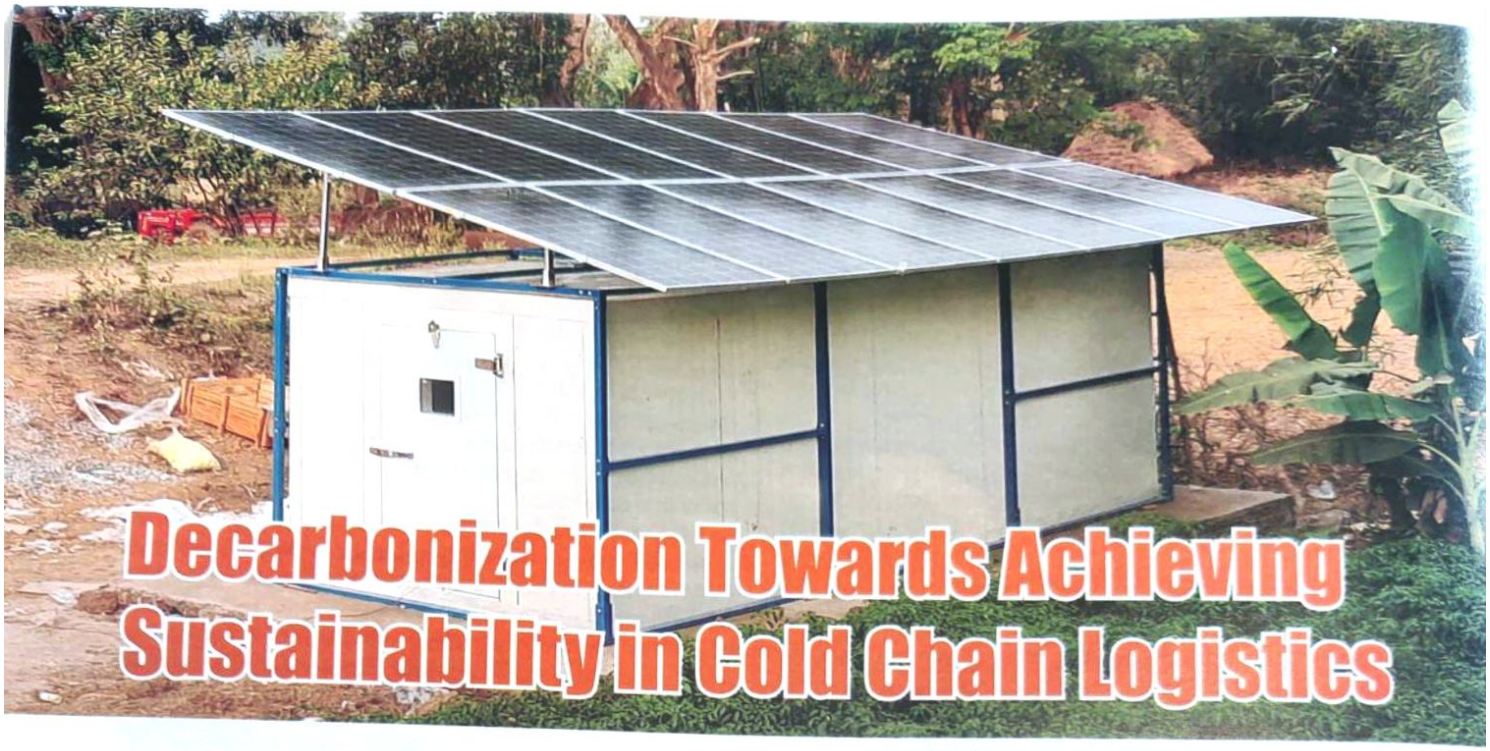

Decarbonization Towards Achieving Sustainability in Cold Chain Logistics

Off-grid micro-cold room using thermal energy storage
(Image courtesy Pluss Advanced Technologies)

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Introduction

On 12 December, 2015, the Paris agreement was signed by 196 countries at the UN Climate Change Conference (COP21) in Paris with the goal to mitigate climate change and its adverse impact. The agreement sets the following long-term goals to guide all nations:

- Substantially reduce global greenhouse gas (GHG) emissions to limit the global temperature increase in this century to 2°C while pursuing efforts to limit the increase even further to 1.5°C;
- Review countries' commitments every five years;
- Provide financing to developing countries to mitigate climate change, strengthen resilience and enhance abilities to adapt to climate impacts.

Focus on Value Chain Emission – Scope 3

The initial focus was on Scope 1 and Scope 2 set forth by the GHG protocol, which essentially are defined as emissions produced from assets or equipment owned or controlled and emissions that are indirectly emitted from the generation of purchased energy.

Organizations are also pledging to reduce their Scope 3 emissions, which essentially are the result of upstream and downstream value chain. The Scope 3 emissions are the largest contributors to emissions – as much as 90% of the total emissions – which represents a significant opportunity towards reaching the larger goal. For instance, in 2021, Kraft Foods verified that their value chain emissions comprised 95 per cent of the company's total emissions. Developing a full GHG emissions inventory – incorporating corporate-level Scope 1, Scope 2, and Scope 3 emissions – enables companies to understand their full value chain emissions and to focus their efforts on the greatest GHG reduction opportunities.

Approach to Identify Opportunities to Decarbonize Supply Chain

Some of the most efficient supply chains entail collaboration in the quest for an excellent customer experience with every entity – producers, distributors and wholesalers – focused on this outcome. It is a similar story for decarbonization, combining the collective resources to help cut emissions, eliminate food wastage, optimize energy use and ensuring that supply chains remain resilient and sustainable.

A framework to setup a strategy towards decarbonization would be in three steps:

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A. Forming an internal team to identify the areas and quantify the current emissions,
B. Secondly, mapping technologies or process augmentation that are required corresponding to each of identified areas along with a technical and commercial study, and
C. Lastly, implementation and measurement of the outcome.

Up to 30 percent of the total Scope 3 emissions could be reduced through relatively straightforward measures such as product and logistics optimization and procurement of low-carbon energy by suppliers. While these measures would require intensive collaboration with both suppliers and customers, half of the changes would be cost-neutral for the company. Even if the emission reduction costs are eventually passed on to vendors or customers, they are not at all significant, especially as the whole market is set to adopt similar measures. The adoption of many of the climate technologies enables reduction in the OPEX cost with a payback period of less than two years. Companies could leverage this aspect to consider innovative business models such as pay per use or having a hybrid model to recover the capital cost partially and to have a continuous stream of revenue from the cost savings for the customer.

Constant Pursuit for Appropriate Climate Technologies

As per the United Nations Framework Convention on Climate Change (UNFCCC), Climate Technologies are any technologies that we use to address climate change, which is explicitly focused on reducing GHG emissions.

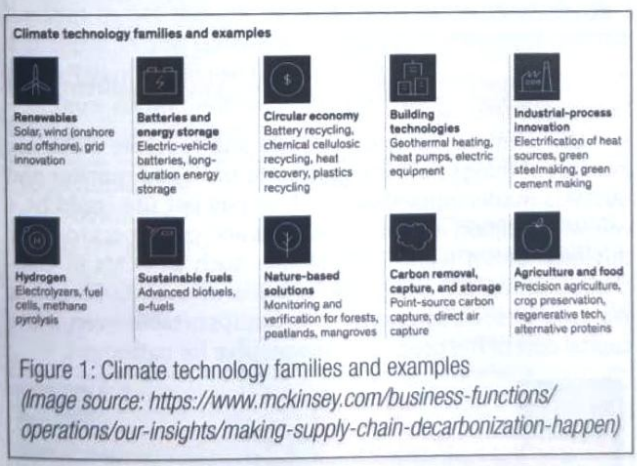

Figure 1: Climate technology families and examples
(Image source: https://www.mckinsey.com/business-functions/operations/our-insights/making-supply-chain-decarbonization-happen)

There is a growing recognition and understanding of government, business and public responsibilities for responding to climate change. There is also a growing awareness of the need to have clear guidance across the value chain in both adapting to and mitigating climate change and creating science-based and transparent frameworks to accelerate the transition to sustainable logistics services. Broadly, climate technologies can be classified into ten families critical to meeting the net-zero challenge.

Climate Technologies for Cold-chain Logistics

Out of the ten families of climate technologies shown in *Figure 1*, we have narrowed down on two families of technologies or products relevant to the cold chain sector. This list would provide a quick guide on the opportunities of interventions for stakeholders in the cold chain industry such as manufacturers of chilled and frozen food products, e-retailers, hotel-restaurant-catering (HoReCa) and logistics providers, helping them to reduce the carbon footprint in their value chain.

Batteries and Energy Storage

Renewable Energy for Cooling Applications

We have known solar as the most commonly and largely adopted renewable source of energy. The challenge of using renewables to its full potential is the intermittent nature of its availability. In case of value chain at the first mile where the challenge is accessibility to a constant supply of power, solar or wind power can be harnessed to provide energy. Since the final energy requirement in this case is in the form of cooling, thermal energy storage strategy could be applied to integrate with renewable power instead of electric batteries. For instance, a solar-based cold room of size 10 ft x 10 ft would require a lead acid battery, which has a service life of three years. In addition, there is a substantial loss in multiple conversions of the energy. There are at least three conversions – electrical energy to chemical energy, chemical energy to electrical energy and electrical energy to cooling energy.

To enable a 100% off-grid solar micro-cold room, a 4 kWp solar PV panel coupled with refrigeration unit, which provides energy for the day time cooling as well as thermal energy storage for night time that totals up to 14kWh (*thermal units). Now, if this unit was to draw power from electrical battery storage, the required installed capacity would be 17 kWh (electrical units).

Table 1: Key parameter comparison

	Thermal Energy Storage	Battery storage
Cost of storage, per kWh	INR 8,000	INR 5,000
End of life, years	15 years	3 years
Conversion efficiency	95%	80%

**1.2 kWh of electrical energy is needed to produce 1 kWh of thermal energy*

Table 1 offers the key parameter comparison that points towards a high carbon footprint for an electrical battery considering replacement every three years and conversion efficiency alone. The end-of-life disposal and its environmental hazard is also great for electric batteries while, in case of thermal energy storage for cold applications, the core materials used are non-toxic or environmentally safe salt hydrates with water as a major constituent.

Back-up and Thermal Efficiency for Cooling Application

The most common backup system used to tackle power outages is diesel generators, which at the current rate costs Rs 38 per unit of electricity. In terms of carbon emissions, a liter of

diesel contributes to 2.62 kgs of carbon emissions. Cleaner and more efficient storage technologies such as Li-ion batteries and thermal energy storage strategies could be applied to operate large cold warehouses. Li-ion batteries have a very high electrical energy density; however, the high capital costs could prove to be a limitation for these to be implemented for applications where energy in the final consumption stage is in the form of electricity. For refrigeration or HVAC systems, thermal energy storage systems again prove to be a carbon-neutral solution, and also have decent payback of less than two years on CAPEX.

The incorporation of Phase Change Materials (PCM) as a thermal energy storage (TES) strategy improves the thermal performance of the refrigeration unit as well enables reduction in the run time of the compressor.

Figure 2: Commercial chest freezers with TES
(Image courtesy: Pluss Advanced Technologies)

Electrification of Reefer Trucks

The cost of a reefer truck is on an average about 60% higher than a normal truck varying slightly depending on the capacity. Reefer trucks form a crucial part of cold chain for both short and long duration transport.

Hybrid reefer trucks enable a way to eliminate the use of diesel to run the cooling unit. For first mile intra-city distribution, these trucks provide up to 16 hours of temperature-controlled delivery with only eight hours of electric charging, which would offset about 30-35 liters of diesel. It is important to underline that the refrigeration unit is used to *maintain* the temperature range of product load and not cool it down.

This is a case in example of using a combination of electrical battery storage and thermal energy storage. 50% of the fuel used in reefer vehicle is consumed towards operating the cooling unit; therefore, thermal energy storage makes more sense than deploying electric batteries.

Figure 3: Partially electric refrigerated truck with TES
(Image courtesy: Pluss Advanced Technologies)

Circular Economy

A circular economy is an economic system aimed at eliminating waste and the continual use of resources. Circular systems enable re-use, sharing, repair, and refurbishment, re-manufacturing, and recycling. This closed-loop system minimizes resource inputs and reduces waste, pollution, and carbon emissions. In cold chain logistics, for small volume distribution and for long distances, small capacity shipper boxes are used, which are often heavily packaged with thermal insulation packaging; PCMs or ice packs constitute up to 50% of the total weight and volume. In most cases, the common reason for resistance towards designing one's business around circular economy is the cost of reverse logistics not being viable. However, strategically, we are bound to lose in the long term as the cost of these single use systems is bound to rise due to indirect costs such as waste generation, emissions, depleting resources and rising energy costs, which are indirect effects of a single use economy.

Figure 4: Circular economy
(Image source: https://www.triumvirate.com/blog/do-you-know-about-the-circular-economy)

Digital Transformation Integrated with Resilient and Reusable Materials

Use of more durable materials and reusable materials, internet of things (IoT) integration to track and monitor and business model innovations such as pay per use could be a win-win situation for both producers and customers to make this mechanism work. Technologies such as PCMs in cold-chain logistics are designed for a life of over 3,000 cycles. Wastage of such components is unsupportable even if the capital cost of the product is inexpensive for customers.

Figure 5: Use of PCMs in shipper boxes
(Image courtesy: Pluss Advanced Technologies)

A case in example of the economic and environmental benefit is in long duration logistics for pharmaceuticals. Typically, a shipper box carrying pharmaceuticals uses

expanded polystyrene (EPS), commonly known as thermocol, which is slow to degrade and if proper consideration towards disposal is not given, it can leach chemicals that contaminate water sources. Further, the manufacturing of EPS releases significant amounts of hydrofluorocarbons (HFCs), also known as super greenhouse gases. HFCs have far greater impact towards global warming than carbon dioxide, as illustrated in *Figure 6*.

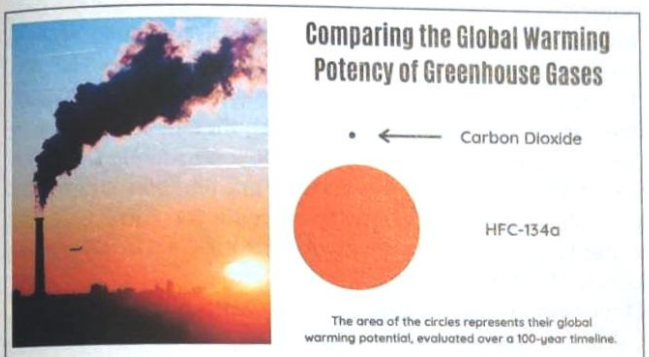

Figure 6: Comparing the global warming potency of greenhouse gases

Using reusable alternatives can enable one to do more with less. Essentially, by reusing, a company can typically use 50% of the packaging material to ship the same quantity of products. The capital cost of such reusable packs would be five times that of disposable ones, and yet the total cost is reduced due to lower freight cost made possible by the better payload to total volume ratio of up to 25%. This reduction in cost is taking into consideration the added cost of reverse logistics to get the empty shipper box back. *Table 2* offers a glimpse of the comparative analysis between single use shipper vs multiple use shipper strategy.

Table 2: Comparative analysis between single use shipper vs multiple use shipper strategy

Total number of vaccines moved (units per month)	**75,000**	
	Current situation with EPS Box	**Proposed rental program (with sustainable packaging materials) solution**
Vaccines per box, units	50	100
Times the box can be reused in a month, no.	0	4
Boxes required per month, nos.	1,500	187.5
Cost per box, Rs.	860	
Rental per month per box, Rs.		6000
Total Box Cost, Rs.	**12,90,000**	**11,25,000**
Weight per box (kg)	30	13
Total number of vaccines moved (units per month)	**75,000**	
	Current situation with EPS Box	**Proposed rental program (with sustainable packaging materials) solution**
Forward freight (@ Rs. 15 per kg)	6,75,000	1,46,250
Reverse freight, Rs.		1,46,250
Total Freight, Rs.	**6,75,000**	**2,92,500**
Total Cost, Rs.	**19,65,000**	**14,17,500**

Cost benefit template: Domestic inter-city shipment spanning from 48 to 72 hours

Moving Away from Analysis Paralysis and Cost-Centricity Approach

Companies in cold chain logistic services or ones in the business of temperature-sensitive products have a very huge opportunity to make a difference to the fight against climate change. In comparison to the rest of the world, the Indian cold chain industry is still in its growing phase, which in itself offers India an opportunity to set up its infrastructure with new, efficient and far more environmentally resilient systems. Therefore, there is a need to implement climate technologies in small scale pilots with careful baseline data preparation to measure and evaluate the benefits. At the rate of acceleration in the global climate change, we do not have the luxury to analyze in theory or wait to follow the western world. On the ground, deployment of innovations must be a priority with the intention to fail fast and move on to different solutions and iterate.

Conclusion

Sustainability and decarbonization have to become everybody's business and entrenched in the organization's culture. The strategic plan with goals towards operating cost reduction, fossil fuel elimination and elimination of GHG emission is required to be set for the organization by a dedicated internal team responsible for sustainable initiatives. It is imperative to give ourselves a wake-up call that being sustainable is not a cost center, but a non-negotiable element of the growth strategy for the organization.

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