STUDY ON

REFRIGERATION USE AND COOLING OPERATIONS IN INDIA'S CONVENIENCE STORES

OZONE CELL

MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE
GOVERNMENT OF INDIA

STUDY ON
REFRIGERATION USE AND COOLING OPERATIONS IN INDIA'S CONVENIENCE STORES

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OZONE CELL
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सत्यमेव जयते

MINISTER
ENVIRONMENT, FOREST AND CLIMATE CHANGE
GOVERNMENT OF INDIA

भूपेन्द्र यादव
BHUPENDER YADAV

MESSAGE

As India's economy continues its dynamic growth, our retail sector is undergoing a remarkable transformation. Convenience stores have emerged as a cornerstone of this evolution, ensuring access to essential goods for millions. At the heart of this sector lies the critical function of refrigeration, which is indispensable for food safety, quality, and building a resilient national cold chain.

The Study on "**Refrigeration Use and Cooling Operations in India's Convenience Stores**," provides a comprehensive analysis of a sector that is vital to our daily lives yet carries a significant energy and environmental footprint. It offers insights into the concentration of commercial refrigeration equipment in these stores and identifies actionable pathways for reducing energy intensity. Furthermore, the report rightly emphasizes that capacity building and the adoption of good servicing practices among refrigeration technicians are crucial to achieving long-term sustainability on the ground. Promoting sustainable and energy-efficient refrigeration is not just a regulatory goal, but a strategic imperative that supports our national commitments under the Montreal Protocol and the Kigali Amendment.

By embracing climate-friendly and energy-efficient technologies, we can foster green growth, strengthen our domestic capabilities in manufacturing, and advance the principles of Mission LiFE (Lifestyle for Environment). This report serves as a useful document for policymakers, industry leaders, and all stakeholders to collaboratively build a sustainable and prosperous future.

(Bhupender Yadav)

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भारत सरकार
MINISTER OF STATE
ENVIRONMENT, FOREST AND CLIMATE CHANGE
EXTERNAL AFFAIRS
GOVERNMENT OF INDIA

MESSAGE

Refrigeration is the silent engine of the modern convenience store, playing an essential role in delivering safe, high-quality products to consumers. As our nation's demand for cooling grows, ensuring this service is delivered sustainably is paramount. This study provides a crucial evidence base for understanding the challenges and opportunities in this rapidly expanding sector.

The findings of this comprehensive study reinforce the strategic objectives of the India Cooling Action Plan (ICAP), which advocates for a deeply integrated and holistic approach to sustainable cooling. Facilitating a nationwide transition toward highly energy-efficient equipment and low-Global Warming Potential (GWP) alternatives within our expanding convenience retail sector is vital to accelerating our sustainable development. This transition is critical to optimizing cooling demand, driving down peak power consumption, and accelerating our phasedown of Hydrofluorocarbons (HFCs) in alignment with India's international environmental commitments.

This study on **"Refrigeration Use and Cooling Operations in India's Convenience Stores"** outlines the way forward for deploying energy-efficient refrigeration technologies, strengthening the nation's retail cold chain, and empowering the MSMEs, small business owners, and skilled servicing technicians who form the backbone of this vital economic sector.

I commend the work of the team associated in preparing this report.

(Kirti Vardhan Singh)

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SECRETARY
GOVERNMENT OF INDIA
MINISTRY OF ENVIRONMENT, FOREST AND CLIMATE CHANGE

MESSAGE

India's convenience-store sector has witnessed rapid growth, supported by increasing urbanisation, changing consumer preferences, and the expansion of organised retail and quick-commerce platforms. The growing number of convenience stores has increased the demand for commercial refrigeration systems, which serve as the final link between the refrigerated supply chain and consumers. As the sector continues to expand, the adoption of low-global warming potential technologies, energy-efficient equipment and appropriate operating practices can support efficient store operations and strengthen the retail cold chain.

The study on "Refrigeration Use and Cooling Operations in India's Convenience Stores" provides insights into refrigeration practices across convenience stores and their role in the retail cold chain. Crucially, the study demonstrates that integrating energy-efficient equipment with standardized, best-in-class servicing practices presents a massive, untapped opportunity for demand-side energy conservation and direct greenhouse gas emissions reduction. It also offers useful information to support stakeholders in improving refrigeration efficiency, strengthening operational practices and promoting the adoption of non-ODS and low-GWP technologies in the sector. The data and recommendations compiled in this report will serve as an essential reference for industry stakeholders to build the institutional capacity required to transition this vital sector towards sustainable cooling.

I complement the team associated with the publication of this report.

(Tanmay Kumar)

Place: New Delhi
Dated: September 7, 2026

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ABBREVIATIONS

Abbreviation	Full Form
AI	Artificial Intelligence
BEE	Bureau of Energy Efficiency
BIS	Bureau of Indian Standards
CAGR	Compound Annual Growth Rate
COP	Coefficient of Performance
EC	Electronically Commutated
EMS	Energy Management System
FSSAI	Food Safety and Standards Authority of India
GWP	Global Warming Potential
HACCP	Hazard Analysis and Critical Control Points
HCFC	Hydro chlorofluorocarbon
HFC	Hydrofluorocarbon
HPMP	HCFC Phase out Management Plan
HVAC	Heating, Ventilation and Air Conditioning
ICAP	India Cooling Action Plan
IEC	International Electrotechnical Commission
IoT	Internet of Things
IS	Indian Standard
ISO	International Organization for Standardization
LED	Light Emitting Diode
NIT	National Institute of Technology
ODP	Ozone Depletion Potential
ODS	Ozone Depleting Substances
PCM	Phase Change Material
RAC	Refrigeration and Air Conditioning
TRL	Technology Readiness Level
UNEP	United Nations Environment Programme

EXECUTIVE SUMMARY

India's convenience store sector is expanding with organised retail, quick commerce and increasing demand for chilled and frozen products. Refrigeration is essential for food safety and product quality but is also a major source of electricity consumption and refrigerant related emissions. This study assesses refrigeration practices and transition opportunities using literature review, field observations and consultations with approximately 500 stakeholders across selected Tier I and Tier II cities. It examines beverage coolers, reach in refrigerators, chest freezers, vertical freezers, open display cabinets and walk in cold rooms.

Refrigeration accounts for approximately 45% - 65% of electricity consumption in the stores assessed. The overall saving potential is estimated at 15% - 30% of refrigeration energy, equivalent to around 7% - 20% of total store electricity use. Beverage coolers had the highest deployment at approximately 35%, followed by reach in refrigerators at 25%. Walk in cold rooms had the lowest deployment at about 3% but consumed approximately 100 kWh per day per installation. Closed refrigerated cabinets can reduce energy use by approximately 40% - 45% compared with open configurations. LED cabinet lighting can reduce lighting energy by 40% - 80%, while EC condenser fans can reduce fan power by 15% - 30%. Preventive maintenance, correct refrigerant charging, temperature optimisation, defrost control, energy monitoring and appropriate temperature zoning can provide further savings. The installed equipment base includes R22, R134a, R404A and R507A, alongside use of R290 and R600a. R290 and R600a provide the most immediate low GWP options for factory designed standalone equipment. Efficient R290 equipment can improve energy performance by approximately 10% - 20% compared with the conventional baseline considered. Larger applications may consider R290 water loop, CO_2 and other low GWP systems after evaluating climatic performance, safety and technical support.

The transition does not require immediate replacement of all existing equipment. Efficient and reliable systems can remain in service with proper maintenance and leakage control. Inefficient, leakage prone or end of life equipment can be prioritised for replacement. Direct conversion to incompatible or flammable refrigerants is not recommended because of safety and reliability risks. Only approximately 36% of assessed technicians reported relevant training, while refrigerant recovery was practised by about 25% of surveyed commercial technicians. Practical training, appropriate tools, spare parts and refrigerant recovery networks therefore require strengthening, particularly in Tier II markets.

The recommended pathway is gradual and lifecycle oriented. It combines improved operation of existing equipment, efficient low GWP technologies during normal replacement, technician training, energy monitoring and refrigerant recovery. Coordinated implementation can reduce electricity consumption, operating costs and refrigerant emissions while maintaining reliable cooling, food safety and product quality across India's growing convenience retail sector.

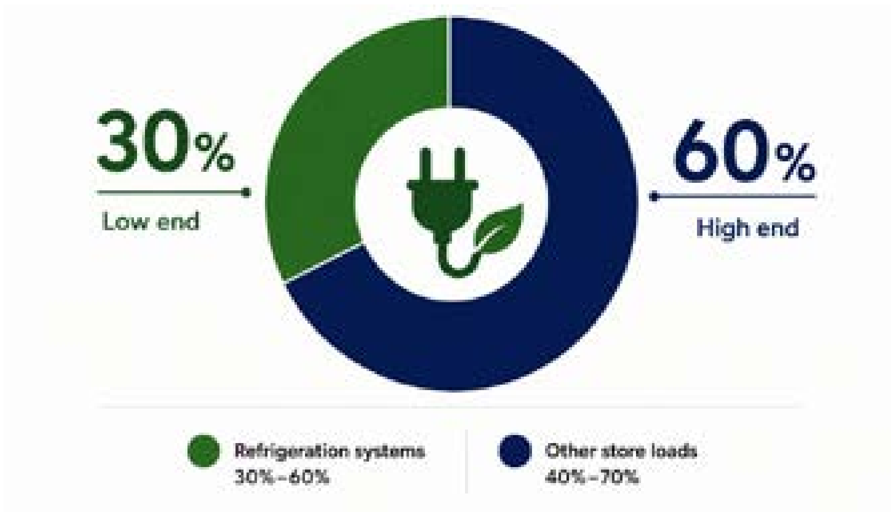
CHAPTER 1

INTRODUCTION

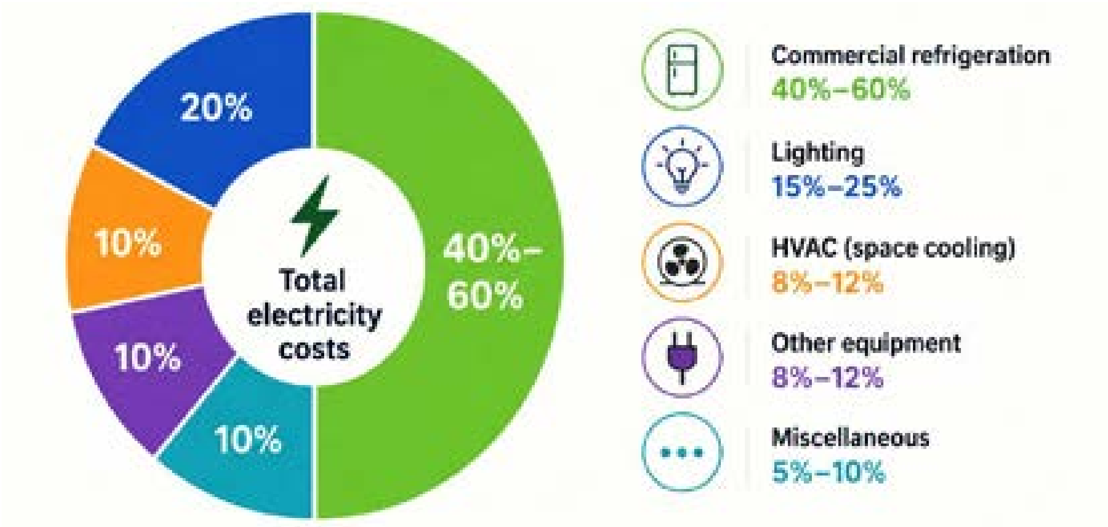
Chapter 1: Introduction

Convenience stores are an important part of the retail food sector and serve as a key link between the cold chain and consumers. They provide access to a range of chilled, frozen and other temperature sensitive food and beverage products (Figure 1.1). As the convenience store sector expands across India, the need for reliable and efficient cooling is also expected to grow. Refrigeration is central to maintaining the quality and safety of these products until they reach consumers. Convenience stores use a range of refrigeration equipment, including beverage coolers, refrigerators, freezers, display cabinets and cold rooms. These systems maintain the required product temperatures and help reduce spoilage, preserve shelf life and support food safety. As the final point of the cold chain, the performance of refrigeration systems in convenience stores is therefore important for maintaining the integrity of temperature sensitive products. Refrigeration accounts for about 30%– 60% of total energy use in food retail stores (Figure 1.2), alongside lighting, space cooling and other equipment [1]. The share varies by store type, equipment and operating conditions. Improving refrigeration efficiency can reduce electricity use and operating costs while maintaining the temperature and quality of the products in the cold chain. Proper equipment selection, installation, operation and maintenance are therefore important for both energy performance and the reliable operation of the cold chain.

Figure 1.1: Convenience store food storage zones and indicative temperatures for maintaining freshness and safety.



(a) Refrigeration share of energy use in convenience stores



(b) Typical electricity consumption breakdown highlighting refrigeration use in convenience stores

Figure 1.2: Estimated share of refrigeration in food retail energy use [1].

1.1 India’s Montreal Protocol Progress and Sustainable Cooling Transition

India has been a Party to the Montreal Protocol since 1992 and has taken significant steps to phase out ozone depleting substances (ODS). The country has successfully phased out several controlled substances and is currently implementing Stage III of the HCFC Phase out Management Plan (HPMP). A major milestone was reached on 1 January 2025, when the use of HCFCs in the manufacturing of all new equipment, including refrigeration and air conditioning (RAC) equipment, was prohibited in India under the Ozone Depleting Substances (Regulation and Control) Amendment Rules, 2014. HPMP Stage III supports the transition away from HCFCs through technology conversion, capacity building, technician training and stakeholder awareness. Under HPMP Stage III, the present study has been commissioned to the National Institute of Technology (NIT), Rourkela to assess refrigeration use and cooling operations in India’s convenience stores.

The prohibition on HCFC use in the manufacture of new equipment from 1 January 2025 represents an important step in the transition of the RAC sector. However, HCFCs may still be required for servicing the existing installed equipment during the transition period. Under the Montreal Protocol schedule applicable to India, HCFC production and consumption are subject to a 67.5% reduction from the baseline from 1 January 2025, followed by complete phase out in 2030, with a limited servicing allowance thereafter for existing RAC equipment. The transition away from HCFCs has increased the use of alternative refrigerants. However, some alternatives, particularly certain hydrofluorocarbons (HFCs), have high global warming potential (GWP). The next stage of refrigerant transition therefore needs to address both ozone protection and climate impact. India ratified the Kigali Amendment to the Montreal Protocol in 2021, under which the country will gradually reduce the production and consumption of HFCs. India’s HFC phase down will begin with a freeze in 2028, followed by progressive reductions of 10% by 2032, 20% by 2037, 30% by 2042 and 85% by 2047, relative to the agreed baseline [2,3]. The baseline is based on average HFC production and consumption during 2024 to 2026, together with 65% of the HCFC baseline.

The Kigali Amendment therefore represents the next stage of refrigerant transition for the refrigeration sector, encouraging a shift towards lower GWP alternatives. Since refrigeration equipment can remain in service for many years, equipment and refrigerant choices made today can influence future electricity consumption and refrigerant demand. Energy efficient, low GWP equipment may therefore be considered for new installations and replacement of existing systems, while taking into account safety, servicing capability, climatic suitability and lifecycle costs. This transition is also consistent with the India Cooling Action Plan (ICAP), launched in 2019, which provides a national framework for addressing India's growing cooling demand through improved energy efficiency, reduced refrigerant demand, sustainable cooling technologies and strengthened technician capacity. In this context, the present study assesses existing refrigeration practices, refrigerant use and cooling requirements in India's convenience store sector and provides technical findings and recommendations for consideration by relevant stakeholders.

1.2 Role of Convenience Stores in the Cold Chain

Convenience stores form the final link between refrigerated supply chains and consumers. Their refrigeration systems must maintain the required product temperatures, often for long operating hours and under demanding climatic conditions. Reliable refrigeration helps maintain food safety, reduce spoilage, extend product shelf life and support the sale of chilled and frozen products. It also strengthens the final stage of the cold chain by ensuring that products remain safe and suitable for consumers.

1.3 Study Objective

The study aims to assess current cooling practices and refrigerant use in India's small format convenience stores and identify practical opportunities for transitioning to energy efficient, non ODS and low GWP refrigeration technologies. It aligns with the broader priorities of the India Cooling Action Plan. Figure 1.3 highlights key targets for reducing cooling demand, energy consumption and refrigerant demand, while strengthening the training and certification of servicing technicians **[2–4].** The assessment considers refrigerant choice together with equipment efficiency, safety, climatic suitability, market availability, servicing capacity and operating costs.

Figure 1.3: Selected national priorities for sustainable cooling [4].

1.4 Scope of Work

The study combines desk research, field visits and stakeholder consultations to examine refrigeration use in convenience stores across selected Tier I and Tier II cities. It focuses on six commonly used systems such as beverage coolers, reach in refrigerators, chest freezers, vertical freezers, open display cabinets and walk in cold rooms. The assessment covers their operation, energy use, refrigerants, safety, market availability and potential transition to energy efficient, non ODS and low GWP alternatives. The present work examines,

- Store operations, infrastructure and cooling requirements
- Refrigeration equipment and refrigerants currently in use
- Energy consumption and efficiency monitoring
- Relevant safety and energy efficiency requirements
- Availability of manufacturers, suppliers and technicians
- International safety, operation and maintenance practices
- Low GWP and non ODS transition opportunities
- Stakeholder consultation and awareness

CHAPTER 2

STUDY APPROACH AND METHODOLOGY

Chapter 2: Study Approach and Methodology

2.1 Overall Research Framework

The study draws on published literature, visits to selected convenience stores and consultations with stakeholders involved in refrigeration. The desk review establishes the market, policy and technical context and helps determine the information required from the fieldwork. The assessment begins with a review of population, urbanisation and socio economic information for the selected cities. Retail density information is used to develop an indicative estimate of the number of stores. Stores are then grouped by retail format, and relevant market penetration and city specific factors are applied. Refrigeration infrastructure is examined in terms of installed equipment, refrigerant use, cooling capacity and energy consumption. The resulting information is checked against available directories, industry reports, stakeholder inputs and data from comparable cities. The overall framework is presented in Figure 2.1 and follows the scope established for the study on refrigeration use and cooling operations in India's convenience stores.

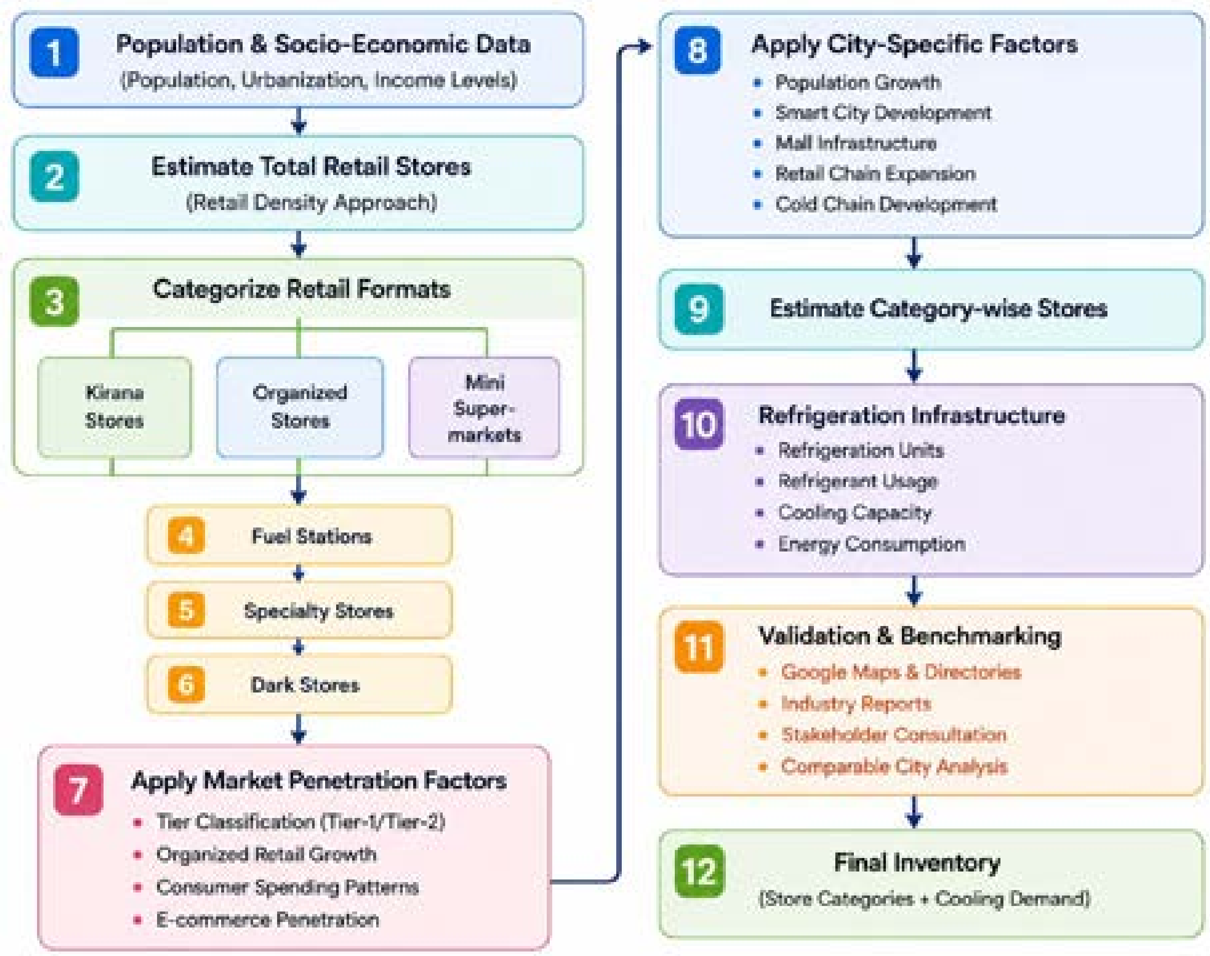


Figure 2.1: Framework for estimating and assessing convenience stores and refrigeration systems.

The work is organised into five broad stages:

- Desk research and review of available evidence
- Selection of cities and convenience stores
- Store visits and equipment level data collection
- Stakeholder consultations and workshops
- Validation, analysis and interpretation of the findings

2.2 Desk Research Methodology

The desk review covers government publications, market reports, technical literature, industry information and relevant standards. It establishes the broader retail context and identifies the questions requiring examination during store visits and stakeholder consultations. Available estimates indicate that India's retail market could increase from approximately USD 750 billion in 2015 to USD 2 trillion by 2032 (i.e., 34% growth in organized retail), as shown in Figure 2.2 [5]. This growth is likely to increase the number of organised and small format retail outlets and, consequently, the demand for refrigeration equipment.

Figure 2.2: Projected growth of India's retail market from 2015 to 2032 [5].

Food and grocery products account for a substantial part of retail activity in India. Figure 2.3 provides an international comparison and places India among the world's five largest food and grocery retail markets [5–7]. These values indicate the broad scale of the market.

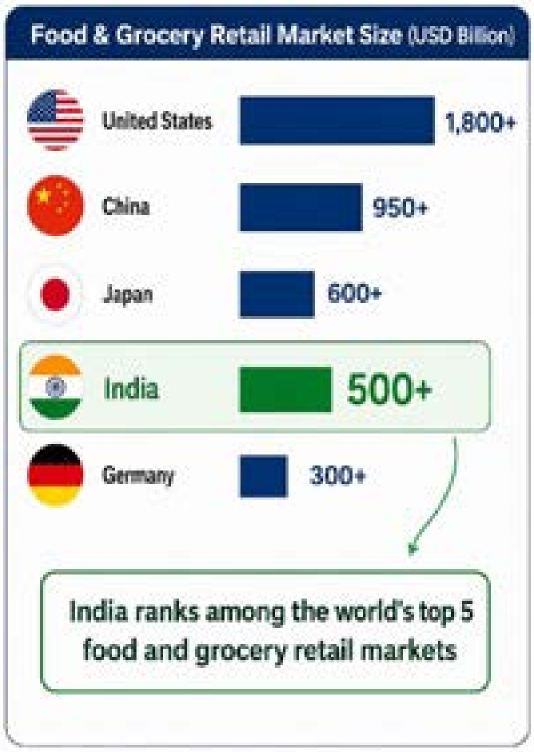


Figure 2.3: Food and grocery retail market size in selected countries [5–7].

The review also considers changes in the products sold through convenience stores. Figure 2.4 presents reported annual growth rates for chilled beverages, dairy products, frozen foods and ready to eat foods [8–11]. Although the rates differ by category, each group depends on reliable temperature control during storage and sale. Growth in these categories will affect the number, type, capacity and operating pattern of refrigeration systems required at the store level.

Figure 2.4: Reported growth of selected refrigeration dependent product categories in India [8–11].

The wider desk review examines refrigeration equipment commonly used in small format stores, refrigerants available in India, energy performance, safety requirements, servicing practices and low GWP alternatives. It also covers the Montreal Protocol, the Kigali Amendment, India's HCFC Phase out Management Plan, the India Cooling Action Plan and relevant guidance issued by BIS and BEE. Preference is given to information published by government agencies, international organisations, recognised research institutions, industry associations and equipment manufacturers. The findings are used to refine the store questionnaire, equipment checklist and stakeholder consultation instruments.

2.3 Field Survey and Store Visit Methodology

Store visits are used to document refrigeration practices under actual operating conditions. Information is obtained through discussions with store owners, managers or operating staff and through direct observation of the installed equipment. The visits document the characteristics of each store, the products requiring refrigeration and the type and condition of the installed equipment. Information on refrigerants, temperature settings, maintenance arrangements, electricity use and operating practices is also collected where available. The detailed instruments used for this purpose are described in Section 2.7.

Equipment nameplates, electricity bills and maintenance records are reviewed when stores make them available. Where possible, the survey records equipment power ratings, operating hours and any separate energy monitoring information maintained by the store. These data are used to describe refrigeration energy use and operating patterns. Estimated values are clearly distinguished from measured or billed electricity consumption. Photographs are taken only with permission and are used to document equipment condition, installation arrangements and operating practices. The visits are intended to identify common practices and operational difficulties rather than serve as regulatory inspections or formal compliance audits.

2.4 Selection of Tier I and Tier II Cities

The study covers selected Tier I and Tier II cities to reflect differences in climate, retail development, infrastructure, equipment availability and access to refrigeration services. Including both city categories provides a broader view of the conditions under which convenience store refrigeration systems operate.

City selection considers:

- Geographical representation
- Type of climatic condition
- Presence of convenience store formats
- Availability of refrigeration equipment and servicing networks
- Presence of manufacturers, suppliers and relevant institutions
- Accessibility and feasibility of conducting fieldwork

Tier I cities generally have more developed retail markets, organised supply chains and wider access to refrigeration technologies and technical services. Tier II cities provide insight into emerging markets where the range of equipment and servicing options may be more limited. Figure 2.5 presents the geographical distribution of the cities selected for the study. Only cities in which store surveys, stakeholder consultations or other study activities were completed are shown in this figure.

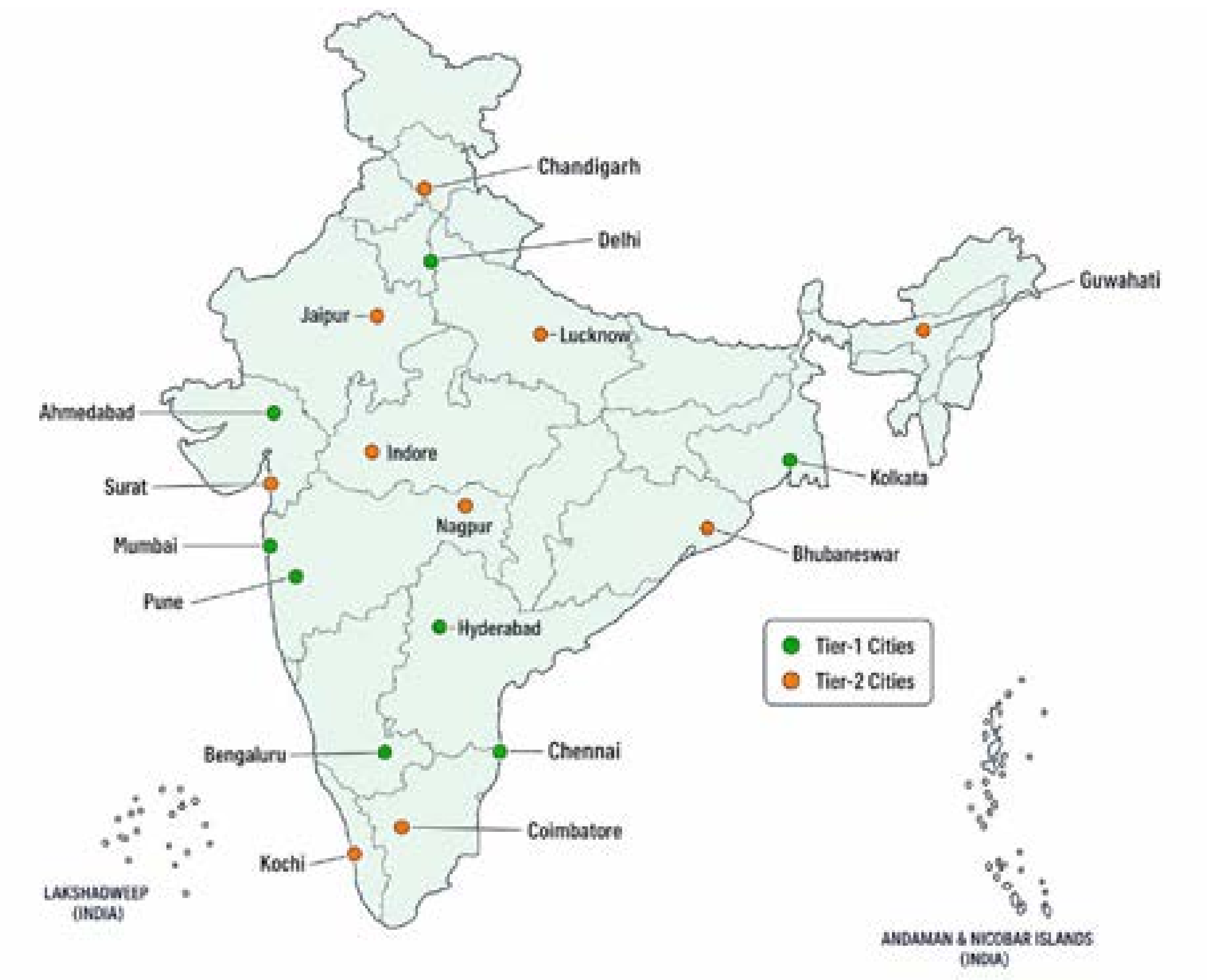


Figure 2.5: Geographical distribution of the selected Tier I and Tier II cities.

2.5 Store Sampling Framework

Stores are selected purposively because a complete national database containing store level refrigeration information is not available. The sample is designed to include variation in store size, ownership, operating model, product range and refrigeration requirements.

The selection considers:

- Independent and organised convenience stores
- Standalone outlets and stores attached to fuel stations or other facilities
- Stores of different sizes and operating schedules
- Stores selling chilled, frozen and other temperature sensitive products
- Stores using different types and ages of refrigeration equipment
- Locations representing different climatic and market conditions

The sample is intended to identify recurring practices, technology patterns and operational challenges rather than provide a statistically complete representation of every convenience store in India. The findings should therefore be interpreted in relation to the number and types of stores assessed.

2.6 Stakeholder Identification and Consultation

Storelevel observations are supplemented by consultations with organisations and individuals involved in refrigeration policy, equipment supply, retail operation, servicing and training.

The stakeholder groups include:

- Government ministries and implementing agencies
- Conveniencestore owners, managers and retail associations
- Refrigeration equipment manufacturers
- Refrigerant manufacturers and suppliers
- Equipment dealers and distributors
- Refrigeration technicians and servicing enterprises
- Training institutions and certification bodies
- Standards and energyefficiency organisations
- Academic and research institutions
- Environmental organisations and industry experts

Consultations are conducted through interviews, meetings, questionnaires or workshops, depending on the stakeholder and the information required. Discussions cover equipment and refrigerant availability, cost, energy performance, safety, maintenance, technician capacity and barriers to adopting non ODS and low GWP alternatives. Stakeholder views help explain the market and institutional factors associated with the practices observed during the fieldwork. Important statements are compared with published evidence, available records and information from other stakeholders where possible.

2.7 Data Collection Instruments

A common set of instruments is used to maintain consistency across store visits and stakeholder consultations. These include:

- Store profile questionnaire
- Refrigeration equipment inventory
- Equipment observation checklist
- Electricity use and billing information format
- Refrigerant and servicing information sheet
- Stakeholder interview guides
- Photographic documentation checklist
- Field notes template

The store questionnaire records basic information about each outlet, including its operating schedule and product range. The equipment inventory captures unitlevel details such as equipment type, manufacturer, model, age, capacity and refrigerant.

It also records available refrigerant charge information, rated cooling capacity and electricity related information shown on the equipment nameplate. The observation checklist documents equipment placement, ventilation, cleanliness, door condition and visible maintenance concerns. Separate interview guides are prepared for store operators, manufacturers, suppliers, technicians and government stakeholders. The instruments may be refined after initial field testing if questions are unclear or the requested information is generally unavailable.

2.8 Data Validation and Analysis

Completed survey forms are checked for missing values, inconsistencies and unusual entries before analysis. Equipment information is compared with nameplates and manufacturer literature where possible. Reported practices are also checked against field observations, photographs, electricity records and maintenance information. Quantitative information is grouped by equipment type, refrigerant, store format, equipment age and city category. Qualitative responses are reviewed under recurring themes such as equipment availability, maintenance, safety, technician capacity, cost and barriers to technology transition. Evidence from the desk review, store visits and stakeholder consultations is compared before conclusions are drawn. Where sources do not agree, the difference is reported rather than resolved through assumption. Data gaps, uncertain estimates and other limitations are identified during the analysis.

CHAPTER 3

CURRENT STATUS OF CONVENIENCE STORES

- Industry Overview
- Evolution of Convenience Stores
- Store Types & Business Models
- Refrigeration Intensity
- Sector Significance

Chapter 3: Current Status of Convenience Stores

Convenience stores are an important small format segment of India’s food retail sector, providing quick access to food, beverages and everyday essentials. They include neighbourhood stores, organised outlets and fuel station stores, typically characterised by compact floor area, extended operating hours and continuous refrigeration requirements. For this study, convenience stores are considered as outlets of up to approximately 2,000 sq. ft., while mini supermarkets of 2,000 to 5,000 sq. ft. are treated separately due to their wider product range and higher refrigeration requirements. Larger supermarkets, hypermarkets and wholesale stores are outside the primary scope. Convenience stores predominantly use plug in refrigeration equipment, including beverage coolers, reach in refrigerators and freezers, to maintain chilled and frozen products. Equipment type, capacity, operating hours and product load collectively influence refrigeration energy use and refrigerant demand. As illustrated in **Figure 3.1**, convenience stores form the smallest retail category considered in the study, followed by mini supermarkets, supermarkets, hypermarkets and wholesale stores. The classification provides a practical basis for distinguishing small format convenience retail from larger and more refrigeration intensive formats. The floor area ranges are indicative working classifications adopted for the present study.

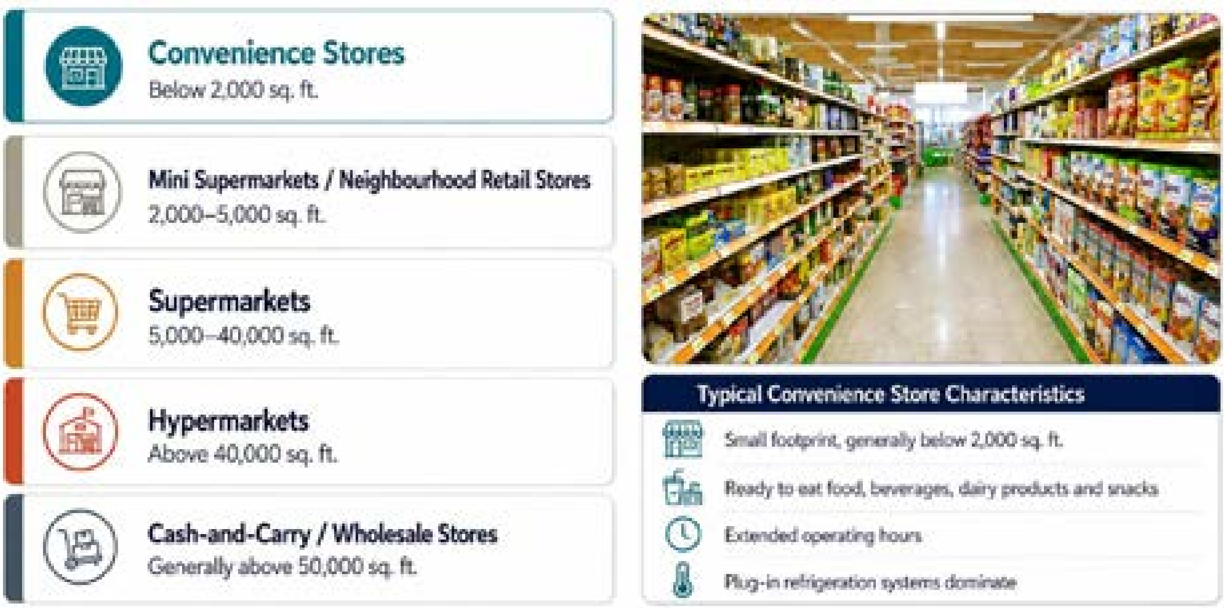


Figure 3.1: Classification of convenience stores within India’s food retail sector.

3.1 Evolution of Convenience Stores in India

The evolution of convenience stores in India has been closely linked with changes in food retail, consumer demand and refrigeration technology. As illustrated in **Figure 3.2**, traditional family operated kirana stores dominated the sector for much of the twentieth century, primarily selling dry groceries and household essentials with limited refrigeration. During the 1980s, wider availability of domestic refrigerators, packaged foods and bottled beverages enabled neighbourhood stores to expand into chilled products such as dairy and soft drinks. Following economic liberalisation in the 1990s, commercial refrigerators and freezers became more common, supporting a wider range of chilled and frozen products. From around 2005, organised retail, mini supermarkets and fuel station stores expanded, bringing self-service layouts, glass door display cabinets and more structured refrigeration practices. Refrigeration increasingly served both product preservation and refrigerated display. After 2015, digital payments, online ordering and computerised inventory systems became increasingly integrated into retail operations. A further shift occurred after 2020 with the rapid growth of quick commerce, dark stores and micro fulfilment centres. These formats require reliable refrigeration for dairy products, beverages, frozen foods, ice cream, fresh produce and prepared foods, along with greater use of multiple temperature storage and remote monitoring. Overall, Figure 3.2 demonstrates the transition from limited household scale cooling to commercial refrigeration and digitally supported cooling operations, reflecting the growing importance of refrigeration in India’s convenience retail sector.

Figure 3.2: Evolution of convenience stores and retail refrigeration in India.

3.2 Store Types and Business Models

Six store formats are considered in this study: kirana stores, organised convenience stores, mini supermarkets, fuel station convenience stores, specialty stores, and quick commerce or dark stores. Convenience retail in India operates through a range of formats that differ in store size, ownership, product mix, operating hours and refrigeration intensity. For the present study, the major retail formats are classified as follows:

- **Kirana Stores:** Predominantly independent and family operated neighbourhood outlets. Refrigeration is generally limited to self contained equipment such as domestic refrigerators, beverage coolers and ice cream freezers. Equipment may be store owned or provided by product suppliers.

- **Organized Convenience Stores:** Operate under a common retail identity with relatively standardised procurement, product display, inventory management and servicing practices. Refrigeration equipment is generally selected more systematically, with maintenance often supported through service contracts.

- **Mini Supermarkets:** Larger self-service neighbourhood stores with a broader range of chilled and frozen products. Multiple reach in refrigerators, glass door display cabinets and freezers may operate simultaneously, resulting in higher refrigeration capacity and electricity demand.

- **Fuel Station Convenience Stores:** Compact outlets serving motorists, passengers and nearby customers, with beverages, dairy products, ice cream, snacks and ready to eat foods forming important product categories. Extended operating hours, frequent door openings, dust and local climatic conditions can place additional demands on refrigeration systems.

- **Specialty Stores:** Focus on temperature sensitive products such as dairy, frozen foods, meat, seafood, fresh foods or prepared foods. Refrigeration forms a core operational requirement, making reliable cooling and appropriate product storage conditions particularly important.

- **Quick Commerce and Dark Stores:** Designed primarily for rapid online order fulfilment rather than conventional walk in retail. Frequent product replenishment and order picking can increase refrigerator, freezer and cold room access, resulting in variable refrigeration loads and a greater need for reliable cooling and temperature monitoring.

As illustrated in **Figure 3.3**, these formats represent different levels of refrigeration intensity and operational complexity. The boundaries between them are not always distinct; for example, kirana stores may provide online delivery, while organised stores may also function as local fulfilment centres. Therefore, for the purpose of this study, each surveyed outlet is classified according to its primary operating model and refrigeration characteristics.

Figure 3.3: Principal convenience store formats covered by the study.

3.3 Infrastructural Characteristics

Convenience stores generally operate within compact retail spaces, where refrigeration equipment must be accommodated alongside shelving, counters, storage areas and customer movement. In many existing stores, the premises were not originally designed around refrigeration requirements. Consequently, equipment placement is often influenced by available floor space, product visibility and access to electrical connections. Self contained plug in refrigeration units therefore dominate small format stores.

Typical equipment includes upright beverage coolers, domestic and commercial refrigerators, chest freezers, ice cream freezers and glass door display cabinets. Mini supermarkets and quick commerce facilities may additionally use multiple door cabinets, open display units and small walk in cold rooms. A single outlet may operate equipment of different capacities, ages and refrigerant types, resulting in varying energy performance and servicing requirements.

Installation conditions have a direct influence on refrigeration performance. Adequate airflow around the condenser and effective heat rejection are essential for efficient operation. Restricted ventilation, inadequate clearance, exposure to direct solar radiation and dust accumulation on condenser coils can increase compressor operating time and electricity consumption. These conditions can be particularly relevant for stores located along busy roads and at fuel stations. Electrical supply and power quality are also important infrastructural considerations. Voltage fluctuations and power interruptions can affect compressor operation, controls and product storage conditions. Although backup power is available in some stores, its capacity may not always be sufficient to support the complete refrigeration load.

Maintenance arrangements vary across retail formats. Organised stores generally have greater scope for planned preventive maintenance, service contracts and equipment records, whereas smaller independent stores often rely on local service technicians and maintenance on demand. Therefore, access to trained technicians, appropriate tools and spare parts is important for maintaining equipment efficiency, reliability and service life.

3.4 Products Requiring Refrigeration

The range of refrigerated products varies across store types and depends on customer demand. Milk, curd, yoghurt, paneer, butter, bottled beverages, fruit drinks, ice cream and frozen snacks are widely encountered categories. Organised outlets and specialty stores may also carry meat, poultry, seafood, frozen vegetables, ready to cook products, prepared meals and cut produce. The reason for cooling is not the same for every category. Beverages are often chilled mainly to meet customer preference. Dairy products, meat, seafood and prepared foods depend on temperature control for safety and shelf life. Frozen goods must remain frozen to avoid damage caused by thawing and refreezing. Retail handling can interrupt an otherwise well managed cold chain. Products may arrive at the correct temperature but become warm during unloading or shelf replenishment. Overfilled cabinets and blocked internal air passages can also produce uneven cooling. The increase in refrigerated products does not affect every store in the same way. A small kirana store may respond by adding a single beverage cooler or freezer. A mini supermarket or dark store may require several cabinets and separate chilled and frozen zones.

3.5 Cooling and Temperature Requirements

Storage temperature should be determined by the product, its packaging, shelf life and the instructions given by the manufacturer. One temperature range cannot be applied to every refrigerated product.

Table 3.1: Indicative temperature requirements for selected product categories

Product category	Indicative storage condition	Main concern
Chilled dairy products	Commonly 0°C to 5°C	Maintaining continuous chilled storage
Fresh meat and poultry	Commonly 0°C to 4°C	Food safety and segregation
Fresh or chilled fish	Close to 0°C and not above 4°C	Rapid deterioration at higher temperatures
Frozen foods	Generally −18°C or below	Preventing thawing and refreezing
Ice cream and frozen desserts	Generally −18°C or below	Maintaining texture and product quality
Chilled beverages	Commonly 2°C to 8°C	Consumer preference and product quality
Ready to eat chilled food	Commonly 0°C to 5°C	Short shelf life and frequent handling
Fresh produce	Product specific	Avoiding deterioration or chilling injury

The values in Table 3.1 are indicative. FSSAI guidance for fresh and chilled fish specifies temperatures between 0°C and 4°C, while frozen fish should be maintained at −18°C or below [12]. FSSAI hygiene requirements also call for suitable facilities for refrigeration, freezing and temperature monitoring [13]. Cabinet air temperature changes during compressor cycling, defrosting, restocking and door opening. A control panel reading may therefore differ from the temperature of the products. The location of the sensor, loading pattern and condition of door seals must be considered when evaluating performance. Cabinets should not be packed beyond their intended capacity. Air outlets and return paths must remain clear. Raw products should also be kept separate from ready to eat food to reduce the risk of cross contamination.

3.6 Store Operating Hours and Usage Patterns

Store operations directly influence refrigeration energy use and equipment performance. The main operating characteristics observed across convenience store formats include:

- **Operating Hours:** Neighbourhood stores generally operate for extended hours, while outlets near fuel stations, hospitals and transport facilities, as well as some quick commerce facilities, may operate 24 hours. Refrigeration equipment typically continues operating even when the store is closed.
- **Refrigeration Load:** Cooling load varies with customer activity, product loading, door opening frequency, store conditions and climatic conditions. Loading warm products and frequent cabinet access increase compressor operation, while infiltration of warm and humid air can increase cooling and defrost requirements.

- **Operating Practices:** Practices such as maintaining appropriate temperature settings, keeping doors and lids closed, avoiding overloading, cleaning condenser coils and using night covers where applicable can reduce unnecessary energy consumption. Switching off refrigeration equipment is generally unsuitable for products requiring continuous temperature control.
- **Energy Monitoring:** Dedicated refrigeration energy metering is relatively uncommon in small stores. Electricity bills generally represent the combined consumption of refrigeration, lighting, air conditioning and other electrical loads, making it difficult for store operators to identify refrigeration specific energy use and assess equipment efficiency.

3.7 Tier I and Tier II Market Characteristics

The comparison between Tier I and Tier II cities reflects differences in retail structure, refrigeration intensity, equipment availability and servicing infrastructure **(Table 3.2)**. These categories are used to assess market conditions rather than to rank cities.

Table 3.2: Comparative Characteristics of Convenience Store Markets in Tier I and Tier II Cities

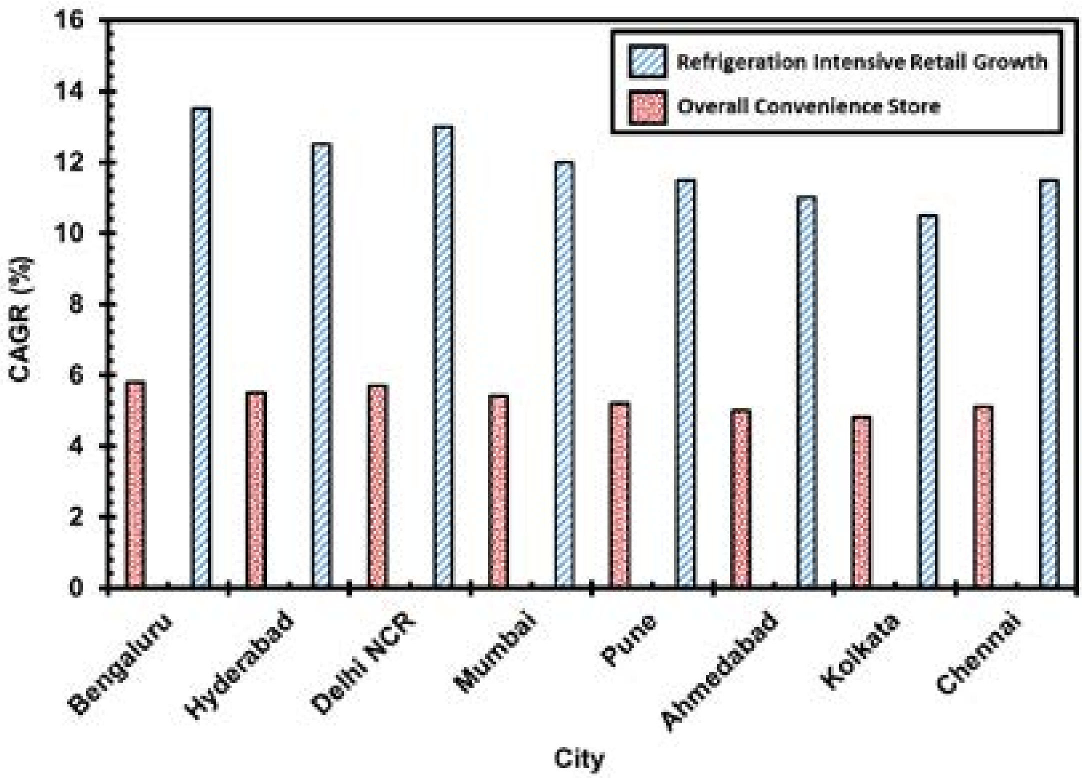
Characteristic	Tier I Cities	Tier II Cities
Retail structure	Higher presence of organised retail, mini supermarkets, specialty stores and quick commerce	Higher share of independent and locally operated stores
Refrigeration load	Generally higher due to wider chilled, frozen and ready to eat product ranges	Generally moderate, but increasing with organised retail expansion
Equipment selection	Greater access to commercial and advanced refrigeration equipment	More influenced by initial cost, local availability and technician familiarity
Equipment mix	Greater standardisation in organised formats	Wider mix of new, older and supplier provided equipment
Service infrastructure	Better availability of authorised service providers and specialist contractors	Greater dependence on local technicians and available spare parts
Operating conditions	Long operating hours, high customer traffic and space constraints can increase refrigeration demand	Operating conditions vary considerably with local market and infrastructure
Market trend	Mature, organised and digitally enabled retail ecosystem	Rapid growth in organised retail, digital payments and app based ordering

3.8 Growth and Market Trends

India's convenience retail market is being reshaped by urban growth, changing work patterns, increasing household incomes and the wider availability of packaged food. Customers are purchasing more chilled beverages, dairy products, frozen snacks and prepared foods. This change in product mix is increasing refrigeration demand even where the number of stores is growing slowly. Organised retailers are extending their presence into residential areas and smaller cities. Industry estimates cited by the India Brand Equity Foundation place the organised retail market at approximately USD 230 billion by 2030 [14, 15]. Such forecasts indicate the expected direction of development but remain dependent on economic conditions and consumer demand.

India's quick commerce sector has expanded rapidly, with gross order value estimated at approximately ₹64,000 crore in FY 2025 and projected to reach around ₹2 lakh crore by FY 2028. The number of dark stores also increased by approximately 71% in FY 2025, indicating rapid expansion of fulfilment infrastructure and increasing penetration beyond major metropolitan markets [16]. Future growth of the sector is expected to be influenced by operational efficiency, profitability, expansion into Tier II and Tier III cities, and continued improvement in delivery and technology infrastructure. The field survey examined how these broader market changes were reflected in the selected Tier I and Tier II cities. Information was collected on store establishment, changes in store numbers, product ranges, the installation of refrigeration equipment and the growth of retail formats dependent on chilled or frozen storage. Available store records and published market information were used to support the survey responses.

3.8.1 Growth across Tier I and Tier II Cities

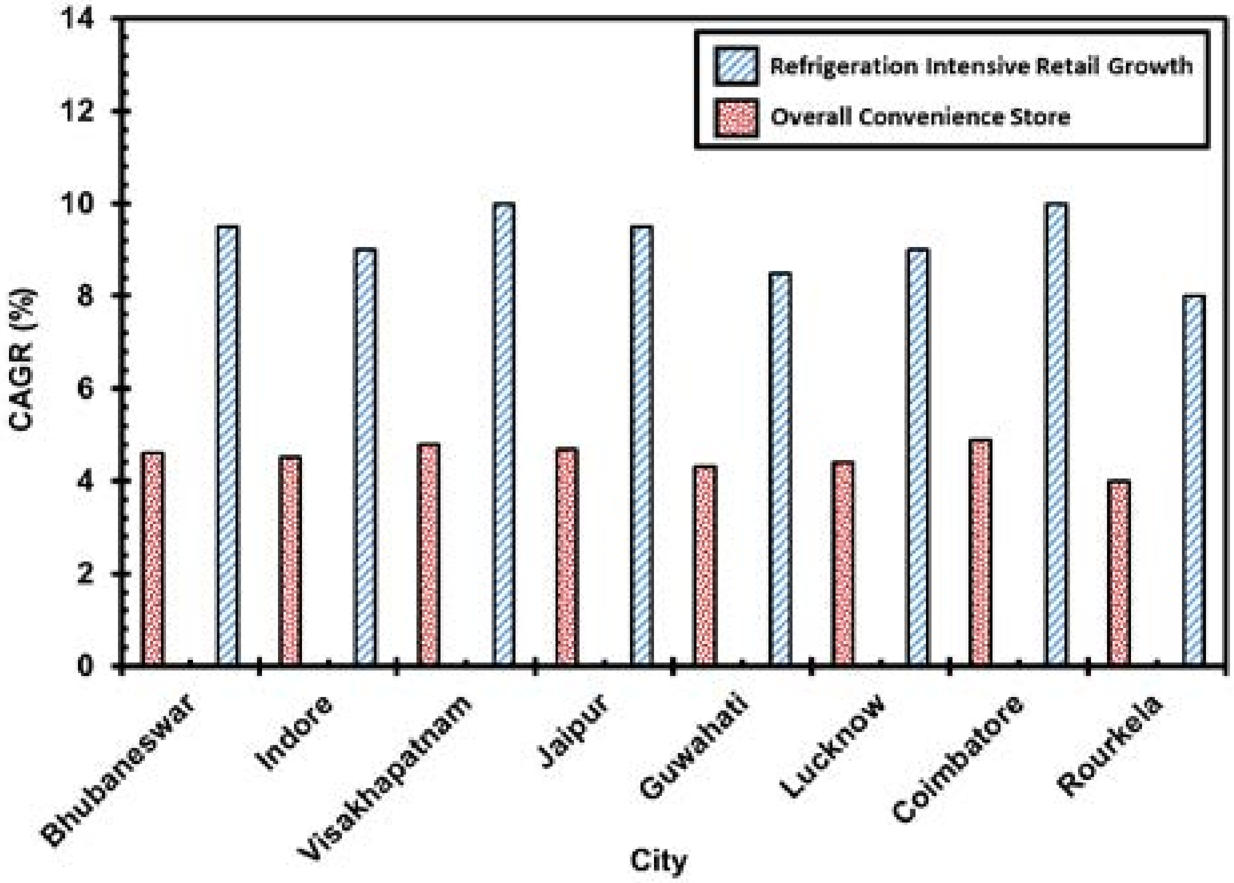


(a) Tier I cities

The growth of convenience stores does not necessarily translate into refrigeration growth at the same rate. A store may operate with little or no refrigeration initially and later add beverage coolers, refrigerators or freezers as demand for chilled and frozen products increases. Therefore, **Figure 3.4** considers two separate growth indicators: the growth in the total number of convenience stores and the growth in the number of stores equipped with refrigeration. The Compound Annual Growth Rate (CAGR) represents the average annual rate of change between the number of stores recorded at the beginning and at the end of the assessment period. For refrigeration, the calculation is based on refrigeration equipped outlets, not on the number of individual refrigeration units, installed cooling capacity or electricity consumption.

Tier I cities generally show stronger growth in refrigeration equipped outlets because of the greater presence of organised convenience stores, mini supermarkets, specialty food outlets and quick commerce facilities. Wider availability of chilled, frozen and ready to eat products, longer operating hours and better access to commercial refrigeration equipment and servicing infrastructure also contribute to this growth. Tier II cities show a similar trend, supported by expanding organised retail, improved distribution of chilled and frozen products and increasing access to refrigeration equipment and technical services.

The findings indicate that refrigeration demand is growing for two main reasons. First, more convenience stores are becoming refrigeration equipped. Second, existing stores are increasing their refrigeration requirements by adding equipment, expanding chilled and frozen product ranges and increasing refrigerated display and storage space. The growth of quick commerce and extended operating hours further increases cooling requirements. **Figure 3.4** should therefore be interpreted as an indicator of retail growth and refrigeration penetration, rather than a direct measure of refrigeration capacity or electricity consumption.



(b) Tier II cities

Figure 3.4: Indicative growth of convenience stores and refrigeration intensive retail in selected Tier I and Tier II cities.

3.8.2 Growth by Store Format

Figure 3.5 shows the indicative average annual growth rate of different convenience store formats covered in the study. In simple terms, the percentage represents how quickly each store format has expanded on average during the assessment period. Traditional kirana stores show the lowest growth, at approximately 3 to 3.5%, mainly because they already have a very large and established market presence. Fuel station convenience stores show moderate growth of around 7 to 8%, while organised convenience stores and mini supermarkets show higher growth of approximately 11 to 13%. Specialty frozen and fresh food stores show growth of around 12.5 to 14%, reflecting increasing demand for chilled and frozen products. Quick commerce shows the highest indicative growth, at approximately 25 to 30%, driven by the rapid expansion of dark stores and app based delivery services. However, quick commerce is a relatively new format and has grown from a much smaller initial base. Its growth is assessed mainly for 2020 to 2026, whereas the other formats are assessed over the longer 2000 to 2026 period. The quick commerce growth rate should therefore be interpreted separately rather than directly compared with the other formats.

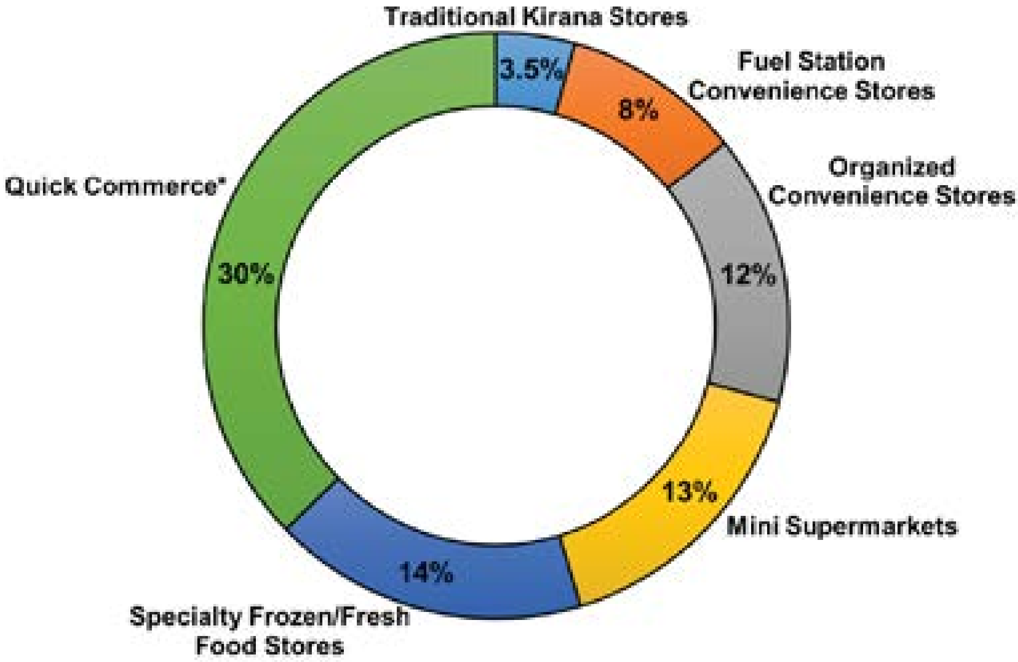


Figure 3.5: Indicative annual growth rates of convenience store formats in India.

3.8.3 Growth of Refrigeration Intensive Retail

Figure 3.6 depicts how the growth of different store formats is influencing the use of refrigeration. As stores expand their range of chilled and frozen products, they require more beverage coolers, refrigerators, freezers, refrigerated display cabinets and, in some cases, cold rooms. Kirana stores generally increase refrigeration gradually by adding individual cooling units, while organised stores and fuel station outlets use more refrigerated display equipment for beverages, dairy products, frozen foods and ready to eat products. Mini supermarkets and specialty stores have greater refrigeration requirements because a larger proportion of their products requires chilled or frozen storage. Quick commerce shows the strongest growth in refrigeration intensive activity because dark stores need multiple chilled and frozen storage facilities to keep products ready for rapid delivery.

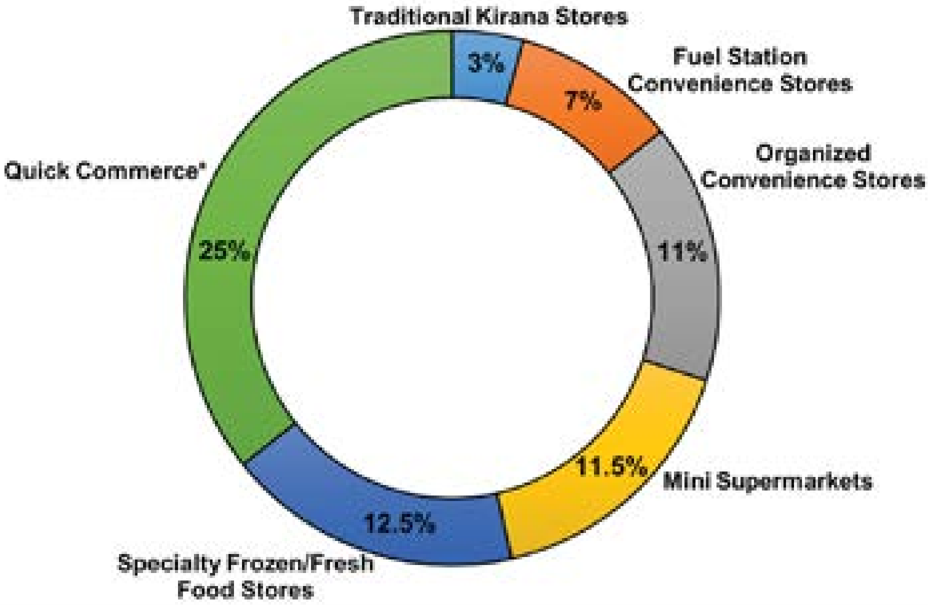


Figure 3.6: Indicative annual growth of refrigeration intensive retail by store format.

Thus, **Figures 3.4 to 3.6** indicate that refrigeration demand is increasing due to both the growth of retail outlets and the increasing use of refrigeration within individual stores. The CAGR values represent the average annual growth between the beginning and end of the respective assessment periods and should not be interpreted as identical growth in every year. This increasing refrigeration intensity creates greater demand for energy efficient equipment, suitable refrigerants, reliable operation and trained servicing personnel, which are examined in the subsequent chapters.

CHAPTER 4

EXISTING REFRIGERATION SYSTEMS AND REFRIGERANT USE

Equipment Inventory

Performance Assessment

Deployment Analysis

Operating Temperature Ranges

Refrigerants in Use

Technical Specifications

Chapter 4: Existing Refrigeration Systems and Refrigerant Use

4.1 Refrigeration Equipment Inventory

The surveyed convenience stores used different refrigeration systems according to store size, product range, sales volume and business model. The principal equipment categories were beverage coolers, reach in refrigerators, chest freezers, vertical freezers, open display cabinets and walk in cold rooms. Domestic refrigerators were also used in small kirana stores. All the identified equipment operated on the vapour compression refrigeration principle, which remains the predominant technology for domestic and commercial refrigeration applications [17]. Figure 4.1 presents the six principal equipment categories and their normal operating temperature ranges. It illustrates the progression from compact standalone cabinets used in small stores to walk in cold rooms employed for bulk storage in larger retail formats.

Figure 4.1: Refrigeration Equipment Used in Convenience Stores.

Equipment performance was assessed using the coefficient of performance, average daily electricity consumption, estimated annual electricity consumption and deployment rate. The coefficient of performance represents the ratio of useful refrigeration produced to the electrical energy supplied:

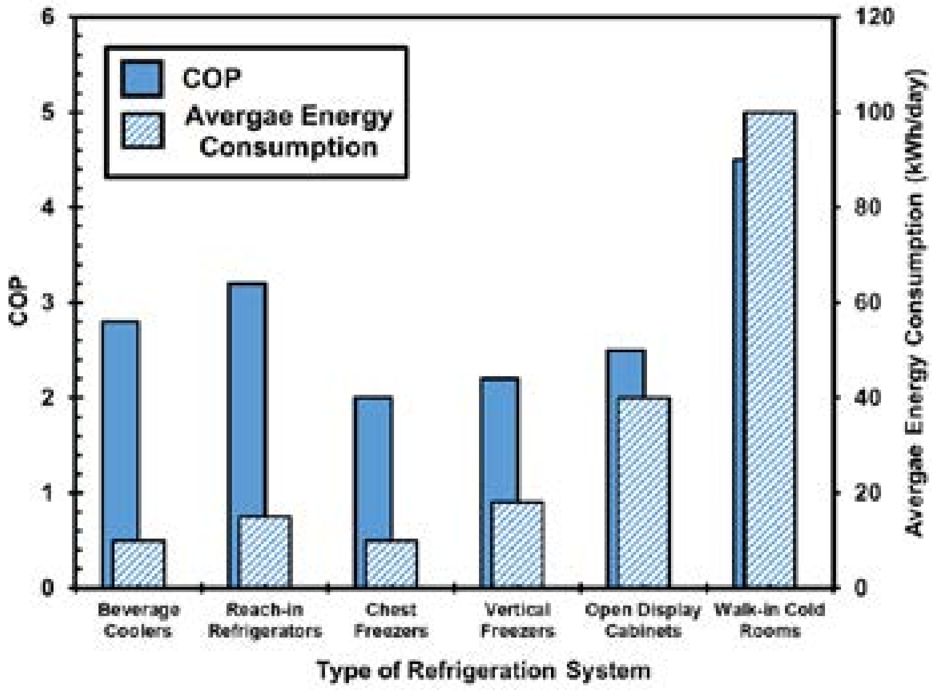
$$COP = \frac{\text{Refrigeration effect}}{\text{Electrical energy input}} \tag{4.1}$$

A higher COP indicates that more cooling is produced per unit of electrical energy. However, COP alone does not determine total electricity consumption because equipment capacity, operating hours, temperature level, product load and access frequency also influence energy use [17].

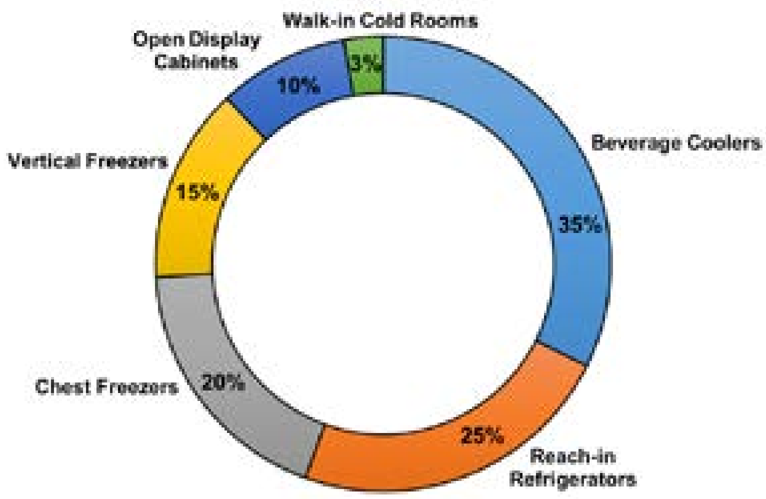
Annual electricity consumption was estimated as:

$$E_{\mathrm{annual}} = E_{\mathrm{daily}} \times 365 \quad (4.2)$$

where E_{annual} is the estimated annual electricity consumption in kWh/year and E_{daily} is the average daily electricity consumption in kWh/day.



(a) COP and average energy consumption



(b) Deployment rate

Figure 4.2: Coefficient of Performance, Electricity Consumption and Deployment Rate of Refrigeration Equipment.

Figure 4.2 compares the COP and average daily electricity consumption of the identified equipment. It also presents the deployment rate of each category. Beverage coolers had the highest deployment, while walk in cold rooms had the lowest deployment but the highest electricity consumption per installation. Deployment rate represents the proportion of surveyed stores in which a particular equipment category was identified. Since an individual store could contain several equipment types, the deployment percentages are not mutually exclusive and do not add up to 100% as shown in **Figure 4.2.** The discussion on results obtained for the COP, average energy consumption and deployment rate is presented in individual refrigeration systems description.

4.2 Beverage Coolers

Beverage coolers **(Figure 4.1)** had the highest deployment at approximately 35%, with an average COP of 2.8 and electricity consumption of about 10 kWh/day per unit. Older units mainly use R-134a, while newer equipment increasingly uses low GWP R290 **[18].**

4.3 Reach in Refrigerators

Reach in refrigerators **(Figure 4.1)** accounted for approximately 25% of deployment, with an average COP of 3.2 and electricity consumption of about 15 kWh/day per unit. R-134a, R-290 and R-600a were identified, with hydrocarbons increasingly used in newer equipment.

4.4 Chest Freezers

Chest freezers **(Figure 4.1)** represented approximately 20% of deployment, with an average COP of 2.0 and electricity consumption of about 10 kWh/day per unit. Their top opening design limits cold air loss, while R290 is increasingly replacing R404A in newer equipment **[19].**

4.5 Vertical Freezers

Vertical freezers **(Figure 4.1)** accounted for approximately 15% of deployment, with an average COP of 2.2 and electricity consumption of about 18 kWh/day per unit. Energy use is influenced by door openings, lighting and anti-sweat heaters, with R290 increasingly used in newer models.

4.6 Open Display Cabinets

Open display cabinets **(Figure 4.1)** represented approximately 10% of deployment, with an average COP of 2.5 and comparatively high electricity consumption of about 40 kWh/day per cabinet. Warm and humid air infiltration increases the refrigeration load, making cabinet enclosure and efficient components important energy saving measures **[20].**

4.7 Walk In Cold Rooms

Walk in cold rooms **(Figure 4.1)** had the lowest deployment at approximately 3%, but the highest electricity consumption at about 100 kWh/day per installation, despite an average COP of 4.5. Performance depends strongly on insulation, infiltration, product loading and defrost operation **[21].**

4.8 Equipment Technical Specifications

Table 4.1 consolidates the principal technical, economic and operational characteristics of the surveyed equipment. It compares application, temperature range, storage capacity, refrigerant, capital cost, efficiency level, operational advantages, challenges and low GWP transition potential.

Table 4.1: Technical and Operational Characteristics of Refrigeration Equipment

Parameter	Beverage Coolers	Reachin Refrigerators	Chest Freezers	Vertical Freezers	Open Display Cabinets	Walkin Cold Rooms
Primary Application	Chilled beverages	Dairy, fresh foods, ready to eat products	Frozen foods, ice cream	Frozen foods and frozen retail display	Dairy, beverages, fresh produce	Bulk storage
Temperature Range (°C)	2–8	0–5	−18 to −25	−18 to −25	2–8	0–5 or −18 to −25
Typical Capacity	200–1200 L	300–1500 L	150–800 L	300–1200 L	500–3000 L	5–100 m³
Common Refrigerants	R-134a, R-290	R-134a, R-290, R-600a	R-290, R-404A	R-290, R-404A	R-290, R-404A	R-404A, R-448A, NH_3, CO_2
Cooling Technology	VCRS	VCRS	VCRS	VCRS	VCRS	VCRS
Capital Cost (₹)	20,000–80,000	30,000–1,20,000	20,000–70,000	40,000–1,50,000	1–5 lakh	3–50 lakh
Energy Efficiency Level	Medium	Medium–High	High	Medium	Low–Medium	High
Major Advantages	High visibility	Multiproduct storage	Low cost, high storage density	Better merchandising	Easy customer access	Large storage capacity
Major Challenges	Frequent door opening	Condenser fouling	Product retrieval inconvenience	Higher energy use	High infiltration losses	High initial investment
Transition Potential to LowGWP Refrigerants	High	High	High	High	High	Moderate–High

Table 4.1 shows that equipment selection involved a balance among temperature requirement, storage capacity, product visibility, capital cost and operating efficiency. Standalone cabinets provided flexibility and lower initial investment, whereas open display cabinets and cold rooms supported greater product volumes but required higher capital and electricity expenditure. The table also indicates high low GWP transition potential for most standalone equipment. Commercial refrigeration is progressively adopting R-290 and other low GWP alternatives. However, hydrocarbon systems require factory designed equipment, controlled refrigerant charges, appropriate safety measures and trained technicians because of their flammability [22].

4.9 Refrigeration Capacity, Temperature Range and Load Distribution

The equipment operated within chilled and frozen temperature ranges. Reach in refrigerators and chilled cold rooms maintained lower chilled temperatures, while beverage coolers and open display cabinets operated at moderately higher chilled temperatures. Chest freezers, vertical freezers and frozen cold rooms provided low temperature storage for frozen products. Required refrigeration capacity increased with cabinet volume, product load and the temperature difference between the refrigerated space and the surrounding environment. Door opening, restocking, lighting, fans, defrosting and antisweat heaters added to the electrical demand. Consequently, high COP did not necessarily result in low total electricity consumption. Figure 4.3 presents the estimated refrigeration load distribution derived from the field survey based on equipment deployment, operating patterns and product storage requirements. Beverages contributed the highest share at 35%, followed by dairy products at 25%, frozen foods and fresh and ready to eat products at 15% each, and ice cream at 10%. These values represent estimated load shares rather than direct product level cooling load measurements.

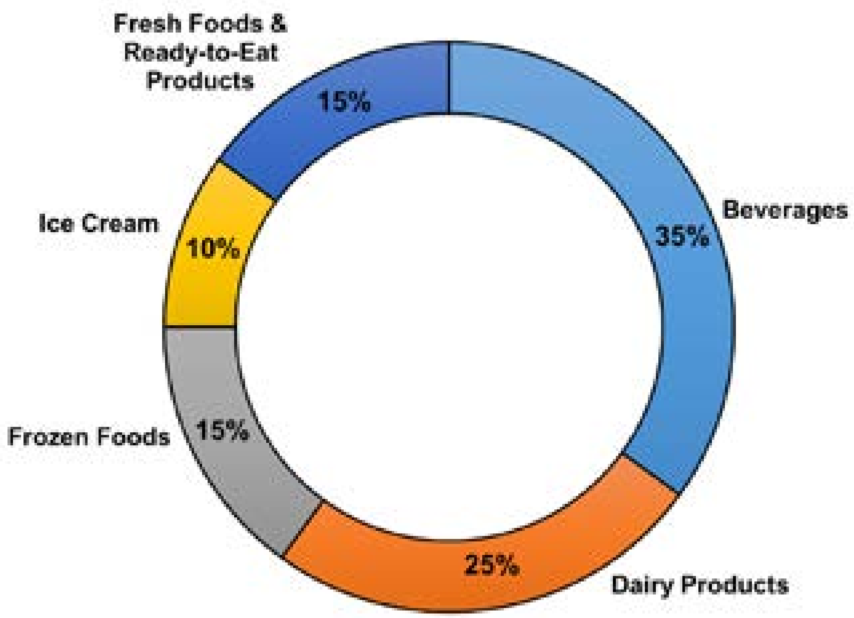


Figure 4.3: Refrigeration Load Distribution in Convenience Stores.

The largest share associated with beverages was consistent with the widespread deployment of beverage coolers. Dairy products created the second largest requirement because uninterrupted chilled storage was necessary for maintaining quality and shelf life. Fresh foods and ready to eat products were more prominent in organised stores, mini supermarkets and quick commerce facilities. Frozen foods and ice cream together accounted for 25% of the load. Although their combined share was lower than that of chilled products, their lower storage temperature increased the temperature lift across the refrigeration cycle and the work required from the compressor. Refrigeration load distribution, equipment deployment rate and electricity consumption represent different indicators. Load distribution describes the relative cooling requirement of product categories. Deployment rate indicates the proportion of surveyed stores using a particular equipment category. Electricity consumption represents the energy required to operate the equipment under the observed conditions.

4.10 Refrigerants

The surveyed equipment used different refrigerants depending on equipment type, age, operating temperature, capacity and system configuration. Older equipment was commonly associated with R-134a, R-404A and R-507A, while newer standalone refrigeration increasingly used R-290 and R-600a. Other refrigerants, including R-410A, R-448A, ammonia (R-717), carbon dioxide (R-744) and HFO blends, were identified in selected commercial and larger refrigeration applications. Table 4.2 summarises the major refrigerants identified during the study, their typical applications and their relevance to the ongoing transition towards lower GWP refrigeration. The inventory therefore indicates a gradual transition from high GWP HFCs such as R-134a, R-404A and R-507A towards R-290, R-600a, CO_2 and other lower GWP alternatives. The transition is more evident in newly manufactured standalone equipment, while older cold rooms and larger systems continue to contain legacy refrigerants [22, 23]. Transition to lower GWP refrigerants requires refrigerant compatible and appropriately designed equipment rather than simple field replacement. For flammable refrigerants such as R-290 and R-600a, equipment design, refrigerant charge, ventilation, ignition risk control, leak prevention and safe servicing practices require particular attention. Wider adoption therefore depends on the availability of suitable equipment, applicable safety provisions, appropriate servicing tools and trained technicians.

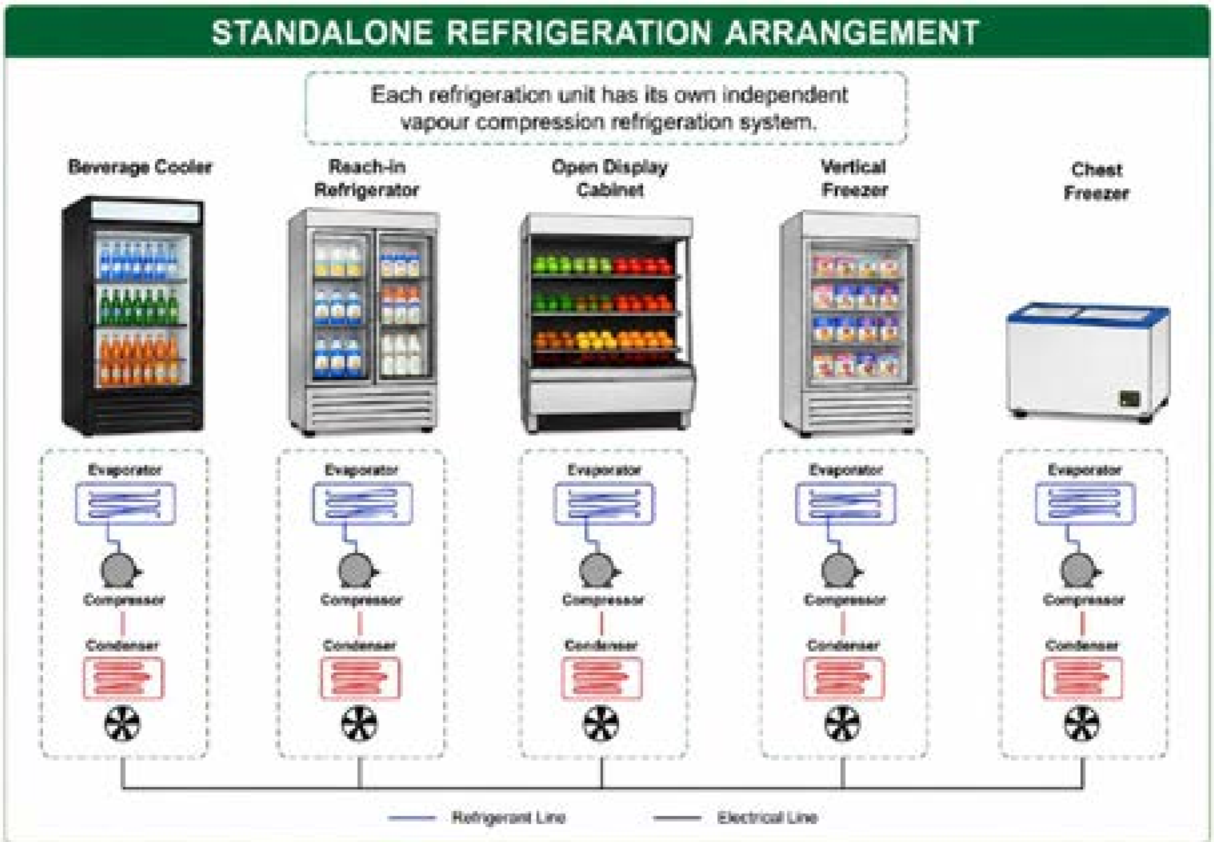
Table 4.2: Refrigerants Identified in Convenience Store Refrigeration Equipment and Their Relevance

Refrigerant	Typical application	Relevance to transition
R-134a	Older refrigerators and light commercial equipment	High GWP HFC present in existing equipment
R-404A	Freezers and low temperature commercial systems	Very high GWP HFC associated mainly with older equipment
R-507A	Low temperature commercial refrigeration	Very high GWP HFC associated mainly with older systems
R-410A	Selected systems in mini supermarkets	High GWP HFC present in some existing systems
R-290	Beverage coolers, reach in refrigerators and freezers	Very low GWP alternative increasingly used in new standalone equipment
R-600a	Domestic refrigerators and small factory sealed equipment	Very low GWP refrigerant established in small systems
R-448A	Larger commercial refrigeration systems	Lower GWP alternative to R404A and R507A
R-744 (CO_2)	Larger and advanced commercial systems	Very low GWP option requiring suitable system design
R-717 (Ammonia)	Selected cold room and larger refrigeration applications	Zero GWP option requiring specialised safety provisions
HFO blends	Selected newer commercial systems	Emerging lower GWP alternatives depending on blend composition

4.11 Equipment Age and Condition

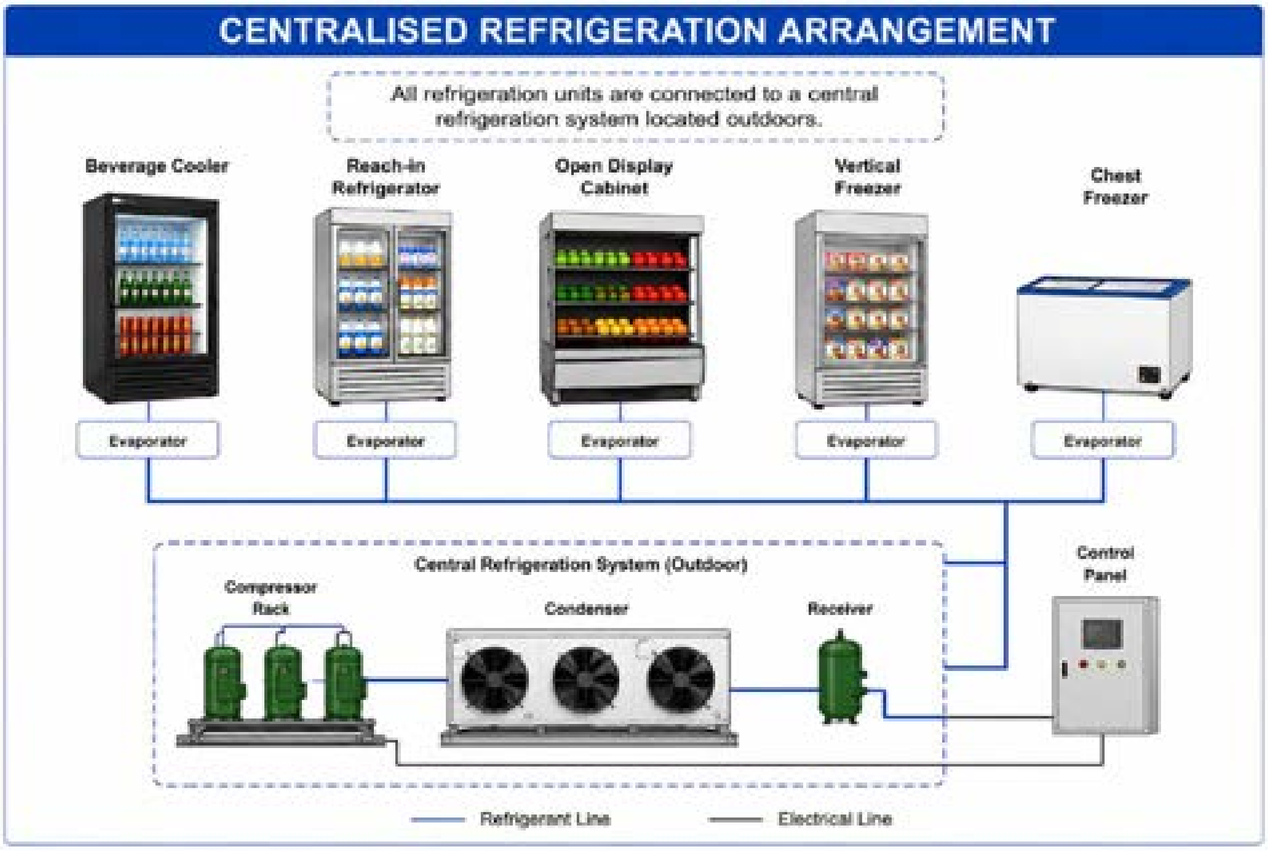
The installed equipment included systems of different ages, refrigerants and efficiency levels. Typical service life varies by equipment type: beverage coolers 8 to 12 years, reach in refrigerators 10 to 15 years, chest freezers 10 to 15 years, vertical freezers 8 to 12 years, open display cabinets 10 to 15 years, and walk in cold rooms 15 to 20 years, subject to operating conditions and maintenance. Common issues included worn door gaskets, condenser fouling, frost formation, damaged insulation, restricted airflow and control inaccuracies, which can increase compressor runtime and energy consumption. Regular preventive maintenance is therefore important for maintaining energy efficiency, refrigerant containment, temperature stability and equipment service life.

4.12 Centralised and Standalone Systems



(a) Standalone Refrigeration Arrangement

Small stores relied mainly on standalone refrigeration equipment. Each cabinet contained an independent compressor, condenser, expansion device and evaporator. This arrangement allowed stores to add equipment gradually as their refrigerated product range expanded. Standalone equipment involved lower initial investment and provided operational flexibility. Failure of one unit did not interrupt the operation of other cabinets. However, stores containing several standalone systems had multiple compressors and condensers, increasing the number of components requiring maintenance. Larger stores used remote or centralised arrangements in which multiple cabinets or temperature zones were connected to common refrigeration equipment. These systems supported greater cooling loads, coordinated control and multizone storage but required higher initial investment, larger refrigerant charges and specialised servicing. Comparative research has demonstrated that standalone, remote and centralised supermarket refrigeration configurations differ in their energy use, refrigerant charge and environmental impact [24]. Figure 4.4 illustrates the basic difference between these arrangements. In a standalone system, each cabinet contains an independent refrigeration circuit. In a centralised system, a common compressor rack or condensing unit supplies several display cabinets or cold rooms through a shared refrigerant network.



(b) Centralised Refrigeration Arrangement

Figure 4.4: Standalone and Centralised Refrigeration Arrangements in Convenience Stores.

The figure explains why standalone systems were more suitable for kirana stores and fuel station outlets, whereas centralised systems were more applicable to mini supermarkets, specialty stores and quick commerce facilities. Carbon dioxide booster systems represent a potential low GWP option for organised retail applications, although their performance is influenced by ambient temperature, system configuration and high side pressure control [24, 25].

4.13 Equipment Deployment by Store Type

Table 4.3 summarises the relationship between store category, cooling intensity, installed equipment and refrigerant use. The comparison shows that increasing product diversity and sales volume resulted in greater cooling intensity and more complex refrigeration arrangements.

Table 4.3: Refrigeration Equipment and Refrigerants by Store Type

Store type	Cooling intensity	Typical refrigeration equipment	Common refrigerants
Traditional kirana store	Low	Domestic refrigerator and beverage cooler	R-600a, R-134a
Fuel station convenience store	Low to moderate	Beverage cooler and ice cream freezer	R-290, R-600a
Organised convenience store	Moderate	Vertical display cooler and reach in refrigerator	R-290, R-134a, R-404A
Mini supermarket	High	Multideck cabinet, chest freezer and dairy cooler	R-404A, R-410A, R-290
Specialty frozen food or meat store	Very high	Deep freezer, display freezer and walk in cold room	R-404A, R-507A
Quick commerce fulfilment centre	High to very high	Multizone refrigeration, chilled room and freezer room	R-404A, CO_2, HFO blends
Advanced low GWP retail store	High	Centralised system and CO_2 booster arrangement	CO_2, HFO blends, R-290

Table 4.3 shows that refrigeration requirements vary across store formats. Kirana and fuel station convenience stores generally rely on compact standalone equipment, while organised stores, mini supermarkets, specialty stores and quick commerce facilities use a wider range of chilled and frozen equipment, resulting in higher refrigeration capacity and more complex cooling requirements. Quick commerce facilities may additionally require multiple temperature zones and continuous refrigeration to support rapid inventory movement. The refrigerant used also varies with equipment type, age and system configuration. The surveyed equipment includes both legacy high GWP refrigerants and newer lower GWP alternatives, reflecting the ongoing transition of the refrigeration sector. Overall, the findings show a progression from simple standalone systems in smaller stores towards multiple equipment and centralised refrigeration arrangements in refrigeration intensive retail formats. Energy performance and refrigerant transition pathways are discussed further in Chapters 5 and 9, respectively.

CHAPTER 5

ENERGY USE, EFFICIENCY AND CLIMATIC PERFORMANCE

- Refrigeration Energy Use
- Efficiency Improvement Opportunities
- Monitoring and Preventive Maintenance
- Climatic Influence on Performance
- Low GWP and Emerging Technologies
- Key Takeaways and Implications

Chapter 5: Energy Use, Efficiency and Climatic Performance

This chapter examines how refrigeration contributes to energy use in Indian convenience stores and how its performance is influenced by monitoring practices, maintenance, climate, store location and technology choice. The equipment characteristics, refrigerants and operating parameters have already been established in Chapter 4; the discussion here therefore focuses on their energy and climatic implications.

5.1 Refrigeration Energy Use and Efficiency

Electricity is the principal energy source for refrigeration in convenience stores, with refrigeration accounting for approximately 45 to 65% of total store electricity consumption in the present assessment **[24].** Energy demand depends on both equipment deployment and operating intensity, including capacity, operating hours, storage temperature, climatic conditions and maintenance status. Beverage coolers and reach in refrigerators account for approximately 32% and 23% of equipment deployment, while open display cabinets and walk in cold rooms represent only about 9% and 7%, respectively; however, the latter can have substantially higher unit electricity consumption. Equipment efficiency must therefore be assessed together with total energy use. COP values range from approximately 1.2 to 1.8 for chest freezers to about 4.5 for walk in cold rooms, but a higher COP does not necessarily mean lower electricity consumption because system capacity and operating duration also influence annual demand. Open display cabinets incur additional sensible and latent cooling loads due to infiltration of warm and humid air, while adding doors can significantly reduce this energy penalty **[20].** For suitable standalone applications, high efficiency R-290 equipment can provide approximately 10 to 20% efficiency improvement over ageing conventional equipment, although actual savings depend on equipment condition, compressor and heat exchanger design, controls and operating environment **[18].** These findings indicate that energy efficiency measures should address both widely deployed equipment and less common but energy intensive refrigeration systems.

5.2 Energy Monitoring and Preventive Maintenance

The field assessment indicates that temperature monitoring is considerably more common than equipment specific electricity monitoring. Smaller stores generally rely on thermostat readings and the total monthly electricity bill, making it difficult to identify refrigeration equipment that is consuming more electricity than expected. Energy monitoring becomes more useful when temperature and electricity consumption are assessed together. A cabinet may continue to maintain its prescribed temperature even when its efficiency has deteriorated because the compressor compensates by operating for longer periods. Tracking compressor runtime, electricity consumption, cabinet temperature, ambient temperature and humidity therefore provides a more reliable indication of actual performance.

This is particularly relevant because refrigeration represents approximately 45 to 65% of store electricity consumption. Even a 10% reduction in refrigeration electricity use would correspond to approximately 4.5 to 6.5% reduction in total store electricity consumption, assuming other loads remain unchanged. This illustrates the value of equipment level monitoring even when relatively modest refrigeration efficiency improvements are achieved. Preventive maintenance has a direct effect on these savings. Condenser fouling increases condensing temperature, evaporator icing reduces heat transfer, damaged door seals increase infiltration, and incorrect refrigerant charge increases compressor runtime. Routine condenser cleaning, evaporator inspection, gasket replacement, leak detection, fan maintenance and verification of temperature and defrost controls can therefore prevent avoidable electricity consumption.

The technician survey identified a significant refrigerant management gap, with only approximately 25% of surveyed commercial technicians practising refrigerant recovery. Strengthening training, recovery practices and access to appropriate servicing tools is therefore important. These efforts can be complemented by AI and IoT based monitoring for continuous performance tracking, fault detection and remote alarms. With an assessed TRL of approximately 9, these technologies are commercially mature for organised store networks.

5.3 Performance across Indian Climatic Zones

India's climatic diversity has a direct influence on refrigeration performance. The Energy Conservation Building Code identifies five principal climatic zones: hot dry, warm humid, composite, temperate and cold [26]. As shown in Figure 5.1, refrigeration equipment therefore operates under different combinations of ambient temperature and relative humidity. High ambient temperature increases the sensible cooling load and also raises the condensing temperature required for heat rejection, increasing compressor work. High relative humidity increases the latent cooling load when moisture laden ambient air enters refrigerated spaces through door openings or open display surfaces. Consequently, warm humid climates impose both sensible and latent cooling loads, whereas hot dry climates are influenced predominantly by high sensible load and elevated condensing temperatures.

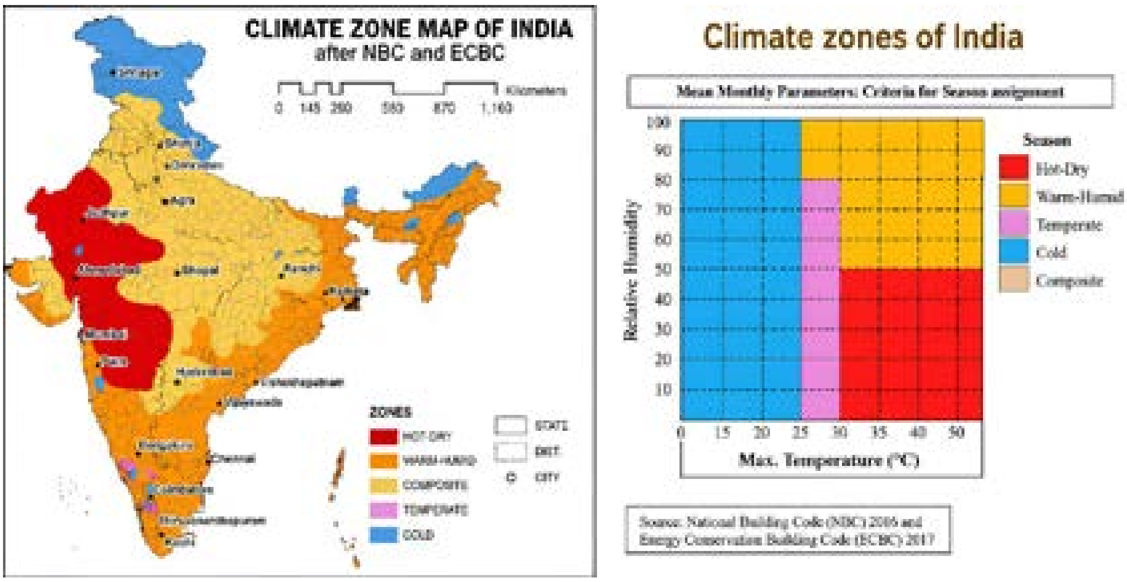


Figure 5.1: Climate Zones of India [26].

The climatic suitability assessment for the six principal refrigeration equipment categories is presented in Table 5.1 [27]. Beverage coolers and reach in refrigerators using the recommended R-290 and R-600a options receive an Excellent rating across all five climatic zones. Chest and vertical freezers receive Excellent ratings in three zones and Very Good ratings in the remaining two. Greater climatic sensitivity is observed for open display cabinets and walk in cold rooms because of their higher interaction with the surrounding environment. Open display cabinets range from Good in hot dry conditions to Excellent in temperate and cold conditions, while walk in cold rooms range from Good in warm humid conditions to Excellent in temperate and cold conditions. These results demonstrate that ambient temperature primarily affects sensible load and heat rejection, while ambient humidity governs the additional latent load associated with moisture infiltration, making climatic conditions increasingly important for refrigeration systems with greater exposure to ambient air.

Table 5.1: Refrigerant Suitability under Indian Climatic Conditions

Equipment Type	Existing Refrigerants	Recommended Refrigerants	Hot Dry	Warm Humid	Composite	Temperate/ Moderate/ Mild	Cold
Beverage coolers	R-134a	R-290, R-600a	Excellent	Excellent	Excellent	Excellent	Excellent
Reach in refrigerators	R-134a, R-600a	R-290, R-600a	Excellent	Excellent	Excellent	Excellent	Excellent
Chest freezers	R-404A	R-290	Excellent	Very Good	Excellent	Excellent	Very Good
Vertical freezers	R-404A	R-290, R-455A	Excellent	Very Good	Excellent	Excellent	Very Good
Open display cabinets	R-404A, R-448A	R-290, CO_2, R-455A	Good	Very Good	Very Good	Excellent	Excellent
Walk in cold rooms	R-404A, R-449A	CO_2, NH_3, NH_3/ CO_2 cascade, R290	Very Good	Good	Very Good	Excellent	Excellent

5.4 Tier I and Tier II Climatic Performance

The climatic assessment was extended to 18 selected Indian cities, comprising eight Tier I and eight Tier II locations. For beverage coolers and reach in refrigerators, all 8 of 8 Tier I cities are rated Highly Suitable. Chest and vertical freezers are Highly Suitable in 5 of 8 cities, equivalent to 62.5% of the assessed Tier I locations (Table 5.2). Open display cabinets are Highly Suitable in 5 of 8 cities, while walk in cold rooms receive this rating in only 2 of 8 cities, namely Bengaluru and Pune. Across all six equipment categories, Bengaluru and Pune achieve 6 out of 6 Highly Suitable ratings. The results indicate that smaller standalone refrigeration systems are relatively insensitive to city level climatic differences, whereas larger systems require greater consideration of local operating conditions.

Table 5.2: Climatic Suitability of Alternative Refrigerants for Selected Tier I Cities

Equipment Type	Recommended Refrigerants	Delhi NCR	Mumbai	Bengaluru	Chennai	Hyderabad	Kolkata	Pune	Ahmedabad
Beverage coolers	R-290, R-600a	HS	HS	HS	HS	HS	HS	HS	HS
Reach in refrigerators	R-290, R-600a	HS	HS	HS	HS	HS	HS	HS	HS
Chest freezers	R-290	HS	S	HS	S	HS	S	HS	HS
Vertical freezers	R-290, R-455A	HS	S	HS	S	HS	S	HS	HS
Open display cabinets	R-290, CO_2, R-455A	S	HS	HS	HS	S	HS	HS	S
Walk in cold rooms	CO_2, NH_3, NH_3/CO_2 cascade	S	MS	HS	MS	S	MS	HS	S

HS: Highly Suitable; S: Suitable; MS: Moderately Suitable.

Table 5.3: Climatic Suitability of Alternative Refrigerants for Selected Tier II Cities

Equipment Type	Recommended Refrigerants	Bhubaneswar	Rourkela	Guwahati	Jaipur	Lucknow	Indore	Coimbatore	Visakhapatnam	Chandigarh	Nagpur
Beverage coolers	R-290, R-600a	HS	HS	HS	HS	HS	HS	HS	HS	HS	HS
Reach in refrigerators	R-290, R-600a	HS	HS	HS	HS	HS	HS	HS	HS	HS	HS
Chest freezers	R-290	S	HS	S	HS	HS	HS	HS	S	HS	HS
Vertical freezers	R-290, R-455A	S	HS	S	HS	HS	HS	HS	S	HS	HS
Open display cabinets	R-290, CO_2, R-455A	HS	HS	S	HS	HS	HS	HS	HS	HS	S
Walk in cold rooms	CO_2, NH_3, NH_3/CO_2 cascade	MS	HS	MS	S	S	HS	HS	MS	S	S

The Tier II assessment shows the same 8 of 8 Highly Suitable rating for beverage coolers and reach in refrigerators (**Table 5.3**). Chest and vertical freezers are Highly Suitable in 5 of 8 cities, while open display cabinets achieve this rating in 7 of 8 cities, or 87.5% of the assessed locations. Walk in cold rooms are Highly Suitable in 3 of 8 cities, namely Rourkela, Indore and Coimbatore. Rourkela, Indore and Coimbatore each achieve 6 out of 6 Highly Suitable ratings. The numerical comparison therefore shows that Tier II cities are not inherently less suitable for efficient refrigeration. In fact, 3 of the 8 Tier II cities, compared with 2 of the 8 Tier I cities, receive Highly Suitable ratings across all six equipment categories. The distinction between the two groups is more evident in implementation readiness as indicated in **Table 5.4.**

Table 5.4: Tier I and Tier II Energy Performance Readiness

Performance Area	Tier I Cities	Tier II Cities
Equipment level monitoring	Greater readiness	Limited but increasing
Low GWP standalone equipment	Wider availability	Increasing availability
Advanced servicing	Better specialist access	More limited
Refrigerant recovery	Better infrastructure	Limited facilities
Data based maintenance	Greater potential	Early stage adoption
Integrated refrigeration systems	Suitable for selected stores	Dependent on local service capability

The comparison indicates that the principal Tier I advantage lies in access to monitoring, specialised servicing and refrigerant management rather than climatic performance itself. High efficiency standalone systems can therefore be introduced in both city groups, while larger integrated systems require greater attention to local service capability.

5.5 Energy Saving Opportunities

The study identifies an overall potential reduction of approximately 15 to 30% in refrigeration electricity consumption through a combination of load reduction, component efficiency, monitoring and maintenance. Since refrigeration represents approximately 45 to 65% of store electricity consumption, this corresponds approximately to a 7 to 20% reduction in total store electricity use where the full refrigeration saving is realised and other store loads remain unchanged as listed in **Table 5.5**.

Table 5.5: Principal Refrigeration Energy Saving Opportunities

Measure	Indicative Energy Benefit	Principal Mechanism
Closed door refrigerated cabinets	~40 to 45% refrigeration energy	Reduced ambient air infiltration
LED cabinet lighting	~40 to 80% lighting energy	Reduced electrical input and internal heat gain
High efficiency fans EC condenser fans	>10% fan energy ~15 to 30% fan energy	Reduced motor consumption Efficient variable speed operation
Efficient R290 based replacement equipment	~10 to 20%	Improved refrigeration system efficiency
Preventive maintenance	Site dependent	Restoration of equipment performance
Energy monitoring	Site dependent	Identification of inefficient operation

Among the measures considered, closed door refrigerated cabinets provide one of the largest individual opportunities, with approximately 40 to 45% reduction in refrigeration energy compared with comparable open configurations. This saving arises mainly from reduced infiltration of warm and humid ambient air [20]. LED cabinet lighting provides approximately 40 to 80% reduction in lighting electricity, while high efficiency fans can reduce fan energy by more than 10%. EC condenser fans provide approximately 15 to 30% savings in fan electricity through efficient variable speed operation. Appropriate replacement with efficient R290 equipment can provide approximately 10 to 20% improvement, depending on the baseline equipment [18]. Emerging technologies can provide further improvements in energy management.

5.6 Emerging and Advanced Technologies

There are five emerging technology groups for energy efficient refrigeration system operations. Low GWP natural refrigerant systems and AI/IoT refrigeration are assessed at TRL 9, heat recovery at TRL 8, PCM thermal energy storage at TRL 7, and digital twin technology at TRL 6. The figure indicates an application dependent energy saving potential of up to approximately 20% for the emerging technology portfolio. Natural refrigerant systems based on R-290 and CO_2/R744 are the most mature options considered, with TRL 9 readiness. R-290 is particularly relevant to standalone systems, while CO_2 is better suited to larger integrated refrigeration applications where appropriate design and servicing capability are available [18,24,25,27]. AI and IoT refrigeration is also assessed at TRL 9. Rather than producing cooling directly, these systems reduce avoidable energy use by identifying abnormal compressor operation, temperature deviations and equipment faults.

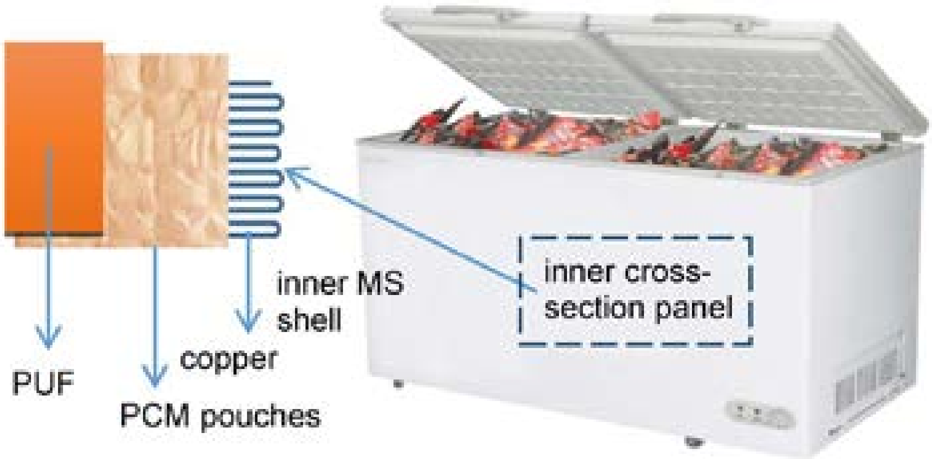


Figure 5.2: PCM Based Thermal Energy Storage Integrated with a Refrigerated Freezer Cabinet.

Figure 5.2 shows the integration of PCM pouches within the refrigerated cabinet structure. PCM technology is assessed at TRL 7, placing it below commercially mature monitoring and natural refrigerant technologies but above digital twins in technology readiness. The stored latent cooling can reduce temperature fluctuations and support the cabinet during compressor off periods or short duration peak loads [28].

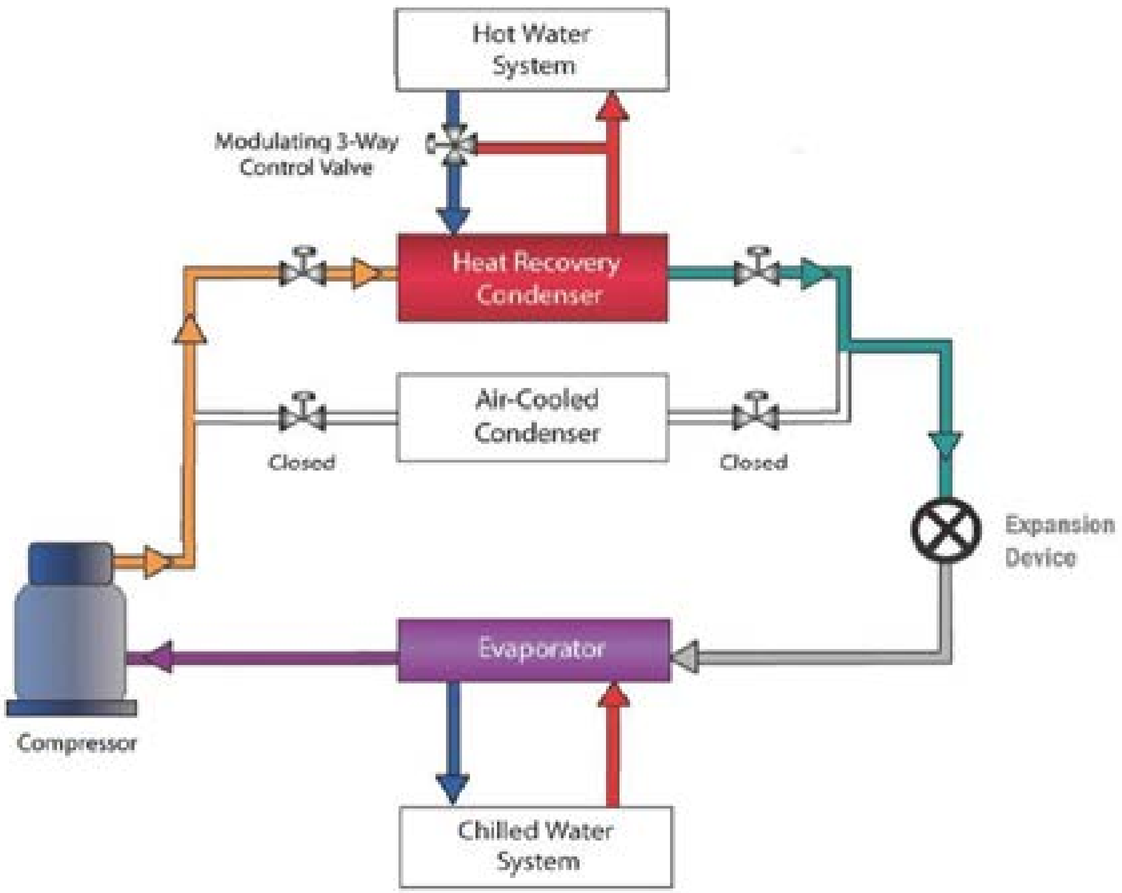


Figure 5.3: Heat Recovery Refrigeration System for Simultaneous Cooling and Hot Water Production.

Figure 5.3 shows the use of condenser heat for useful hot water production. Heat recovery is assessed at TRL 8, indicating relatively high technology maturity. The system does not eliminate the refrigeration load; instead, it recovers part of the heat that would otherwise be rejected to ambient. The approach is therefore most useful where refrigeration and hot water demand occur simultaneously [29]. **Figure 5.4** presents a thermally driven adsorption refrigeration arrangement in which biomass energy provides the principal driving heat. Unlike conventional vapour compression systems, the technology can substitute part of the electrical compressor requirement with thermal energy. Its application is more appropriate for walk in cold rooms and larger refrigerated facilities than for small standalone cabinets. Pumps, fans and controls continue to require electrical input. A fixed saving percentage or TRL has not been assigned because performance depends strongly on the heat source, adsorption pair, operating temperature and system scale.

Figure 5.4: Biomass Driven Adsorption Refrigeration System for Cold Room and Refrigeration Intensive Applications.

Overall, Digital twin technology has the lowest maturity among the technologies assigned a TRL in the present assessment, at TRL 6 **(Table 5.6)**. It is therefore more appropriate for initial deployment in organised and highly instrumented facilities where sufficient operating data are available for predictive diagnostics and control optimisation. The numerical comparison shows a clear progression in technology maturity. Two technologies are already at TRL 9, one at TRL 8, one at TRL 7 and one at TRL 6 as listed in **Table 5.6**. Immediate deployment can therefore focus on natural refrigerants, efficient components and smart monitoring, while PCM storage, heat recovery and digital twins can be introduced selectively according to store scale and operating requirements.

Table 5.6: Comparative Assessment of Emerging Refrigeration Technologies

Technology	Maturity	Principal Benefit	Relevant Application
Low GWP natural refrigerant systems	TRL 9	Efficient cooling with reduced direct climate impact	Standalone and integrated systems
AI/IoT refrigeration	TRL 9	Monitoring and operational optimisation	Organised store networks
Heat recovery refrigeration	TRL 8	Utilisation of condenser heat	Stores with useful heating demand
PCM thermal energy storage	TRL 7	Thermal buffering and peak load management	Freezers and refrigerated cabinets
Digital twin technology	TRL 6	Predictive diagnostics and optimisation	Advanced organised facilities
Biomass driven adsorption refrigeration	Application specific	Reduced grid electricity dependence	Cold rooms and larger refrigerated facilities

CHAPTER 6

SAFETY STANDARDS AND REGULATORY FRAMEWORK

Safety Standards

Regulatory Requirements

Refrigerant Safety

Installation & Servicing Compliance

Environmental Compliance

Policy & Compliance Framework

Chapter 6: Safety Standards and Regulatory Framework

Convenience store refrigeration is governed by requirements covering equipment safety, refrigerant classification, installation, servicing, electrical and fire safety, energy efficiency, food safety and environmental management. Since the stores assessed in this study use equipment ranging from standalone beverage coolers and freezers to refrigerated display cabinets and walk in cold rooms, the applicable requirements vary with equipment type, refrigerant, capacity and installation configuration. The regulatory assessment therefore considers the complete refrigeration life cycle, from equipment selection and installation to operation, servicing, refrigerant management and end of life handling.

6.1 Refrigeration Equipment and Safety Standards

The principal safety requirements applicable to convenience store refrigeration are summarised in **Table 6.1.** The eight standards and standard parts address commercial appliance safety, system classification, design, installation, operation, maintenance, refrigerant classification and personnel competence **[30,31].**

Table 6.1: Essential Refrigeration Safety Standards [30, 31]

Standard/Framework	Application	Relevance
IS 18689:2024	Safety of commercial refrigerating appliances and ice makers	Essential
IS 16678 (Part 1):2018 / ISO 51491:2014	Definitions, classification and selection criteria	Essential
IS 16678 (Part 2):2018 / ISO 51492:2014	Design, construction, testing, marking and documentation	Essential
IS 16678 (Part 3):2018 / ISO 51493:2014	Installation site and personal protection	Essential
IS 16678 (Part 4):2024 / ISO 51494:2022	Operation, maintenance, repair and refrigerant recovery	Essential
IS 16656:2017 / ISO 817:2014	Refrigerant designation and safety classification	Essential
IS 5610:2025	Refrigerant quality, testing, packaging and marking	Essential
IS 18847:2024 / ISO 22712:2023	Competence of refrigeration personnel	Essential

As indicated in **Table 6.1**, IS 16678 provides a four part framework extending from system classification and design to installation, operation, maintenance and refrigerant recovery. IS 16656 provides the basis for refrigerant designation and safety classification. These provisions become increasingly relevant as convenience store refrigeration moves towards low GWP refrigerants with different flammability and toxicity characteristics **[30,31].** The applicable standard also varies with equipment configuration. **Table 6.2** summarises the equipment specific standards relevant to the refrigeration systems identified in the study.

Table 6.2: Equipment Specific Standards Applicable to Convenience Store Refrigeration [30]

Equipment/Application	Applicable Standard	Relevance
Commercial beverage coolers/ visi coolers	IS 2167:2025/ISO 22044:2021, MOD	Essential when present
Top access deep freezers up to 1,000 L	IS 7872:2020	Essential when present
Refrigerated display cabinets	IS 16672 (Part 2):2024/ ISO 239532:2015	Essential when present
Professional refrigerated storage cabinets and counters	IS 18801:2023 / ISO 22041:2019	Conditional
Walk in cold rooms, 5–200 kL	IS 2370:2014	Essential when applicable
Cold room thermal insulation	IS 661:2019	Essential for cold rooms
Selfcontained automatic ice makers	IS 11328:2022	Conditional
Refrigerant condensing units	IS 11327:2022	Conditional
Professional blast chillers and blast freezers	IS 18802:2023 / ISO 22042:2021	Conditional
Household and similar refrigerating appliances	IS 17550 (Part 1):2024	Where domestic type equipment is used

Table 6.2 covers 10 equipment and application categories. IS 7872:2020 applies to top access deep freezers up to 1,000 L, whereas IS 2370:2014 covers applicable walk in cold rooms within the 5–200 kL range. Cold rooms additionally require attention to thermal insulation under IS 661:2019. This equipment specific approach is necessary because a beverage cooler, deep freezer, display cabinet and cold room cannot be assessed using a common equipment standard. The component level requirements supporting equipment compliance are presented in **Table 6.3.**

Table 6.3: Refrigeration Component Standards [30]

Component	Applicable Standard	Application
Hermetic motor compressors	IS 10617:2018	Compressor performance
Desiccant driers and filter driers	IS 12249:2021	Moisture and contaminant control
Thermostatic expansion valves	IS 10594:2021	Refrigerant flow control
Electronic expansion valves	IS 18932:2024	Electronic refrigerant flow control
Refrigeration oil separators	IS 11330:2021	Oil separation
Condensing units	IS 11327:2022	Remote refrigeration systems

The six component standards in Table 6.3 cover key elements of the refrigeration circuit. Component conformity alone is not sufficient; refrigerant compatibility, design pressure, operating temperature and system configuration also need to be considered during selection and replacement.

6.2 Refrigerant Handling and Alternative Refrigerant Safety

Refrigerant safety extends beyond equipment operation to refrigerant identification, charging, recovery, recycling, storage and technician competence. The principal requirements are consolidated in Table 6.4 [30,31].

Table 6.4: Refrigerant Handling and Servicing Requirements [30, 31]

Standard/Framework	Application	Relevance
IS 16678 (Part 4):2024	Operation, maintenance, repair and recovery	Essential
IS 18847:2024 / ISO 22712:2023	Technician competence	Essential
IS/ISO 11650:1999	Recovery and recycling equipment	Service providers
IS 5610:2025	Refrigerant quality and packaging	Essential
IS 16656:2017 / ISO 817:2014	Refrigerant identification and safety classification	Essential
IS 4379:2021	Identification of industrial gas cylinder contents	Conditional
IS 3710:1978	Filling ratios for low pressure liquefiable gases	Conditional

As shown in Table 6.4, refrigerant management involves seven principal requirements covering both the refrigerant and the servicing process. Correct identification and classification should precede charging or recovery, while competent personnel and appropriate recovery equipment are necessary during maintenance and end of life handling. The requirements become more specific when alternative refrigerants are considered. Table 6.5 summarises the standards relevant to specialist and alternative refrigerants.

Table 6.5: Standards Relevant to Specialist and Alternative Refrigerants [30, 31]

Standard/Framework	Application	Relevance
IS 18689:2024	Commercial appliances using applicable flammable refrigerants	Essential where applicable
IS 16678 Parts 1–4	System safety across refrigerant safety classes	Essential where applicable
IS 17773:2022	Closed circuit ammonia refrigeration systems	Ammonia systems
IS 16656:2017 / ISO 817:2014	Refrigerant safety classification	Essential
IS 5610:2025	Refrigerant specification	Essential

Table 6.5 highlights that environmental performance cannot be considered independently of safety. For example, R-290 offers very low GWP but requires equipment, installation and servicing practices appropriate to a flammable refrigerant. The preferred transition pathway is therefore the deployment of equipment designed and certified for the intended refrigerant rather than uncontrolled field conversion of existing systems.

6.3 Building, Electrical, Fire and Cylinder Safety

Refrigeration installations form part of the wider building environment. Their safe operation therefore depends on appropriate ventilation, electrical installations, fire protection and refrigerant storage arrangements. The building and cold room requirements relevant to convenience stores are summarised in Table 6.6.

Table 6.6: Building and Cold Room Safety Requirements [30]

Standard/Framework	Application	Relevance
SP 7:2026, Part D, Section 2	Electrical and allied installations	Relevant
SP 7:2026, Part D, Section 3	Mechanical ventilation and cold store refrigeration	Relevant
SP 7:2026, Part F	Fire and life safety	Relevant
SP 7:2026, Group FI	Mercantile building classification	Relevant
IS 2370:2014	Walk in cold rooms	Conditional
IS 661:2019	Cold room insulation	Conditional
IS 3594:2024	Warehousing and cold storage fire safety	Applicable to relevant facilities

As indicated in **Table 6.6**, cold room compliance extends beyond the refrigeration machinery to enclosure insulation, ventilation and building safety. Cold storage specific requirements should therefore be applied according to the actual installation and not uniformly to all convenience stores. Electrical requirements are summarised in **Table 6.7**.

Table 6.7: Electrical Safety Requirements [30]

Standard/Framework	Application	Relevance
IS 732:2019	Electrical wiring installations	Relevant
IS 3043:2018	Electrical earthing	Relevant
IS 1646:2015	Fire safety of electrical installations	Relevant
IS 302 (Part 1):2024 / IEC 603351:2020	General electrical appliance safety	General reference
IS 18689:2024	Commercial refrigeration appliance safety	Principal refrigeration reference

The five references in **Table 6.7** address wiring, earthing, electrical fire protection and appliance safety. These provisions are important because refrigeration equipment generally operates continuously or for extended periods, making adequate electrical protection integral to equipment reliability and fire risk management. The broader fire protection requirements are given in **Table 6.8**.

Table 6.8: Fire and Life Safety Requirements [30]

Standard/Framework	Application	Relevance
SP 7:2026, Part F	Fire and life safety	Principal reference
IS 1641:2013	Fire grading and classification	Supporting
IS 1642:2013	Fire safety of building construction	Supporting
IS 1644:2013	Exit requirements and personal hazards	Supporting
IS 1646:2015	Fire safety of electrical installations	Supporting
IS 2189:2026	Fire detection and alarm systems	Where required
IS 2190:2024	Portable and mobile fire extinguishers	Where required
IS 15105:2021	Automatic sprinkler systems	Where required
IS 3844:1989	Internal hydrants and hose reels	Where required
IS 3594:2024	Warehouses and cold storage premises	Applicable to relevant facilities

The 10 references in **Table 6.8** have different levels of applicability. Fire detection, extinguishers, sprinklers and hydrants should be determined according to the building configuration and applicable fire provisions. Cold storage specific requirements apply only where the premises fall within their intended scope. Refrigerant cylinders introduce additional requirements during storage, transport and servicing. These are presented in **Table 6.9.**

Table 6.9: Refrigerant Cylinder, Storage and Handling Requirements [30, 32]

Standard/Framework	Application	Relevance
Gas Cylinders Rules, 2016, as amended	Filling, storage, possession, transport and handling	Statutory where applicable
SMPV (Unfired) Rules, 2016, as amended	Bulk pressure storage installations	Conditional
IS 3196 (Part 2):2006	Welded cylinders above 5 L for specified liquefiable gases	Conditional
IS 3710:1978	Filling ratios for low pressure liquefiable gases	Conditional
IS 4379:2021	Identification of industrial gas cylinder contents	Conditional
IS 1260 (Part 1):1973	Pictorial marking for dangerous goods	Conditional

As shown in Table 6.9, cylinder safety covers filling, possession, storage, transportation, identification and marking. These requirements are particularly relevant to technicians, service organisations and facilities storing refrigerants. The Gas Cylinders Rules, 2016 provide the principal statutory framework for applicable cylinders [32].

6.4 Energy Efficiency and Food Safety Requirements

Energy efficiency forms an additional regulatory consideration because refrigeration operates for long periods and can represent a substantial share of store electricity consumption. The relevant energy efficiency frameworks are summarised in Table 6.10.

Table 6.10: Energy Efficiency Frameworks Relevant to Convenience Store Refrigeration [33]

Standard/Framework	Application	Relevance
Energy Conservation Act, 2001, as amended	National energy efficiency framework	Statutory framework
BEE Schedule 37	Commercial beverage coolers	Directly relevant
Applicable BEE requirements for deep freezers	Energy performance and labelling	Where notified/ applicable
ISO 50001:2018/Amd 1:2024	Energy management systems	Voluntary
ISO 500021:2025	Energy audit principles	Voluntary
ISO 500022:2025	Building energy audits	Voluntary
ISO 500023:2025	Process energy audits	Voluntary
ISO 50006:2023	Energy baselines and performance indicators	Voluntary

Table 6.10 distinguishes equipment related energy efficiency requirements from voluntary energy management frameworks. BEE requirements are directly relevant to applicable commercial refrigeration equipment, while the ISO 50000 series provides a structured basis for energy auditing, baselining and performance monitoring, particularly for organised multi outlet store networks **[33].** Refrigeration performance is also directly linked with food safety because chilled and frozen products must remain within appropriate storage conditions. The relevant requirements are summarised in **Table 6.11.**

Table 6.11: Food Safety and Temperature Management Frameworks [34]

Standard/Framework	Application	Relevance
Food Safety and Standards Act, 2006	Food safety legislation	Statutory
FSSAI Licensing and Registration Regulations, 2011, Schedule 4	Hygiene, storage and temperature management	Statutory where applicable
Codex CXC 11969, revised through 2022	General principles of food hygiene and HACCP	International guidance
ISO 22000:2018/Amd 1:2024	Food safety management systems	Voluntary
ISO 22005:2007	Food chain traceability	Voluntary

As shown in **Table 6.11,** refrigeration has a dual function: maintaining equipment performance and preserving temperature sensitive products. Appropriate storage conditions and temperature management should therefore form part of routine store operation rather than being considered only as equipment performance parameters **[34].**

6.5 Environmental and End of Life Requirements

Environmental requirements become important during refrigerant transition, servicing and equipment retirement. The applicable frameworks are consolidated in **Table 6.12**.

Table 6.12: Environmental and End of Life Frameworks [35, 36]

Standard/Framework	Application	Relevance
Environment (Protection) Act, 1986	Parent environmental legislation	Statutory
ODS (Regulation and Control) Rules, 2000, as amended	Control of ozone depleting substances	Statutory
Montreal Protocol	ODS phase out	International policy framework
Kigali Amendment	HFC phasedown	International policy framework
E Waste (Management) Rules, 2022, as amended	End of life equipment where covered	Statutory
Hazardous and Other Wastes Rules, 2016, as amended	Applicable classified waste streams	Conditional
ISO 14001:2015/Amd 1:2024	Environmental management	Voluntary
ISO 14040:2006 and ISO 14044:2006	Life cycle assessment	Voluntary
ISO 14067:2018	Product carbon footprint	Voluntary

As indicated in Table 6.12, the environmental framework extends from control of ozone depleting substances to HFC phasedown and end of life equipment management. The ODS Rules provide the domestic regulatory basis for controlling ozone depleting substances, while the Montreal Protocol and its Kigali Amendment establish the international framework for ODS phase out and HFC phasedown [35,36]. Refrigerant recovery before equipment dismantling or disposal is particularly important. Environmental performance should therefore consider both indirect emissions associated with electricity consumption and direct emissions resulting from refrigerant leakage or release.

CHAPTER 7

MARKET, SUPPLY CHAIN AND SERVICE TECHNICIAN ECOSYSTEM

Market Landscape

Supply Chain Stages

Equipment Availability & Manufacturers

Tier I vs Tier II Market Differences

Technician Ecosystem

Refrigerant Recovery & Good Practices

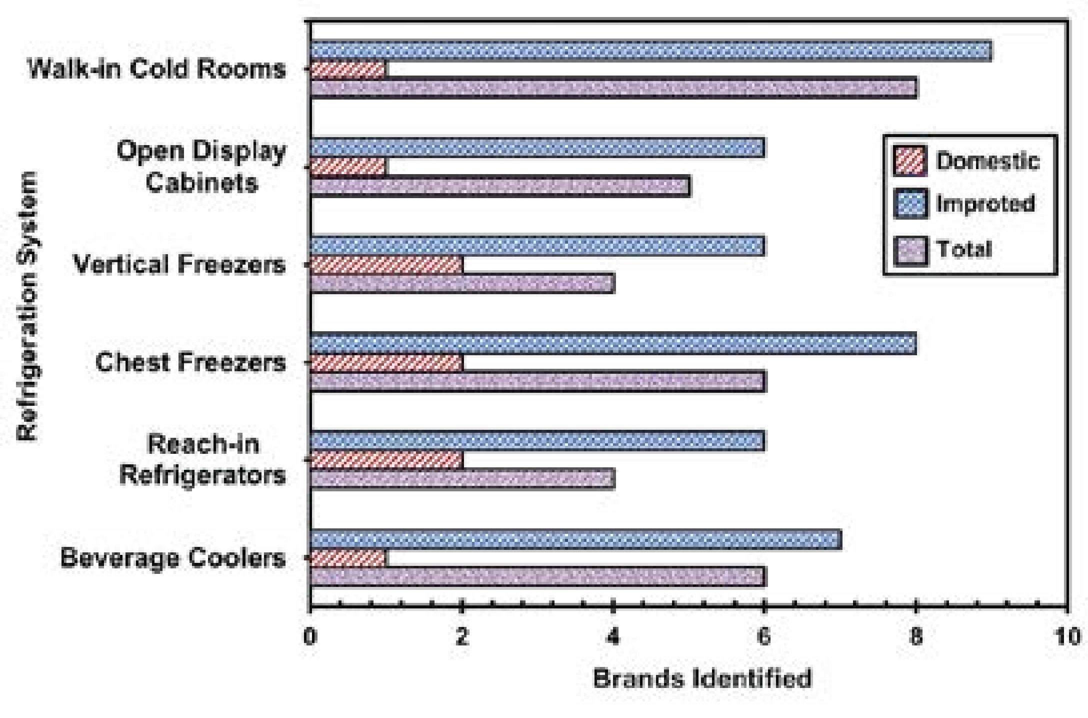
Chapter 7: Market, Supply Chain and Service Technician Ecosystem

The convenience store refrigeration sector is supported by manufacturers, suppliers, dealers, service providers and technicians. The study assessed this ecosystem through interactions with around 500 stakeholders, including technicians, refrigeration professionals, suppliers, dealers and service personnel across selected Tier I and Tier II locations. The assessment covered equipment and spare part availability, servicing, technician skills, refrigerant recovery and preparedness for low GWP technologies. The findings indicate that basic refrigeration equipment is generally available, but specialised equipment and the supporting service ecosystem require greater technical capability and infrastructure. This becomes increasingly important as the sector moves towards lower GWP refrigerants and more advanced refrigeration systems.

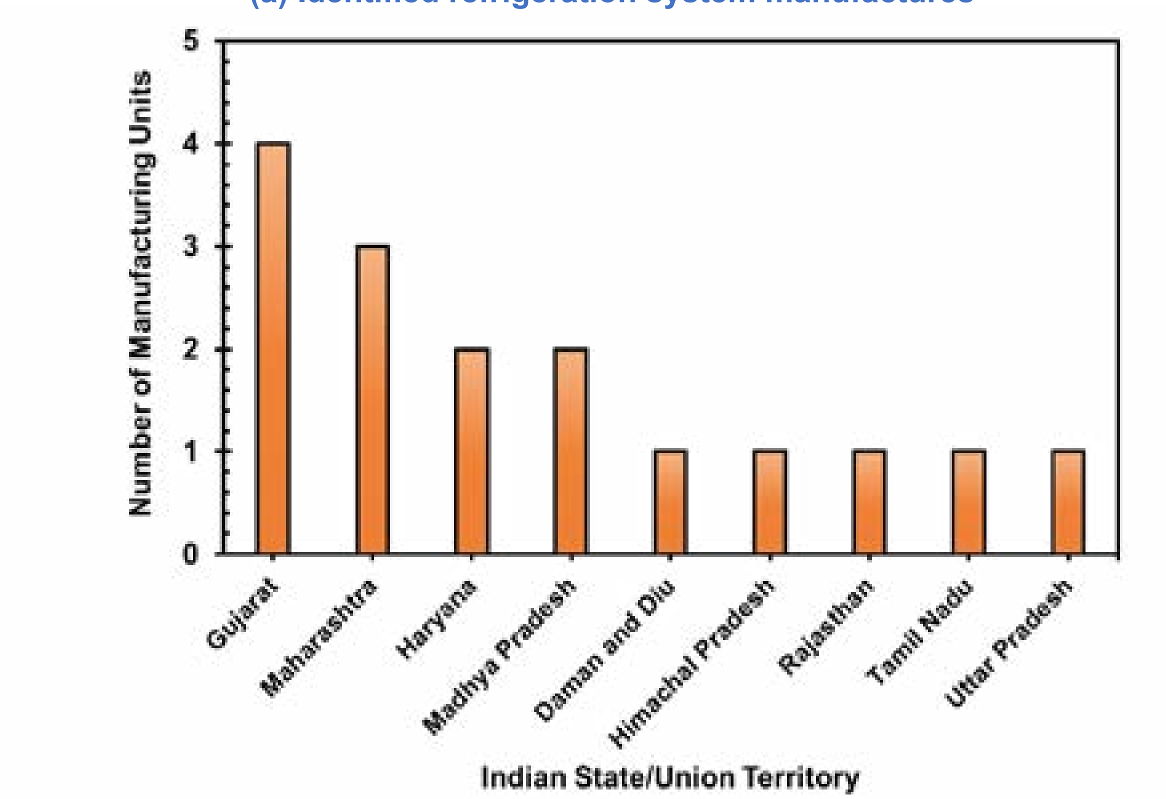
7.1 Basic Equipment Availability and Specialised Service Needs

The survey indicates that commonly used standalone equipment has a relatively established supply network. Beverage coolers, reach-in refrigerators, chest freezers and vertical freezers are available through relatively broad supply channels. In contrast, open display cabinets and walkin cold rooms depend more on specialized suppliers, installers and service contractors. The refrigeration supply chain extends beyond the initial purchase and installation of equipment. Continued operation also depends on the availability of spare parts, refrigerants, servicing tools and competent technicians. Refrigerant recovery and responsible disposal become important during major servicing and at the end of equipment life. Figure 7.1 illustrates these different stages of the equipment and service supply chain.

Figure 7.1: Refrigeration Equipment and Service Supply Chain.



(a) Identified refrigeration system manufactures



(b) Manufacturing units in each state

Figure 7.2: Manufacturers Available by Refrigeration Equipment Category.

Figure 7.2 shows the manufacturers identified across the six principal refrigeration equipment categories. The findings indicate wider manufacturer availability for commonly used standalone equipment and a more specialized supplier base for open display cabinets and walkin cold rooms. For the transition to low GWP refrigeration, equipment availability alone is therefore not sufficient. Compatible components, spare parts, refrigerants, servicing tools and technical support also need to be available. This is particularly relevant for R-290, CO_2 and other low GWP technologies that require refrigerantspecific knowledge and servicing capability [37, 38].

7.2 Specialised Service and Support Infrastructure Differences

The study compared selected Tier I and Tier II cities across equipment availability, low GWP equipment, spare parts, service networks, technician training, specialist tools, refrigerant recovery and service response. The comparison indicates that basic standalone refrigeration equipment is generally available in both Tier I and Tier II markets. The differences are more visible in specialized equipment and supporting services.

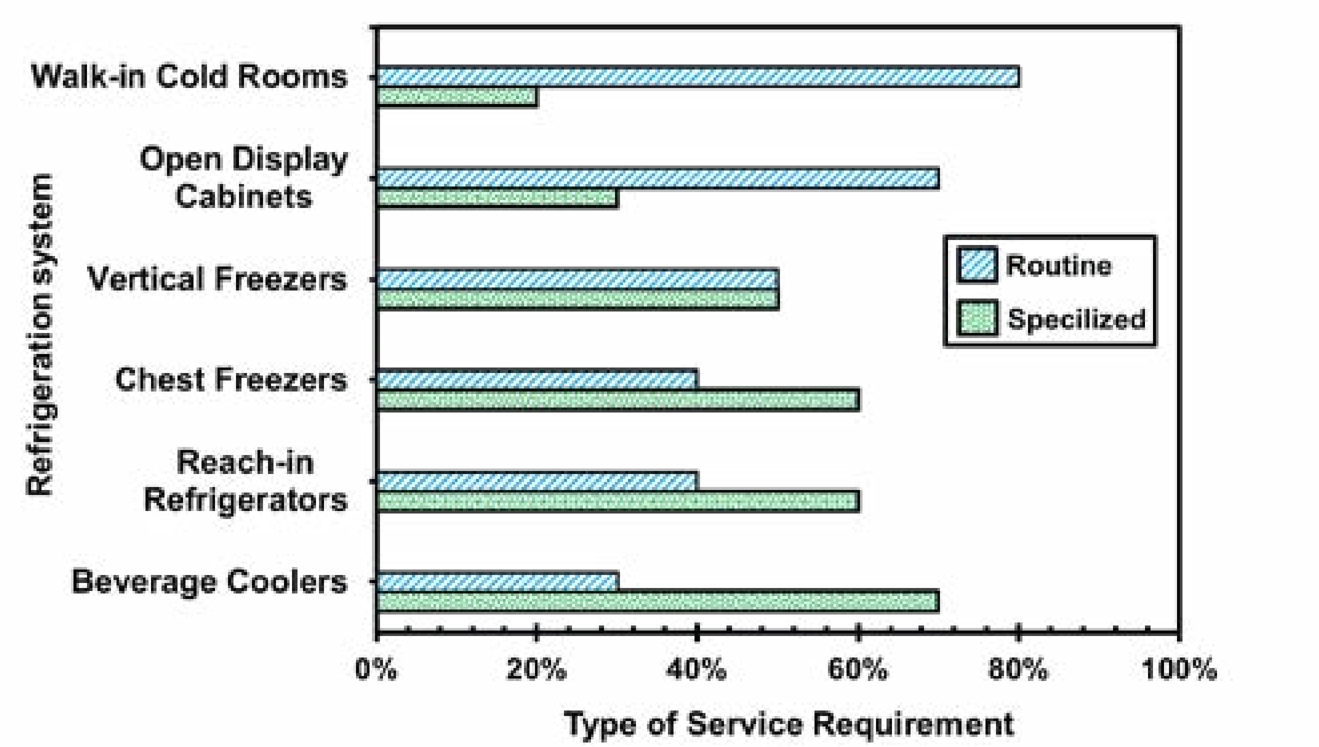
Table 7.1: Tier I and Tier II Refrigeration Market and Supply Chain Differences

Assessment Area	Tier I Cities	Tier II Cities
Equipment availability	Range of brands and technologies	Availability of selected models
Low GWP equipment	Availability and supplier awareness	Availability and lead time
Spare parts	Authorised and independent supply	Dependence on regional distributors
Service network	Manufacturer and third party services	Independent technicians
Technician training	Access to formal training	Dependence on workplace learning
Specialist tools	Availability and use	Availability and affordability
Refrigerant recovery	Access to equipment and facilities	Limited infrastructure
Response time	Service coverage and contractual support	Travel and logistics constraints

Tier I cities generally showed wider equipment and technology choices, greater supplier awareness of low GWP alternatives, stronger spare parts networks and better access to manufacturer supported and third party servicing (Table 7.1). Tier II cities showed greater dependence on regional distributors and independent technicians. Access to specialist tools, formal training and refrigerant recovery facilities was also more limited in the surveyed Tier II locations. As a result, the main difference between the two city categories is in servicing and support infrastructure rather than the basic availability of refrigeration equipment. This distinction is important for low GWP technologies, as their continued use requires not only equipment availability but also technicians, tools and servicing infrastructure.

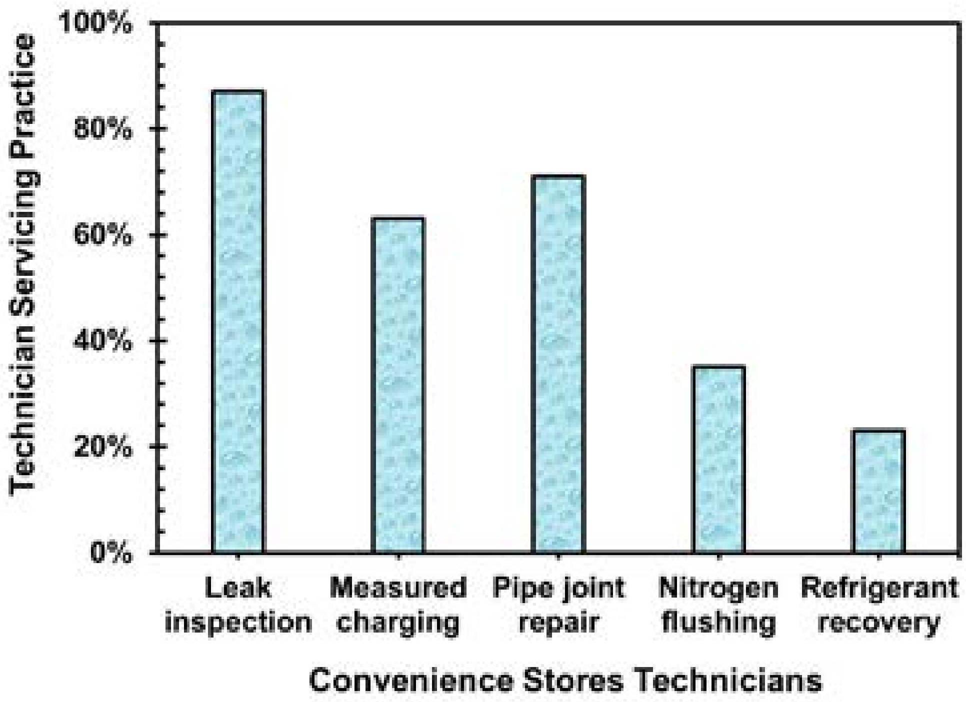
7.3 Technician Servicing Practices

The technician survey examined routine maintenance, refrigerant handling and recovery, availability of servicing tools, and preparedness to work with alternative refrigerants. The survey found that routine repair and maintenance practices were more commonly followed, while specialized practices such as refrigerant recovery, documentation and the use of specialized equipment were less consistently followed. Refrigerant recovery emerged as a significant gap. Only about 25% of the surveyed commercial technicians reported practicing refrigerant recovery, meaning that approximately 75% did not report recovery as a routine servicing practice. Figure 7.3 also shows that servicing requirements vary across equipment types. More specialized systems, such as walking cold rooms and open display cabinets, require greater technical capability than simpler standalone equipment.



(a) Service requirement for different refrigeration systems

The transition to lower GWP refrigerants will further increase the need for appropriate servicing practices. R-290 requires procedures suited to its flammability characteristics, while CO_2 systems require knowledge of different operating pressures, components and system configurations. Technician capability therefore needs to develop alongside the adoption of these technologies.



(b) Technician survey undertaken in the convenience stores

Figure 7.3: Technician Servicing Practice Benchmarks for Convenience Store Refrigeration in India.

7.4 Technician Ecosystem Gaps

The survey found that 36% of the assessed technicians had received relevant technical training, indicating a reported training gap of approximately 64%. In practical terms, almost two out of every three technicians in the assessed sample had not received the relevant structured training **(Figure 7.4)**. This gap becomes more important as refrigeration systems increasingly use low GWP refrigerants, electronic controls, variable speed components and digital monitoring. However, training alone may not be sufficient to improve servicing practices. The survey suggests that technicians also need access to appropriate tools, refrigerant recovery equipment, standard servicing procedures and practical experience. This is particularly relevant to convenience stores because a single outlet may contain equipment of different ages, manufacturers, capacities and refrigerant types. Technicians therefore need to be able to identify equipment and refrigerants, diagnose electrical and refrigeration problems, detect leaks, charge systems correctly, recover refrigerants and carry out safe servicing **[37]**.

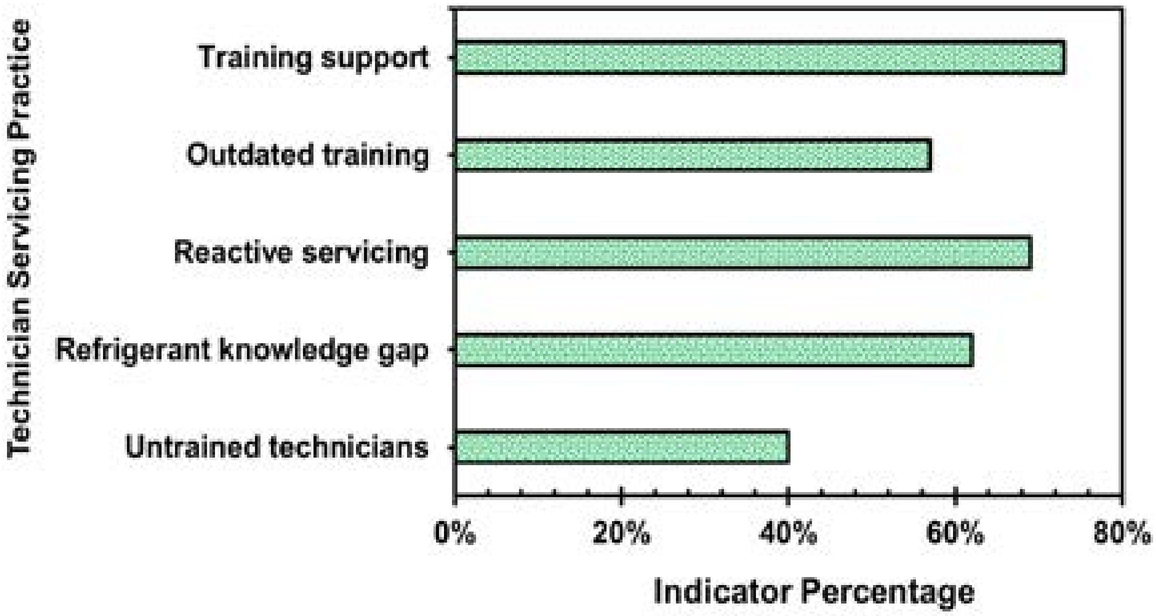


Figure 7.4.: Technician Ecosystem Gaps in India.

7.5 Key Gaps and Service Priorities for Low GWP Refrigeration Transition

The survey identified six key market and service gaps that may affect the adoption and continued operation of low GWP refrigeration in convenience stores (Table 7.2). The findings relate to technician capability, refrigerant management, service economics, customer preferences and equipment records.

Table 7.2: Key Gaps and Service Priorities in the Convenience Store Refrigeration Ecosystem

Key gap	Survey evidence	Consequence for convenience stores	Required intervention
Limited technical training	Only 36% of assessed technicians reported receiving relevant technical training.	Limited ability to safely install, maintain and troubleshoot newer refrigeration systems and alternative refrigerants.	Strengthen commercial refrigeration training, including practical training on low GWP refrigerants and newer equipment.
Gaps in refrigerant recovery	Only about 25% of surveyed commercial technicians reported practising refrigerant recovery as part of routine servicing.	Refrigerant may be released during servicing, and stores may have limited access to responsible recovery services.	Improve access to recovery equipment and strengthen training and procedures for refrigerant recovery.
Low service margins	Technicians reported limited returns from servicing, particularly where customers are reluctant to pay for preventive maintenance.	May discourage investment in technician training, specialist tools and preventive servicing.	Promote preventive maintenance and develop service models that support investment in skills and equipment.

Key gap	Survey evidence	Consequence for convenience stores	Required intervention
Customer price sensitivity	Equipment purchase decisions are influenced strongly by upfront cost, particularly among smaller stores.	Lower initial cost may be prioritised over energy efficiency, refrigerant choice and longer term operating costs.	Increase awareness of lifecycle costs, energy savings and the benefits of efficient, lowerGWP equipment.
Weak service records	Equipment level records covering refrigerant type, charge, servicing and leakage are not consistently maintained.	Difficult to track equipment performance, refrigerant use, recurring faults and maintenance history.	Encourage simple equipment and service records covering refrigerant, servicing, leakage and component replacement.
Limited knowledge of alternative refrigerants	The assessment identified gaps in technician knowledge and practical experience with alternative refrigerants.	May limit safe adoption and servicing of systems using R-290, CO_2 and other lower GWP refrigerants.	Provide refrigerant specific training covering safe handling, servicing procedures, tools and system requirements.

The findings indicate that convenience stores need more than the availability of suitable equipment to transition to low GWP refrigeration. Four of the six identified gaps relate directly to technical and servicing capability, while the remaining gaps relate mainly to service economics and customer preferences. This highlights the need to strengthen technician skills, servicing capacity and supporting infrastructure alongside the availability of low GWP equipment. The survey also identified a need for better equipment level records, including refrigerant type and charge, servicing history, refrigerant additions, leakage repairs and component replacements. Such records can improve traceability and help identify recurring equipment problems. Strengthening these areas can help ensure that new refrigeration technologies are operated and maintained safely and effectively [37–39].

CHAPTER 8

GLOBAL REFRIGERATION TRANSITION AND INTERNATIONAL BEST PRACTICES

Global Refrigerant Transition Trends

International Case Studies

Energy Efficiency & System Design

Technician Training & Competence

Monitoring & Digitalization

Responsible Refrigerant Management

Chapter 8: Global Refrigeration Transition and International Best Practices

Global commercial refrigeration is progressively transitioning towards energy efficient equipment, low GWP refrigerants, refrigerant specific safety, preventive maintenance, performance monitoring, technician competence and responsible refrigerant recovery. International experience demonstrates that refrigerant transition cannot be achieved through refrigerant substitution alone. Equipment design, climatic performance, installation quality, operation and maintenance, servicing capability and end of life refrigerant management collectively determine the energy and environmental performance of refrigeration systems [40–42]. This chapter therefore examines the global direction of refrigerant transition, selected international experiences and the lessons relevant to Indian convenience stores.

8.1 Global Direction of Refrigerant Transition

Commercial refrigeration is progressively moving from HCFC and high GWP HFC based systems towards lower GWP alternatives. The transition is application specific because refrigeration requirements vary considerably between small factory sealed cabinets, multiple cabinet retail systems and larger centralised refrigeration installations. For small standalone equipment, R-290 and R-600a have become important alternatives because of their very low GWP and favourable thermodynamic characteristics. These refrigerants are particularly relevant to factory designed beverage coolers, refrigerators and freezers. For larger commercial refrigeration applications, CO_2 (R-744) is increasingly used, while NH_3 (R-717), CO_2 and NH_3/CO_2 cascade configurations remain relevant to suitable larger cold storage and industrial applications [40,41]. These technology directions are consistent with the global trends identified in the existing assessment.

The refrigerant transition is also being accompanied by improvements in compressors, heat exchangers, insulation, fans, electronic controls and monitoring. Consequently, the environmental benefit of adopting a low GWP refrigerant needs to be considered together with equipment energy consumption, refrigerant leakage, maintenance requirements and lifecycle performance. As illustrated in Figure 8.1, the global transition can be represented through five interconnected stages: legacy refrigeration systems, high efficiency equipment, low GWP refrigerants, advanced controls and monitoring, and refrigerant recovery and lifecycle management. Three broad technology pathways are evident: R-290 and R-600a for smaller standalone equipment; CO_2 and other lower GWP alternatives for larger commercial systems; and NH_3, CO_2 and cascade configurations for larger cold storage applications. Figure 8.1 demonstrates that there is no single refrigerant or refrigeration architecture suitable for every application. Technology selection therefore needs to consider refrigeration capacity, operating temperature, climate, refrigerant safety, servicing capability and lifecycle energy performance.

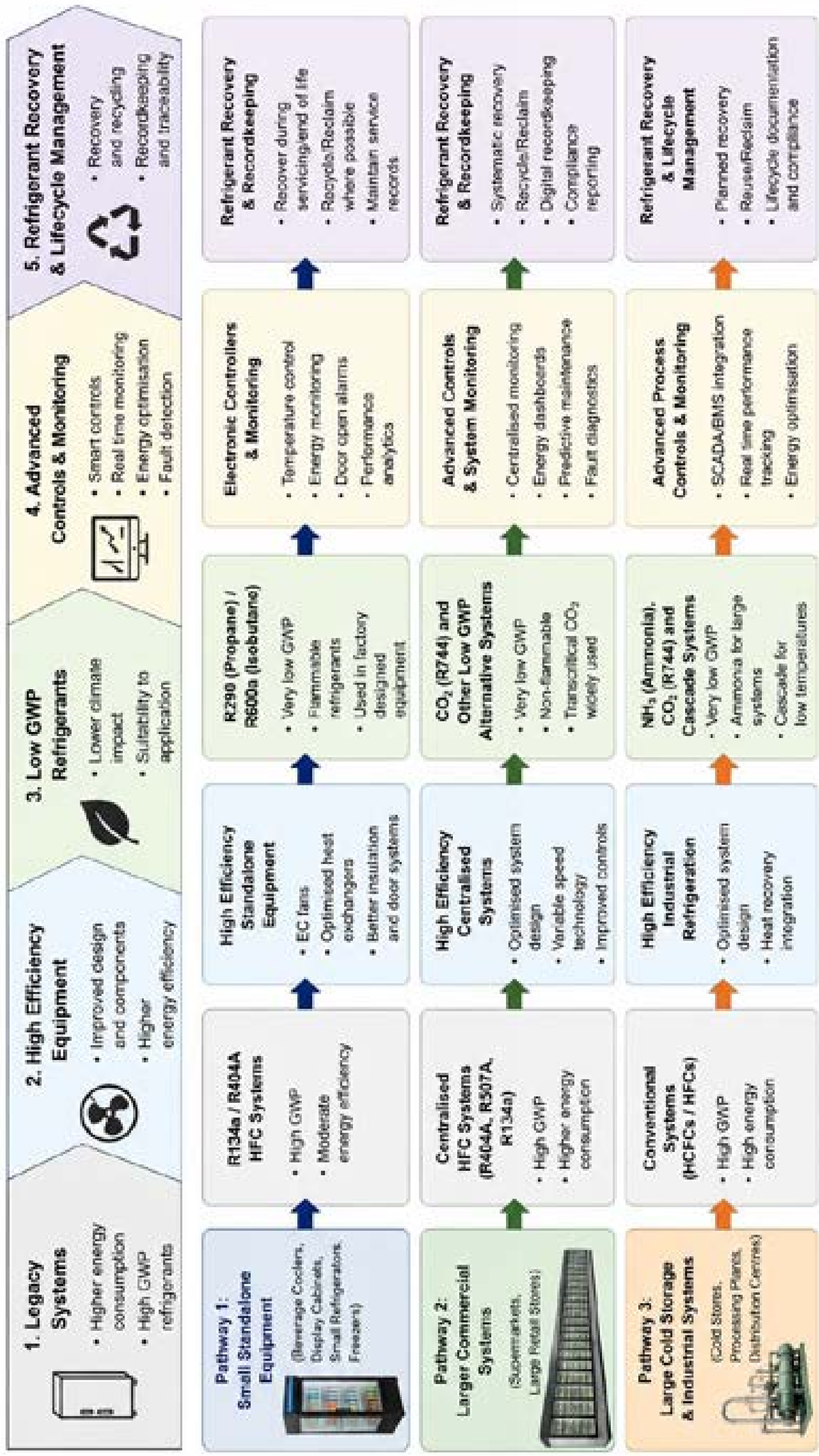


Figure 8.1: Global Transition Pathways for Commercial Refrigeration.

8.2 International Case Studies

International applications provide practical evidence of how low GWP refrigerants are being integrated into commercial refrigeration. The selected cases represent different equipment scales and system configurations and provide useful lessons for assessing their applicability to Indian convenience stores.

8.2.1 CO_2 Commercial Refrigeration in Europe

European commercial refrigeration has increasingly adopted transcritical CO_2 systems, particularly in supermarkets and larger food retail applications. Field studies have demonstrated that the performance of CO_2 systems depends strongly on system configuration, ambient conditions and control strategy. Developments such as improved gas cooler control, parallel compression, mechanical subcooling and integrated system configurations have progressively improved their operating performance [44–46]. The European experience demonstrates that the suitability of CO_2 refrigeration should not be assessed only from the low GWP of the refrigerant. System architecture, heat rejection conditions, compressor operation and controls are equally important in determining energy performance.

8.2.2 CO_2 Refrigeration under High Ambient Conditions

The application of transcritical CO_2 refrigeration under warmer climatic conditions is particularly relevant to India. International research and field assessments have examined approaches such as adiabatic gas cooling, mechanical subcooling and optimised gas cooler pressure control to improve performance as outdoor temperature increases [44–46]. These studies demonstrate that high ambient temperature does not necessarily exclude CO_2 from commercial refrigeration, but it increases the importance of system design and control. For Indian applications, CO_2 systems therefore require assessment under representative local climatic conditions rather than direct replication of configurations developed for cooler climates.

8.2.3 Hydrocarbon Refrigeration for Small Retail Applications

Internationally, R-290 and R-600a are increasingly established in small hermetically sealed refrigeration equipment. These refrigerants are particularly suited to beverage coolers, reach in refrigerators, freezers and other standalone retail cabinets because the refrigerant circuit can be factory designed and optimised for the intended refrigerant [40–42]. A further configuration is the R-290 water loop system, in which individual cabinets contain independent R-290 refrigeration circuits while condenser heat is transferred to a common water loop. This retains the modular characteristics of standalone refrigeration while providing common heat rejection and reducing the need for multiple individual condenser heat rejection arrangements within the retail space. Table 8.1 summarises the selected international refrigeration experiences and identifies their principal relevance to Indian convenience stores.

Table 8.1: Selected International Refrigeration Case Studies and Lessons for India

Country/region	Demonstrated best practice	Reported evidence	Relevance to Indian convenience stores
Japan	CO_2 refrigeration across convenience store networks	Lawson reported CO_2 freezing and refrigeration systems in approximately 5,300 stores by February 2023	Strong example of chain wide technology standardisation, monitoring and technician support
United States/ Canada	Energy management systems, efficient HVAC, LED lighting and lower GWP remote systems	7-Eleven reported EMS in 6,831 stores, with estimated savings of 16,323 kWh/store/ year; R448A adopted for new remote condensing systems	Suitable model for remote monitoring and gradual replacement of existing equipment
Germany	Transcritical CO_2 systems with heat recovery and optimised controls	European field studies found appropriately designed CO_2 systems could outperform standard and optimised R-404A systems	Relevant mainly to supermarkets and large format stores
United Kingdom	Doors on refrigerated display cases and transition away from high GWP refrigerants	Evidence reviewed by EIA indicates doors can reduce refrigeration energy use by up to 40%	Highly transferable to vertical freezers and display cabinets
Southern Europe	Warmclimate CO_2 optimisation using ejectors, parallel compression and subcooling	EU case studies document transcritical CO_2, stand alone and indirect systems in warmer climates	Useful technical reference, but requires Indian climate pilot testing
Australia	Licensing and controlled handling of fluorinated refrigerants	Refrigerant handling and equipment work are regulated through licensing requirements	Relevant model for technician certification, refrigerant recovery and record keeping

As shown in **Table 8.1**, international experience does not indicate a single preferred refrigeration architecture. R-290 and R-600a are particularly relevant to smaller standalone applications, whereas CO_2 and more integrated configurations become increasingly relevant as refrigeration capacity and system complexity increase.

8.3 Good Installation and Safety Practices

International experience demonstrates that low GWP refrigerants require appropriate equipment design, installation and commissioning. Equipment should be specifically designed for the intended refrigerant and operated within its specified charge, temperature and pressure limits. This is particularly important for R290 and other flammable refrigerants, where refrigerant charge, ignition risk control, ventilation and servicing procedures require specific consideration [41,42]. Good installation includes correct piping and jointing, pressure testing, evacuation to remove air and moisture, accurate refrigerant charging, adequate condenser airflow, electrical protection and verification of system operation during commissioning. Table 8.2 summarises these principal installation and safety practices.

Table 8.2: Good Installation and Safety Practices

Area	Good Practice
Refrigerant selection	Identify refrigerant and safety classification
Equipment	Use purpose designed and compliant equipment
Refrigerant charge	Maintain specified charge quantity
Equipment location	Provide adequate airflow and service clearance
Refrigerant piping	Correct sizing, routing and jointing
Pressure testing	Conduct before commissioning
Evacuation	Remove air and moisture adequately
Refrigerant charging	Charge accurately to manufacturer specification
Electrical installation	Provide appropriate protection and earthing
Commissioning	Verify temperature, controls and system operation
Documentation	Record refrigerant, charge and commissioning details

As indicated in Table 8.2, installation quality influences both safety and energy performance. Incorrect refrigerant charge, inadequate evacuation, poor jointing or restricted condenser airflow can reduce cooling performance and increase compressor operation. For hydrocarbon refrigerants, international practice therefore favours purpose designed factory manufactured equipment rather than uncontrolled field conversion of equipment designed for another refrigerant.

8.4 Good Operation and Maintenance Practices

International good practice increasingly favours preventive and condition based maintenance rather than servicing refrigeration equipment only after failure. Routine inspection of condensers, evaporators, door seals, fans, refrigerant circuits, defrost controls and temperature sensors helps maintain the original energy and cooling performance of the equipment. Table 8.3 presents the principal O&M practices applicable to commercial refrigeration equipment.

Table 8.3: Good Operation and Maintenance Practices

Activity	Recommended Practice
Condenser	Periodic inspection and cleaning
Evaporator	Check frost, airflow and cleanliness
Door seals	Inspect and replace damaged seals
Refrigerant circuit	Leak check before adding refrigerant
Refrigerant charge	Avoid repeated topping up without leak repair
Defrost	Verify timing and termination
Fans	Check operation and airflow
Temperature controls	Verify sensor accuracy and set point
Compressor	Monitor operating condition and runtime
Service records	Record faults, repairs and refrigerant additions

As shown in **Table 8.3**, many good O&M practices can be implemented without major equipment modification, making them particularly relevant to existing convenience stores. Clean heat exchangers, correct refrigerant charge, effective door seals and appropriate temperature settings can reduce unnecessary compressor operation and help maintain stable product temperatures. **Figure 8.2** and **Table 8.4** extends these practices across the complete refrigeration equipment lifecycle, beginning with equipment and refrigerant selection and progressing through installation, efficient operation, monitoring, preventive maintenance, refrigerant recovery, end of life management and eventual equipment replacement.

Table 8.4: Recommended country models by store format

Indian store format	Best international reference	Preferred pathway
Small independent store	UK	Factory sealed R-290 equipment with closed doors
Convenience-store chain	Japan and USA	Standardised equipment, remote monitoring and organised service contracts
Medium food-retail store	Japan and Southern Europe	R-290 water loop or pilot compact CO_2 system
Large supermarket-type store	Germany and Japan	Optimised transcritical CO_2 with heat recovery
Existing HFC-based store	USA/Canada and Australia	Leak reduction, monitoring and planned replacement rather than unsafe retrofit

The lifecycle approach is important because equipment that performs efficiently when commissioned can progressively deteriorate because of condenser fouling, damaged door seals, refrigerant leakage, incorrect controls or inadequate servicing. Digital monitoring can provide additional support to O&M. Temperature sensors, electricity meters, compressor runtime monitoring, door sensors, pressure measurements and refrigeration controllers can identify abnormal operating conditions before complete equipment failure. Figure 8.3 illustrates how data from individual refrigeration units can be transmitted through a local gateway to a monitoring platform for performance tracking, fault detection and service alerts. For organised convenience store networks, the monitoring arrangement shown in Figure 8.3 can also support comparison of equipment across multiple outlets and identify units with unusually high electricity consumption, excessive compressor runtime, temperature deviation, abnormal defrost operation or other developing faults. This supports a gradual transition from reactive servicing towards condition based maintenance.

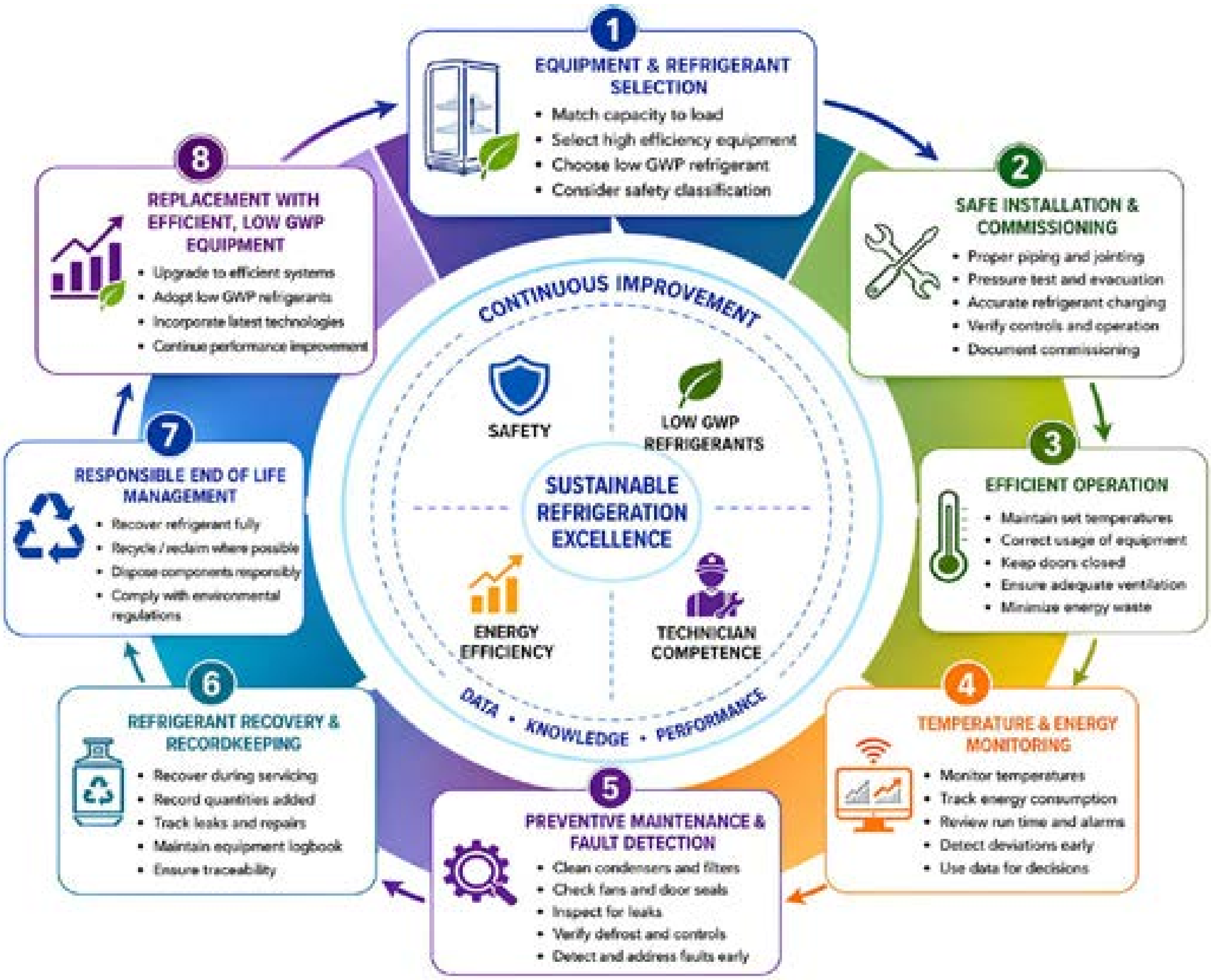


Figure 8.2: International Best Practice Lifecycle for Commercial Refrigeration.

Figure 8.3: Smart Energy Monitoring and Fault Detection Architecture for Convenience Store Refrigeration.

8.5 Technician Competence and Refrigerant Recovery

International experience demonstrates that refrigerant transition requires a corresponding improvement in technician knowledge and practical servicing capability. Conventional refrigeration skills need to be complemented by refrigerant specific competence, particularly when handling flammable refrigerants such as R-290 or higher pressure CO_2 systems. Technician competence covers the complete servicing process, including refrigeration fundamentals, refrigerant identification, leak testing, evacuation, accurate charging, recovery, electrical safety, system diagnosis and documentation. Table 8.5 summarises the principal competence requirements.

Table 8.5: International Technician Competence Requirements

Competence Area	Typical Requirement
Refrigeration fundamentals	System operation and diagnosis
Refrigerant identification	Correct refrigerant and safety classification
Leak testing	Appropriate detection procedure
Evacuation	Correct use of vacuum equipment
Charging	Accurate refrigerant charging
Recovery	Safe refrigerant removal
Flammable refrigerants	Refrigerant specific safety competence
Electrical safety	Safe diagnosis and servicing
Documentation	Service and refrigerant records

As indicated in Table 8.5, technician competence extends beyond conventional fault repair. Refrigerant identification, accurate charging, recovery and refrigerant specific safety become increasingly important as the market transitions towards alternative refrigerants. Refrigerant recovery is similarly an integral part of international good practice. Refrigerant should be recovered during applicable servicing and before equipment disposal rather than intentionally released. Maintaining records of refrigerant type, initial charge, subsequent additions, leak repairs and quantities recovered provides traceability throughout the equipment lifecycle [40,42]. Table 8.6 presents the principal refrigerant recovery and recordkeeping practices.

Table 8.6: Good Refrigerant Recovery and Recordkeeping Practices

Stage	Good Practice
Installation	Record refrigerant type and initial charge
Routine servicing	Record equipment condition and leak inspection
Refrigerant addition	Record quantity and reason
Leak repair	Document fault and repair
Recovery	Record quantity recovered
Recycling or reclamation	Maintain material traceability
Refrigerant replacement	Record original and replacement refrigerant
Equipment disposal	Recover refrigerant before dismantling
Service history	Maintain equipment level records

The practices presented in Table 8.6 provide traceability from installation to equipment retirement and can help identify equipment experiencing recurrent leakage or repeated refrigerant additions. International experience therefore links technician competence and refrigerant recovery directly with effective lifecycle refrigerant management.

8.6 What India Can Learn from International Experience

International experience demonstrates that India does not require a single refrigeration technology pathway for all convenience store formats. The appropriate technology depends on equipment capacity, refrigeration load, climatic conditions, refrigerant safety, servicing capability and lifecycle economics. For the predominantly standalone equipment used in Indian convenience stores, factory designed high efficiency R-290 and R-600a equipment represents one of the most directly relevant international pathways. These technologies are applicable to beverage coolers, reach in refrigerators and suitable freezers without requiring the complexity of large centralised refrigeration plants. International practice also reinforces the importance of correct installation, accurate refrigerant charging, leak detection, preventive maintenance, monitoring and refrigerant recovery.

For organised convenience stores and mini supermarkets operating multiple refrigeration units, R-290 water loop systems provide a potential intermediate configuration between individual air cooled standalone equipment and fully centralised refrigeration. For larger and more concentrated refrigeration loads, CO_2 systems may be considered where climatic performance, technical support and lifecycle economics are favourable. International experience with CO_2 under high ambient conditions is particularly relevant to assessing its suitability under Indian climatic conditions [44– 46]. Table 8.7 consolidates the principal international lessons and their relevance to Indian convenience store refrigeration.

Table 8.7: International Lessons and Their Relevance to Indian Convenience Stores

International Practice	Relevance to India	Potential Application
High efficiency standalone equipment	High	Existing and new convenience stores
Factory designed R-290/ R-600a equipment	High	Beverage coolers, refrigerators and freezers
Preventive maintenance	High	All refrigeration equipment
Accurate charging and leak testing	High	Installation and servicing
Temperature and energy monitoring	High	Particularly organised stores
Refrigerant recovery	High	Servicing and end of life management
Technician competence	High	Refrigeration servicing ecosystem

International Practice	Relevance to India	Potential Application
Remote monitoring and fault detection	High for organised networks	Multi outlet store networks
R290 water loop systems	Promising	Organised stores and mini supermarkets
CO_2 refrigeration	Application dependent	Higher and concentrated refrigeration loads
Refrigerant reclamation	Important at sector level	Longer term refrigerant management

As summarised in **Table 8.7**, the practices with the greatest immediate relevance to Indian convenience stores are efficient standalone equipment, factory designed R-290 and R600a systems, preventive maintenance, accurate charging, leak detection, temperature monitoring, technician competence and refrigerant recovery. More integrated technologies such as R-290 water loop and CO_2 refrigeration can be considered for suitable higher load applications where their performance can be validated under Indian climatic and servicing conditions.

Therefore, the international evidence demonstrates that a sustainable refrigeration transition is most effective when refrigerant selection, energy efficiency, safety, installation quality, O&M, monitoring, technician competence and refrigerant recovery are considered together. For India, the international experience provides a useful technical reference rather than a model for direct replication. The most relevant practices can therefore be adapted according to the characteristics of Indian convenience stores, climatic conditions and the existing refrigeration service ecosystem.

CHAPTER 9

WAY FORWARD FOR SUSTAINABLE REFRIGERATION IN INDIAN CONVENIENCE STORES

- Technology Pathway
- Policy Alignment & Regulatory Support
- Safe Conversion & Installation Practices
- Technician Capacity Building
- Performance Monitoring & Maintenance
- Refrigerant Recovery & Lifecycle Management

CONVENIENCE STORE

Stores → Distribution & Supply → Refrigeration Equipment → Service & Maintenance → Standards & Compliance

Chapter 9: Way Forward for Sustainable Refrigeration in Indian Convenience Stores

India's convenience store sector is evolving, with refrigeration playing an important role in maintaining product quality and supporting store operations. Globally, the refrigeration sector is transitioning towards more energy efficient equipment and lower GWP refrigerants. India has an opportunity to support this transition through approaches suited to its diverse climatic conditions and market requirements. The study recommends a phased transition, beginning with improvements to the performance of existing equipment, followed by the adoption of energy efficient, low GWP technologies during equipment replacement, alongside strengthening the service and maintenance ecosystem.

9.1 Choosing the Right Refrigeration Technology

Indian convenience stores use refrigeration equipment of different types and capacities; therefore, no single technology is suitable for every store. The transition towards sustainable refrigeration should be guided by the equipment type and condition, as well as the store's refrigeration requirements. For commonly used standalone equipment, such as beverage coolers, refrigerators and freezers, factory designed low GWP options using R-290 and R-600a provide a practical pathway when replacement is required. These refrigerants have very low GWP and are suitable for equipment specifically designed to operate safely within the permitted refrigerant charge limits.

Immediate replacement of all existing equipment is not necessary. Equipment that remains efficient, reliable and leak free can continue to operate with proper maintenance. Older equipment that is inefficient, frequently leaks or requires repeated major repairs should be prioritised for replacement. This approach avoids premature disposal while gradually moving the sector towards more efficient, low GWP equipment. For stores with larger or more concentrated refrigeration loads, R-290 water loop and CO_2 systems may provide additional options. Their suitability should be assessed based on refrigeration load, climatic conditions, maintenance requirements and the availability of technical support. CO_2 refrigeration is a potential low GWP option, but its application in India requires appropriate system design, high side pressure control and supplementary measures to maintain efficient performance under high ambient temperatures [44–46]. Compliance with applicable safety requirements and the availability of trained technicians should also be ensured. The main technology options are summarised in Table 9.1.

Table 9.1: Refrigeration Technology Options for Indian Convenience Stores

Equipment/Application	Existing or Legacy Refrigerants	Suitable Transition Direction
Beverage coolers	R-134a in older equipment	Factory designed R-290/ R-600a
Reach in refrigerators	R-134a/R-600a	R-290/R-600a in purpose designed equipment
Chest freezers	R-404A and other legacy systems	R-290
Vertical freezers	R-404A and other HFC systems	R-290 or suitable low GWP alternative
Open display cabinets	R-404A/R-448A and similar systems	Efficient closed R-290 cabinets, CO_2 or suitable low GWP systems
Walk in cold rooms	R-22/R-404A/R-449A and other systems	Application specific R-290, CO_2, NH_3/CO_2 or other suitable low GWP system
Stores with multiple cabinets	Multiple standalone systems	R-290 water loop where technically justified
Higher refrigeration loads	Centralised HFC systems	Appropriately designed CO_2 or other low GWP systems

9.2 Supporting India's Transition to nonODS and low GWP Refrigeration

India is moving away from HCFC-based refrigeration and towards lower-GWP alternatives, in line with its commitments under the Montreal Protocol and the Kigali Amendment. The transition has already been demonstrated across both domestic and commercial refrigeration. The domestic refrigeration sector successfully transitioned to R-600a (isobutane) as an alternative refrigerant, establishing the feasibility of adopting low-GWP alternatives at scale. Under HCFC Phase-out Management Plan (HPMP) the transition in commercial refrigeration from HFC-based refrigerants to lower-GWP alternatives, particularly R-290 (propane), has also been completed. The transition to R-290 has been supported across 37 commercial refrigeration enterprises. Industry experience has already demonstrated the potential for such a transition. Accordingly the R-290 technology is well established in the country.

Figure 9.1 illustrates the proposed transition from legacy refrigerants to suitable low GWP technologies for standalone, medium capacity and larger refrigeration systems.

The transition should be managed through planned equipment replacement. Older R-22 equipment nearing end of life, with recurrent leakage or frequent repairs, can be prioritised for replacement, while ageing R-134a and R-404A equipment can be replaced during normal renewal. Functional HFC-based equipment need not be replaced prematurely; remaining useful life, energy performance, leakage history and maintenance requirements should be considered. This approach can reduce premature disposal while enabling the phased introduction of efficient, low-GWP technologies. **Table 9.2** summarises key considerations for existing refrigeration equipment and the appropriate approach to replacement.

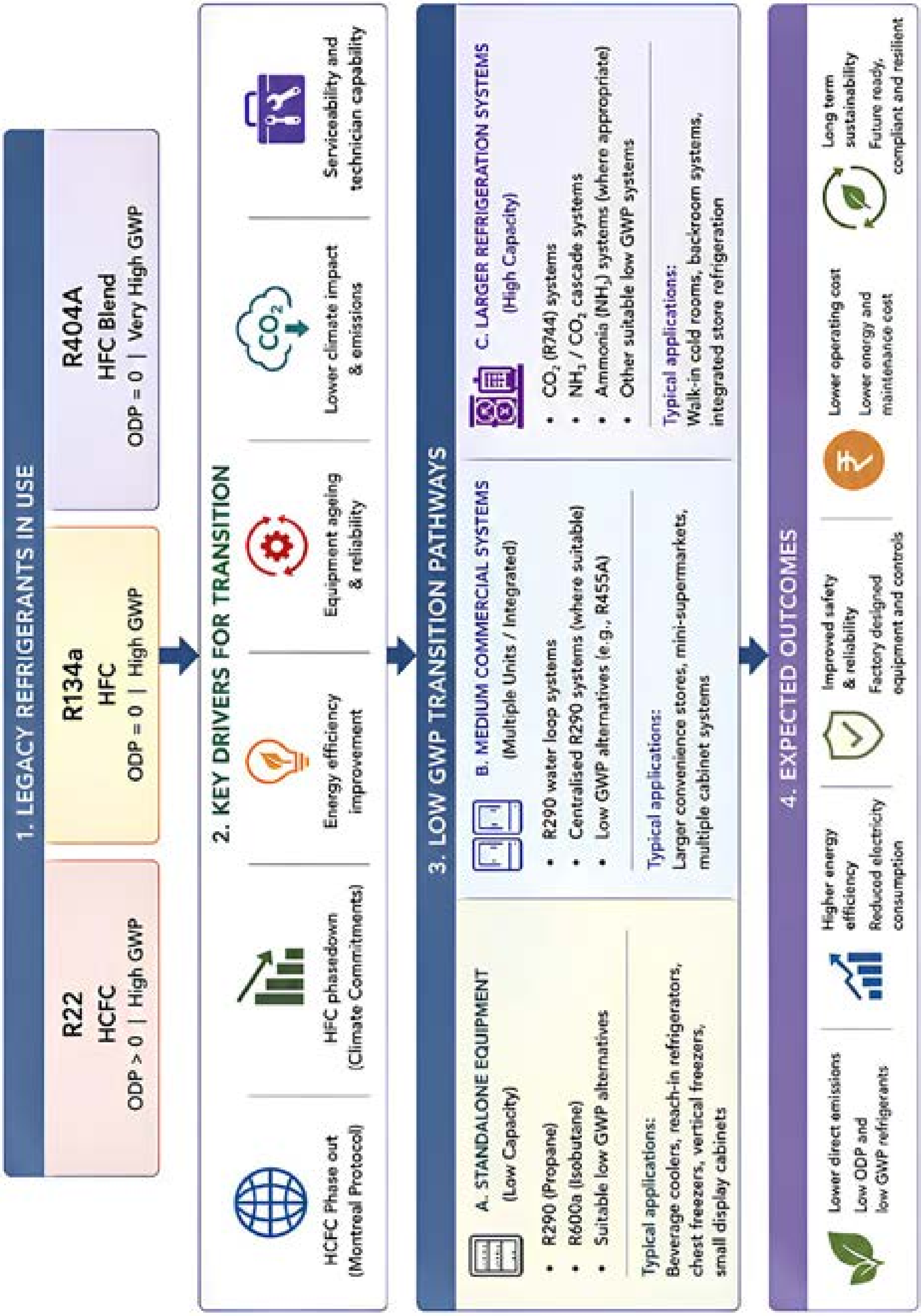


Figure 9.1: Refrigerant Transition Pathways for Indian Convenience Store Refrigeration.

Table 9.2: Considerations for Refrigeration Equipment Replacement

Existing Condition	Main Consideration	Suitable Direction
Ageing R-22 equipment	HCFC dependence and equipment age	Planned replacement
Leakage prone R-404A equipment	Very high GWP and recurrent refrigerant loss	Higher replacement priority
Ageing R-134a equipment	Energy and refrigerant performance	Replace during normal renewal
Efficient functioning equipment	Remaining useful life	Maintain appropriately and plan future transition
New equipment procurement	Potential future refrigerant lock in	Prefer efficient low GWP technology
End of life equipment	Residual refrigerant	Recover refrigerant before disposal

9.3 Improving Energy Efficiency

Refrigeration is a major part of the electricity use of convenience stores, accounting for approximately 45–65% of total electricity consumption in the stores assessed. Improving the energy efficiency of refrigeration equipment can therefore have a significant impact on overall store electricity consumption and operating costs.

Existing equipment can often be made more efficient through regular maintenance and simple operational measures, including cleaning heat-transfer surfaces, maintaining door seals, using appropriate temperature settings, ensuring the correct refrigerant charge and optimising defrost cycles. Figure 9.2 presents the recommended transition pathway for existing equipment. Functional systems can remain in operation with regular maintenance and leakage assessment and be replaced with factory designed low GWP equipment at the end of their useful life.

The design of display cabinets also affects energy use: open cabinets can consume approximately 20–40% more energy than comparable closed configurations. Adding doors, along with using efficient fans, LED lighting and improved controls, can provide further energy-saving opportunities. These measures are summarized in Table 9.3.

Figure 9.3 presents the adoption of selected energy efficiency measures. LED cabinet lighting recorded the highest adoption at approximately 60%, followed by adaptive anti sweat controls at 50%, closed refrigerated cabinets at 45%, EC condenser fans at 30% and high efficiency fans at approximately 13%.

Supermarkets and hypermarkets can further improve performance through internal energy audits and appropriate temperature zoning. These measures help identify energy saving opportunities, prevent unnecessary overcooling and maintain product quality.

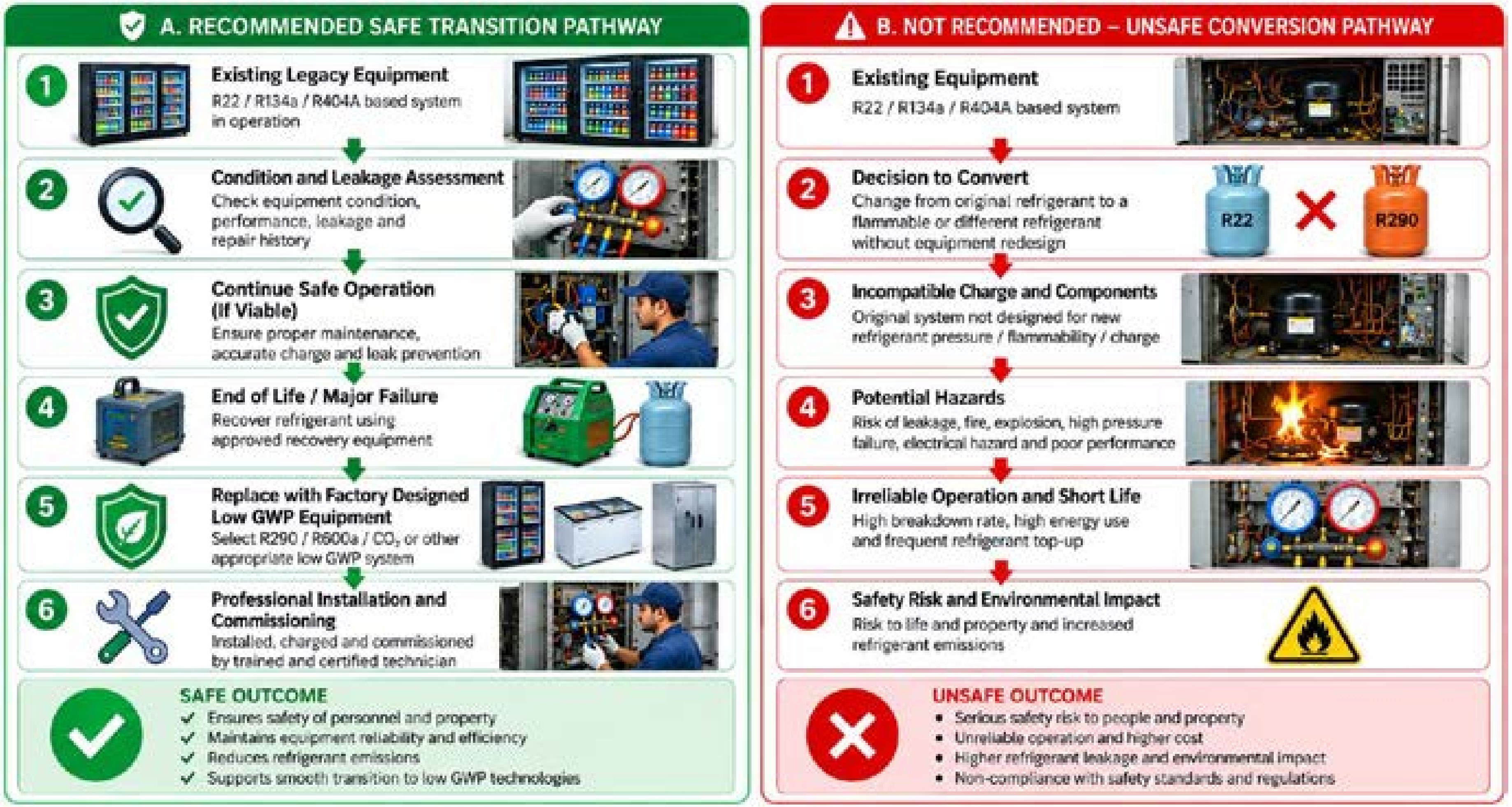


Figure 9.2: Safe Equipment Transition Versus Unsafe Refrigerant Conversion.

Table 9.3: Energy Efficiency Measures Supporting Sustainable Refrigeration

Measure	Technical Effect	Indicative Potential/ Priority
Condenser and evaporator cleaning	Improves heat transfer and reduces compressor load	Immediate
Door gasket maintenance	Reduces ambient air infiltration	Immediate
Temperature set point optimisation	Avoids unnecessary cooling	Immediate
Correct refrigerant charge	Maintains capacity and efficiency	Immediate
Defrost optimisation	Reduces unnecessary energy use	Immediate
Closed display cabinets or door retrofit	Reduces infiltration load	≈40–45% saving potential
High efficiency fans	Reduces auxiliary electricity	>10% fan energy reduction
EC condenser fans	Improves part load fan performance	≈15–30% fan energy reduction
Equipment level monitoring	Identifies abnormal operation	High priority

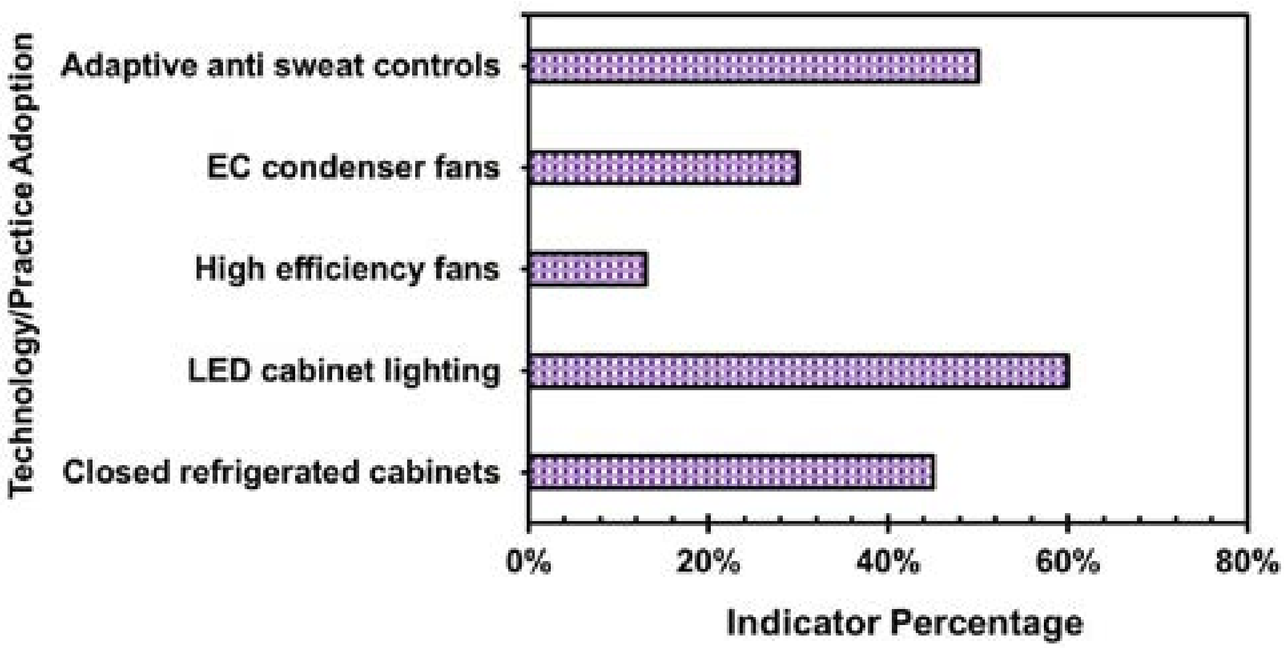


Figure 9.3: Adoption of Energy Efficiency Technologies and Practices in Convenience Store Refrigeration.

9.4 Good Practices for Refrigeration Equipment

The performance of refrigeration equipment depends not only on its technology and refrigerant, but also on how it is installed and operated. Poor refrigerant charging, inadequate airflow, inappropriate temperature settings and insufficient maintenance can reduce efficiency and affect reliable operation. Key good practices are outlined below, with additional practices summarised in Table 9.4.

- **Equipment selection:** Selection should consider the refrigeration requirement, energy performance, refrigerant, safety, climatic suitability and availability of servicing support. Where applicable, Bureau of Energy Efficiency (BEE) requirements and energy performance information can support procurement decisions. For equipment not covered by such requirements, daily and annual electricity consumption, cooling performance and service requirements can be considered.
- **Safety:** Safety is particularly important when using alternative refrigerants. Equipment should be purpose designed for the refrigerant being used and installed and serviced using appropriate procedures. This is especially important for flammable refrigerants such as R-290 and R-600a and for higher pressure CO_2 systems.
- **Lifecycle management:** Good practices should be followed throughout the life of the equipment from selection and installation through operation, servicing and end of life.

Table 9.4: Good Practice Framework for Convenience Store Refrigeration

Stage	Good Practice
Equipment selection	Match equipment capacity and configuration to the refrigeration requirement
Energy performance	Consider applicable BEE requirements and annual energy consumption
Refrigerant selection	Consider ODP, GWP and safety classification
Installation	Ensure appropriate airflow, clearance and electrical protection
Pressure testing	Verify system integrity
Evacuation	Remove air and moisture before charging
Charging	Use accurate and calibrated procedures
Commissioning	Verify temperature, controls and system operation
Operation	Maintain appropriate product temperatures and set points
Maintenance	Follow preventive maintenance practices
Leak management	Identify and repair leakage before refrigerant addition
Servicing	Use appropriate refrigerant specific tools and procedures
Documentation	Maintain equipment and refrigerant service records
End of life	Recover refrigerant before dismantling or disposal

9.5 Strengthening Technician Skill

The transition to low GWP refrigeration will require technicians to have the practical knowledge and skills needed to safely service a wider range of refrigerants and refrigeration technologies. The technician assessment identified gaps in formal training, familiarity with newer refrigerants and the use of specialised servicing practices. While routine servicing activities are relatively well established, practices such as accurate refrigerant charging and refrigerant recovery are less consistently followed.

These findings highlight the need to strengthen practical, refrigerant specific training and competency development, supported by appropriate servicing tools, recovery equipment and standard procedures. Technicians will need to be able to identify refrigerants, detect and repair leaks, carry out correct charging and recovery, diagnose equipment and follow appropriate safety procedures. Key areas for technician capacity building are presented in **Table 9.5**.

Table 9.5: Key Areas for Technician Capacity Building

Area	Requirement
Training	Practical training on newer refrigerants and equipment
Refrigerant handling	Identification, leak detection, evacuation and accurate charging
Refrigerant recovery	Appropriate recovery practices
Electrical skills	Electrical diagnosis
Documentation	Appropriate service and refrigerant records
Refrigerant specific skills	Safe handling of flammable refrigerants and higher pressure CO_2 systems
Competency	Competency assessment and certification
Training	Practical training on newer refrigerants and equipment
Refrigerant handling	Identification, leak detection, evacuation and accurate charging
Refrigerant recovery	Appropriate recovery practices

9.6 Strengthening Equipment and Service Supply Chain

The availability of refrigeration equipment alone is not sufficient to support the transition to low GWP technologies. Equipment needs to be supported by compatible spare parts, servicing tools, technical information and access to qualified service providers. The survey indicates that Tier II markets rely more on regional distributors and independent service technicians for equipment and servicing. Strengthening regional supply and service networks can therefore help support the adoption of new technologies in these markets. The key requirements for strengthening the equipment and service supply chain are presented in Table 9.6.

Table 9.6: Key Requirements for Equipment and Service Support

Area	Requirement
Equipment	Availability of lowGWP refrigeration equipment
Spare parts	Access to compatible replacement components
Servicing tools	Availability of appropriate specialist tools
Technical information	Access to equipment and servicing information
Recovery facilities	Availability of refrigerant recovery facilities
Distribution	Reliable regional distribution, particularly in Tier II markets
Service network	Availability of capable service providers
Equipment	Availability of lowGWP refrigeration equipment
Spare parts	Access to compatible replacement components

9.7 Refrigerant Recovery and Lifecycle Management

Refrigerant recovery should become a routine part of servicing, repair and equipment retirement. Refrigerant removed from equipment should be recovered using appropriate equipment and cylinders rather than released. Recovered refrigerant can then be collected for testing, recycling or reclamation, where appropriate. Given the geographical spread of the refrigeration service market, local collection and regional aggregation can provide a practical approach, particularly in Tier II markets, with recovered refrigerant transported to suitable processing facilities. Figure 9.4 illustrates the key elements of an effective refrigerant recovery system.

9.8 Equipment Procurement and Lifecycle Performance Evaluation

The choice of refrigeration equipment can influence energy use, maintenance requirements, refrigerant management and operating costs throughout its useful life. Equipment selection should therefore consider more than the initial purchase price. Energy consumption, refrigerant choice, safety, maintenance needs and endoflife management should be considered when selecting equipment. These factors can help identify equipment that is suitable not only at the time of purchase but also for reliable and efficient operation over its lifetime. Table 9.7 summarizes key criteria for lifecyclebased equipment selection and performance evaluation.

Table 9.7: Equipment Selection and Lifecycle Performance Criteria

Criterion	Performance Consideration
Energy performance	Daily and annual electricity consumption
Refrigerant	Refrigerant type, GWP, ODP, charge and safety
Cooling performance	Ability to maintain required product temperatures
Climatic suitability	Performance under representative Indian ambient conditions
Maintenance	Ease and frequency of servicing
Spare parts	Availability and potential repair downtime
Safety	Applicable equipment and installation requirements
Monitoring	Compatibility with temperature and energy monitoring
Refrigerant integrity	Leakage and refrigerant additions
Lifecycle cost	Purchase, energy, maintenance and servicing costs
End of life	Provision for refrigerant recovery

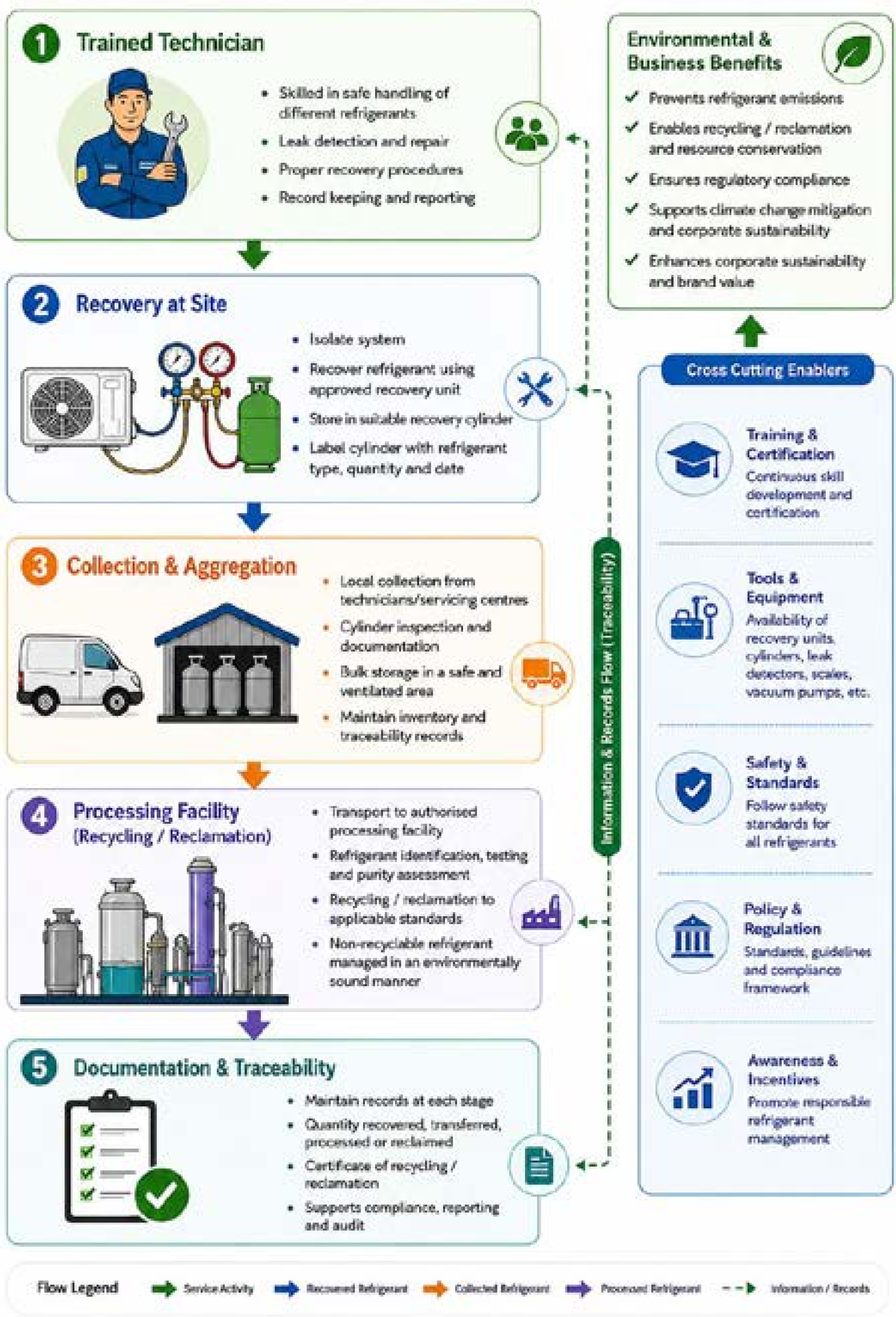


Figure 9.4: Integrated Technician and Refrigerant Recovery Ecosystem.

9.9 Way Forward for Refrigeration in Convenience Stores

The transition to more efficient and lowGWP refrigeration does not require all existing equipment to be replaced at once. A practical approach is to improve the performance of existing equipment and introduce better technologies as equipment is renewed, while strengthening the skills and services needed to support them.

The key priorities are:

1. **Improve existing equipment**

- Maintain equipment regularly and address refrigerant leakage.
- Ensure correct refrigerant charging and appropriate temperature settings.
- Adopt operating practices that improve energy performance.

2. **Make informed replacement decisions**

- Select efficient, factory designed low GWP equipment where appropriate.
- Consider energy performance, refrigerant type, safety, climatic suitability and maintenance requirements.
- Continue using existing equipment while it remains efficient, reliable and leak free.

3. **Strengthen technical and servicing capacity**

- Improve technician training and practical competency.
- Expand access to appropriate servicing tools, spare parts and technical information.
- Develop refrigerant recovery and servicing networks, particularly in Tier II markets.

4. **Adopt advanced technologies where appropriate**

- Consider R-290 water loop and CO_2 systems, thermal storage, heat recovery and smart fault detection for suitable applications.
- Evaluate each technology against refrigeration demand, climatic conditions and available technical support.

5. **Manage refrigerants throughout their lifecycle**

- Recover refrigerants during major servicing and equipment retirement.
- Improve collection, recycling and reclamation arrangements to minimise refrigerant release.

Table 9.8 summaries these priorities and the expected outcomes. Figure 9.5 brings together the key elements needed for more efficient and lower GWP refrigeration in convenience stores.

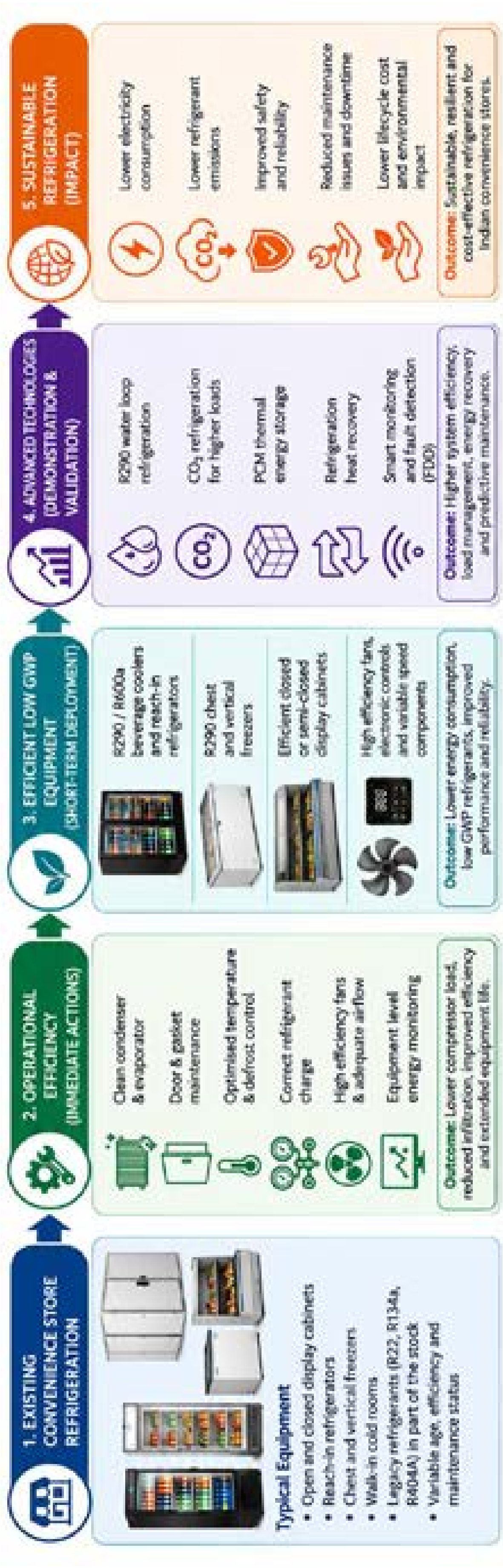


Figure 9.5: Sustainable Refrigeration Pathway for Indian Convenience Stores.

Table 9.8: Priorities for Improving Refrigeration in Convenience Stores

Priority	Key Action	Expected Outcome
Existing equipment	Preventive maintenance, leak reduction, correct charging, temperature optimisation and efficient operation	Improve performance of existing equipment
Equipment renewal	Adopt efficient, lowGWP equipment when replacement is needed	Lower energy use and reduced high GWP refrigerant use
Technician capability	Training and practical competency	Safe and effective servicing
Service support	Improve access to tools, spare parts and technical support	Reliable equipment operation
Refrigerant management	Recovery, collection and appropriate recycling/reclamation	Reduced refrigerant release
Advanced technologies	Consider suitable technologies for higher or specialized loads	Appropriate adoption of emerging solutions

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