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CONFERENCE PROCEEDINGS

Developing a low-carbon roadmap for Tamil Nadu's food processing sector

SUMMARY OF THE ROUNDTABLE DISCUSSION

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Introduction

The food processing sector in India plays a vital role in the national economy and is often referred to as a "sunrise sector" (Invest India 2023), with significant potential to drive value addition, generate employment, strengthen market linkages, and enhance the competitiveness of Indian processed food products in domestic and international markets. In Tamil Nadu, the sector has emerged as an important pillar of the state's economy, with the state accounting for approximately 8 percent of India's food-processing output (MoFPI 2025). The state also accounts for around 9 percent of India's food-processing and manufacturing workforce, with women playing a significant role across several processing activities (Kapoor et al. 2025). Tamil Nadu is also home to several important food-processing value chains, including turmeric, sago, seafood, dairy, and pulses, supported by a growing network of processing clusters, food parks, and cold-chain infrastructure (Guidance Tamil Nadu n.d.). These value chains matter not only for domestic consumption and livelihoods, but also for the state's export competitiveness.

Despite its strong growth potential, the sector faces several challenges, including high energy consumption; inefficient processing technologies; dependence on conventional fuels such as coal and natural gas; water-intensive operations; inefficient management of wastewater and organic waste streams; and limited access to and awareness of finance for technology upgrades. Export-oriented units are also increasingly exposed to evolving sustainability requirements in international markets (the European Union [EU], the United States, Southeast Asia, etc.), including expectations around carbon footprint reduction, resource efficiency, supply chain traceability compliance such as the US Food Safety Modernisation Act (FSMA) (FDA 2026), and compliance with emerging regulations such as the EU Deforestation Regulation (EUDR) (EUDR Compliance 2025), making sustainability performance an important factor for maintaining market access and competitiveness.

Recognising these challenges and opportunities and aiming to support the transition, WRI India, in collaboration with Tamil Nadu Food Processing and Agri Export Promotion Corporation (TNAPEx), convened a stakeholder roundtable titled 'Developing a Low-Carbon Roadmap for Tamil Nadu's Food

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"Processing Sector" on August 13, 2026, in Chennai, Tamil Nadu. The goal of the roundtable was to understand the ground realities of the selected food-processing clusters in Tamil Nadu, with an initial focus on the turmeric, sago, and seafood-processing value chains across Erode, Salem, Tuticorin, and Ramanathapuram.

The dialogue brought together representatives from various sectors, including government agencies; industry associations; micro, small, and medium enterprises (MSMEs); research institutions; technology providers; seafood exporters; sago manufacturers; spice processors; sustainability experts; and financial institutions. Participating organisations included the Agricultural and Processed Food Products Export Development Authority (APEDA), MSME–Development and Facilitation Office (MSME-DFO), TNAPEx, Tamil Nadu Infrastructure Fund Management Corporation (TNIFMC), National Bank for Agriculture and Rural Development (NABARD), Small Industries Development Bank of India (SIDBI), State Bank of India (SBI), and Tamil Nadu Agricultural University (TNAU). Collectively, approximately 40 participants shared perspectives on sectoral challenges, emerging opportunities, and the interventions required to support a low-carbon transition.

The roundtable followed an interactive, solution-oriented format. The inaugural segment set the context for the low-carbon transition of Tamil Nadu's food-processing sector by highlighting emerging sustainability trends, industrial competitiveness considerations, export market requirements, and opportunities for resource-efficient growth. This was followed by three thematic discussions.

- "Session 1: Sector Challenges, Competitiveness and Transition Drivers" explored sector-specific operational challenges, changing market expectations, sustainability requirements, export competitiveness, and the factors influencing the adoption of low-carbon practices across food-processing value chains.
- "Session 2: Emissions Hotspots, Resource Use and Low-Carbon Technologies" focused on energy consumption patterns, emissions sources, resource-use challenges, digitalisation opportunities, circular economy approaches, and potential technology solutions across the turmeric, sago, and seafood-processing clusters.
- "Session 3: Financing and Institutional Support" focused on investment requirements, access to finance, risk-sharing mechanisms, public support schemes, innovative financing approaches, and the institutional actions needed to accelerate the adoption of low-carbon technologies among MSMEs and larger enterprises.

During the discussions, the participants emphasised that achieving a low-carbon transition in Tamil Nadu's food-processing sector will require coordinated action across the domains of technology deployment, financing, policy support, infrastructure development, and capacity-building.

Inaugural session

The inaugural session set the context by highlighting the strategic importance of Tamil Nadu's food-processing sector and its role in supporting the state's vision of becoming a US$1.5 trillion economy by 2036 (Tamil Nadu Finance Department 2026). The session highlighted that Tamil Nadu is among the leading producers of agricultural commodities such as turmeric, tapioca, and seafood. The speakers voiced the concern that despite a strong production base, processing levels remain relatively low, resulting in limited value addition and significant post-harvest losses across several commodities.

The discussions further emphasised that the food-processing sector is highly fragmented and dominated by MSMEs that play an important role in employment generation, value addition, exports, and rural livelihoods. At the same time, the sector was recognised as a resource- and energy-intensive sector, with emissions occurring at multiple points in the value chain, including:

- Energy use: Thermal energy, refrigeration, electricity consumption, and cold-chain operations
- Resource use: Water-intensive processing operations and material losses
- Logistics and packaging: Transport, storage, packaging, and distribution activities
- Waste generation: Food-processing waste, wastewater, organic residues, and by-products

A key message was that decarbonisation should be viewed as a phased transition rather than a single intervention. Several interventions were discussed namely, improving energy efficiency, adopting renewable energy (RE) technologies, promoting circular economy practices, recovering value from waste streams, and integrating digital technologies into industrial operations. Reducing food loss and waste was highlighted as one of the most immediate opportunities to improve both environmental performance and business efficiency.

FIGURE 1 | Delegates and participants at the roundtable



Photo credit: WRI India.

The speakers also highlighted the increasing importance of food product traceability from farm to fork, sustainability practices, and the carbon footprint associated with processing, packaging, and transport in international markets. Global buyers are increasingly moving beyond traditional food safety and quality requirements and seeking greater transparency into product origin, production practices, and environmental performance. Considering this, traceability systems, sustainable production practices, and certification mechanisms were identified as critical enablers of future export competitiveness.

From a financing perspective, a representative of the Government of Tamil Nadu highlighted the growing role of climate finance in supporting the food-processing sector's low-carbon transition and the availability of dedicated investment mechanisms to advance sustainable industrial growth. The priority investment areas identified by them included energy efficiency, RE, electrified logistics, circular economy solutions, agri-waste utilisation, and food loss reduction. The speaker also emphasised that reducing post-harvest losses, improving agricultural productivity, and developing commercially viable low-carbon solutions represent significant opportunities to simultaneously strengthen competitiveness, enhance resilience, and attract climate-aligned investments.

From a policy perspective, the speakers representing state and national institutions highlighted several ongoing initiatives to support MSME competitiveness, sustainability, and technology adoption. These included export promotion programmes, such as buyer-seller meets; international trade fairs; market access support led by APEDA and TNAPEx; traceability and certification initiatives such as Good Agricultural Practices (GAP) and National Program for Organic Certification (NPOP) programmes; technology-transfer partnerships with research institutions such as TNAU, National Institute of Food Technology, Entrepreneurship and Management (NIFTEM), and other food technology institutes; and financing mechanisms to encourage resource-efficient production systems. The participants highlighted the Micro and Small Enterprises – Cluster Development Programme (MSE-CDP) as a mechanism for establishing Common Facility Centres (CFCs) and shared infrastructure for MSMEs. However, the participants noted that although food-processing clusters exist across Tamil Nadu, the full potential of the scheme remains unrealised. The representatives highlighted that many proposals submitted under the programme are structured as individual production facilities rather than as common infrastructure projects, limiting their eligibility. They, therefore, emphasised the need for greater awareness, stronger cluster-level coordination, and viable proposals for shared facilities such as testing laboratories, processing infrastructure, and common

services. Overall, the inaugural session established a comprehensive understanding of the food-processing sector's economic significance, resource-use challenges, market opportunities, and low-carbon transition requirements.

Session 1: Sector challenges, competitiveness, and low-carbon transition drivers

Following the inaugural session, Session 1 focused on the sectoral challenges, competitiveness, and low-carbon transition drivers affecting Tamil Nadu's food-processing ecosystem, with particular emphasis on turmeric, sago, and seafood processing.

Competitiveness and on-the-ground operational challenges

Rising production and operating costs: A recurring concern across the turmeric, sago, and seafood value chains is rising production and operating costs, particularly energy-related costs. Participants from the sago sector highlighted a substantial rise in electricity costs due to successive tariff revisions, particularly increases in energy and fixed charges, which raised operational expenses and put financial pressure on enterprises. Participants from the seafood sector highlighted the rising feed costs and electricity requirements, particularly for continuous aeration in shrimp farming, as important cost pressures. In the turmeric sector, low agricultural productivity, quality-related losses, post-harvest wastage, and inefficient processing practices reduce raw material utilisation and increase energy and other resource consumption, raising production costs (TNERC 2022, 2023, 2024, 2025).

Raw material availability, productivity, and quality: Raw material availability, low agricultural productivity, and inconsistent quality were highlighted as key concerns across the turmeric sector. Processors often depend on raw materials from outside Tamil Nadu because insufficient quality produce is available locally. In the seafood sector, seasonal and unpredictable raw material availability, along with low yields, quality variation, and inadequate post-harvest mechanisation, was reported to affect processing efficiency and profitability.

Market access, technology, and competitiveness: In the turmeric sector, poor raw material quality, limited access to testing infrastructure and residue-testing facilities, and lack of support for certifications such as GAP were identified as constraints to export readiness and market access. The participants noted that export buyers required compliance with pesticide-residue standards but testing often occurred only at the shipment stage rather than at the harvesting or post-harvest stages. The stakeholders highlighted the limited availability of testing laboratories near production centres, as well as the high cost and extended turnaround time associated with residue testing. The participants also identified gaps in traceability systems, noting that traceability often stopped at the manufacturing unit and was not adequately linked to quality and residue testing results. They emphasised that traceability should align with test reports rather than simply identify the produce's source, which is a major challenge.

FIGURE 2 | Session on sector challenges, competitiveness, and low-carbon transition drivers



Photo credit: WRI India.

Further, stakeholders highlighted operational bottlenecks in the existing electronic National Agriculture Market (e-NAM), particularly in aggregating lots with small batches supplied by marginal farmers, which could increase the risk of distress when produce remains unsold.

Participants from the sago sector expressed concerns regarding weak market positioning, limited value addition, and strong competition from countries such as Thailand, Vietnam, and China, which have adopted more advanced technologies and processing systems. They also noted that a lack of direct export channels, limited awareness, and continued reliance on conventional processing methods affect the sago sector's competitiveness.

Stakeholders from the seafood sector highlighted increasing competitive pressure from major exporting countries such as Ecuador and Vietnam. They identified ageing processing infrastructure, high technology-upgrading costs, and evolving buyer requirements related to traceability, sustainability, and supply-chain transparency as key factors influencing competitiveness and access to international markets.

Infrastructure gaps and the need for common infrastructure: Key infrastructure and service gaps include testing laboratories, common processing facilities, cold-chain infrastructure, common pre-processing centres, common effluent treatment plants (CETPs), and access to RE for MSMEs.

For turmeric clusters, farmyards require CFCs in close proximity to support pre-cleaning, boiling, drying, polishing, and other post-harvest operations. The participants also highlighted the need for accessible accredited turmeric testing laboratories with affordable testing services and sustainable staffing and operational models. Several existing initiatives were reported to be underutilised due to operational constraints rather than a lack of capital investment.

Further, the discussion highlighted the importance of sector-specific infrastructure design. A participant cited an earlier investment in silo storage with specialised cooling systems for long-term storage of ground turmeric. However, the high natural oil content in turmeric reportedly caused the powder to compact and deteriorate during storage, requiring the system to be repurposed for spices with low oil content, such as coriander and cumin. The experience highlighted the importance of tailoring storage and material-handling solutions to the properties of turmeric, rather than adopting technologies used for other commodities.

The age and design of existing infrastructure were also identified as constraints in the turmeric, sago, and seafood clusters. Several processing facilities established decades ago are not designed to meet the current requirements for automation, energy efficiency, hygiene, traceability, and export compliance. The participants, therefore, emphasised the need for a structured pathway to retrofit and modernise existing facilities alongside investment in new infrastructure.

For seafood, the participants highlighted the need for appropriately located bulk cold storage facilities, common pre-processing and processing centres with effluent treatment plants (ETPs), and seafood parks, particularly closer to the coast where proximity to fresh raw materials is important.

The discussion also highlighted that organisations such as APEDA and TNAPEx provide some infrastructure and institutional support. However, access, location, and stakeholder awareness remain concerns.

Emerging market requirements and transition drivers

Changing market, sustainability, and low-carbon requirements: Businesses are increasingly expected to meet the quality, food safety, traceability, and sustainability requirements of both domestic and international markets. For turmeric, these include residue-free produce, maximum residue limit (MRL) compliance, NPOP certification, and microbial-load control. For seafood, businesses need to address issues related to Marine Products Export Development Authority (MPEDA) licensing, environmental/Coastal Regulation Zone (CRZ) compliance, export requirements, and product quality standards, while sago processors increasingly focus on value addition, organic and chemical-free positioning, and international market requirements such as multilingual labels and recipes.

Rising energy costs, international market requirements, and buyer expectations are increasingly driving businesses towards sustainable, low-carbon practices. Industries are also seeking to minimise waste and maximise resource utilisation through improved technologies. For example, sago industries use methane generated through effluent treatment for power generation, improving resource utilisation.

Session 2: Emissions hotspots, resource use, and low-carbon technologies

Session 2 focused on identifying emissions hotspots, resource use, and practical technology pathways to enable a low-carbon transition across Tamil Nadu's selected food-processing clusters.

Turmeric and sago processing

The breakout discussion on turmeric and sago processing in the Salem-Erode clusters focused on identifying energy- and resource-use hotspots, exploring opportunities for low-carbon and resource-efficient technologies, and understanding the enabling conditions needed to modernise processing infrastructure.

Although turmeric and sago follow distinct processing methods, stakeholders identified several common challenges around infrastructure, energy-intensive operations, water use, technology adoption, product quality, market access, and the limited ability of individual MSMEs to invest in advanced processing systems. The discussion also highlighted that improving resource efficiency is closely linked to improving product quality, export competitiveness, and operational efficiency.

Energy consumption and emissions hotspots

The discussion began with an overview of the two processing ecosystems. Turmeric processing typically involves washing and cleaning, cooking, drying, polishing, grinding, storage, and packaging, whereas sago processing involves washing, peeling, crushing or rasping, filtration, sedimentation, globulation, roasting, drying, polishing, and packaging. The stakeholders noted that the nature and intensity of resource use vary considerably across these stages.

FIGURE 3 | Session on emissions hotspots, resource use, and low-carbon technologies in turmeric and sago processing



Photo credit: WRI India.

For turmeric, thermal energy use during cooking and drying and electricity consumption during grinding emerged as important hotspots. For sago, water consumption during washing and processing, together with energy use for drying and roasting, were identified as key areas requiring continued attention.

The participants noted the need to carefully balance process optimisation with product quality considerations. In turmeric processing, excessive thermal exposure during drying or grinding can affect the quality and retention of essential oils and other desirable characteristics. Similarly, in sago processing, the choice of drying technology affects not only energy consumption but also food safety and export market requirements.

Low-carbon technology opportunities

Modernising turmeric processing and drying: A significant part of the discussion focused on the ongoing transition from traditional turmeric processing practices towards more automated and controlled systems. The stakeholders noted that traditional turmeric cooking practices have evolved considerably over the past two decades. Earlier practices involved immersing turmeric in boiling water, while in some traditional methods, animal-derived material was reportedly added, such as cow dung slurry, to cooking water. This has raised concerns in export markets about the use of animal derivatives.

The industry has recently increasingly used mobile steam units in which a single boiler supplies steam to several cooking compartments loaded with turmeric. These units use agricultural residues such as dried turmeric leaves as fuel, reducing dependence on fossil fuels. Further discussions also identified an opportunity to improve the efficiency and scale of steam-based cooking through more centralised and mechanised steaming systems. Such systems could reduce energy losses, labour requirements, and processing time

The discussion also considered electrifying the cooking stage instead of using biomass-fuelled boilers, to further decarbonise it. The participants, however, noted several reasons why this is not yet a practical option. On-farm electrification is both operationally challenging and considerably more expensive than direct biomass firing, which draws on agricultural residues already available at the farm. More fundamentally, grid electricity in the state remains predominantly generated from coal and lignite. Shifting cooking from biomass to grid power would, therefore, move emissions upstream to fossil-based generation instead of removing them and could raise the carbon footprint of this stage compared with the current residue-fuelled system that is largely circular and low in external energy use. Electrification would make sense only after grid power becomes substantially cleaner. Until then, biomass-based steam cooking, alongside the emerging microwave-based option discussed in the next sub-section, remains the more promising near-term direction for this stage of processing.

Improving turmeric drying: Drying emerged as one of the most important opportunities for improving both resource efficiency and product quality. Traditional open-sun drying uses minimal direct energy but raises concerns about contamination and process control. The participants discussed several alternatives, including mechanical drying, solar-assisted systems, biomass-based drying, and hybrid solar-biomass dryers. A representative from TNAU highlighted hybrid solar-biomass drying as a potential intervention to reduce drying time and energy use.

Another technology pathway discussed was granular drying in which fresh turmeric is sliced or diced into smaller pieces before drying. Reducing the distance moisture must travel from the core of the product to the surface could improve drying efficiency and reduce energy requirements. The upcoming automated facility is expected to provide an opportunity to generate practical data on energy consumption and process performance at a commercial scale.

The participants also discussed microwave-based cooking and drying as an emerging technology option. Because microwave energy interacts directly with water molecules within the product, it was identified as a potentially energy-efficient alternative for controlled processing. However, the technology is not yet widely available for commercial turmeric processing, and targeted capital support and demonstration projects are needed to assess its viability for MSMEs.

Sago processing-Mechanisation and water efficiency: The sago industry presented a contrasting picture, with stakeholders noting that mechanisation has already progressed significantly across several stages of production. The participants noted that mechanical drying has largely replaced open-yard sun drying in the sago sector. The production line is now substantially mechanised, including heat application during roasting to support phytosanitary requirements.

Water management, however, remains a key area for resource efficiency in the sago sector. The stakeholders described using treated water from on-site ETPs for initial washing in a closed-loop system, with fresh water reserved for more critical stages such as crushing, rasping, and final washing. This approach demonstrates how water recycling can reduce freshwater demand without compromising process requirements.

The discussion, nevertheless, highlighted the need to better measure water consumption at the unit level. Establishing benchmarks, such as litres of freshwater consumed per tonne of tapioca processed, could help identify inefficiencies and support more systematic water management strategies across the cluster.

The participants highlighted that technology selection should consider factors beyond energy efficiency. Concerns were raised that direct-heating systems could create undesirable residues and affect export acceptance. The stakeholders, therefore emphasised the importance of clean solar drying, indirect heating, and appropriately designed mechanical drying systems that can meet moisture requirements without compromising food safety or product quality.

Energy efficiency, automation, and infrastructure: For turmeric processing, grinding and pulverisation were identified as major electricity consuming operations. The participants highlighted the potential for high-efficiency motors, including IE4 and IE5 motors, combined with variable frequency drives (VFDs) to reduce electricity consumption and enable better control of equipment loading.

However, the adoption of such technologies remains limited. The participants estimated that the proportion of units adopting advanced levels of automation across the cluster remains very low. A major reason identified was the high upfront capital requirement.

An important technical discussion centred on the relationship between grinding energy and product quality. Conventional pulverisation generates substantial frictional heat. In turmeric and other spices, excessive heat during grinding can lead to the loss of volatile oils and affect the sensory and functional characteristics of the final product. Technologies such as ambient air-flotation pulverisers and cryogenic or low-temperature grinding systems can help minimise thermal exposure. Again, the relatively high capital cost of advanced systems was identified as a significant barrier for MSMEs.

Digital quality assessment and market access: Beyond plant-level processing changes, the discussion also highlighted market integration mechanisms, from farm-to-gate testing to digital trading platforms, that directly accelerate the cluster's low-carbon transition. The discussions also highlighted that portable testing equipment capable of assessing parameters such as curcumin, starch, oleoresin, and moisture can enable processors to evaluate raw turmeric closer to the farm gate. A TNAU official stated that under the Government of India's Bharat's Hub for Agritech, Resilience, Advancement and Incubation for Export Enablement (BHARATI) initiative, which supports agri-food entrepreneurs in developing export infrastructure and new technologies, six entrepreneurs from Tamil Nadu were selected, including a team that developed a compact testing instrument for spices such as turmeric. The instrument enables rapid assessment of key quality parameters, including moisture, curcumin, oleoresin and starch, reducing the dependence on conventional laboratory-based testing. The stakeholders noted that the technology has already been tested under field conditions, with processors using the equipment at farm gates and local markets to assess turmeric quality before procurement.

This farm-level dimension was also more broadly linked to sustainability. Erode is among Tamil Nadu's leading turmeric districts, and farmer sensitisation to GAP, including reduced pesticide use and a transition towards organic cultivation, is already underway.

Circularity and by-product utilisation: Circular economy practices are already present across both clusters. Sago peels and fibrous residues are used as feed for cattle and aquaculture, while turmeric polishing residues—depending on their quality—can be directed towards agricultural applications or industries manufacturing incense sticks and mosquito coils.

The participants also raised concerns regarding the traceability of residues generated after commercial curcumin extraction. Once valuable compounds are extracted from turmeric, the remaining fibrous material may have limited food value but could be diverted to industrial applications. The stakeholders cautioned that inadequate traceability increases the risk of turmeric residues re-entering informal food markets as adulterated material.

Research institutions are also exploring higher-value applications for turmeric residues. The TNAU representatives highlighted ongoing research into the use of suitable turmeric processing residues for value-added products and functional applications, indicating opportunities to move beyond low-value waste utilisation towards higher-value resource recovery.

A recurring discussion was the need for cluster-level common infrastructure to overcome the capital and technical constraints faced by MSMEs. Potential facilities could include advanced drying systems, testing laboratories, pilot-scale R&D facilities, specialised low-temperature grinding machines, automated processing equipment, and technology demonstration centres. Shared facilities could enable MSMEs to access advanced technologies on either a service or pay-per-use basis without requiring individual investments.

Seafood processing

The breakout discussion on seafood processing focused on identifying the major energy and emissions hotspots across the value chain, the potential for low-carbon and resource-efficient technologies, opportunities for circularity and resource recovery, and the enabling conditions needed to support wider adoption.

Energy consumption and emissions hotspots

The stakeholders noted that refrigeration-related activities consume the most energy, accounting for nearly 80 percent of electricity use and are the major emissions hotspots in the seafood-processing value chain (TERI 2017). Energy use is particularly concentrated in ice production, cold storage, blast freezing, individual quick freezing (IQF), and refrigerated transport, making cold-chain efficiency a critical priority for reducing both operational costs and emissions.

The discussions also revealed that the sector still relies heavily on grid electricity to meet its cooling and refrigeration needs, with diesel generator sets continuing to serve as backup systems during power outages. The participants also stated that many seafood units in Tamil Nadu operate on ageing infrastructure developed several decades ago. Fluctuations in raw material availability and seasonal production patterns often lead to underutilisation of cold storage and processing infrastructure, reducing operational efficiency and increasing the unit cost of processing.

Additionally, the importance of considering emissions upstream of processing operations—those related to fuel use in fishing vessels and mechanised trawlers—and transport from landing sites to processing facilities was also discussed. The participants

FIGURE 4 | Session on emissions hotspots, resource use, and low-carbon technologies in seafood processing



Photo credit: WRI India.

noted that addressing these upstream emissions, alongside improvements in processing and cold-chain infrastructure, will be essential for developing a comprehensive low-carbon transition pathway for the seafood-processing sector.

Low-carbon technology opportunities

The discussion highlighted several technology pathways that could reduce emissions while improving operational efficiency.

Improving refrigeration efficiency: Refrigeration emerged as one of the most important areas for technology upgrading. Industry experts noted that many seafood exporters have already replaced conventional freezing systems with more efficient IQF-based systems. These were considered advantageous because they improve freezing consistency, reduce product losses, and deliver higher product quality (Stephen et al. 2026). Continued improvements in refrigeration efficiency were, therefore, seen as an important opportunity for reducing both energy use and operating costs.

The choice of refrigerant was another area of discussion. The participants noted that ammonia-based systems are widely used within Indian seafood-processing facilities due to their high efficiency and low global warming potential. At the same time, the stakeholders highlighted emerging opportunities for carbon dioxide-based refrigeration systems and ammonia-carbon dioxide cascade configurations that have demonstrated improved refrigeration performance, reduced energy consumption, and enhanced suitability for low-temperature freezing compared with conventional two-stage ammonia and hydrofluorocarbon (HFC)-based refrigeration systems used in seafood-processing applications (Kumar et al. n.d.). However, their adoption remains limited due to higher capital costs, dependence on imported components, and limited awareness among MSMEs.

Heat recovery and process integration: Heat recovery was identified as another potential opportunity to recover and utilise waste heat generated from refrigeration systems through heat pumps. Such systems can recover thermal energy from refrigeration operations and produce hot water for cleaning and processing applications, thereby increasing overall energy efficiency. Although the technology has been successfully adopted in industries such as dairy processing, the participants noted that its adoption within seafood processing remains at an early stage and would require demonstration projects and greater industry awareness.

RE adoption: RE adoption, particularly solar photovoltaic systems, was recognised as another practical option for reducing the electricity costs and emissions associated with grid electricity. However, the participants noted that adoption remains limited due to ageing infrastructure, structural limitations of existing facilities, and limited awareness about available financing and support schemes.

Alternative models, including group-captive solar arrangements and renewable power procurement through utility providers, were discussed for reducing electricity costs while lowering emissions.

Digitalisation, traceability, and resource monitoring: The participants acknowledged that seafood exports are now increasingly driven by traceability requirements from international buyers and retail chains. Many export-oriented processing facilities have already adopted automated production systems, sensor-based refrigeration monitoring, programmable logic controllers (PLCs), and enterprise resource planning (ERP) systems.

However, the stakeholders noted that although data collection systems are being introduced, the integration of production, energy, traceability, and sustainability data remains limited. They broadly agreed that future competitiveness will increasingly depend on the ability to provide transparent, verifiable information across the value chain, from harvest and processing through transport and export. Technologies such as Internet of Things (IoT) sensors, blockchain-based traceability systems, ERP platforms, and digital monitoring tools can support both operational efficiency and compliance with export market requirements.

Circular economy and resource recovery opportunities: The stakeholders identified seafood by-products as a major untapped opportunity within the sector. Fish heads, skin, scales, shells, and other processing residues are currently either sold through informal channels or disposed of at the processors' expense. The participants noted that these materials have strong commercial potential for producing fishmeal, fish oil, protein concentrates, chitin, chitosan, animal feed products, and other value-added applications.

Several participants observed that individual processors often generate too little waste to justify investing in dedicated processing facilities. This makes cluster-level aggregation of seafood waste an attractive model for enabling commercially viable resource recovery and circular economy initiatives. The stakeholders suggested that shared waste processing facilities could reduce disposal costs, generate new revenue streams, and lower emissions through improved resource utilisation.

Wastewater management and shared infrastructure: Wastewater management emerged as another key concern, particularly for smaller enterprises that face high costs associated with effluent treatment infrastructure and regulatory compliance. The participants highlighted the need for common facilities, such as a CETP, to reduce costs and improve resource efficiency.

The participants repeatedly raised the concept of shared infrastructure and extended it beyond wastewater management. They suggested that seafood-processing clusters could benefit from common facilities for cold storage, refrigeration, waste processing, testing laboratories, and logistics infrastructure. Such facilities were seen as an effective way to reduce operating costs, improve resource efficiency, and enhance the competitiveness of MSMEs, which currently struggle with low-capacity utilisation and thin profit margins.

The stakeholders also highlighted the need for basic common pre-processing facilities and ice-making infrastructure at fishing harbours and landing centres. Establishing facilities for cleaning, grading, sorting, and initial handling closer to the point of landing was considered an important measure to reduce post-harvest losses, maintain product quality, and strengthen cold-chain continuity from harvest to processing.

Overall, the stakeholders agreed that improving refrigeration efficiency, modernising cold-chain infrastructure, strengthening traceability systems, promoting resource recovery from seafood waste, and developing shared infrastructure facilities represent key priorities for reducing emissions while enhancing the competitiveness of Tamil Nadu's seafood-processing sector.

Session 3: Financing and institutional support

The session focused on the financing and institutional practices required to enable food-processing MSMEs to adopt clean technologies and improve resource efficiency. The discussions examined the barriers to accessing finance, opportunities for deploying innovative and aggregated financing models, and the role of government and financial institutions in strengthening the enabling ecosystem.

The discussion also considered Tamil Nadu's existing financial and institutional support ecosystem, including special purpose vehicles (SPVs), public-private investment in food parks, capital subsidies for cleaner technologies, and support through state agencies and industrial departments. This provided a basis for identifying how existing financing and institutional mechanisms could be better leveraged to support technology adoption among food-processing MSMEs.

FIGURE 5 | Session on financing and institutional support to strengthen the enabling ecosystem for food-processing sector MSMEs



Photo credit: WRI India.

Financing challenges: Access to and deployment of finance

The participants identified high upfront capital costs and technology risk as key barriers to adopting advanced technologies in the turmeric processing value chain, including microwave-based cooking and drying and low-temperature cryogenic pulverisation. They noted that although these technologies are commercially available, their cost and limited deployment could hinder MSME investment. They, therefore, discussed risk-sharing arrangements involving MSMEs, technology providers, lenders, and public agencies, including models where technology providers support performance or guarantees and early-stage technology risks are shared among stakeholders. A risk-cushioned pilot or sandbox approach was also discussed, in which successful demonstrations could transition to conventional lending while the risks associated with unsuccessful trials could be shared among the participating stakeholders.

The participants also identified a gap in pilot-scale product development and incubation facilities. Small enterprises need access to facilities with lower processing capacity and where product formulations, processing methods, and new equipment configurations can be tested before large capital commitments are made. Although incubation schemes exist, the participants noted that they are generally oriented towards larger investment sizes. The discussion highlighted the need to consider how to support the capital and operating costs of such facilities.

Collateral requirements emerged as another major constraint. The participants called for greater use of credit guarantees to support investments in capital equipment, while financial institutions highlighted existing mechanisms such as the Credit Guarantee Fund Trust for Micro and Small Enterprises (CGTMSE), including hybrid security structures under which a portion of a credit facility can be secured through collateral while the remaining amount is covered by a credit guarantee. The participants also discussed extending state and central guarantee programmes to support investments in green capital equipment rather than limiting their application primarily to working-capital financing.

The participants also discussed Priority Sector Lending (PSL) as a potential route to concessional finance, particularly where eligible machinery, equipment, or procurement activities meet the applicable lending criteria. They noted that linking energy-efficient and low-carbon capital investments to PSL eligibility and guarantee mechanisms could help address financing constraints and improve access to capital for adopting cleaner technologies.

The Partial Risk Sharing Facility for Energy Efficiency (PRSF) implemented by the SIDBI, with World Bank support, was also highlighted as an existing risk-sharing mechanism for energy efficiency investments. This was discussed alongside the broader need for financing structures that reduce the risk faced by lenders and MSMEs when investing in technologies with a limited deployment track record.

Working capital constraints were particularly pronounced because agricultural commodities must often be procured during short harvesting windows. Processors may therefore need to mobilise substantial funds within a limited period to purchase and hold raw materials. The participants proposed dedicated seasonal procurement finance with less restrictive collateral requirements, while financial institutions highlighted existing cash-credit facilities and warehouse-receipt financing as mechanisms that can support inventory procurement and holding.

The participants also highlighted the financing gap between export-oriented and domestic processing. Although exporters benefit from financing instruments such as export packing credit and preferential interest rates, a substantial share of India's food and spice production is consumed within the domestic market. Extending similar procurement and working-capital financing support to domestic processors was, therefore, identified as a key opportunity. The participants noted that despite the predominance of domestic consumption, several financing incentives remain concentrated on export-oriented processing.

Beyond access to finance, the participants highlighted gaps in awareness and financial readiness among MSMEs. Many enterprises may be unaware of relevant financial products and institutional support mechanisms, or may struggle to translate technology investments and operational requirements into bankable proposals that meet lenders' and Environmental, Social, and Governance (ESG) requirements.

The participants also discussed the potential for a standardised green evaluation framework, similar in concept to a credit score, to assess MSMEs against parameters such as energy savings, emissions reduction, and circular practices. Such an assessment could potentially be used to differentiate financing terms or incentives based on demonstrated environmental performance. Participants from the financial sector further noted the emergence of dedicated green finance pools driven by sustainability reporting and disclosure requirements. However, developing a credible pipeline of eligible, verified, and bankable MSME projects that can meet investment criteria and access these financing opportunities is a key challenge.

Innovative financing models and scalable investments

The participants highlighted financing models that can reduce the upfront capital burden associated with clean technology investments. Under energy service company (ESCO) models, service providers finance and install energy-efficient equipment and recover their investment through energy savings. Renewable energy service company (RESCO) and group-captive models can enable MSMEs to access RE without bearing the full upfront capital cost.

The SIDBI representative highlighted several existing instruments, such as the 4E (End-to-End Energy Efficiency) financing model for energy efficiency and rooftop solar financing; MSE Green Investment and Financing for Transformation (MSE-GIFT), which provides interest subvention for eligible clean technology loans; and MSE Scheme for Promotion and Investment in Circular Economy (MSE-SPICE), which offers capital subsidies for eligible energy-efficient machinery. Other mechanisms discussed included Goods and Services Tax (GST) Sahay for digital invoice discounting and purchase bill financing and MacFin Mart, a digital platform connecting MSMEs with verified equipment suppliers and financing providers.

The participants also discussed measures to reduce the transaction costs associated with accessing these financing instruments. These included support for energy audit costs, including mechanisms to subsidise or reimburse audit expenses, as well as repayment structures that allow lower initial instalments for greenfield and modernisation investments, with repayments increasing as capacity utilisation improves.

Furthermore, the participants suggested that targeted government financial assistance could help accelerate GAP adoption. Such support could complement processing-stage interventions by improving the quality, traceability, and sustainability credentials of raw materials entering the value chain.

The discussion also highlighted the role of cluster-based aggregation in reducing the transaction and due diligence costs associated with financing multiple small investments. Financial institution representatives noted that they already finance industrial clusters and CFCs and that similar approaches could extend to shared RE systems, waste management and resource recovery facilities, testing laboratories, and other common infrastructure. From a lender's perspective, aggregated projects can become more financeable when the scale of investment, expected cash flows, and associated risks can be demonstrated collectively rather than through multiple small individual applications. The participants further noted that cluster-level debt financing for common infrastructure may require targeted government schemes and credit-risk-sharing guarantees to address collateral constraints.

The seafood sector illustrated both the potential and limitations of shared infrastructure. The participants identified shared cold storage as a viable cluster-level investment but noted that centralised industrial refrigeration may be less suitable where processing lines have varying temperature and load requirements. Refrigeration was identified as the single largest source of energy consumption in marine processing, strengthening the case for shared facilities where a sufficient concentration of units exists. The participants also highlighted logistics gaps between harbour landing centres and inland processing hubs, noting that despite investments in cold storage and reefer transport funded under central schemes, refrigerated transport availability along this segment of the supply chain remains inadequate. They also highlighted aggregated electricity demand and group-captive solar as potential ways to reduce energy costs across MSME clusters. They cited comparable approaches in industrial clusters in other states, where units have pooled regional power demand to install shared solar capacity, consume low-cost power on-site, and export surplus to the grid.

Carbon finance was also discussed as a supplementary financing opportunity for aggregated projects. Group RE and other emissions reduction projects could potentially be registered collectively in voluntary carbon markets, with carbon revenues providing viability gap support during the initial stabilisation period rather than substituting for conventional sources of finance.

Institutional support

The participants emphasised the need for stronger coordination among MSMEs, financial institutions, technology providers, government agencies, universities, and industry associations. Although multiple financing products and schemes are available, information gaps and fragmented institutional interfaces can make it difficult for MSMEs to identify, combine, and access appropriate forms of support.

A single-window or integrated digital interface was proposed to bring together central schemes, state incentives, financial products, and technology providers, reducing the burden on MSMEs of identifying and navigating multiple institutions and application processes.

The discussion also highlighted that several existing support mechanisms are strongly export-oriented. APEDA schemes provide assistance for cold storage, reefer transport, processing and upgrading equipment, and testing laboratories but primarily target export infrastructure. The participants highlighted the need to provide comparable support for domestic and intra-state food processing, including processing machinery, CFCs, and testing infrastructure.

The discussion also noted that Tamil Nadu is revising its food processing policy to strengthen support for domestic and intra-state food processing. The proposed measures include support for high-quality processing machinery, farm-level CFCs, and post-harvest testing for non-export-oriented units.

The participants further identified a gap in support for brownfield modernisation. The discussion noted that existing capital support measures often target large investments or new greenfield capacity, whereas many food-processing MSMEs need smaller, incremental investments to retrofit equipment, improve energy efficiency, and expand existing facilities. The participants, therefore, highlighted the need for financing instruments and incentives that are suited to the modernisation and expansion of existing brownfield units.

The participants also highlighted the value of state-supported technology demonstration units in key food-processing clusters. Such facilities could allow MSMEs to observe technologies under real operating conditions and assess energy savings, product quality outcomes, and financial paybacks before making individual investments. This was discussed as a way to reduce uncertainty and build confidence among MSMEs regarding technologies with limited deployment.

Overall, the discussion highlighted that the challenge is not only the availability of finance but also how finance is structured, accessed, and delivered to MSMEs. Cluster-based financing, risk-sharing mechanisms, support for brownfield modernisation, improved financial preparedness, and stronger convergence among government schemes and financial institutions were identified as important elements of a more accessible financing ecosystem. The discussion also underscored the importance of developing a credible pipeline of bankable cluster-level projects, supported by simple measurement of energy and carbon performance, in order to enable the green and institutional finance available to better connect with MSME investment needs.

The way forward

To support the development of a competitive, resilient, and low-carbon food-processing sector in Tamil Nadu, the roundtable identified the following priority areas for action:

Policy frameworks

- Establish baseline assessments of energy use, water consumption, waste generation, and greenhouse gas emissions across priority food-processing clusters to identify hotspots, prioritise interventions, and track progress towards low-carbon transition goals.
- Strengthen e-NAM through standardised quality assaying and grading systems that combine chemical parameters, such as curcumin, starch, oleoresin, and moisture content, with physical parameters, such as length, thickness, and cigarette-beetle infestation.

Information, awareness, and capacity-building

- Strengthen awareness and capacity-building on low-carbon technologies, resource efficiency, traceability, quality standards, available policies, and financing mechanisms through targeted training at the cluster level, demonstration projects, and technical advisory support.

Technological interventions

- Modernise processing infrastructure and improve resource efficiency by adoption of energy-efficient equipment, automation, digital monitoring systems, efficient thermal technologies, improved material handling, and process optimisation across food-processing operations.
- Expand access to clean energy and shared utilities by promoting RE adoption, shared thermal systems, energy-efficient cold chains, and cluster-level energy solutions such as group-captive RE models to improve affordability and resilience for MSMEs.
- Promote circular economy and resource recovery solutions by supporting the productive utilisation of agricultural residues, food-processing by-products, seafood waste streams, and organic waste through value-added applications and waste-to-resource business models.

Finance

- Improve access to finance and strengthen implementation partnerships by developing risk-sharing financing mechanisms, building cluster-based investment pipelines, and fostering collaboration among government agencies, financial institutions, industry associations, research institutions, technology providers, farmers, farmer producer organisations (FPOs), and MSMEs.

Institutional arrangements

- Develop common and cluster-level infrastructure, including testing laboratories, CFCs, cold-chain facilities, pre-processing centres, advanced drying and processing facilities, wastewater treatment systems, and other shared infrastructure to reduce costs and improve access to technology.
- Strengthen state-level collaboration among government, industry, research, and financial institutions to accelerate low-carbon interventions across food-processing clusters.

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Abbreviations

APEDA	Agricultural and Processed Food Products Export Development Authority
BHARATI	Bharat's Hub for Agritech, Resilience, Advancement and Incubation for Export Enablement
CDP	Cluster Development Programme
CETP	Common Effluent Treatment Plant
CFCs	Common Facility Centres
CRZ	Coastal Regulation Zone
ERP	Enterprise Resource Planning
EUDR	EU Deforestation Regulation
FSMA	US Food Safety Modernization Act
GAP	Good Agricultural Practices
GSDP	Gross State Domestic Product
IoT	Internet of Things
IQF	Individual Quick Freezing
MPEDA	Marine Products exports development authority
MRL	Maximum Residue Limit
MSME-DFO	Micro, Small and Medium Enterprise-Development and Facilitation Office
MSMEs	Micro, Small and Medium Enterprises
NPOP	National Programme for Organic Production
NABARD	National Bank for Agriculture and Rural Development
PLCs	Programmable Logic Controllers
SBI	State Bank of India
SIDBI	Small Industries Development Bank of India
TNAPEx	Tamil Nadu Food Processing and Agri Export Promotion Corporation
TNAU	Tamil Nadu Agricultural University
TNIFMC	Tamil Nadu Infrastructure Fund Management Corporation
VFD	Variable Frequency Drives

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WRI India, an independent knowledge organisation registered as India Resources Trust, provides objective information and practical proposals to foster environmentally sound and socially equitable development. Through research, analysis, and recommendations, WRI India puts ideas into action to build transformative solutions to protect the earth, promote livelihoods, and enhance human well-being.

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