Enhancing Energy Efficiency in Fish Cold Chain in South Asia: Pakistan & India

Department for Environment Food & Rural Affairs

WORLD BANK GROUP

Background

Global

- Global estimates of aggregated emissions from refrigerant banks until 2025 are **2.0 Giga tonnes** (Gt) of CO_2 equivalent.
- FAO estimates that **35%** of fish and seafood is wasted, with **8%** of all fish caught being thrown back into the water[2]
- Small-scale fisheries account for **more than half of total** fish production in the world[3]
- **Cold chain development** is essential for the small and medium scale fishing and seafood industries
- Cold storage improves accessibility to fisheries resources, reduces spoilage and expands distribution, resulting in an **increase in incomes and food security**
- Fisheries sector presents an opportunity to become a much stronger engine of **economic growth and social development**[4]
- A **climate-smart, energy-efficient** fish value chain will supplement both NDC and Blue Economy Development dialogue

PAKISTAN

- Pakistan is producing much **lower** yields compared to the region
- Post-harvest processing is outdated and under-capitalized, leading to **low value addition**
- **30-50%** of food produced lost to the lack of sustainable cold supply chains
- Cooling and refrigeration needs are **expected to increase** due to rising temperature
- Significant **strain on power systems** due to growing demand for cooling and refrigeration needs
- **Emissions from power systems** are a major contributor to global emissions
- Pakistan NDC intention aim to reduce 2030 projected GHG emissions by up to **50%**
- National Food Security Policy of Pakistan aims for the **establishment of cold chain** across supply line for meeting international trade requirements

INDIA

- Post-harvest processing (other than for export-oriented shrimp) is outdated, under-capitalized, leading to **high fish waste**
- **30%** of fish lost to the lack of sustainable cold supply chains (especially for domestic market – 90% by volume)
- Cooling needs are **increasing;** Required capacity to be built in next 8-10 years will be 15 times the current capacity (which itself is substantial)

Sources: 1- Papst, Irene – 2018; 2- FAO website; 3- FAO, Post Harvest Fish Loss – 2011; 4- Revitalizing Pakistan's Fisheries, The World Bank

Objectives, Elements & Methodology

Objective

To analyse and get a better understanding of sustainable cold chain systems/ technologies and practices in fish products cold chain logistics in Pakistan, with the aim of informing activities in the lending operation and Analytical and Advisory support under preparation

Elements & Methodology

Fish Product Cold Chain Logistics Profile

Field surveys/Desk study

Policy and Institutional Analysis

Desk study

Market Analysis

Market profile ; Cooling solutions
Business barriers ; Field and desk study

Stakeholder Engagement

Workshop

Knowledge Products

Recommendations

Profile Of The Cold Chain

Ice is extensively used in the fish product cold chain.

Mechanical refrigeration is used in processing plants, mostly in conjunction with fish product export, and block ice producing plants;

60% of the fish product processing plants have old and inefficient equipment that is locally manufactured;

- 30% have average efficiency equipment that is partially imported,
- The balance 10% have imported equipment whose efficiency can still be improved.

Total annual electricity consumption of the 82 identified processing plants ranges from 64,000 to 147,600 MWH;

- Specific electricity consumption: 552 to 667 kWh/ton of fish product processed;
- Block ice plants, estimated around 4,000, have a specific electricity consumption of 100 kWh/ton of ice produced;

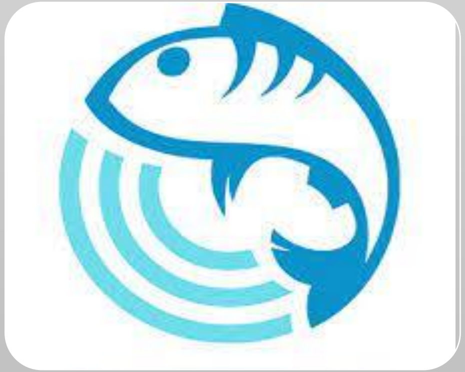
Most equipment at block ice plants and fish product processing plants are ammonia based.

- Ammonia is a climate-friendly refrigerant with good thermodynamic properties conducive to efficient performance in newly designed equipment or retrofit upgrades through component change.

Recommendations for a More Productive and Sustainable Sector

Improvement of access to sustainable refrigeration through:

- awareness on the benefits of preserving fish products,
- encouraging the sector to move to efficient technologies,
- assistance in upgrading of processing plants, equipment, and cold stores to climate-friendly technologies through incentives and pilot projects.



Improvement of sustainability of the fish value chain through:

- Improving hygienic conditions,
- improving sustainability of fish capture through the adoption of international codes and guidelines,
- improving the sustainability of fish processing through the adoption of energy efficiency measures.

Energy Efficiency Potential of the Fisheries Cold Chain

The market potential for energy efficiency upgrades at 82 fish product processing plants is US$ 12.5 million:

- potential for annual energy savings in the range of 33,579 to 77,529 MWh,
- translating into saving to owners between US$ 4.5 to 10.1 million per annum in energy bills,
- a payback period of 1.2 to 2.8 years,
- the specific energy consumption is reduced from a range of 502 - 667 kWh/ton of product to 247 - 316 kWh/ton of fish product.

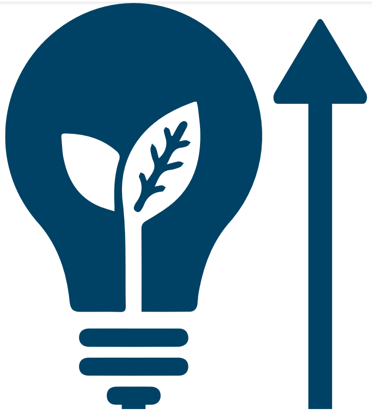
The market potential of implementing energy-efficient refrigeration technologies at 4,000 block ice plants is US$ 243 million:

- estimated at US$ 60,674 per plant with
- potential energy savings per annum between 158,400 to 475,200 kWh,
- translating into savings to the owner between US$ 23,100 to 69,400 per annum
- a payback of 1.1 to 2.8 years,
- the specific energy consumption is reduced from 100 kWh/ton of ice to 56 kWh/ton of ice.

Proposed measures:

variable speed compressors, electronic expansion valves, premium efficiency motors for compressors, variable speed motors for fans, cold stores' wall insulation, and insulation of brine solution tanks and pipelines.

Climate Impact Of Energy Efficiency Upgrades



Based on annual electricity consumption figure of **64,000 to 147,600 MWh** by 82 fish product processing plants, annual CO_2 emissions of the sector are estimated to be **32,000 to 74,000 tons of CO_2 equivalent**,

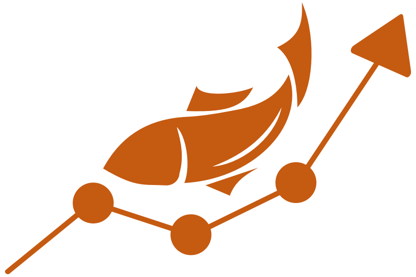
Annually, about **17,000 to 39,000 tons of CO_2 equivalent emissions** can be reduced by implementing energy efficiency measures in fish processing plants.

Based on a monthly electricity consumption range of 30,000 to 90,000 kWh by each block ice plant, annual emissions of a plant is **180 to 541 tons of CO_2 equivalent**,

Annually, **about 80 to 238 tons of CO_2 equivalent** of emissions can be reduced by implementing energy efficiency measures by each block ice plant.

- The CO_2 emission factor for the grid supply is 0.501 kg CO_2/kWh (ADB, 2017)
- One MWh produces 0.501 ton of CO_2 equivalent in emissions.

Market barriers and investment opportunities



Barriers

- Dependence on ice
- Lack of mechanical refrigeration on board fishing vessels
- Inefficiency at fish product processing plants
- Lack of mechanical refrigerated transport
- Inadequate commercial refrigeration
- Lack of institutional support

Opportunities

- Market potential for upgrading 4,000 ice plants is US$ 243 million.
- Refrigeration increases capture potential and adds value to the products
- Market potential of upgrading 82 plants is US$ 12.5 million.
- Providing incentives for importing refrigerated trucks
- Assisting local refrigeration manufacturers/assemblers to make their products more affordable and energy efficient
- Assisting local refrigeration manufacturers to upgrade their products
- Using renewable sources ae plants

Guidelines

Low Global Warming Potential (GWP) refrigerants used in the cold chain include ammonia, which is almost exclusively used in the fisheries sector in Pakistan, making a transition to other refrigerants unnecessary.

For future applications of refrigeration in the fish product cold chain, study includes

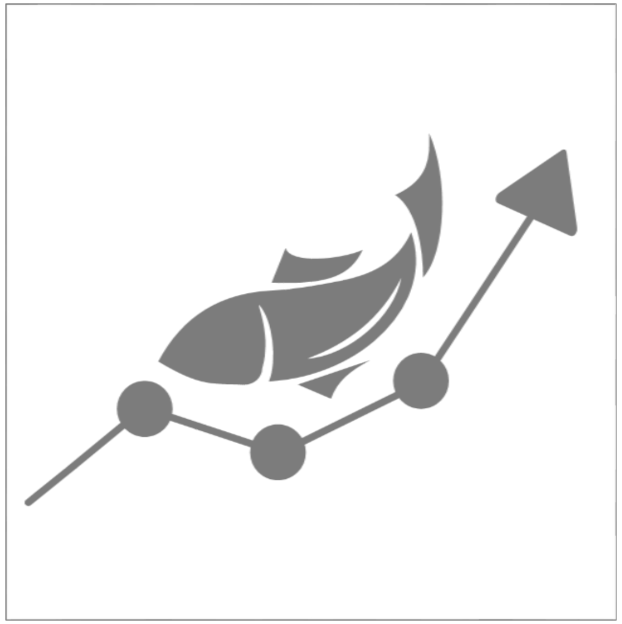
Guidelines on low-GWP refrigerants for each part of the chain	Guidelines on component selection	Guidelines on safety and performance standards

Conclusion

Pakistan Fisheries resources (marine, inland, and aquaculture) offer attractive potential for supporting food security and revenue generation, contributing to an increased GDP.

At present, low value addition in the fisheries sector is due to outdated and inefficient post-harvest processing practices and technologies, under-capitalization of the sector, and noncompliance to environmental and social legislations and standards.

- Fish product cold chain development can be achieved through energy-efficient processing and improvement in the value chain management which will contribute to achieve the SDGs of Pakistan as well as Montreal Protocol and Kigali HFC phase-down plan goals.
- The target to achieve US$ 2.0 billion in export of fish products by 2030 requires reforming the policy and legislative framework and the development of logistics and processing to match international best practices in systems and guidelines.



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Energy Efficiency and reduction of use and emission of HGWPR and ODS in Fisheries Sector Cold Chains

Part 1:

Understanding the need

Walk-through Energy & GHG/GWP Audits of Fishery Sector Value Chain entities (6 sample value chains)

Appraisal of local/ national and international best practices

Understanding the need (near completion)

a) Energy use, high GWP refrigerants and ODS in the sector, along with technologies used

b) Lessons, good practices, anecdotes and improved practices

c) Brief report on incentives, policies and opportunities for EE/LGWPR in fisheries cold chain

Walk-through Energy & GHG/GWP Audits completed for 5 (of planned 6) Fisheries Sector Value Chains

a) Status paper on the current energy usage and GHG emissions

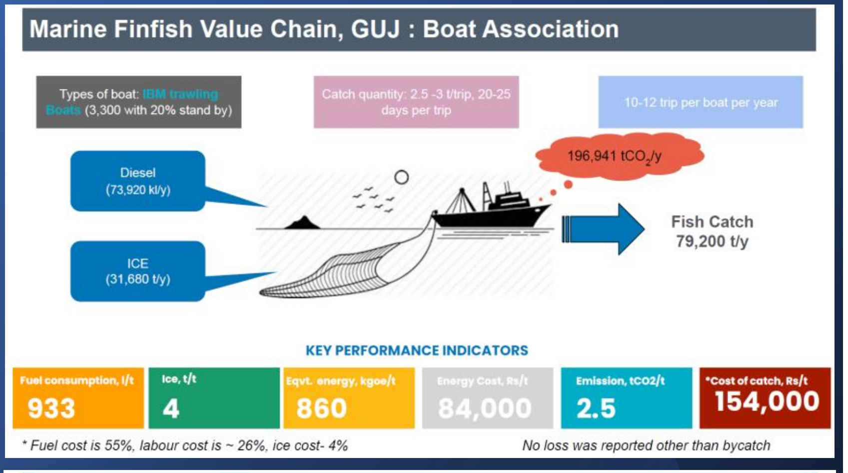
b) Status paper on benchmarking

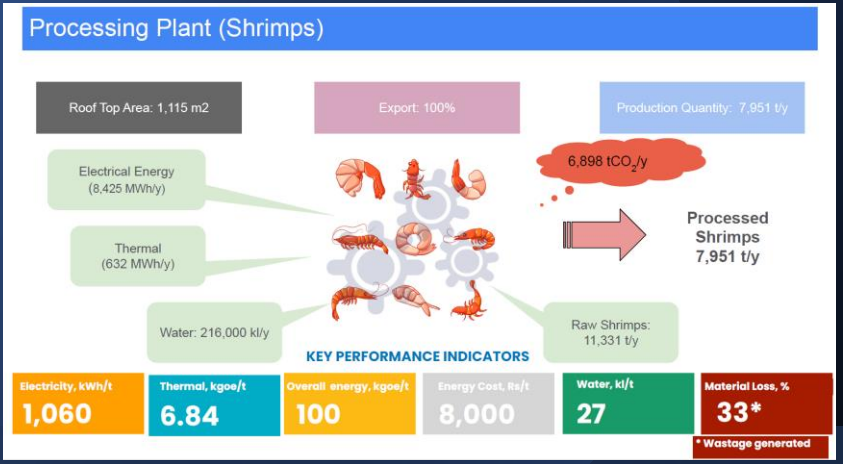
c) Draft energy audit reports

d) Status paper on the best practices for improving participation of women

Appraisal of local/ national and international best practices (ongoing)

- Energy Efficiency
- Use of refrigerants and ODS
- Technologies used best practices
- Policies, incentives, barriers





Part 1:

The Walk-Through Audits in All Entities of 5 Value Chains

Current energy use and GHG emissions in fisheries sector

Current energy use has been computed based on SEC values (kWh/kg) derived from walk through assessments and reported production.

States	Electricity consumption (kWh/y)	Diesel consumption (kL/y)	Total energy consumption (toe/y)	GHG emissions (tCO2/y)	Total production (tonnes)
Andhra Pradesh	624,006,898	1,952	55,447	504,457	620,149
Gujarat	11,176,243	35	993	9,035	11,107
Karnataka	7,450,829	23	662	6,023	7,405
Kerala	119,213,258	373	10,593	96,374	118,476
Odisha	121,075,965	379	10,758	97,880	120,327
Tamil Nadu	149,016,573	466	13,241	120,467	148,095
West Bengal	143,428,451	449	12,745	115,950	142,542
Daman and Diu, D and N haveli	1,862,707	6	166	1,506	1,851
Total	**1,177,230,924**	**3,683**	**104,605**	**951,693**	**1,169,952**

The major energy source is observed to be from the grid electricity itself. The diesel is only consumed in case of power shortages in most cases.

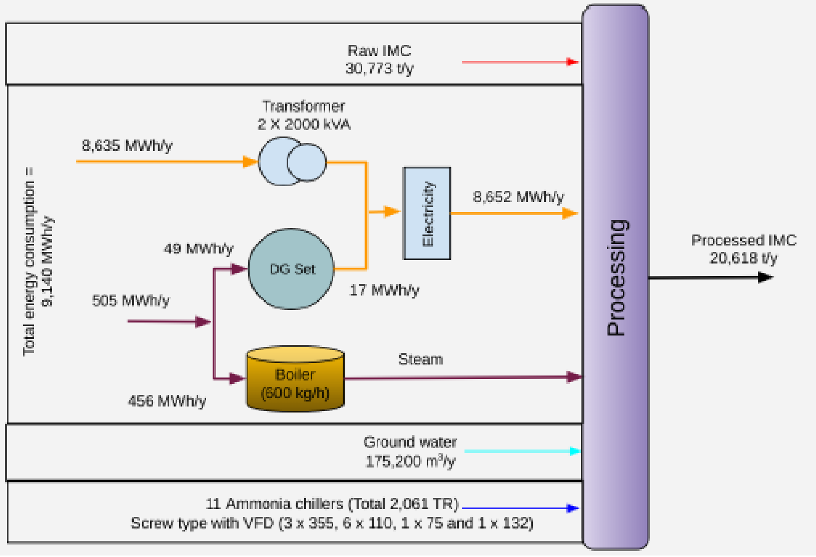


Figure 46: *Global overview of gate to gate energy consumption (Godavari)*

Frozen Shrimp Aquaculture in AP

	Ananda Foods	Ananda Enterprises	Godavari	BMR
Farm ownership	No	No	Yes	Yes
Processing capacity			20,617	7,952 t/y
Energy consumption	Electricity + DG	Electricity + DG + Diesel	Electricity + DG + Diesel	Electricity + DG
Electricity use	65,336 kWh/m	-	695,094 kWh/m	789,895 kWh/m
Cooling Load	590 TR	1150 TR	2,065 TR	1,800 TR
Refrigerants used	NH_3	R 134A and NH_3	NH_3	NH_3
Market	100% Export	100% Export	100% Export	100% Export
Employment	400	300	700	600

Energy Efficiency and reduction of use and emission of HGWPR and ODS in Fisheries Sector Cold Chains

Part 1:

Major Findings and Recommendations SO FAR

Energy savings and corresponding GHG Emission Reduction:

- Opportunities to reduce energy consumption by 5% to 25% across different operations in the value chains
- The potential includes fuel switch and renewable energy interventions. Opportunities range:
  - Operational improvements,
  - Technology interventions some of which are well established, while some are techno-economically viable, but not yet mainstream;
  - Technology interventions which are more novel (require further work to assess the economic viability)

HGWPR and ODS Elimination:

- Most of the Cold Storages, Processing Facilities and Ice Plants use ammonia-based
- Of course, there are a few HFC based chillers
- HFC based chillers are however the mainstay in refrigerated trucks.

Efficiency of Water and Other Resources:

- Various specific opportunities to reduce usage of water, promote re-use of water
- However, unavailability of benchmarks is an issue (comparison not plausible)
- In established aquaculture value chains, the feed to product ratio in is optimal (~well managed corporate businesses)
- Smaller (value-chain independent) firms need training and handholding.

Fish Wastes:

- Wastage levels are high (even if for established value chains wastage is minimized)
- Many examples of reuse of wasted fish i.e., offal (fish, kitten, and chicken litter feed)
- However, not enough information if these are the best use of fish waste
- Yet incomplete - Quantification of actual wastage resulting in solid waste emissions (of GHG)

Possible Targeting of Policy and Program Interventions market:

- States with high contributions in sourcing. Value chains targeting domestic market/consumption (86% of the sourced fish are transported unprocessed for domestic consumption)
- Main opportunities are in (a) aquaculture farms, (b) fishing boats, (c) logistics – transport and wholesale markets, and (d) retail kiosks and shops

Energy Efficiency and reduction of use and emission of HGWPR and ODS in Fisheries Sector Cold Chains

Part 2:

Stakeholder dialogues and dissemination of Study

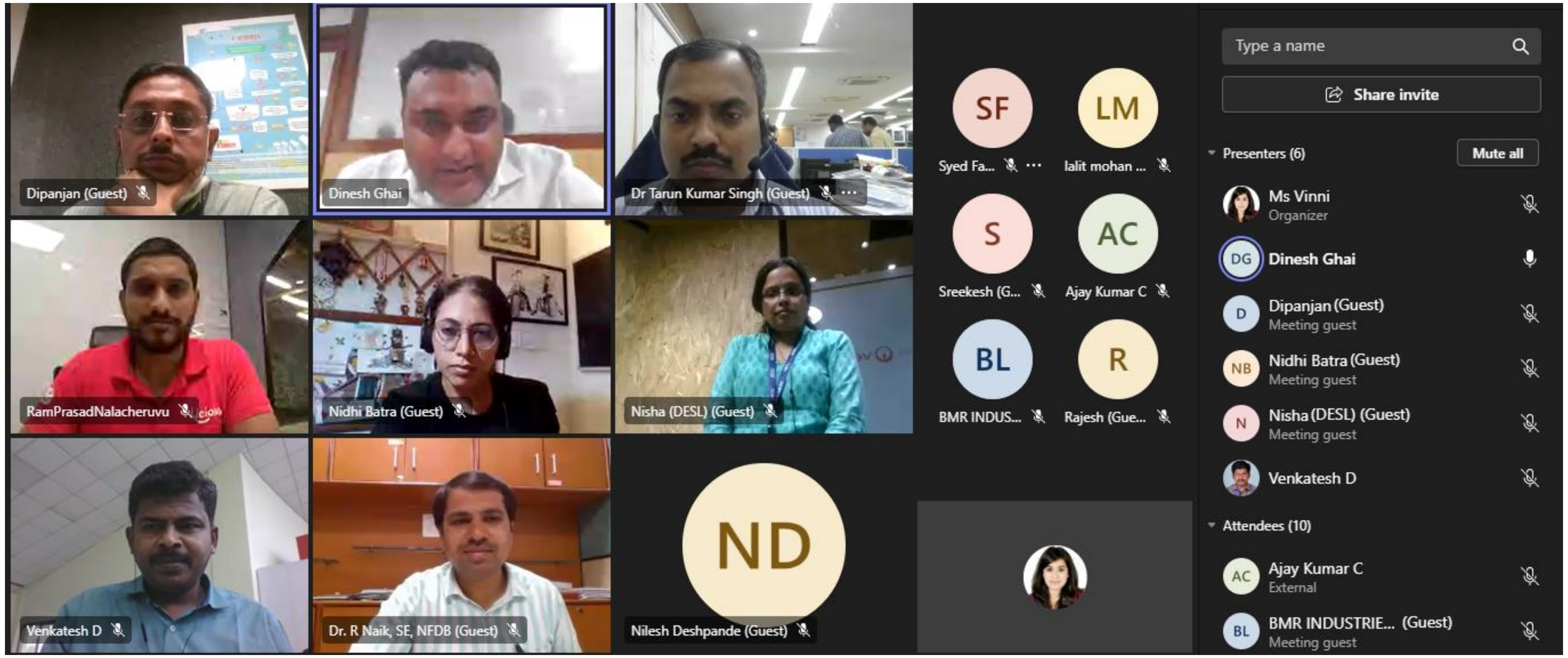
Design competitions

Good Practice Guidance Notes

Recommendations for improvement of the value chains.

Stakeholder dialogues and dissemination of (available findings from) Study

- Started from June 2022. Will continue through July-August 2022. Participants:
  - Government Officials (Federal and States)
  - Cold storage companies (in addition to who had been contacted during Walk-In Audits)
  - Logistics companies
  - Startups in the sector
- Content of Dialogues:
  - Presentation of findings from walk-through and detailed energy audits
  - Draft of best practices available
  - Discussion to elicit more of the good/best practices



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National Design Challenge for (1) Mobile kiosk for Fish vending, and (2) Energy-Efficient & Safe Transport of Live Fish

- **Objective**: To provide a platform to innovators, start-ups, technology providers, students, research institutes/associations to come up with innovative solutions
- To push awareness re the quality of fish, minimizing wastage, making the fisheries sector transport and retailing systems green and affordable
- The challenge was Launched on 28th March 2022; Competition Entries Received till 12th May 2022. Jury and presentation by shortlisted entries on 19th May 2022. Award announced on 26th May 2022.
- Jury included officials from Government Officials (Ministry of Fisheries, Ministry of Science & technology), Fisheries Sector Institutions (National Institute of Fisheries Post Harvest Technology and Training, National Fisheries Development Board), and experts from Private Sector (Licious Pvt. Ltd., Snowman Logistics India, Fresh to Home Pvt. Ltd.)

Energy Efficiency and reduction of use and emission of HGWPR and ODS in Fisheries Sector Cold Chains

Part 2:

Stakeholder dialogues and dissemination of Study

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Good Practice Guidance Notes

Recommendations for improvement of the value chains.

Winners of the National Design Challenge for (1) Mobile kiosk for Fish vending, and (2) Energy-Efficient & Safe Transport of Live Fish

Category: Mobile Kiosk for Fish Vending

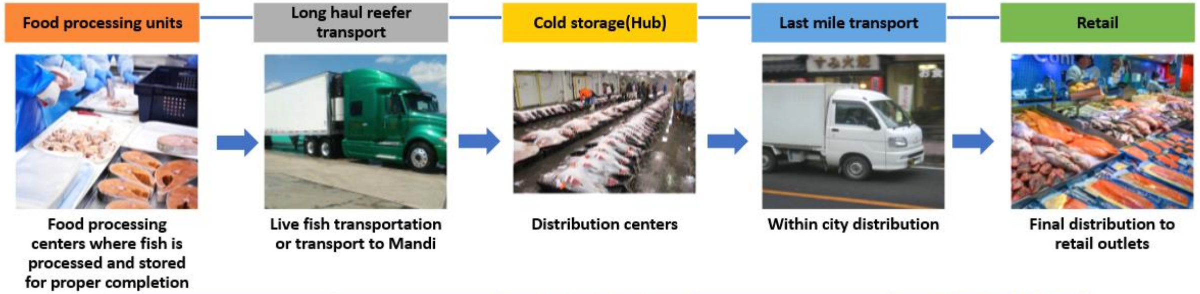
Prize	Team details	Organization
First prize	1. Mr. Ajay Kumar 2. Mr. Harish Chander 3. Mr. MD Moidur Rahman 4. Mr. Sajan Gupta 5. Mr. Simarpreet Singh	GNA University
Second Prize	1. Mr. Tahaer Zoyab 2. Ms. Sarojini Gandhi 3. Ms. Sushruti Krishnan 4. Ms. Maahira Fathima Niazi 5. Mr. Hareesh AN	Triple O Studio
Certificate of Merit	1. Mr. Mustaqim S Zardoz 2. Ms. Maithili A Ghosarwadkar 3. Mr. Sumit R Kamble	KLS Gogte Institute of Technology
Certificate of Merit	1. Mr. Mr. Ananth Sai Shankar V 2. Mr. Sathiyan AR 3. Mr. Yokesh J 4. Ms. Kaviya S	Velammal Engineering College
Certificate of Merit	1. Mr. Sanyam Soni 2. Mr. Karanbir Singh 3. Mr. Jaspreet Singh 4. Mr. Harwinder Singh 5. Mr. Gurjit	GNA University
To invite for presentation	1. Ms. Nandini Jain 2. Mr. Sumit Raushan 3. Mr. Vicrant 4. Mr. Udit Narayan 5. Ms. Swati Singh	School of Planning and Architecture, New Delhi

Category: Energy Efficient & Safe Transport of Live Fish

Prize	Team details	Organization
First prize	1. Mr. Suvo Sircar 2. Mr. Subho Dutta 3. Mr. Sundheep Xavier	SNRASSYSTEMS
Second Prize	1. Mr. Raj Mirun M 2. Mr. Rudhran S	MaDeIT Innovation Foundation, IIITDM Kancheepuram
Certificate of Merit	Mr. Armaan U. Muzaddadi	ICAR- Central Institute of Post-Harvest Engineering and Technology, Ludhiana
Certificate of Merit	1. Mr. Haridharan M 2.Mr. Vignesh B	MaDeIT Innovation Foundation, IIITDM Kancheepuram
Certificate of Merit	1. Mr. E. Hino Fernando 2. Mr. Jayapavithran Chokkalingam 3. Mr. Rajeshwaran	ICAR- KVK, Sikkal ICAR-CIBA, Chennai ICAR- CIFE, Mumbai

Discussions underway to facilitate: (i) the Ministry of Fisheries supporting prototype development, and support for incubation, (ii) development of linkages in the "Make in India" program, and (iii) supporting roll-out of the solutions through Government of India Program (PMMSY)

INDIA – Fishery Sector Cold Chain Infrastructure



Post harvest infrastructure	Nos	Capacity in MT (2020 – 21)	Nos	Capacity in MT (2029 – 30)
Processing plants	611	34,495	858	69,496
Ice plants	79	2,262	79	2,410
Peeling sheds	690	10,859	781	26,382
Conveyance	227	211,102	293	3,121,102
Storages	790	476,324	1170	1,192,957
Fresh/Chilled FHC	67	1,196	132	1,251
Live fish HC	63	1,676	137	1,753
Salted/Dried FHC	133	2,473	200	14,096

- **Emphasis on Value Chain Efficiency** (for EE and reduction of GHG/GWP)
  - Efficient cold chain technologies needed for the quality standards to compete with international market
  - Need to minimize fish losses incurred at each stage
  - Increased economic use of fisheries byproducts (along entire supply chain
- **Efficient cold solutions along the entire supply chain, not focusing on cold storages only**
  - Refrigerants in reefer vehicles – main element of reducing ODS
  - Logistic/distribution businesses must move towards sustainable and green transport (say, EV)
  - Adoption of solar/electric vessels – need for policies/incentives to change the composition of the motorized vessels (~60% of fishing fleet)
- **For the domestic supply chain, for which the cold chains are yet to be in place:**
  - To be set up only with best technology. Need focused awareness programs
  - Technology available in the market. Incentives needed to induce adoption
  - Use IoT to identify and arrest the fugitive emissions (leak of refrigerants)

Energy Efficiency and reduction of use and emission of HGWPR and ODS in Fisheries Sector Cold Chains

Part 2:

Stakeholder Feedback SO FAR

Annex

Guidelines on Refrigerant Selection

Processing Plants	Alternative lower GWP refrigerants (GWP values in parentheses)
Small facility	- HC-290 (5) - HC-1270 (1.8) - R-744 (1) - HFO blends, e.g., R-454C (146)
Large facility	- Single R-717 (0) with glycol - Two-stage: R-717 in high temperature and R-744 in low temperature

Cold Stores	Alternative lower GWP refrigerants (GWP values in parentheses)
Small cold stores (< 100 m^3)	- HC-290 (5) - HC-1270 (1.8) - HFO-1234yf (4) - HFO blends, example: R-454C (146),
Large cold stores (> 100 m^3)	- Primary R-717 (0) and R-744 (1) - Secondary: brine, glycol

Guidelines on Components

Electronic expansion devices (instead of thermostatic expansion valves or capillary tubes etc.) can help lower the condensing temperature and compressor power while also increasing capacity contributing to a higher efficiency;

Mechanical or Vapor Injected subcooling decreases the liquid temperature leaving the condenser coil, which increases the capacity of the system and enables the expansion device to operate more efficiently, all serving to decrease power anywhere from 10% to 30% depending on conditions;

Suction line heat exchange in which the cool vapor leaving the evaporator is used to sub-cool the liquid entering the expansion device without the aid of an external sub-cooler;

Variable capacity compressors allow for better matching of the refrigeration load to the capacity and reduce the number of on-off cycles of the compressor, thus resulting in less thermal and electric cycling losses;

Evaporative condensing consists of adding a mist of water to the air that is being drawn over the condensing coils. This type of evaporative condenser has become popular with the growth of trans-critical CO_2 technology.

Condenser cleaning. Fouling of condensing coils through dust, foreign particles, etc. leads to reduced performance of the condenser but can also result in higher power consumption, longer run-time, loss of temperature and loss of food or products being refrigerated.

Heat recovery and system integration: This form of system efficiency improvement has been increasingly used with the growth of R-744 as a refrigerant. Utilisation of heat recovery can contribute to improve the overall efficiency of the entire refrigeration system.

Guidelines on Standards

Standards set the requirements and the limitations of putting new equipment into the market and their conditions of use.

Standards need to be adopted into local regulation in order to become enforceable.

The relevant standards to the introduction of new technology with low-GWP energy-efficient refrigerants are those on safety and energy efficiency.

Safety standards can be adopted into building codes and energy efficiency standards are used for labeling regulation.

Safety Standards specify the requirements for the safety of persons and properties:

- They provide guidance for the protection of the environment and establishes procedures for the operation, maintenance and repair of refrigerating, air conditioning and heat pump systems, as well as the recovery of refrigerants.
- Standards also place refrigerant charge limits based on usage like the minimum occupied volume of the room where the equipment is expected to be used.

There are no Minimum Energy Performance Standards related to the fish product cold chain in Pakistan.

- Energy efficiency for fish processing is measured in kWh/ton of product.
- Efficiency of cold stores can be measured in kWh/m^3 of storage.