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SEforALL SDG7 IMPACT THAILAND

EFFICIENCY OPPORTUNITIES IN THAILAND'S DAIRY COLD CHAIN

ACKNOWLEDGEMENTS

This report is based on a comprehensive review of recent literature, industry reports, case studies, and data from the Thai dairy industry. Data were collected from various sources, including official statistics from the Thai Ministry of Commerce, the Dairy Farming Promotion Organisation of Thailand (DPO), the Ministry of Agriculture and Cooperatives, and academic research from Thai universities and local studies.

The report was prepared by the SEforALL team with invaluable contributions from Sommai Phon-Amnuaisuk, Vice President for Asia-Pacific at IIEC Asia Regional Operations in Bangkok, Thailand. It was developed under the technical guidance and support of the SEforALL Cooling Team, led by Brian Dean and Ben Hartley. Additional valuable inputs were provided by Giorgia Pasqualetto and Rosa Garcia.

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EXECUTIVE SUMMARY

Thailand's dairy industry has grown steadily in recent years, driven by rising domestic consumption and export demand. The country is the largest producer and exporter of dairy products in ASEAN, with milk consumption reaching around 1.2 million tonnes in 2022. Exports total approximately 300,000 tonnes annually, primarily milk drinks such as yoghurt and ultra-high temperature (UHT) milk, which account for about 95 percent of total export volumes.

The industry comprises about 17,000 dairy farms, ranging from small household operations to large commercial farms, with a combined raw milk production capacity of approximately 3,200 tonnes per day. However, domestic production remains insufficient, requiring imports of skimmed milk and milk powders. Thailand has 75 milk processing facilities, mainly in the central and northern regions, of which 60 focus on pasteurised milk production, consuming about 36 percent of the local raw milk supply.

A key feature of the sector is the School Milk Programme, which accounts for more than 30 percent of total demand. Introduced in 1992, it provides free 200 ml portions of non-flavoured milk to students in 34,000 public schools. Pasteurised milk is distributed during school terms, while UHT milk is supplied during breaks. All milk under the programme is produced from domestic raw milk.

Cooling systems are critical to the dairy supply chain, shaping product quality, energy efficiency, and sector performance. This report analyses operational stages, energy consumption patterns, and opportunities for efficiency improvement in Thailand's dairy cold chain. Section 2 presents a profile of the cold chain and its key components. Section 3 reviews the technological landscape, focusing on cold storage infrastructure and refrigerated transport systems. Section 4 examines energy efficiency potential across different stages and identifies practical measures for optimisation. The annexes provide supplementary data, including major facilities, technical specifications, and process details.

The study finds that:

01

Dairy cold chain activities are highly energy intensive, with major consumption in processing, storage, and distribution.

02

Pasteurised milk processing could achieve up to **30 percent energy savings** through best practices and renewable energy integration.

03

Refrigerated transport consumes more than **19 million litres of diesel annually**, with significant potential for optimisation and electrification.

04

Ice-making for non-refrigerated distribution could deliver **37 percent energy savings**, with further reductions possible by shifting to refrigerated vehicles.

05

Some facilities have adopted rooftop and floating solar PV, but efficiency measures are not yet systematically applied.

06

Data on cold chain operations remains fragmented, limiting effective planning and monitoring.

Enhancing energy efficiency, improving data systems, and fostering stronger collaboration among stakeholders will be essential to improve product quality, extend shelf life, and increase farmer and business returns. Advancing sustainable cold chain practices and technologies will be critical to supporting the long-term competitiveness and resilience of Thailand's dairy industry.

1 INTRODUCTION

The dairy industry in Southeast Asia has developed steadily, although levels of milk sufficiency across the region remain low to moderate. Most countries rely heavily on imports to meet the needs of their growing populations. According to the Food and Agriculture Organization (FAO), Malaysia, the Philippines, Singapore, and Thailand record particularly high levels of dairy imports.

The structure of the Thai dairy sector is diverse. It comprises about 17,000 farms, ranging from small-scale household operations to large commercial enterprises, with a combined raw milk production capacity of around 3,200 tonnes per day. Despite this capacity, domestic production remains insufficient, requiring imports of skimmed milk and milk powders to meet total demand.

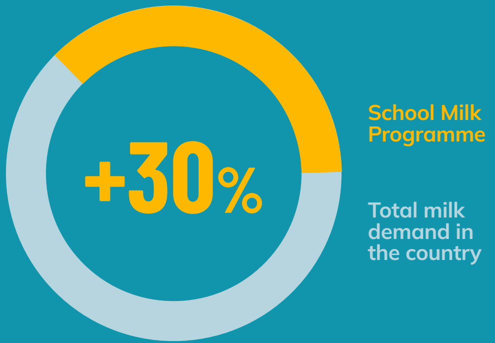
Milk processing represents a central component of the value chain. As of 2022, there were 130 processing facilities nationwide, concentrated mainly in the central and northern regions. Of these, 60 facilities focus on pasteurised milk production, which consumes approximately 36 percent of the domestic raw milk supply. The remainder process UHT milk and a variety of other dairy products.

A distinctive feature of the Thai dairy sector is the Government's School Milk Programme, introduced in 1992 to support farmers and promote milk consumption among children. Today the programme accounts for more than 30 percent of total market demand. It provides each student in 34,000 public schools with a free daily portion of 200 ml of non-flavoured milk. Pasteurised milk is distributed during school terms, while UHT milk is supplied during school breaks. All milk provided under the programme is processed from domestic raw milk (see Box 1).

BOX 1

SCHOOL MILK PROGRAMME

The School Milk Programme is a vital component of the Thai dairy industry. Initiated in 1992, the programme was designed both to support dairy farmers and to improve child nutrition. It now accounts for more than 30 percent of total milk demand in the country.



Under the programme, every student in 34,000 public schools receives a free daily portion of 200 ml of non-flavoured milk. Pasteurised milk is distributed during the school semester, while UHT milk is provided for parents to collect during school breaks. All milk supplied through the programme is processed from the domestic raw milk supply.

Cooling systems are vital at every stage of the dairy supply chain. They safeguard product quality and safety, while also influencing energy consumption, operating costs, and environmental impacts. Enhanced product quality and prolonged shelf life also drive profits for businesses and farmers.

Against this background, this report aims to:

- Profile the structure and characteristics of the Thai dairy industry;
- Identify cooling practices and technologies currently used across the supply chain; and
- Analyse energy consumption patterns and assess opportunities for efficiency improvements in key cold chain elements.

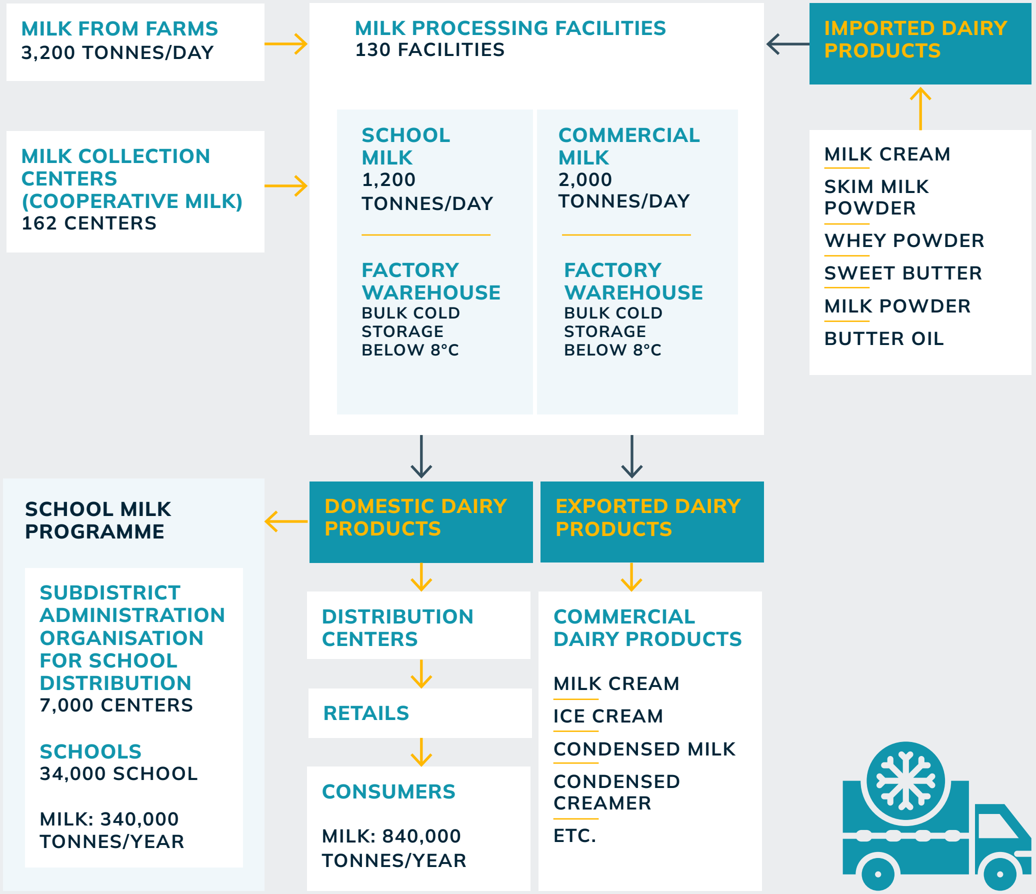
2 DAIRY COLD CHAIN IN THAILAND

Currently, data sources on the Thai dairy industry and associated cold chain infrastructure are fragmented, and no central database for dairy product statistics exists.

Some official statistics are available from the Ministry of Agriculture and Cooperatives and the Ministry of Commerce. Additional information can be found in reports and studies published by the local dairy industry and academic institutions. In contrast, data on cold chain practices and technologies commonly used in the Thai dairy sector are very limited. Relevant insights are available mainly from dairy product manufacturers, logistics and cold storage operators, technology suppliers, and selected research papers. Drawing on these resources, the overall supply chain of the Thai dairy industry has been mapped in Figure 1.

FIGURE 1

Supply Chain of the Thai Dairy Industry



2.1 RAW MILK SUPPLY

Dairy cooperatives in Thailand play an essential role in linking dairy farms with processing facilities. According to the Information and Communication Technology Center of the Ministry of Commerce, there were 90 dairy cooperatives in 2021 acting as intermediaries between farms and processors. These cooperatives operate 162 collection centres nationwide. There is no cold storage either at the farms or at the collection centres, and raw milk is generally kept at room temperature. Thailand's total raw milk supply capacity is approximately 1.2 million tonnes per year.

Wheeler Pickup Truck

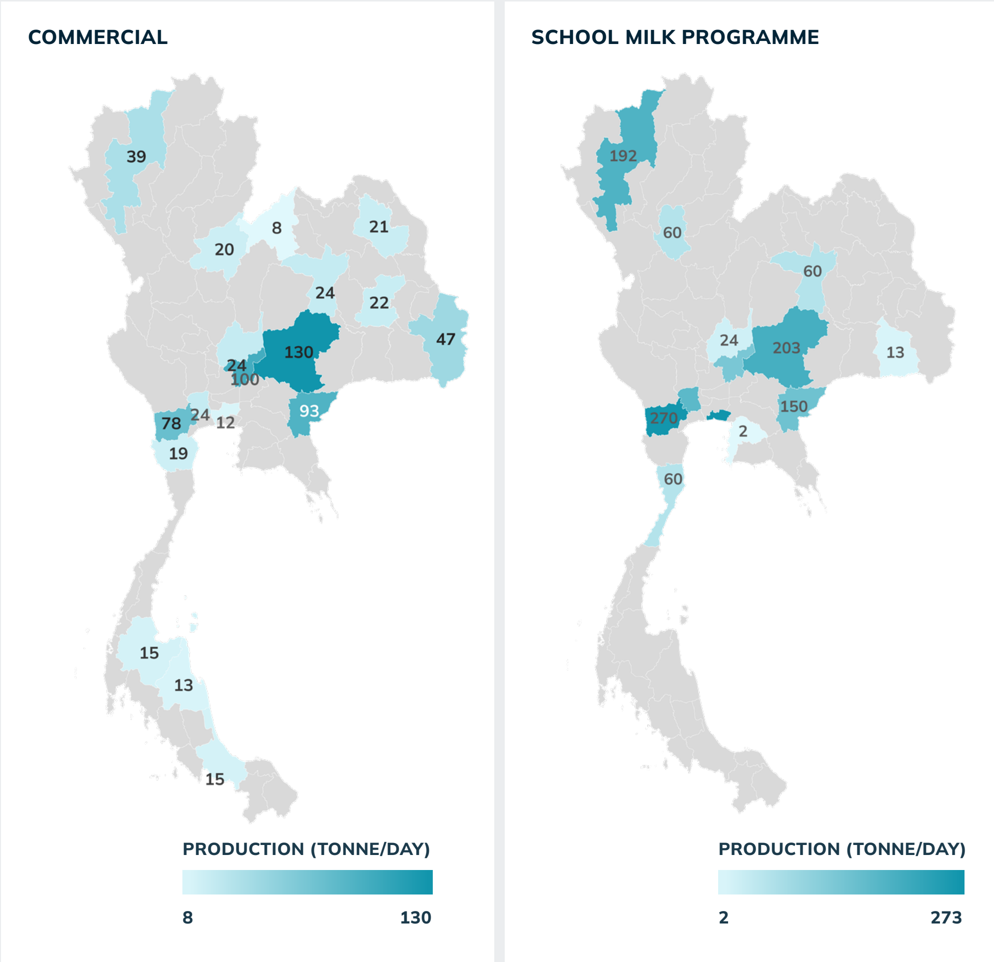
Farmers typically store raw milk in standard tanks with a capacity of 50 kilograms each, awaiting collection in the morning and evening by one-tonne pickup trucks, which are usually non-refrigerated. Each pickup truck can carry up to 20 tanks per trip. Other vehicles used for raw milk transport include 6–8 tonne six-wheel trucks, 15 tonne ten-wheel trucks, and 18.5 tonne twelve-wheel trucks.

Raw milk collected at the centres is transferred to processing facilities for pasteurisation, homogenisation, and packing. Processed milk is also used as an input for other dairy products, including UHT milk, yoghurt, cheese, butter, and ice cream.

10-Wheel Truck for Milk Transportation

FIGURE 2

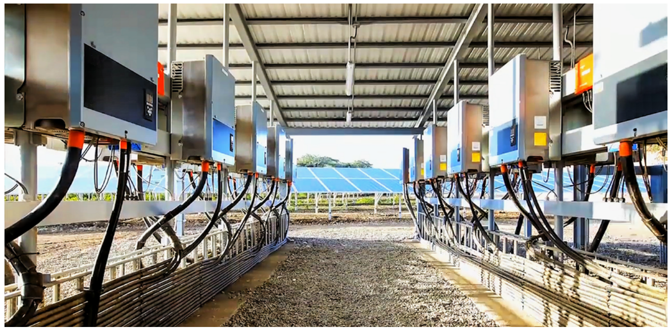
Capacity of Processing Facilities in Thailand



SOURCE: SEforALL analysis 2025

2.2 DAIRY PROCESSING FACILITIES

Processing facilities for commercial dairy products and the School Milk Programme are concentrated in the central and northern regions of the country, where dairy farming activities are also located. There are about 130 milk processing facilities of varying scales nationwide, around 60 percent of which are participating in the School Milk Programme as of 2025. In terms of production capacity, key provinces include Nakhon Ratchasima, Saraburi, Lopburi, Chiang Mai, Ratchaburi, and Prachuap Khiri Khan. The total processing capacity of these facilities is approximately 4.3 million tonnes of pasteurised, UHT, and other dairy products per year. Approximately 95 percent of dairy products produced in Thailand are milk drinks. Further details on major dairy processing facilities are provided in Annex A.



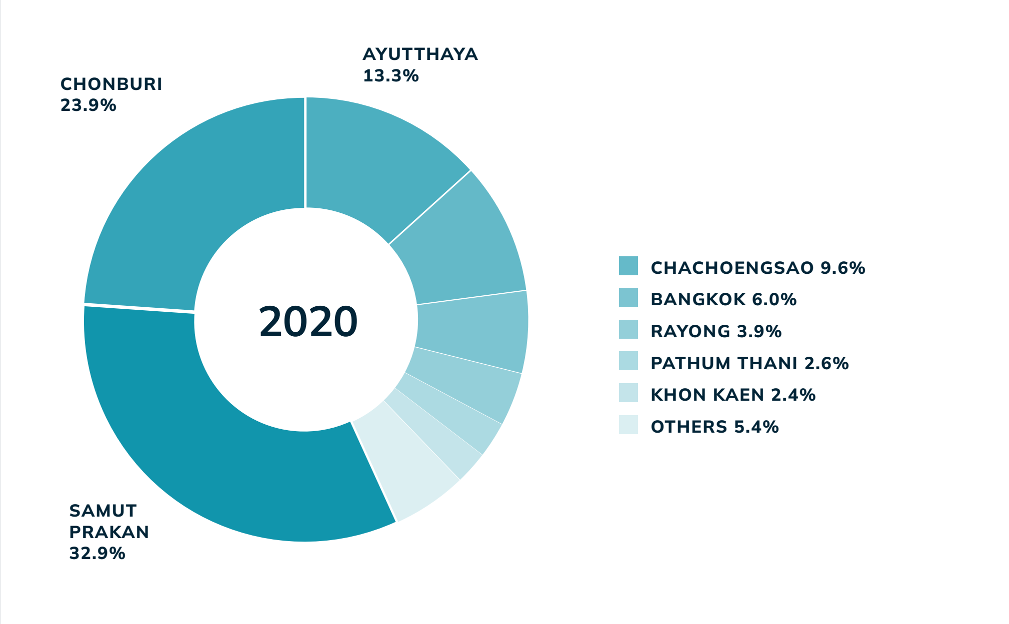
2.3 BULK COLD STORAGE AND WAREHOUSING

Dairy products require specific storage conditions to maintain quality and freshness. Warehouses must therefore provide adequate refrigeration and temperature-controlled areas to store different products at recommended temperatures.

In 2020, there were 157 registered providers of cold storage facilities in Thailand. Approximately 5 percent of these operators were part of larger commercial networks involved in the production and processing of vegetables, fruits, dairy products, meat, and seafood. The remaining 95 percent were small and medium-sized enterprises (SMEs). Most general-purpose cold storage facilities are concentrated in a few provinces in the central region. Approximately 70 percent of the country's total cold storage capacity is located in just three provinces: Samut Prakan (32.9 percent), Chonburi (23.9 percent), and Ayutthaya (13.3 percent). Further details on major warehousing facilities with cold storage are provided in Annex B. However, the available statistics do not provide segregated data on the capacity dedicated specifically to dairy products.

FIGURE 3

Capacity of Bulk Cold Storage/Warehousing in Thailand



SOURCE: WHART

2.4 DISTRIBUTION AND RETAIL

Pasteurised milk under the School Milk Programme is distributed using either refrigerated pickup trucks or non-refrigerated pickup trucks fitted with ice buckets. Approximately 60 percent of pasteurised milk under the programme is transported using refrigerated trucks, while the remaining 40 percent is delivered by non-refrigerated vehicles.UHT milk is predominantly transported using covered pickup trucks.

The refrigerated pickup trucks used for the School Milk Programme are designed to maintain a controlled temperature below 4°C. Standard external dimensions, illustrated in Figure 4, include a height of 1.875 m, a width of 1.8 m, and a length of 2.42 m, giving a total volume of 5.6 m³. Internal dimensions comprise a height of 1.6 m, a width of 1.6 m, and a length of 2.2 m.

For transportation by non-refrigerated pickup truck, pasteurised milk packages are placed between layers of ice in plastic containers, as shown in Figure 5. To maintain temperatures below 8°C for up to nine hours when transporting 100–250 pasteurised milk bags (200 ml each), approximately 16 kilograms of ice is required. Additional ice and layering are necessary to maintain lower temperatures for longer periods or to accommodate larger quantities of milk bags. Figure 6 illustrates standard practices for arranging the quantity and layers of ice when transporting pasteurised milk bags for the School Milk Programme. This method is also recommended for storing pasteurised milk bags at schools.

There are no official statistics on the number of pickup trucks providing distribution services for the School Milk Programme. However, according to the Truck Data Service Center (TDSC) under the Ministry of Transport, 2,280 companies operate approximately 13,000 refrigerated trucks in Thailand, of which about 40 percent (around 5,000 trucks) are pickup and other small refrigerated vehicles.

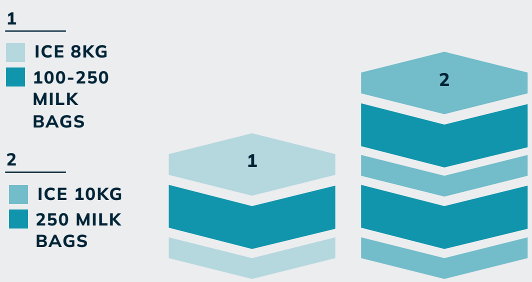
FIGURE 4

Refrigerated One-Tonne Pick-Up Truck for School Milk Programme

FIGURE 5

Typical Plastic Containers for Transportation of Pasteurized Milk Bags

FIGURE 6



Quantity of Ice and Layers required for Transportation of Pasteurized Milk Bags

3 COOLING TECHNOLOGIES FOR DAIRY COLD CHAIN IN THAILAND

Different cooling techniques and cold chain technologies are employed to safeguard the quality of raw milk and maximise the shelf life of dairy products before they reach consumers. UHT milk can be stored at room temperature with a shelf life of 8–10 months, and therefore does not require intensive cooling. By contrast, pasteurised milk— which constitutes the main supply for the School Milk Programme—has a shelf life of only about ten days. Cooling during transportation and storage is therefore a critical element of the programme.

The table on the next page summarises typical cooling requirements and standard cooling technologies used in the Thai dairy industry.

TABLE 1 **Typical Cooling Requirements and Cold Chain Technologies for Dairy Products in Thailand**

SUPPLY CHAIN		COOLING REQUIREMENTS/ TECHNOLOGIES	REMARK
Raw Milk Supply	At the farm	No cooling systems required	Raw milk typically stored in a 50kg milk tank
	At raw milk collection centers	Cooling milk tank to maintain below 4-8°C for transportation to a processing facility	Cooling tank capacity: 5-20 tonnes/tank
Processing	Raw milk storage	Cooling plate 4 to 8°C for storage of raw milk before processing	
	Thermization process	Plate heat exchanger to cool down milk at four °C	
		Cooling tank at 7°C for 12h storage	
	Storage before heat treatment process	Storage at 5°C before pasteurization and UHT	
Bulk Cold Storage	Pasteurized milk	Stored at below 4°C	
	UHT milk	N/A (stored at average room temperatures)	
Transport	Pasteurized milk	Refrigerated trucks at 0 to 4°C from processing facilities to distribution centers Refrigerated trucks at 4 to 8°C and non-refrigerated trucks with ice buckets from distribution centers to consumers	
	UHT milk	N/A (non-refrigerated trucks)	
Retailer/ Household		Commercial and household refrigerators	

SOURCE: Dairy Farming Promotion Organisation of Thailand

3.2 COLD STORAGE IN PROCESSING FACILITIES AND WAREHOUSES

Two main types of cold storage facilities are commonly used in Thailand: built-in cold rooms and container-based cold storage. Both are designed and constructed in accordance with engineering principles and international standards, such as those of the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE), the International Institute of Ammonia Refrigeration (IIAR), and the Thai Refrigeration Association. Cold rooms in Thailand are typically designed to maintain temperatures from 0 to 4°C.

The size of a cold room or storage facility in a dairy factory varies depending on production capacity, product range, and specific storage requirements. Typical facilities range from 2 m wide × 3 m long × 2.5 m high to 20 m wide × 30 m long × 9 m high. Larger dairy factories may operate extensive cold storage areas with multiple temperature-controlled rooms to accommodate different product categories. Chiller capacities in these facilities generally range from 20 to 100 tonnes of refrigeration, and a variety of refrigerants are in use, including R22, R134a, R404a, R507, and ammonia (NH_3). Inventory data on refrigerant use in existing facilities in the Thai dairy sector was not available at the time of preparing this report.

TABLE 2 Typical Logistic Category and Road Type for Refrigerated Trucks

TRUCK APPEARANCE	LOGISTIC CATEGORY	ROAD TYPE
Truck Appearance	Logistic Category	Road Type
4-Wheeler Truck	Distribution in city	City street/lane
6-Wheeler Truck	Distribution between city	Local road/city street
10-Wheeler Truck	Transportation between regions	Highway/local road
Semi-Trailer with 18 and 22 Wheels	Long-haul transportation	Highway/motorway

SOURCE: Preliminary evaluation on specific energy consumption of refrigerated trucks in Thailand's cold chain, 2022

3.3 REFRIGERATED TRUCKS

Thailand does not have a standard national classification system for refrigerated trucks. A preliminary study on the specific energy consumption (SEC) of refrigerated trucks in Thailand, conducted in 2022, classified vehicles according to (i) temperature categories and (ii) vehicle operation and appearance. Based on these criteria, and drawing on data from ASHRAE, the Ministry of Public Health, the Department of Land Transport, and the Ministry of Transport, refrigerated trucks can be grouped by appearance into four categories: 4-wheeler, 6-wheeler, 10-wheeler, and semi-trailers with 18 or 22 wheels. Each of these categories is further classified by operating temperature: (i) above 0°C (chilled trucks); and (ii) below –18°C (frozen trucks).

Refrigerated trucks used to transport dairy products in Thailand are chilled vehicles that operate at controlled temperatures below 4°C. These trucks are designed to preserve product freshness and quality throughout the journey. Various cooling systems are employed to maintain the required temperature inside the cargo compartment and ensure both quality and safety of the transported goods. However, the most common refrigeration systems used in chilled trucks in Thailand include the following:

DIRECT DRIVE (SYSTEM) UNIT 2

This type of refrigerated truck uses the vehicle's engine to power a compressor and is among the most common cooling systems in use. When the truck is in motion and the engine is running, the refrigeration unit is driven directly by the engine's mechanical power. The compressor and other components are connected to the engine's output through a direct drive mechanism, which transfers rotational energy to operate the refrigeration unit and maintain the required temperature inside the cargo compartment. Direct drive systems are generally applied in small refrigeration units, particularly 4-wheel pickup trucks.

SUB-ENGINE SYSTEM OR AUXILIARY POWER UNIT (APU)

In this system, a secondary engine or auxiliary power unit (APU) is installed in refrigerated trucks to operate the refrigeration unit independently of the vehicle's main engine. The APU is typically smaller and more fuel-efficient, designed specifically to supply power to the refrigeration system while the truck is parked or when the main engine is switched off. This enables the desired cargo temperature to be maintained without relying on the main engine, reducing both fuel consumption and emissions.

A common configuration is the **diesel engine-powered APU**. These units typically consist of a compact diesel engine, a compressor, and associated components required for the cooling process. The engine drives the refrigeration compressor, which circulates coolant to maintain compartment temperature. Diesel-powered APUs are generally used in large refrigeration units and can operate both during transit and when parked in locations without access to electrical power.

STANDBY SYSTEM

A standby system, or electric standby capability, allows a refrigeration unit to operate when the truck's engine is switched off or when an external power source is available. In this mode, the refrigeration unit is powered by electricity rather than the vehicle's diesel engine. **Electric standby** is typically used when trucks are stationary at distribution centres or loading docks, where an external power supply can be accessed. The refrigeration unit is connected to the external source, which powers the compressor, fans, and other components. This mode reduces fuel consumption, emissions, and noise pollution, providing environmental and economic benefits when vehicles are parked for extended periods, such as during loading and unloading or overnight.

Typical design specifications of refrigerated trucks in Thailand are provided in Annex D. It should be noted that there is no mandatory energy efficiency standard for refrigerated trucks in Thailand. The Department of Land Transport under the Ministry of Transport, Thailand, has implemented a voluntary standard and certification programme for refrigerated trucks, called "Cold Chain Quality Standard for Truck Operation" or "Q Cold Chain". This Q Cold Chain Programme aims to enhance and improve the effectiveness of Thailand's agri-food transport system to meet the international standard. Q Cold Chain addresses 4 aspects, including:

- 01 Transport operation;
- 02 Cleanliness;
- 03 Refrigerated truck standard and maintenance;
- 04 Human resource development.

Refrigerants used in refrigerated trucks shall be CFC-free refrigerants. However, energy efficiency requirements are not yet considered as part of Q Cold Chain.

FIGURE 7

Common Refrigeration Systems used in Refrigerated Trucks in Thailand

FIGURE 8

Cold Storage Containers of Refrigerated Trucks in Thailand

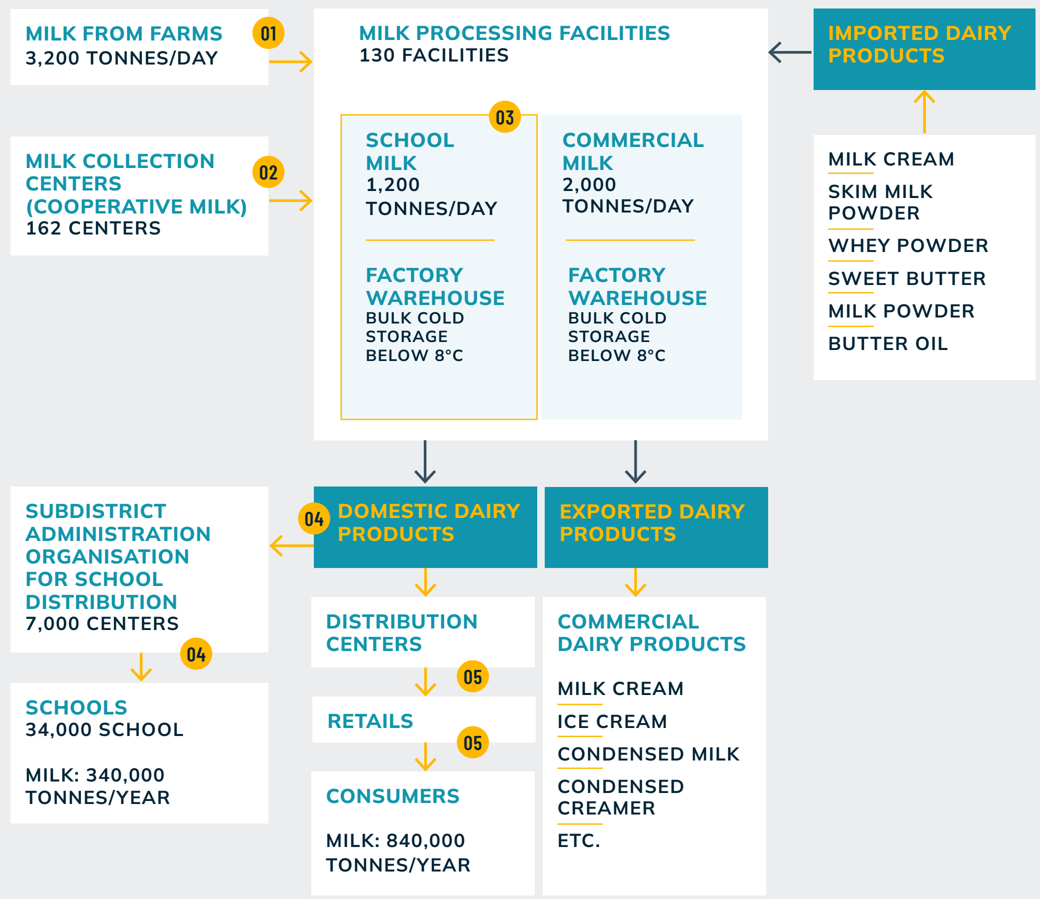
4 ENERGY EFFICIENCY POTENTIAL IN DAIRY COLD CHAIN IN THAILAND

The estimation of annual energy consumption and energy efficiency potential of the Thai dairy cold chain in this report focuses on two main activities: (i) the delivery of raw milk from collection centres to processing plants (approximately 1.2 million tonnes annually); and (ii) the processing, storage, and distribution of pasteurised milk for the School Milk Programme (approximately 330,000 tonnes annually). The key energy-consuming processes and activities in the Thai dairy cold chain are illustrated in Figure 9.

It should be noted that energy consumption by commercial and residential refrigerators is not included in this report, as these have already been addressed under the ongoing energy efficiency standards programme for equipment and appliances.

FIGURE 9

Key Energy Consuming Activities in Thai Dairy Cold Chain



01 Refrigerated transport with controlled temperature below 8°C
Truckload capacity of 10-wheel truck = 15 tonnes

02 No proper cold chain management from farm to milk collection center

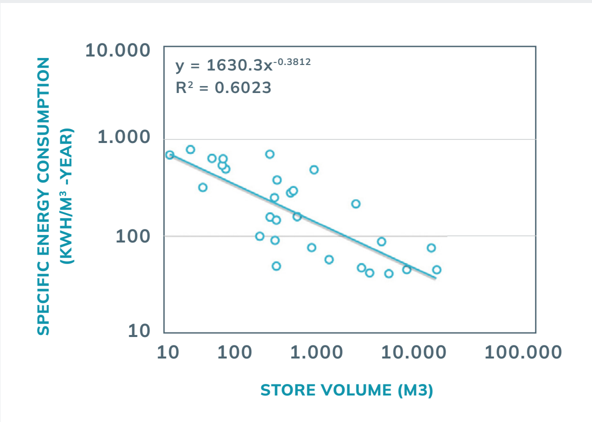
03 Processing and storage of pasteurized milk

04 60% with refrigerated transport by 4-wheel truck
Truckload capacity = 1 tonne
40% with non-refrigerated transport with ice buckets

05 Refrigerated transport with controlled temperature below 8°C
Truckload capacity of 6-wheel truck = 4 tonnes
Truckload capacity of 10-wheel truck = 10 tonnes

FIGURE 10

Relationship between Specific Energy Consumption and Storage Volume



4.1 CHARACTERISTICS OF ENERGY CONSUMPTION BY DAIRY COLD CHAIN IN THAILAND

4.1.1 PASTEURIZED MILK PROCESSING

Energy use in the pasteurised milk industry can be divided into two categories: fuel and electricity. Fuel (fuel oil or gas) is mainly used for heating in the pasteurisation process and for cleaning. Electricity is required for processing operations, compressors, refrigeration and cold storage, as well as other general uses.

The specific energy consumption (SEC) of pasteurised milk processing reported in various studies ranges from 0.7 to 1.1 MJ/kg. An energy audit of the European milk industry in 1985 reported an average SEC of 0.96 MJ/kg, with considerable variation among individual EU member states. A study conducted in 1999 by the Department of Alternative Energy Development and Efficiency (DEDE) under the Ministry of Energy of Thailand reported SEC values of 1.02 MJ/kg for pasteurised milk and 2.32 MJ/kg for UHT milk.

4.1.2 COLD STORAGE

A preliminary study on the specific energy consumption (SEC) of refrigerated warehouses, published in 2022, surveyed 161 cold storage rooms, including 48 chilled rooms (0–10°C) and 113 frozen rooms (≤ –18°C), with storage volumes ranging from 20 to 108,220 m³. The study found an inverse relationship between storage volume and SEC values, with larger storage volumes generally associated with lower SEC.

For chilled cold storage rooms, which are commonly used for dairy products, SEC values ranged from 37 to 212 kWh/m³-year. The study also developed a predictive model for SEC values of chilled cold storage rooms in Thailand as a function of storage volume ($y = 1630.3x^{-0.3812}$), as illustrated in the figure below.

4.1.3 REFRIGERATED TRUCK

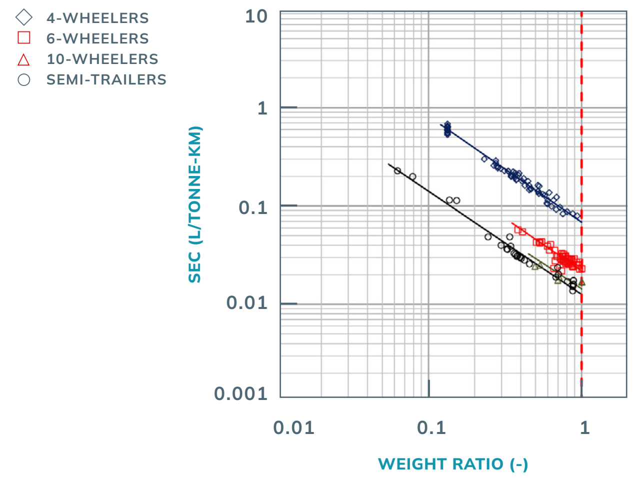
A preliminary evaluation of the specific energy consumption (SEC) of refrigerated trucks, conducted in 2022, suggested that the ratio of goods weight to maximum allowable load weight is the most appropriate parameter for determining SEC. Figure 11 illustrates SEC values for typical refrigerated trucks in Thailand, expressed in litres of fuel consumption (primarily diesel) per tonne of goods weight and round-trip distance in kilometres.

The results show that smaller refrigerated trucks are generally less efficient than larger ones, and that the optimum loading point occurs at a ratio of 1, where the goods weight equals the maximum allowable load weight.

The evaluation also compared the SEC of Thai refrigerated trucks with those in other countries, as shown in Figure 12. Although the international data could not be disaggregated between chilled and frozen trucks, the comparison confirms a consistent trend: smaller vehicles have higher SEC values. Based on these findings, the appropriate choice of refrigerated trucks and optimisation of the goods-to-load weight ratio are critical for improving energy efficiency in Thailand's cold chain logistics.

FIGURE 11

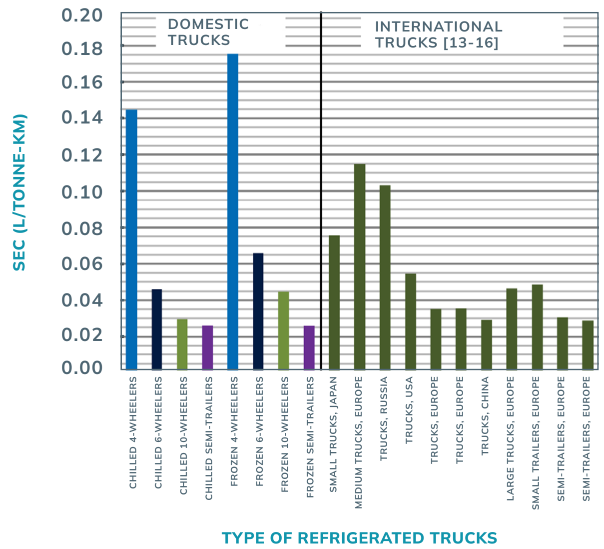
Specific Energy Consumption of Typical Refrigerated Trucks in Thailand



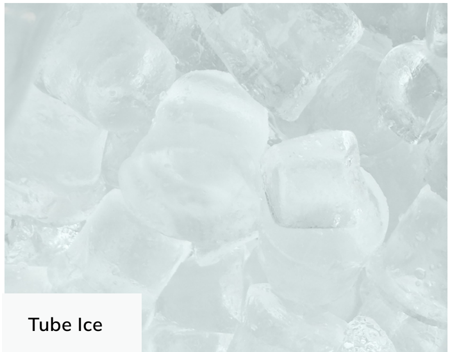
SOURCE: A preliminary study on specific energy consumption (SEC) of refrigerated trucks in Thailand, 2022

FIGURE 12

Comparison Between Thai and International Specific Energy Consumption for Refrigerated Trucks



SOURCE: A preliminary study on specific energy consumption (SEC) of refrigerated trucks in Thailand, 2022



Tube Ice

Block Ice

4.1.4 ENERGY CONSUMPTION IN ICE MAKING IN THAILAND

Electricity is the primary energy source for ice production in Thailand. Two main types of ice are produced: tube ice and block ice (see images). Block ice is typically crushed for use in cold storage applications, including the preservation of pasteurised milk bags and seafood.

An analysis of ice-making factories in Thailand, based on 2015–2018 energy consumption data submitted to the Ministry of Energy by designated factories, found that their specific energy consumption (SEC) ranged from 59 to 133 kWh per tonne of ice. Factories producing either tube ice or block ice had the same average SEC of 94 kWh/tonne, while those producing both types recorded a slightly higher average of around 104 kWh/tonne.

The study also revealed that for factories producing the same type of ice at similar production capacities, SEC values could vary by up to 31 percent. Differences in technology, equipment age, and operating practices were identified as the main causes of this variation. In general, higher production levels were associated with lower SEC values.

4.2 ENERGY CONSUMPTION AND POTENTIAL ENERGY SAVING MEASURES IN DAIRY COLD CHAIN IN THAILAND

Table 3 summarises the estimated annual energy consumption and potential energy-saving measures across key elements of the dairy cold chain in Thailand. These estimates are based on average annual production and consumption of milk drinks, specific energy consumption (SEC) values reported by secondary sources, and the following assumptions and parameters.

Raw Milk Transportation

A total of 162 collection centres nationwide deliver about 3,200 tonnes of raw milk to processing plants each day, equivalent to an average of 20 tonnes per centre. Based on this transportation volume, it is assumed that 6- or 10-wheeler refrigerated trucks are used to transport 1.2 million tonnes of raw cow's milk annually from collection centres to the nearest processing plants. The average round-trip distance from a collection centre to a processing plant in a neighbouring province is estimated at 200 kilometres. Each refrigerated truck operates with a goods-to-load weight ratio of 0.5, resulting in an average specific energy consumption (SEC) of 0.0376 litres of fuel per tonne-kilometre.

Processing of Pasteurized Milk

Annual consumption of school milk in Thailand is estimated at 330,000 tonnes of pasteurised milk produced by local processing plants. According to a study commissioned by the Ministry of Energy, the average specific energy consumption (SEC) of these plants is 1.02 MJ/kg.

Pasteurized Milk Cold Storage

The Thai Food and Drug Administration recommends a shelf life of 10 days for pasteurised milk when stored at temperatures not exceeding 8°C. For this study, it is assumed that each batch of pasteurised milk has an average inventory period of three days before distribution to consumers, and that each tonne of pasteurised milk requires 1.031 cubic metres of cold storage capacity. Based on these assumptions, the total storage requirement for pasteurised milk is estimated at around 3,650 cubic metres to accommodate the annual consumption of 330,000 tonnes. Previous research and market data suggest that the most common size of chilled cold storage in Thailand is 67 cubic metres, with a corresponding specific energy consumption (SEC) of 328 kWh/m^3-year.

School Milk Distribution

Sixty percent of annual pasteurised school milk is delivered by 4-wheel refrigerated trucks operating at a goods-to-load weight ratio of 0.5. Each truck travels an average round-trip distance of 300 kilometres per day. The remaining 40 percent is transported by standard 4-wheel pickup trucks fitted with ice buckets, requiring an estimated 53,000 tonnes of block ice annually for cooling. The distribution shares, daily travel distances, and ice consumption estimates are drawn from previous research studies in Thailand and from guidelines issued by the Thai Food and Drug Administration.

TABLE 3 Estimated Annual Energy Consumption and Potential Energy Saving Measures in Thai Dairy Cold Chain

DAIRY COLD CHAIN ELEMENT	ESTIMATED ANNUAL ENERGY CONSUMPTION	POTENTIAL ENERGY SAVING MEASURES
Raw Milk Transportation (6/10-Wheeler Refrigerated Trucks)	- 8.15 million liters of diesel fuel (292,000,000 MJ)	- Optimization of good weight to load weight ratio - Utilization of e-Trucks
Pasteurized Milk Processing	- 438,600,000 MJ of heat and electrical energy	- 30% energy savings through adoption of best practices in pasteurized milk processing - Installation of onsite renewable energy generation (e.g., rooftop PV) at the processing plants
Pasteurized Milk Cold Storage	- 18.2 MWh - (65,500 MJ)	- Adoption of cooling efficiency technologies - Adoption of onsite renewable energy generation (e.g., rooftop PV) - Low-cost/no-cost measures on reducing cold storage door opening frequency and duration to minimize air infiltration
School Milk Distribution (4-Wheeler Refrigerated Trucks)	- 11.4 million liters of diesel fuel (433,000,000 MJ)	- Optimization of good weight-to-load weight ratio - Utilization of e-Trucks
School Milk Distribution (Non- 4-Wheeler Refrigerated Trucks with Ice Buckets)	- 3,850 MWh for ice making (14,000,000 MJ)	- Adoption of energy efficiency practices in ice making processes (37% energy saving potential) - Switching from ice bucket cold storage to refrigerated truck

The estimated annual energy consumption highlights the importance of energy use across the logistical and processing elements of Thailand's dairy cold chain. A range of energy efficiency measures, together with the installation of onsite renewable energy systems, can help reduce consumption in each element of the chain.

Simple no-cost or low-cost actions—such as reducing the frequency and duration of cold storage door openings to minimise air infiltration, and optimising the goods-to-load weight ratio for refrigerated trucks—can be implemented immediately to improve efficiency.

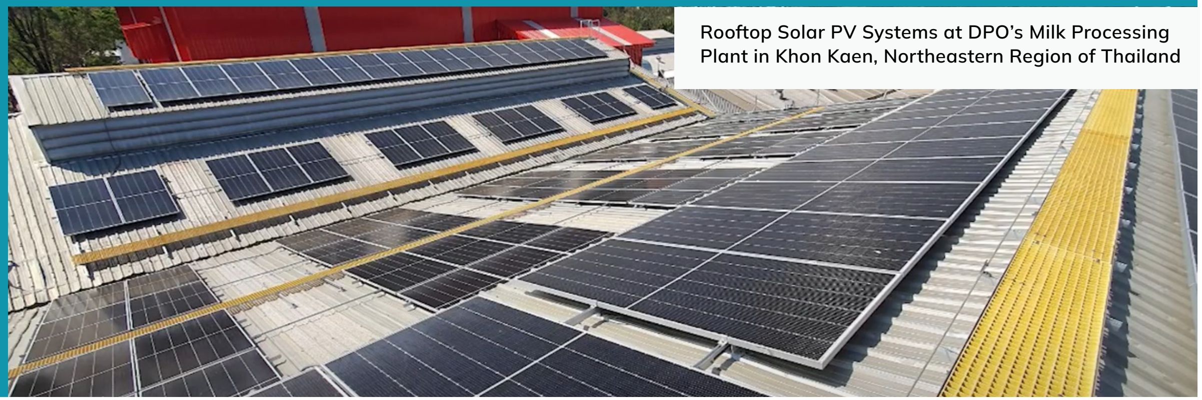
It is worth noting that some milk processing plants in Thailand have already installed onsite renewable energy systems, particularly rooftop and floating solar PV, to help reduce greenhouse gas emissions. However, it remains unclear whether energy efficiency measures are systematically integrated into these climate change mitigation initiatives.

BOX 2

ROOFTOP SOLAR PV AND FLOATING SOLAR PV INSTALLED AT MILK PROCESSING PLANTS IN THAILAND

The Dairy Farming Promotion Organization of Thailand (DPO) has installed multiple solar PV systems in their four milk processing plants located in the Central, Northern, Northeastern, and Southern regions of Thailand. The cumulative installed capacity is 4.85 MWp. The floating solar PV system, shown below, has an installed capacity of 737 kWp, and its annual generating capacity can offset approximately 10% of grid electricity consumption.

Floating Solar PV Systems at DPO's Milk Processing Plant in Pranburi, Southern Region of Thailand



Rooftop Solar PV Systems at DPO's Milk Processing Plant in Khon Kaen, Northeastern Region of Thailand

5 CONCLUSIONS

The choice of cold chain practices and technologies has a direct impact on the performance of Thailand's dairy industry. Studies have reported that milk logistics in the country are costly, and poor logistics contribute to quality losses. The assessment in this report underscores the critical role of logistics across the entire dairy supply chain. It is clear that adopting energy-efficient cold chain practices and technologies, together with onsite renewable energy systems, can reduce both energy consumption and greenhouse gas (GHG) emissions in Thailand's dairy sector.

The study identifies substantial opportunities to improve energy efficiency across Thailand's dairy cold chain, with potential savings in transportation, processing, storage, and ice-making.

For raw milk and school milk transport, optimising the goods-to-load weight ratio and transitioning to electric trucks could significantly reduce diesel consumption. In pasteurised milk processing, best practices could deliver up to 30 percent energy savings, further enhanced by onsite renewable energy such as rooftop solar PV. Cold storage efficiency can also be improved through advanced cooling technologies, renewable energy integration, and no-cost or low-cost measures—for example, reducing the frequency of door openings to minimise air infiltration.

For ice-making used in non-refrigerated school milk distribution, efficiency upgrades could yield savings of around 37 percent, with further benefits from switching to refrigerated trucks. Taken together, these measures provide a clear pathway to strengthen sustainability and energy performance throughout Thailand's dairy cold chain.

The study did not assess energy efficiency opportunities associated with the use of 4-wheel non-refrigerated trucks for transporting raw milk from farms to collection centres. Nor did it examine the technologies and practices used for storing milk within schools, which could offer additional opportunities to improve efficiency and reduce emissions. In some cases, milk is delivered daily, while in others schools are equipped with refrigerators.

Evaluating this potential would require collecting data on current storage methods and equipment used in schools, including the prevalence of refrigeration units or alternative cooling methods, together with delivery schedules and energy consumption patterns to identify inefficiencies. Engagement with stakeholders—such as school administrators, local governments, and dairy suppliers—would be essential to capture practical constraints and identify feasible solutions.

To build on these findings, further data collection and engagement with local stakeholders will be essential. This will support the development of a comprehensive approach to ensure that improvements in cold chain practices and technologies strategically contribute to the sustainable growth of Thailand's dairy industry. In particular, the proposed approach should seek to address the following gaps and challenges identified during the preparation of this report.

- Cold chain–related data is currently dispersed across multiple agencies and organisations, underscoring the need for a strategic approach to consolidation. This could involve strengthening existing databases—for example, by upgrading the online portal managed by the Office of Agricultural Economics under the Ministry of Agriculture and Cooperatives—or establishing a new platform hosted by a private sector body, such as an industry association.
- The role and impact of the cold chain have not been sufficiently recognised at either national or sub-sector level. It is therefore imperative that the cold chain is acknowledged and integrated into relevant policies at both levels.
- Moreover, it is essential to address barriers to efficient and effective cold chain practices through the frameworks and measures developed by government agencies and private sector organisations. At the same time, greater exchange of technologies and know-how across different agri-food sectors should be facilitated.
- Efficient and effective cold chain practices go beyond energy efficiency and climate-friendly technologies. As highlighted in this report, the combined use of electric vehicles and energy-efficient cooling technologies could significantly reduce energy consumption and greenhouse gas emissions from dairy logistics.
- Data on dairy product loss and waste is limited, making it difficult to quantify through desk research alone. As a result, assessing the associated environmental and climate impacts—and determining how cold chain improvements and other management approaches could mitigate them—remains a significant challenge.

Looking ahead, prioritising energy-efficient and sustainable cold chain practices—together with improved data availability and stronger stakeholder collaboration—will be essential to steer Thailand's dairy industry toward a low-carbon future, while also supporting resilience, competitiveness, and the delivery of high-quality dairy products in the years to come.

ANNEX A: MAJOR DAIRY PROCESSING FACILITIES IN THAILAND

PRODUCERS NAME	MANUFACTURER LOCATIONS	RAW MILK COLLECTING CENTER LOCATION	COLLECTING CAPACITY (TONNE/DAY)	CAPACITY (TONNE/YEAR)	NOTE
Dairy Farming Promotion Organisation of Thailand	Muak Lek , Saraburi				
	Chiang Mai		30		
	Prachuap Khiri Khan	(Cha-am, Petchburi)	60		
	Khon Kaen	Nongbuasor in Udonthani	60		
	Sukhothai	Pijit province	60		
Foremost: Friesland Company Thailand	Samrong, Samut Prakarn	Saraburi		100,000	
		Nakhonratchasima			
		Rachaburi			
		Chanthaburi			
		Sakaeo			
Nong Pho, Ratchaburi Cooperative	Rachaburi		270	82,219	
Kamphaengsaen Dairy Co-operative Ltd	Nakhonpathom		70		Provide raw milk to Dutch milk Company
			70		Produce pasteurized milk for School milk
Sisaket Dairy Cooperative Ltd	Sisaket	Sisaket	13		
Sikew Dairy Cooperative Korat	Nakhonratchasima	Nakhonratchasima	48		

PRODUCERS NAME	MANUFACTURER LOCATIONS	RAW MILK COLLECTING CENTER LOCATION	COLLECTING CAPACITY (TONNE/DAY)	CAPACITY (TONNE/YEAR)	NOTE
Nakhonpathom Dairy Cooperative Ltd	Kamphengsene	Kanchanaburi	35		
Ban Beung Dairy Cooperative	Chon Buri		2		
Tiankham Dairy Cooperation Ltd	Saraburi		135		
Pakchong Dairy Cooerpative Ltd	Nakhonratchasima		80		
Country Fresh Company Ltd	Pachong, Nakhonratchasima		74.64		Provide raw milk to Foremost Thailand Ltd
Dutch Mill	Nakhonpathom	18 collecting centers			
Wangnamyen Dairy Cooperative Ltd	Sakeo		150		
Chiangmai Freshmilk company Ltd	Chiang Mai		140		

ANNEX B: MAJOR WAREHOUSES WITH COLD STORAGE FACILITIES IN THAILAND

COMPANY	LOCATION	CAPACITY	AREA	NOTE
JWD Infologistics	Samut Prakan		Area: 16,364 sqm	Food retail and distribution
	Saraburi		Area: 8,000 sqm	
Thai Max Cold Storage Co. Ltd	Samut Prakan	7,300 tonnes	Total area: 6,500 sqm	
		Temperature: +25°c to -20°c	Cold storage Area 3,850 sqm	
	Chachoengsao	12,000 tonnes	Total area: 14,400sqm	
		Temperature: +4°c to -40°c	Cold storage area: 8,500 sqm	
	Samut Prakan	Capacity: 16,000 Tonnes	Total Area: 72,000 sqm	
		Temperature: +25°c to -40°c	Cold storage: 15,000 sqm	
			Dry Storage Area: 1,420 sqm	
Konoike Cool Logistics (Thailand) Co. Ltd	Samut Prakan	10,000 pallets	Total area: 9,858 m2	
		Temperature: -25°c to +15°c	Cold storage: 6,335 m2	
			Loading area: 3,523 m2	
SCG Nichirei Logistics Co. Ltd,	Samut Prakan	22,800 tonnes	Area: 10,800 sqm.	
		Temperature: 0°c to 5°c and -25°c		
		6 cold storages		
Thai Yokorei co Ltd,	Chachoengsao	32,800 Metric tonnes	Area: 23,980 sqm	
		Cold storage: -35°c to -40°c		
		Air-con room: +20°c to +25°c		
	Samut Prakan	19,600 Metric tonnes	Area: 11,624 sqm	
		Cold storage: -18°c to -25°c		
		Air-Con room: +20°c to +25°c		
	Phra Nakhon Si Ayutthaya	42,300 Metric tonnes	Area: 34,000sqm	
		Cold storage: -35°c to -40°c		
		Air-con room +20°c to +25°c		

COMPANY	LOCATION	CAPACITY	AREA	NOTE
Lucky Star Cold Storage,	Samut Prakan	10,000 pallets		
		Cold storage: +25°c to -30°c		
Loxley trading Company Limited	Bankgkok			Loxley trading limited operating as a distributor for Nongpho UHT milk
Hobitat Co., Ltd	Bankgkok			A distributor of Thai-Denmak dairy products
CTI Logistics	Bangkok	3,200 Pallets	5,000 sqm	
		Cold room: -2°c to 5°c, 850 pallets		
		Freezer rooms: -22°c to -25°c, 1,800 pallets		
		Temperature controlled rooms: 18°c to 20°c, 650 pallets		
		Normal temperature Rooms: 200 pallets		
Pacific cold storage (JWD group)	Samut Sakhon			
Piti center cold storage Co., LTD.	Ayuttaya	10,000 tonnes Cold storage: -18°c to -35°c		
	Samut Sakhon			
	Samut Prakan			
Chainavee Coldstorage Co., Ltd.	Samut Sakhon	10,000 tonnes		
Nim See Seng Cold storage	Chiang Mai	Cold storage: +2°c to -20°c		
Passapop 999 Co., Ltd	Pathum	Cold storage: 20°c to -40°c		
Eagles Air & Sea Co., Ltd.	Ladkrabang	500 pallets	45,000 sqm	
			Cold storage Area: 17,000 square feet.	

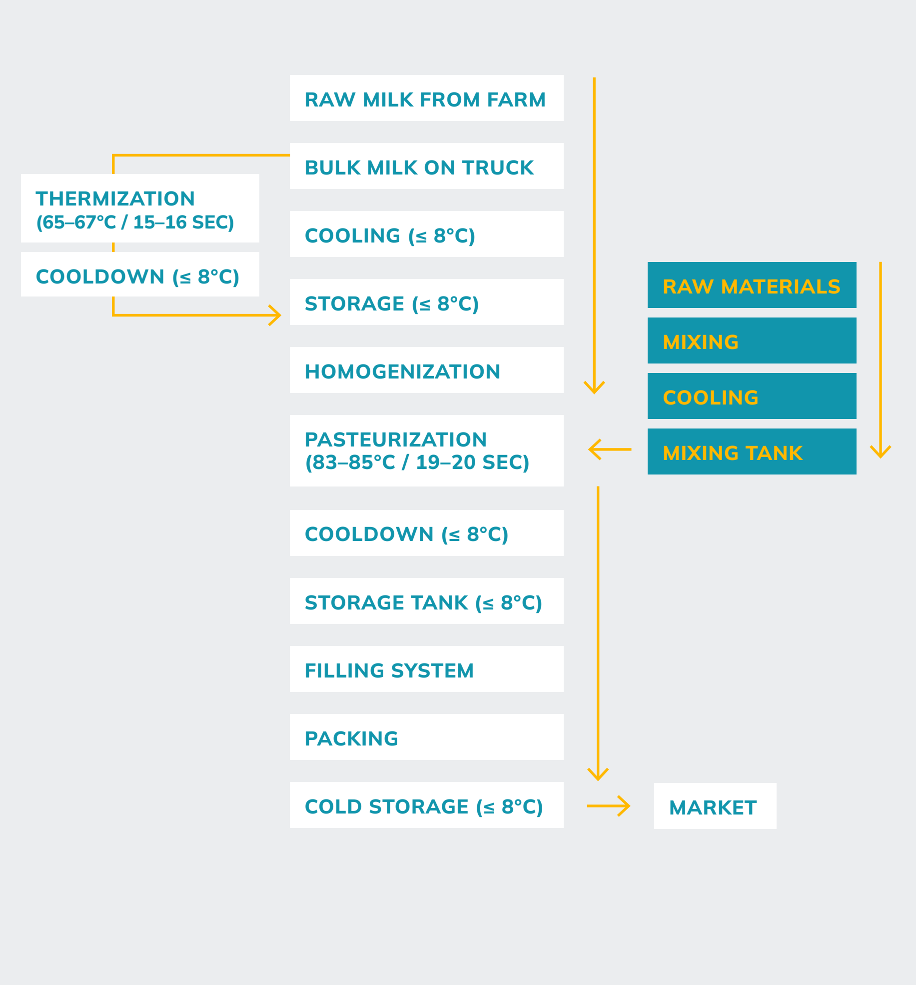
COMPANY	LOCATION	CAPACITY	AREA	NOTE
	Airport Free Zone: Suvarnabhumi Air Cargo	70,600 square feet	1,000 pallets	
	Chaokhuntaharn	24,800 square feet	Temperature controlled: 1,400 pallets	
	Samut Prakan		Customers: Toyota, Sanyo, Ramburi, Index living mall, Shell, Kraft foods	
Mon Group	Laem Chabang	7,500 TEU	80,000 sqm	Container Depot
	Lad Krabang	Cold storage: +15°c to -25°c	168,000 sqm	Logistic service
CTD cold storage	Ayuttaya	Cold storage: +25°c to -25°c	10,000 sqm and 20,000 sqm	Distributing service
	Samut Sakhon		6,000 sqm	
	Bangkok		4,500 sqm	

ANNEX C: PASTEURIZATION AND UHT PROCESS

Processing of raw milk through pasteurization and UHT process involves multiple steps, including the following: 1) Raw milk Reception, 2) Thermization process, 3) Homogenization, 4) Heat treatment process, 5) Filling process, 6) Storage, 7) Transportation. More details on pasteurization and UHT process are illustrated in the flowcharts in Figure 10 and Figure 11 below.

FIGURE 13

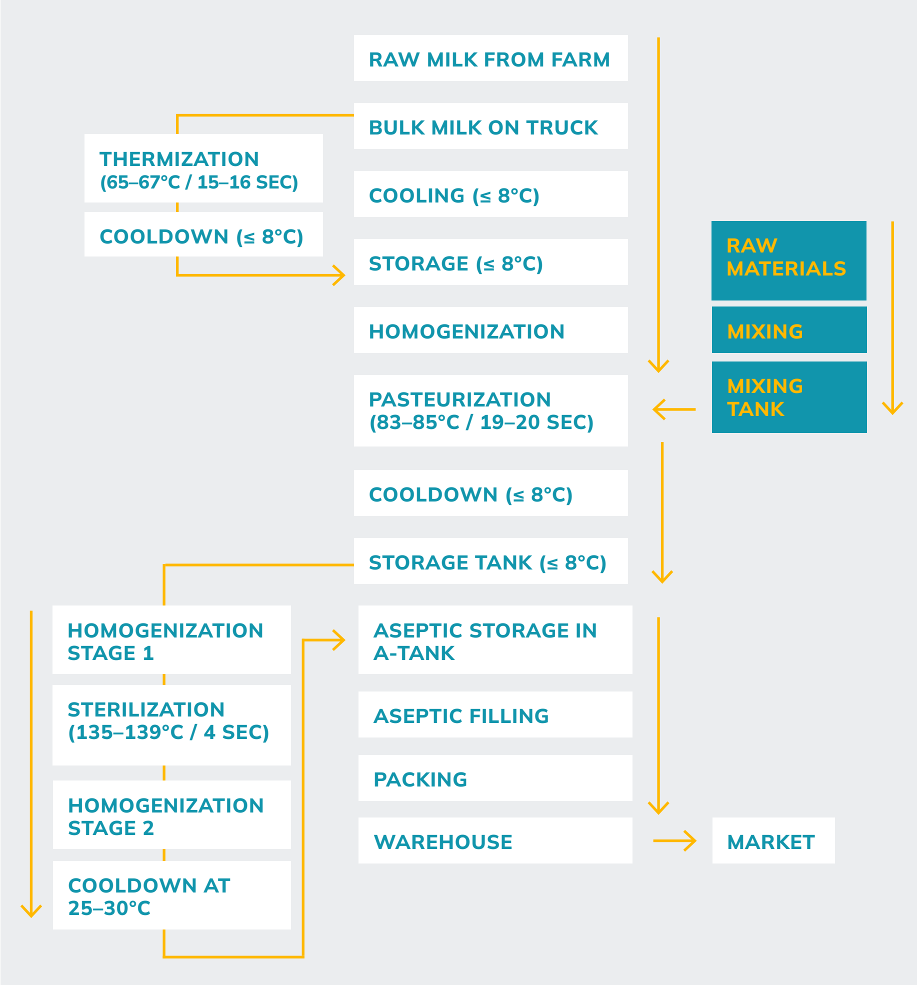
Pasteurization Process



SOURCE: Adapted from the Dairy Farming Promotion Organization (DPO) website: http://www2.dpo.go.th/สาระน่ารู้-2/กระบวนการผลิต/การผลิตแบบพาสเจอร์ไรส์/

FIGURE 14

Ultra-High Temperature Process



SOURCE: Adapted from the Dairy Farming Promotion Organization (DPO) website: http://www2.dpo.go.th/สาระน่ารู้-2/กระบวนการผลิต/การผลิตแบบ-ยู-เอช-ที/

ANNEX D: TYPICAL DESIGN SPECIFICATIONS OF REFRIGERATED TRUCKS IN THAILAND

Refrigerated trucks in Thailand offer a range of controlled temperature truck from 0-5 degree Celsius to -20 degree Celsius. Typical designs of different type and size of refrigerated trucks are given below[36].

4-wheel refrigerated truck

- Size Exterior: Length: 2.4m, Wide: 1.7m, Height: 1.78m,
- Interior container: Length: 2.2m, Wide: 1.63m, Height: 1,42m, Volume: 6.3m3
- Truckload capacity: 1 tonne or 1 pallet
- Refrigeration system capabilities: Direct drive systems: 0 degree Celsius
- Condensing Unit: 12 V
- Freezer Unit: 12 V
- Recommended Compressor: 120-150 cc or Equivalent
- Condenser: Aluminium Fins + Aluminium Tube
- Coil: Aluminium Fins + Aluminium Tube
- Defrost: Manual (Automatic Hot Gas Defrost)
- Cooling Capacity: Ambient Temperature: 35°c
- On Air return: 0°c
- Direct Drive: 4,400 Watts; BTU: 15,100 btu/hr;
- Electric Stand by 50hz: 3,098 Watts; BTU: 10,570) btu/hr;
- Refrigerant: R-134a

6-wheel refrigerated truck

- Size Exterior: Length: 6.20m, Wide:2.05m, Height: 2.08m,
- Inner Container: Length: 5.22m; Wide: 2.37; Height: 2.36m; Volume: 30m3
- Truckload capacity: 4-5 tonnes or 12 pallets
- Refrigeration system capabilities: Direct drive systems: 0°c
- Refrigeration system capabilities: Standby systems: 0°c
- Condensing Unit: 24 V
- Freezer Unit: 24 V
- Recommended Compressor: 150 cc or Equivalent
- Condenser: Aluminium Fins + Aluminium Tube
- Coil: Aluminium Fins + Aluminium Tube
- Defrost: Manual (Automatic Hot Gas Defrost)
- Cooling Capacity: Ambient Temperature: 35c
- On Air return: 0°c
- Direct Drive: 10,000 Watts; BTU: 34,400 btu/hr;
- Electric Stand by 50hz: 7,057 Watts; BTU: 24,080) btu/hr;
- Refrigerant: R-134a

10-wheel refrigerated truck

- Size Exterior: Length: 6.20m, Wide: 2.25m, Height: 2.35m,
- Inner Container: Length: 7.55m; Wide: 2.20m; Height: 2.25m; Volume: 37.5m3
- Truckload capacity: 10-12 tonnes or 12 pallet
- Refrigeration system capabilities: Direct drive systems: 0°c
- Refrigeration system capabilities: Standby systems: 0°c
- Refrigeration system capabilities: Sub-engine systems: -25°c
- Direct drive with standby Unit 10-wheel truck (large-scale)
- Condensing Unit: 24 V
- Freezer Unit: 24 V
- Recommended Compressor: 300cc or Equivalent (GTDE-15: 200cc)
- Condenser: Aluminium Fins + Aluminium Tube
- Coil: Aluminium Fins + Aluminium Tube
- Defrost: Manual (Automatic Hot Gas Defrost)
- Cooling Capacity: Ambient Temperature: 35°c
- On Air return: 0°c
- Direct Drive: 15,000 Watts; BTU: 51,300 btu/hr; (GTDE-15: 14,500 Watts, 49,400btu/hr)
- Electric Stand by 50hz: 10,524 (10134) Watts; BTU: 35,910 (34,580) btu/hr;
- Refrigerant: R-134a

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