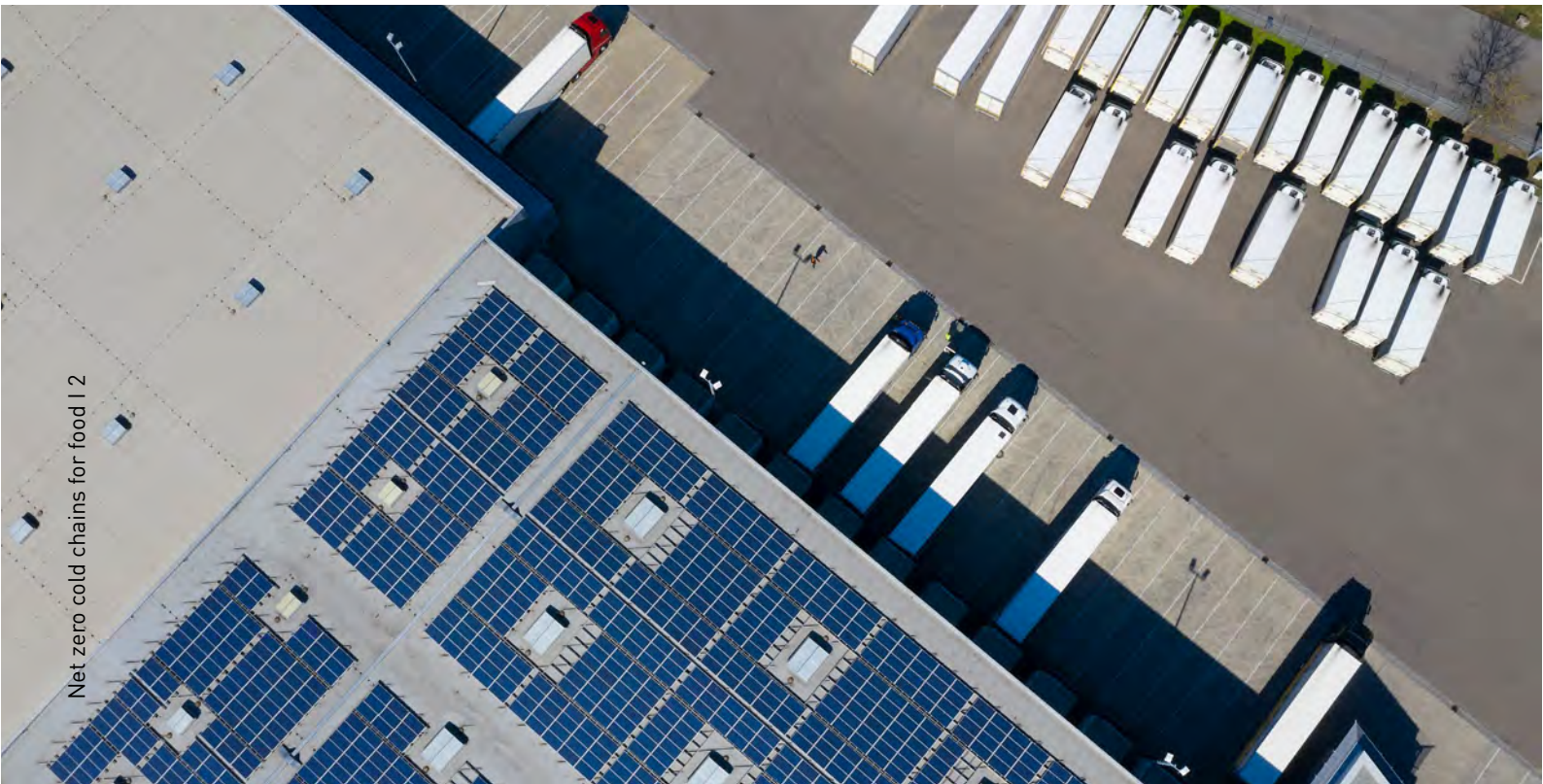
Executive summary

Challenges

- There are immense challenges with delivering food that is affordable, nutritious, and safe whilst providing optimal returns to farmers and others in the value chain as well as and minimising environmental and climate impacts.
- Cold chains are vital to help the food system deliver against those challenges, but their operations can have significant environmental impacts. For example, the food cold chain alone is responsible for a third of hydrofluorocarbon (HFC) emissions, or 1% of global greenhouse gas (GHG) emissions, and these HFC emissions are expected to increase significantly in proportion by 2050.
- GHG emissions from food cold chain infrastructure is already significant in developed countries. For example, food refrigeration contributes 2-4% of total GHG emissions in the UK.
- In developing countries, cold chain GHG emissions are projected to grow significantly. For example, studies in India highlight that GHG emissions from cold chains could more than double by 2027 without active intervention, highlighting the potential pace of growth of the sector and associated emissions.
- Despite these significant environmental impacts, cold chains also mitigate methane emissions by mitigating food loss and minimising wastage of resources used in the production of food.
- Cold chain expansion will likely continue by deploying conventional technologies in mid- and low-income countries, which risks locking-in GHG emissions from high global warming potential (GWP) refrigerants and inefficient energy use. This will make it harder and more expensive to retrofit energy efficiency, climate-friendly refrigerants, and renewable generation in the future.

Solutions

- Cold chains integrate a logistics network of refrigerated assets that facilitate safe custody of goods under care. These assets, when designed with cooling technologies that use climate-friendly refrigerants and maximise the efficient use of low carbon energy, including via energy storage, can make cold chains compatible with net zero GHG emissions.
- There is an opportunity for many countries to leapfrog to net zero cold chain infrastructure and so significantly reduce the GHG emissions from such assets and the wider food system.
- The development of climate-friendly cold chains requires a system transition with multi-actor effort, low carbon infrastructure, access to reliable energy, and appropriate operating procedures, as well as supportive policy, regulation, and commercial incentives.
- Supporting actions now on net zero compatible cold chain solutions can help to 'bend the curve' on GHG emissions in countries that already have significant cold chain infrastructure, and help to avoid significant increases in GHG emissions in countries where cold chain deployment is expected to grow.



The case for philanthropic action

1. An integrated approach to net zero cold chains is unlikely to emerge organically as the effort and benefits are spread across many actors who lack capacity and incentives to coordinate strategically. Further, private sector actors may not consider developing or deploying clean technologies without support to overcome the cost burden of net zero cold chains for food.

2. This presents an opportunity for philanthropy to play a catalytic 'systems integrator' role in this complex sector, to reduce GHG emissions whilst delivering safer food to consumers and higher incomes to farmers. This can deliver climate change mitigation, food security, and poverty reduction objectives that are relevant to a wide range of philanthropic foundations and individuals.

3. A multi-pronged strategy covering: improved data, modelling, and awareness; end-to-end cold chain demonstrations that show how technology, business model, and finance solutions can unlock net zero cold chains; and support for advocacy on net zero cold chains can encourage key actors (policy, business, finance) to adopt more climate friendly practices, either bending the current cold chain pollution curve or leapfrogging to net zero. Working with national governments and other key stakeholders will help philanthropy to catalyse faster action at scale.

1. Introduction to cold chains for food

Cold chains for food are crucial to modern societies: they serve populations with diversified food; reduce the amount of food lost; maintain food quality, value, and safety; and offer opportunities for enhancing farmers' livelihoods.

Cold chains are a temperature- and humidity-controlled system that integrates **a sequence of refrigerated preparatory, storage, and distribution activities** as illustrated in *Figure 2*. Certain production activities under refrigerated conditions can also be the source point of food cold chains. Cold chains exist for a variety of food and beverage commodities, most commonly perishable foods such as vegetables, seafood, meat, or dairy products. **These cold chains are complex to suit the food product under care, with different standard requirements or logistics equipment** and usually specific to a global or regional value chain. Policies driven by different departments such as health, agriculture, finance, and energy, are key enablers that shape cold chain development.

Figure 1: Ripening chambers for bananas in Tamil Nadu, India. Picture courtesy of Danfoss

Figure 2: Schematic overview of food cold chains

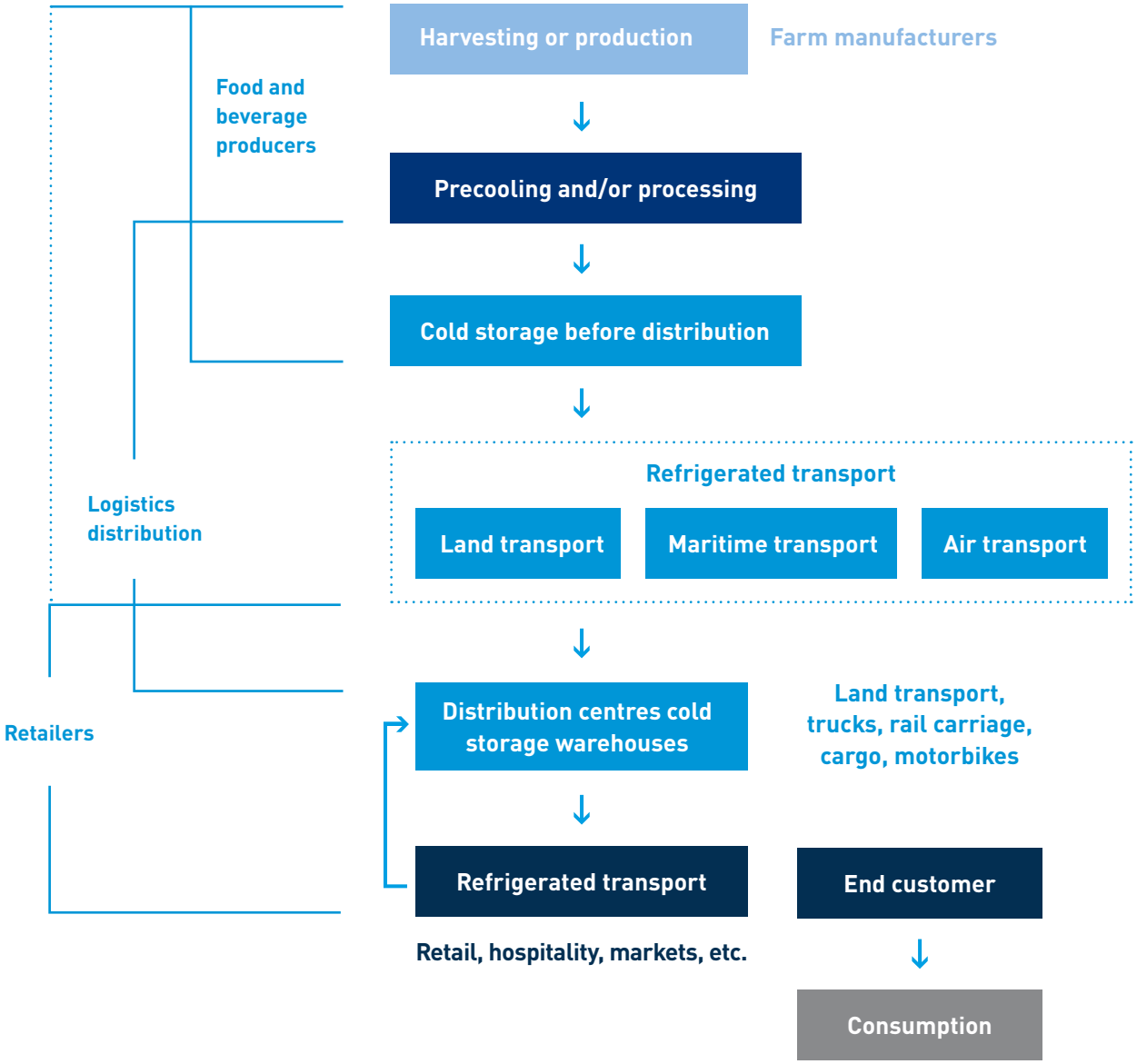
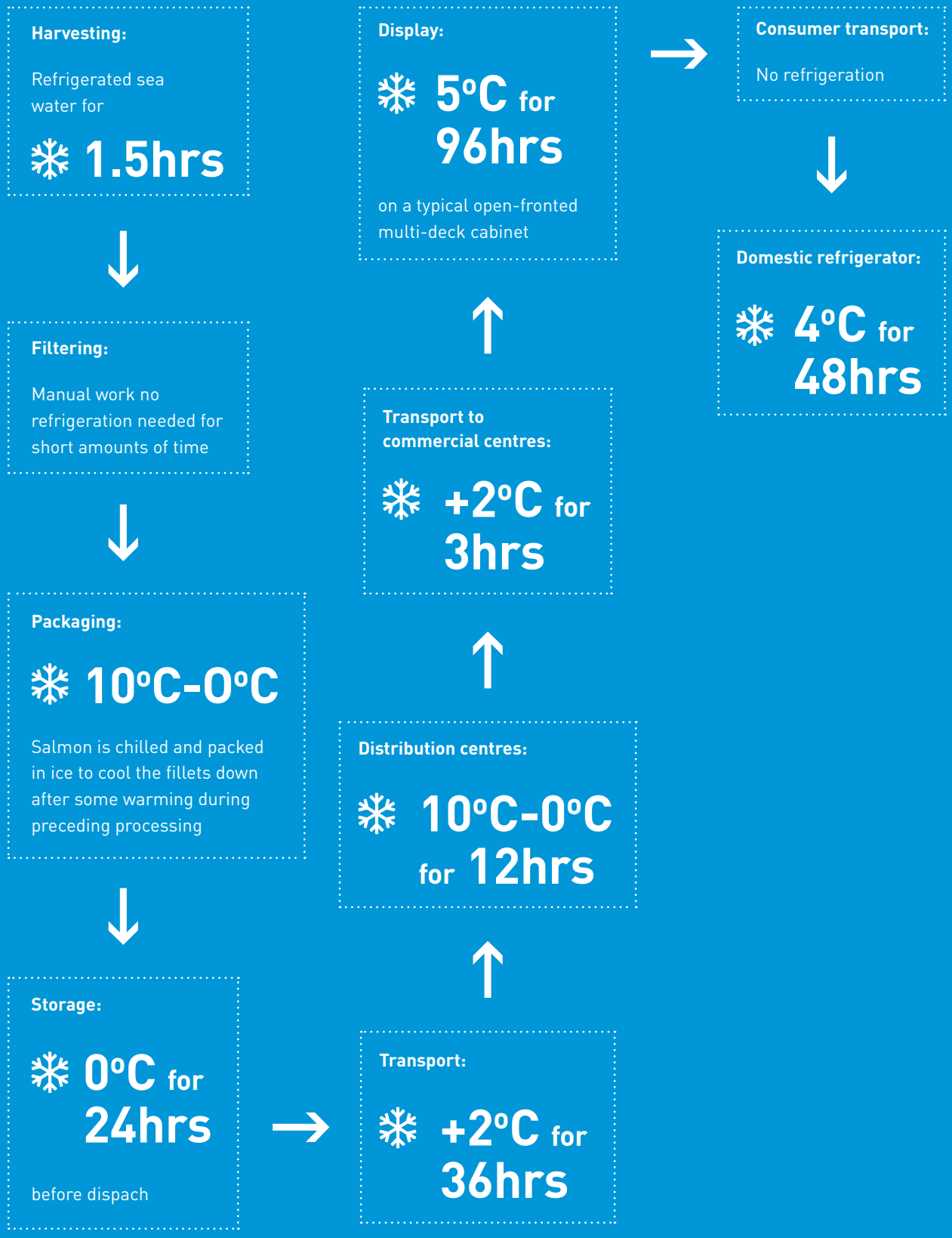


Figure 3: Overview of a salmon cold chain and temperature requirements[a]



[a] *An interpretation from the report: Hoang et al. Life cycel assessment of salmon chold chains: comparison. https://hal.archives-ouvertes.fr/hal-01555607/document (2015)*

2. Building blocks of net zero cold chains

A net zero cold chain can be defined as a safe, monitored, and integrated refrigerated network designed with cooling technologies that uses environmentally-friendly refrigerants and maximises the efficient use of low carbon energy.[e]

In the context of the food sector, it enhances economic wealth, cash flow, and security for farmers, and improves food quality and safety with minimum environmental impact. Food systems are becoming more interconnected and trending more towards fresh and frozen foods. Cold chains are the only known logistics mechanism to manage this.

A net zero cold chain requires an ecosystem of policy, regulation, wider logistics, and energy system development, as well as efficient producer and consumer behaviours to deliver sustainable economic, environmental, and social outcomes. When breaking it down in sections of the conventional cold chain, a sustainable version could include the following elements:[f]

Table 3: Net zero cold chain measures

Cold chain segment	Net zero measures
Policy level	• Sectoral government departments develop a national cooling plan, align to a vision, and join efforts to develop an enabling environment for the development of net zero cold chains
Post harvest precooling, production or manufacturing *Precooler, cold room or cold store*	• Passive cooling • Renewable energy use • Low-GWP and natural refrigerants • Energy efficiency • Storage and flexible demand • Data driven temperature monitoring and optimisation • Innovative business models (e.g. 'cooling as a service')
Refrigerated Transport • *Land, maritime, or air transport*	• Electric Vehicles • Low-GWP and natural refrigerants • Energy Efficiency • Use of green hydrogen and ammonia for ships • Thermal storage • Data driven temperature monitoring and optimisation

[e]For more details on what climate-friendly and energy efficient cold chains could look like, further definitions specific to refrigerators can be found in the following U4E report: https://united4efficiency.org/wp-content/uploads/2019/11/U4E_Refrigerators_Model-Regulation_20191029.pdf
[f]These solutions are in different stages of technical maturity and commercial availability

Distribution centres Cold storage warehouses or cold rooms	• Passive cooling • Renewable energy use • Low-GWP and natural refrigerants • Energy efficiency • Storage and flexible demand • Data driven temperature monitoring and optimisation • Innovative business models (e.g. 'cooling as a service')
Retail – end consumer Retail, hospitability markets, health centres, etc.	• Low-GWP and natural refrigerants • Energy efficiency • Storage and flexible demand • Data driven temperature monitoring and optimisation • Innovative business models • Renewable energy use

Survey Insight Box 4: Perceptions on efficient, climate-friendly cold chains

Survey responses on defining an efficient climate-friendly cold chain

"Cold chain requires a logistics platform that connects demand and supply and allows companies and other cold chain entities to offer services on the cold chain, e.g. think 'Uber of cold chain'."

"Climate-friendly also needs to imply minimising the loss of food - could be that it's better environmentally to power a cold chain with diesel which has zero percent food loss than one that runs on solar but where 50% of food is lost."

"It would be good to directly include the "passive" equivalent measures (i.e. non-mechanical) that are critical to ensuring unbroken cold chains, which includes removing the need for refrigeration (insulation/natural cooling/removing items that do not need to be refrigerated), reducing the amount of refrigeration needed (location of the refrigeration) and changing supply chains to minimize the length of the cold chain."

"An efficient, climate-friendly cold chain in an integrated refrigerated network that uses energy-efficient technologies and environmentally-friendly refrigerants without compromising temperature and hygiene standards or meaningfully increasing direct costs."

Two examples of how net zero cold chains are developing around the world are presented below. The first example highlights how advances in storage technology can make cold warehouses more energy efficient and flexible to enable greater use of renewables. The second highlights the value of taking a strategic approach for cold chain development in terms of environmental and development impact.

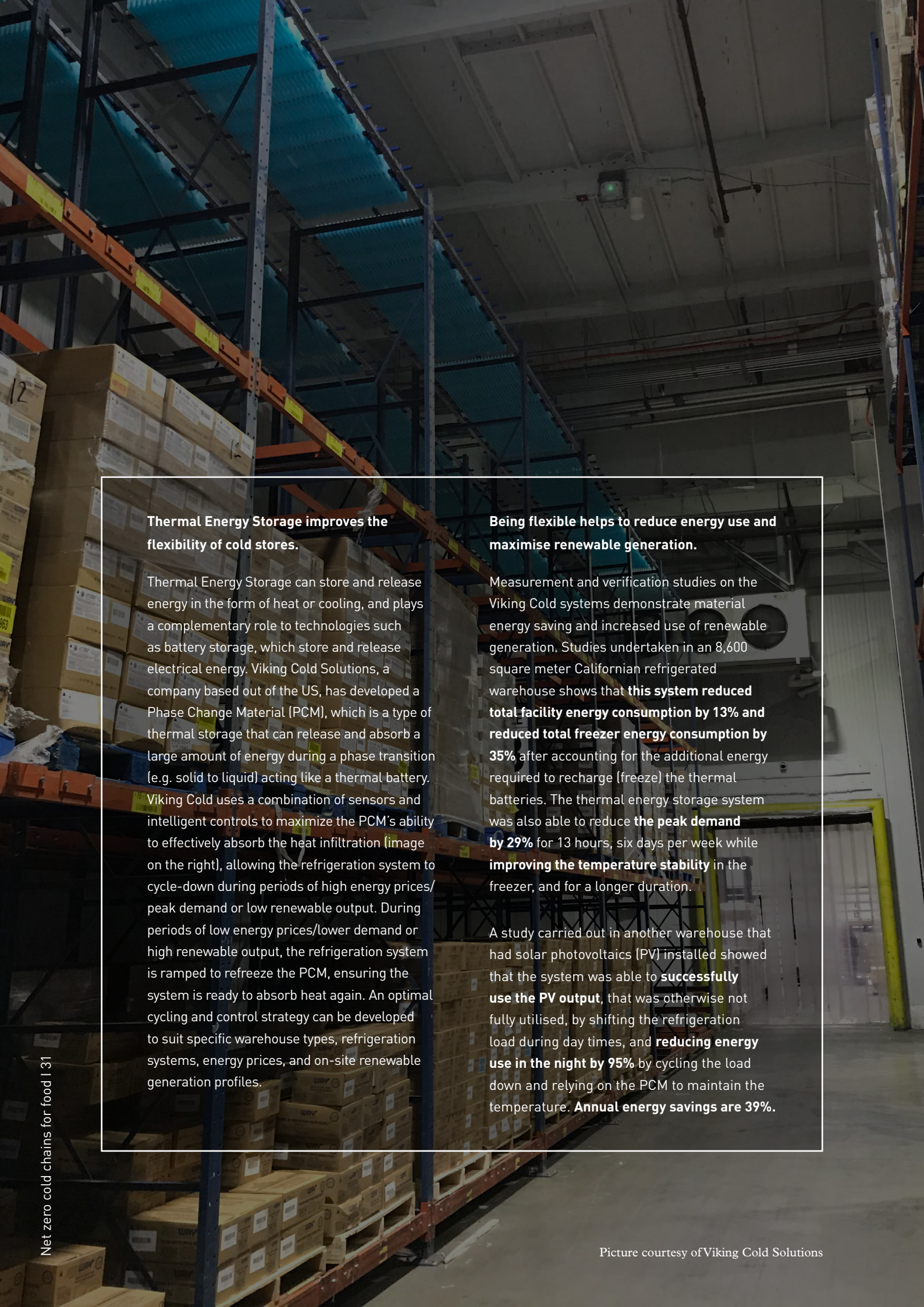
Case Study 1: Insights on flexible and smarter cold stores technologies

Making cold stores smarter and flexible using thermal storage

Why make cold stores flexible?

Low-temperature cold stores are an integral part of a cold chain helping to store perishable food safely and linking them to distribution and retail. Such facilities are also energy intensive and can account for a significant proportion of demand in areas with high commercial, industrial, or retail concentration. Energy is also one of the biggest components of a refrigerated warehouse's operating budget. With the rapid increase in deployment of renewables like wind and solar, the electricity system increasingly relies on generation and demand to be flexible (move up and down) to help manage the system.

This presents opportunities for refrigerated warehouses to contribute positively to ease pressure off the system and reduce energy use and costs while doing so. The key challenge is to make a refrigerated warehouse's demand flexible at certain times while maintaining the temperature guidelines for the food products to be stored safely.



Thermal Energy Storage improves the flexibility of cold stores.

Thermal Energy Storage can store and release energy in the form of heat or cooling, and plays a complementary role to technologies such as battery storage, which store and release electrical energy. Viking Cold Solutions, a company based out of the US, has developed a Phase Change Material (PCM), which is a type of thermal storage that can release and absorb a large amount of energy during a phase transition (e.g. solid to liquid) acting like a thermal battery. Viking Cold uses a combination of sensors and intelligent controls to maximize the PCM's ability to effectively absorb the heat infiltration (image on the right), allowing the refrigeration system to cycle-down during periods of high energy prices/ peak demand or low renewable output. During periods of low energy prices/lower demand or high renewable output, the refrigeration system is ramped to refreeze the PCM, ensuring the system is ready to absorb heat again. An optimal cycling and control strategy can be developed to suit specific warehouse types, refrigeration systems, energy prices, and on-site renewable generation profiles.

Being flexible helps to reduce energy use and maximise renewable generation.

Measurement and verification studies on the Viking Cold systems demonstrate material energy saving and increased use of renewable generation. Studies undertaken in an 8,600 square meter Californian refrigerated warehouse shows that **this system reduced total facility energy consumption by 13% and reduced total freezer energy consumption by 35%** after accounting for the additional energy required to recharge (freeze) the thermal batteries. The thermal energy storage system was also able to reduce **the peak demand by 29%** for 13 hours, six days per week while **improving the temperature stability** in the freezer, and for a longer duration.

A study carried out in another warehouse that had solar photovoltaics (PV) installed showed that the system was able to **successfully use the PV output**, that was otherwise not fully utilised, by shifting the refrigeration load during day times, and **reducing energy use in the night by 95%** by cycling the load down and relying on the PCM to maintain the temperature. **Annual energy savings are 39%.**

Picture courtesy of Viking Cold Solutions