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INDIA'S JOURNEY

— TOWARDS SUSTAINABLE COOLING —

LiFE
Lifestyle for Environment

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पर्यावरण, वन एवं जलवायु परिवर्तन
और
श्रम एवं रोजगार
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ENVIRONMENT, FOREST AND CLIMATE CHANGE
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GOVERNMENT OF INDIA

स्वच्छ भारत
एक कदम स्वच्छता की ओर

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आज़ादी का अमृत महोत्सव

MESSAGE

Cooling requirement is cross-sectoral and is an essential element for economic growth. There is significant use of cooling in different sectors of the economy such as residential and commercial buildings, cold-chain, refrigeration, transport and industries. The cooling demand in these and other sectors will grow in the future due to the expected economic growth of the country, increasing per capita income urbanization etc.

Cooling is also intimately associated with human health, well-being, and productivity and the linkages between cooling and Sustainable Development Goals (SDGs) are well recognized. The cross-sectoral nature of cooling and its use in important development sectors of economy makes provision for cooling an important developmental necessity, which can have bearing on the environment, economy and the quality of life of the citizens of the country.

India's ancient scriptures have always emphasized the importance of sustainable living, with the planet and ecology an integral part of its culture. Traditional building solutions in India involved use of passive cooling measures and local building materials. These ensured effective heat dissipation and were particularly suited to the country's hot climate, having evolved over generations from practices which were in harmony with the environment.

It is important to achieve a balance between economic growth and environmental sustainability. Towards this, the India Cooling Action Plan (ICAP) has been a multi-stakeholder, integrated and consultative process to synergize actions for addressing the cooling demand across all sectors. The ICAP provides a 20-year perspective and recommendations to address the cooling requirements across sectors and ways and means to provide access to sustainable cooling, through a holistic and balanced approach by encompassing both passive and active cooling strategies as well as optimization of cooling loads.

The booklet on "Sustainable Cooling" provides an interesting insight into India's journey towards sustainable cooling and strengthens efforts to work together to make cooling sustainable and accessible for all.

Date: 25 **11.2023**

(Bhupender Yadav)

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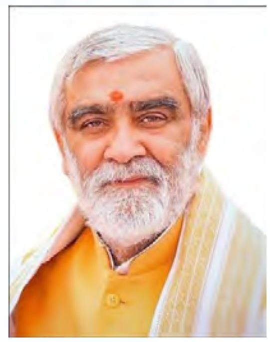

MESSAGE

Access to sustainable cooling and thermal comfort solutions is exigent for sustainability. Cooling solutions, both active and passive, which are environmentally sustainable, efficient, affordable and commercially viable to meet cooling needs for food, nutrition and agriculture; health services; and human comfort and safety are the current global necessities.

The India Cooling Action Plan (ICAP), launched in 2019, has been a multi-stakeholder, integrated and consultative process to synergize actions to address the ever increasing demand for cooling solutions across sectors along with the ways and means to provide access to sustainable cooling. The ICAP enunciates the importance of further development and use of a robust mix of cooling technologies, including the use of appropriate environment-friendly refrigerants as well as appliances, for meeting the growing cooling requirement of the country.

Sustainability, for long, has been at the core of Indian lifestyle and its indigenous knowledge and sustainable practices have played a crucial role in helping people be informed and make environmentally conscious consumption choices. Led by a strong focus on sustainability, the Indian industry is now being poised to play a pivotal role in meeting the increasing domestic and global demand for greener cooling solutions.

This publication "Sustainable Cooling" enumerates and highlights the best practices and initiatives undertaken by the country to meet the rising cooling demand of its fast-growing economy in a sustainable and equitable way.

(ASHWINI KUMAR CHOUBEY)

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MESSAGE

In today's era of global warming, cooling has become essential for human comfort and enterprise. The need to ensure access to cooling on a cross-sectoral basis therefore assumes paramount importance.

India has a reservoir of ancient wisdom on cooling systems. Possessing inherent understanding of scientific cooling principles, India architecture down the ages has accorded priority to thermal comfort in buildings and structures. The development of passive cooling techniques in building design has emerged as a response to the challenges posed by extreme climatic conditions leading to its effective adoption in modern building construction. Efforts towards sustainable cooling have also emerged in the cold chain sector, which is key to food safety and security, besides supporting pharmaceutical growth and the transportation sector in general.

Recognising that wholistic actions have a higher impact than a slew of actions taken in isolation, a long-term vision towards cooling has been developed, in the form of an India Cooling Action Plan (ICAP) which was launched in 2019. The recommendations of the ICAP are implemented through an integrated strategy. The entire approach hinges on establishing synergies between existing government programmes and the on-going actions towards HCFC phase out and HFC phase down.

While the focus of the Montreal Protocol implementation would be on transition to climate friendly alternative refrigerants, the ICAP strives to provide sustainable cooling and thermal comfort for all, while securing environmental and socio-economic benefits for society.

This Booklet on "Sustainable cooling" highlights the various initiatives taken by India. I compliment the entire team associated with the preparation of this Booklet, for their painstaking endeavours.

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Chapter

01

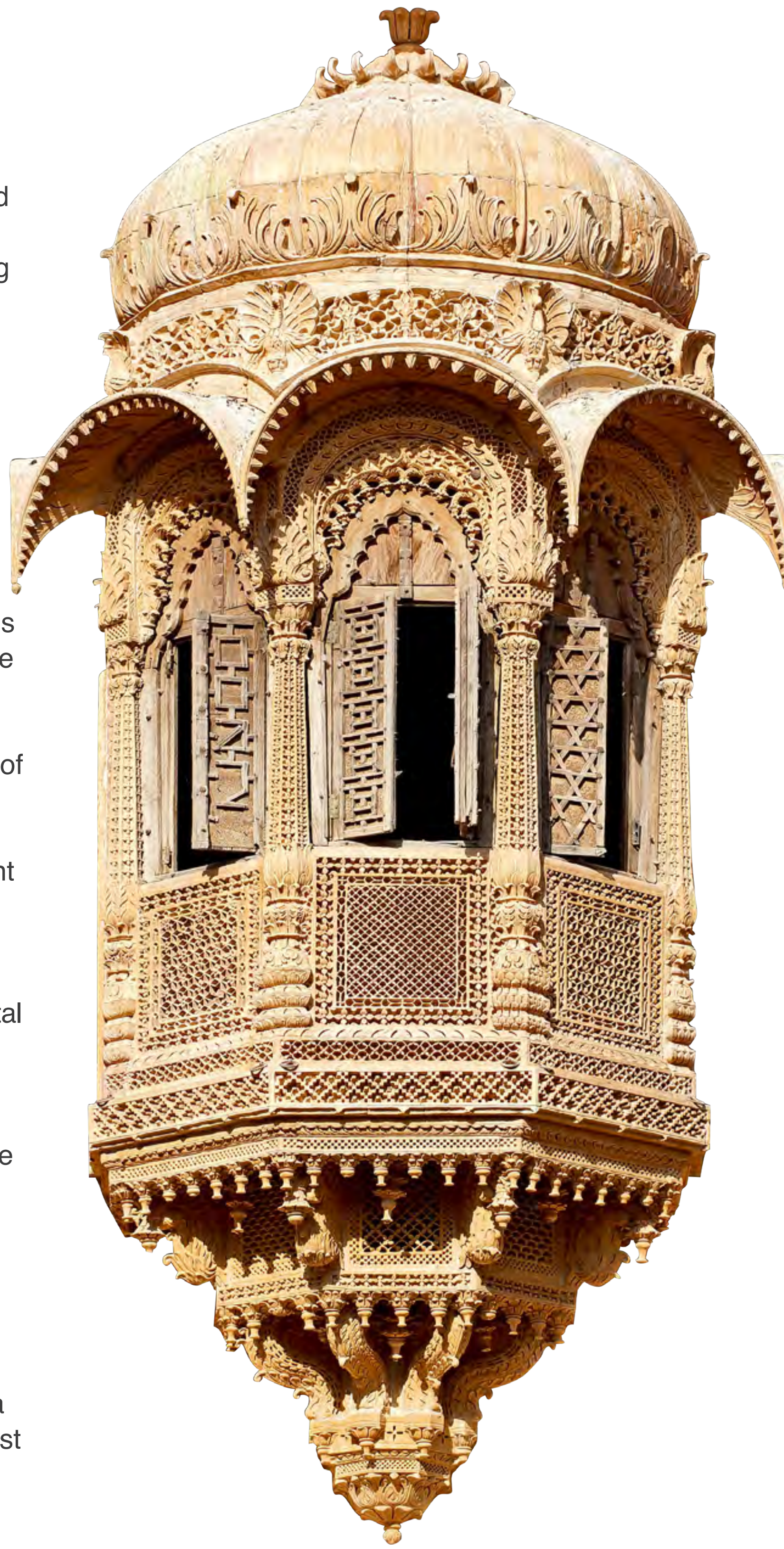
Introduction

1.1 Background

Humanity has always looked at ways and means for comfortable living in harsh environments. In the pre-Industrial era, the need for cooling was largely confined to provision of space cooling. The advent of industrialisation led to a significant increase in the demand for cooling. Cooling became pervasive across different sectors of the economy, such as residential and commercial buildings, cold chain, vaccine storage, refrigeration, transport and industry.

Most parts of India experience harsh, hot, and humid tropical weather conditions. As a result, cooling becomes necessary not only for people's health, well-being, and productivity but also vital to economic growth. Addressing the rising cooling requirement is both a challenging and a unique opportunity, requiring synergies in policy and actions to address the cooling need across sectors as well as make cooling sustainable and accessible to all.

India, over the ages, has understood the interdependence of humans and nature and the need to establish a balance. The Vedas also guide us on the principles of good and healthy living. These are reflected in the cultures of different parts of India regarding working time, building design, architecture, and cuisine. With its heritage values and well-developed concepts of passive cooling, India has managed its development activities with minimal environmental impact. The geographical diversity, traditional living style, and use of local resources helped the country in this endeavour. However, the increasing human activities, industrialization, urbanization, infrastructure development, etc. across the globe have led to rising environmental concerns.



Efficient, affordable, and sustainable cooling can help to alleviate poverty, reduce food losses, improve health, manage energy demand, and combat climate change. The cross-sectoral nature of cooling and its use in the development of the economy makes provision for cooling a vital developmental necessity. In this scenario, it is of utmost importance to utilise learnings from our rich heritage of sustainable ways of cooling to provide access to cooling while minimizing environmental impact.

1.2
India's Geographical Scenario

Climatic Conditions, Temperature Variantion and Humidity

India, the seventh-largest country in the world, presents a rich variety of landscapes. India's climate mirrors its geographical diversity, with most of the country experiencing a tropical climate. The diverse geography of the country manifests varied climate regimes ranging from continental to coastal, hot and cold, aridity and negligible rainfall to excessive humidity and torrential rainfall. The country with its unique geo-climatic conditions is also vulnerable to varying degrees to floods, droughts, cyclones, landslides, avalanches, storms and heat waves.

The climate map of the country presented in **Figure 1.1** shows the different climatic zones, where barring a few states on the foothills of the Himalayas, the climatic conditions of the country are mostly hot and dry, warm and humid, and composite. These conditions make provision of cooling vital for a large part of the country.

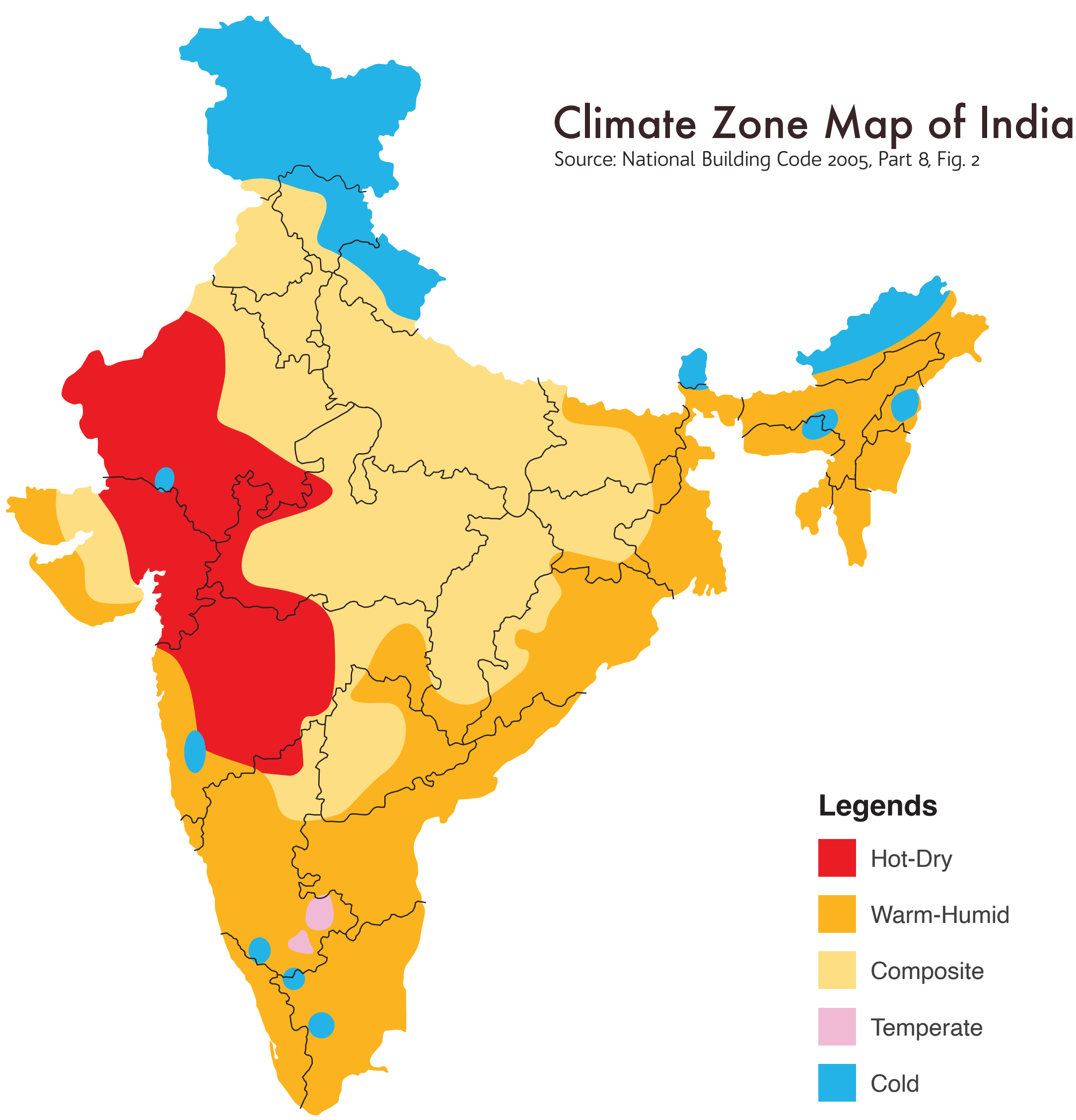


Figure 1. 1: India's Climate Zones

1.3 Cooling Demand

Linkage of Cooling with Economic and Social Development

Cooling is linked with economic growth and recognized as key to food preservation, health, well-being, and productivity in hot climates. India is a fast-growing economy with rising per capita income and rapid urbanization, but still characterized by low penetration of refrigeration and air-conditioning equipment, all of which are expected to lead to an increase in the requirement for cooling in the nearby future.

India's population, which stood at around 360 million after independence in 1951 has now reached 1400 million. Along with the increase in population, income levels have improved significantly – in 1950-51, the per capita net national income at constant prices was INR 12,493/- which has increased to an estimated INR 96,522 by 2022-23 (GOI, 2023). Thus, the demand for the latest means of comfort and convenience, primarily relating to better living and working environments, has also gone up. Cooling today is recognised as a developmental need and is vital for achieving planned economic growth and social development, including addressing many Sustainable Development Goals.

India has one of the lowest accesses to cooling across the world, as shown in **Figure 1.2,** which is reflected in its low per capita levels of energy consumption for space cooling, at 69 kWh, as compared to the world average of 272 kWh (MoEF&CC, 2019).

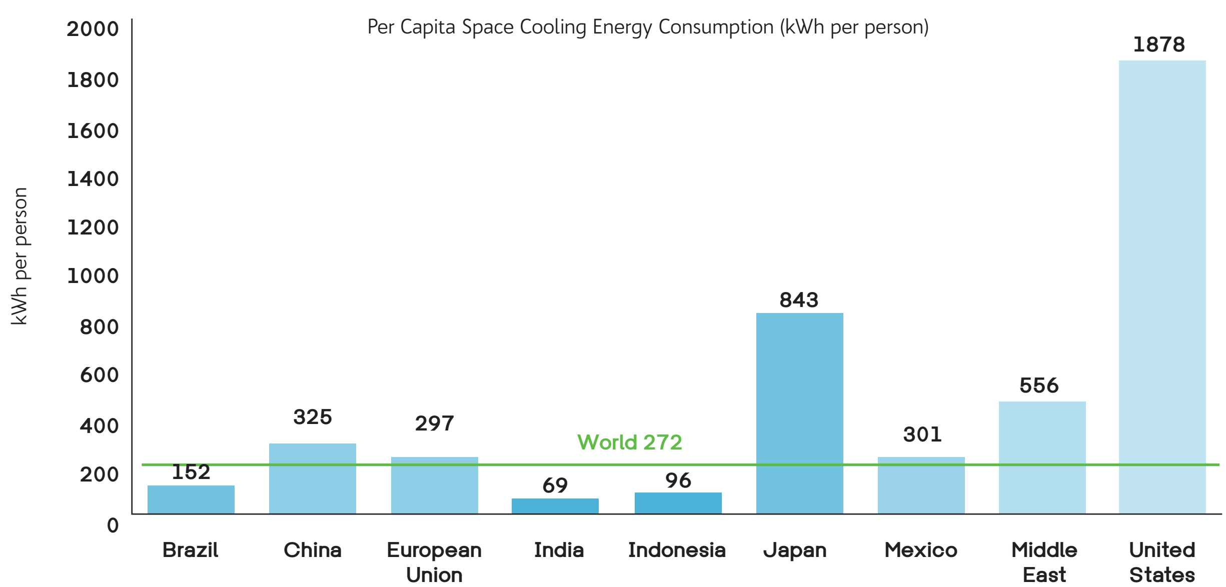


Figure 1. 2: Per Capita Space Cooling Energy Consumption (IEA -2018)

The penetration of air-conditioners in India is only around 8%, growing at an average of 12%, and that of domestic refrigerators is about 5% (MoEF&CC, 2019). These are a few representative examples. The growing demand for cooling and government-led initiatives have been successful in generating interest among the domestic and international industrial community to see India as an emerging domestic market with the potential to cater to the needs of other markets as well.

India's cooling equipment manufacturing industry is engaged in creating a world-class eco-system and synergies for the growth of domestic production, development of micro, small, and medium enterprises, new product development, establishing industry standards, and expanding testing facilities with improved logistics and infrastructure. In fact, the domestic fluorocarbon[1] refrigerant production industry is presently one of the global producers and exporters of fluorocarbon refrigerant gases and has been playing an important role in promoting the government's "Make in India" initiative for many consumer sectors.

Chapter

02

Ancient & Traditional Sustainable Cooling Methods in India

With a deep understanding of scientific cooling principles, India's ancient architecture was well known for providing cool indoor climatic conditions to its occupants using passive and natural cooling methods. Traditionally, natural ventilation and daylight were the prime elements in these designs, which when combined with other concepts like shading, water features, courtyard planning with landscaping, evaporative cooling etc. were able to ensure effective passive cooling in both large buildings and small houses.

Most buildings were made with local materials like mud, stones, bamboo, agricultural waste materials, etc., available in different parts of the country. The typical features of traditional architecture were an east-facing main building facade, thick walls, high roofs, deep shadings on walls, use of jaalis, jharokhas for natural ventilation and daylight; and water bodies, fountains etc. for evaporative cooling.

The Indus Valley Civilization (3300-1300 BCE) and Vedic era (c. 1500 – c. 500 BCE) residents used sustainable construction methods to build intelligently designed, environmentally conscious dwellings by utilizing various materials, including bricks, mud, wood, bamboo, etc. The homes typically featured a central courtyard, which enhanced natural light and ventilation. Building amenities such as wells, bathrooms, and kitchens were also incorporated. The Indus Valley Civilization, being one of the most advanced of its time, made significant contributions to various fields, including architecture and engineering.

Following the Indus Valley Civilization, numerous periods in Indian history witnessed the flourishing of home design. Indian home design has continued to evolve over the centuries, influenced by climate, regional distinctions, and cultural preferences. Nevertheless, the fundamental principles of Indian home design, which prioritize using natural materials, promoting light and ventilation, and seamlessly integrating indoor and outdoor spaces, have endured.

The development of passive cooling techniques in building design emerged as a response to the challenges posed by extreme climatic conditions over centuries; this refinement process led to the creation of several effective passive cooling techniques in building construction.

2.1 Ancient and Traditional Sustainable Cooling Methods in India

Traditional cooling methods in ancient India were essential for maintaining comfort in the hot and arid climate. They were intricately woven into architectural and design principles. Here are some notable sustainable cooling technologies and principles from India:

2.1.1 Microclimate Control

In ancient buildings, architectural features and local materials created a comfortable and healthy indoor environment. These features were critical in hot and humid climates, to ensure that buildings could be kept cool and ventilated. Some of the most common microclimate control techniques used in old buildings included:

Courtyards:
In hot, dry, and humid climate, courtyards served as the heart of a building both socially and environmentally. These courtyards remained shaded throughout the day, regardless of the building's orientation. During the evening, as the air temperature cooled due to re-radiation to the night sky, the heated floor of the courtyard and the adjacent wall surfaces of the buildings raised the temperature of the air within the courtyard. The warmed air, being lighter, would then rise, creating a natural convection effect. Consequently, fresh, and cooler air would flow in to replace the space previously occupied by the hot air. The courtyard design was a remarkable innovation for thermal comfort in ancient architecture, as shown in **Image 2.1.**

Image 2. 1: Courtyard in Shekhawati Haveli, Rajasthan

Verandas:
Verandas acted a buffer for inner spaces to protect people from prickly heat while functioning as a place for organizing their daily activities during hot and rainy seasons. Whenever it got uncomfortable inside the buildings, people used to shift to outside spaces like verandas, **Image 2.2.**

Image 2. 2: Veranda at Ajanta Caves

2.1.2 Natural Ventilation

In historic Indian structures, natural ventilation was driven by wind differentials and temperature variations. Various factors, including microclimate conditions, window size and wind orientation affect the airflow within buildings. Small windows on walls were common features, allowing forceful entry of air. Tapered windows with narrow sections increase air velocity. When higher-velocity air enters a larger space, rapid expansion leads to temperature reduction. In domed spaces, hot air rises, and vents near the ceiling enable its escape, facilitating cooling and comfort, **Image 2.3 and 2.4.**

Image 2. 3: Hawa Mahal, Jaipur

Jaalis (Lattice Screen):
Jaalis are latticework screens made of stone, wood, or metal. These were used to cover windows and doors, providing shade, daylight, and natural ventilation. Jaalis were often decorated with intricate patterns, **Image 2.5.**

Image 2. 4: Air Vents and Shades at Mehrangarh Fort, Jodhpur

Jharokhas:
Jharokhas are projected balconies or windows often found on the upper floors of havelis and other traditional Indian houses. They are typically made of wood or stone and have elaborate carvings and latticework. Jharokhas provide shade and privacy and allow for ventilation and natural light, **Image 2.6.**

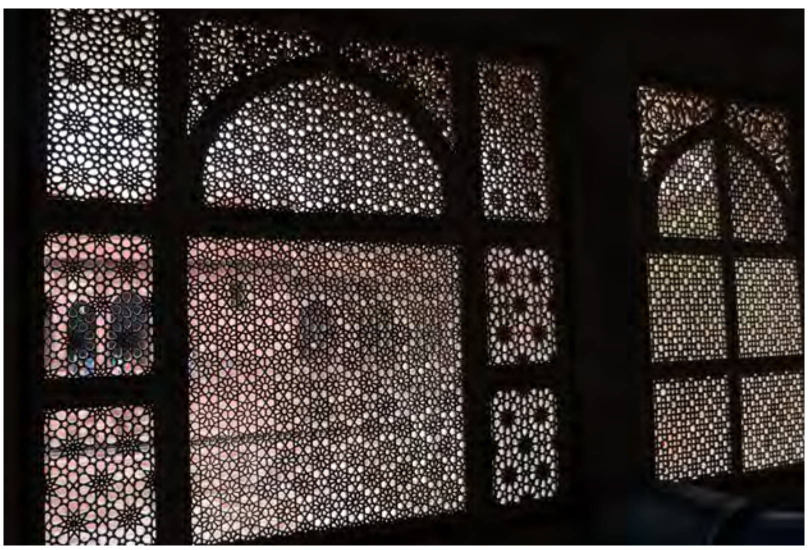


Image 2. 5: Jaalis

Image 2. 6: Jharokhas at a Palace in Rajasthan

2.1.3 Solar Heat Gain Reduction Passive Cooling Methods in Ancient Buildings

Chhajjas (Shading Devices):
Natural cooling was achieved with the use of the chhajja by cutting off the sun's radiation, reducing absorption and slowing heat transmission. A "chhajja" is a traditional architectural feature commonly found in Indian houses. It refers to a projecting horizontal or sloping roof overhanging or shading a window, balcony, or veranda. Chhajjas serve multiple purposes, including providing shade and protection from rain and sunlight, reducing direct sun rays and keeping the interior of the building cool. Chhajjas have been well deployed in several large buildings and small dwellings in rural-urban areas, **Image 2.7.**

Image 2. 7: Chhajja at Ganesh Pol Entrance in Jaipur

Thermal Mass:

Historical buildings have thick walls to support the span and structural limitations of the materials, but these walls were also designed to provide thermal insulation. The rate of heat flow within a wall depends upon the temperature difference between the outer and inner surfaces, **Image 2.8.**

Image 2. 8: Vijay Vilas Palace, Kutch, Gujarat

Domed Roof:

Domed and vaulted roofs are effective in mitigating solar heat. Unlike flat roofs that absorb substantial solar radiation, domed and vaulted roofs deter the summer's intense sun. Arched ceilings allow warm air to gather above the occupants, gradually transmitting heat to the cooler interior surfaces. Due to their larger surface areas, these roofs transmit heat more slowly, enhancing comfort. Some sections of domical roofs stay shaded and simultaneously release heat due to temperature variations, presenting a smart solution for heat management, **Image 2.9 and 2.10.**

Image 2. 9: Brihadeeswara Temple, Tamil Nadu, Domed Roof

Image 2. 10: Domed Roof at Khajuraho Temple, Madhya Pradesh

Mud Huts:

These are among the most common sustainable residential houses of ancient times. They are made from mud, straw, and water and are often whitewashed to keep them cool in the hot summers. Mud huts are naturally insulated, and they can help to regulate the temperature inside, making them comfortable to live in year-round, **Image 2.11.**

Image 2. 11: Mud Hut in Indian village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2.1.4 Evaporative Cooling

Water bodies (still and moving) were added to palaces to improve the humidity in hot and dry regions. The process of evapotranspiration adds water vapours to the air and lowers the air temperature. Fountains are the best way to improve air quality as they sprinkle water drops into the air, making the evaporation process faster, **Image 2.12 and 2.13.**

Baoris (Stepwells):

Baoris were used in ancient buildings with steps that led down to a water reservoir. They also significantly contributed to cooling the microclimate, providing relief from intense heat. These architectural wonders enhanced comfort, particularly in hot regions, as the evaporative cooling effect of the water within the stepwell created a cooler environment, making them essential structures for both practical and climatic reasons, **Image 2.14.**

Image 2. 12: Fountain in the courtyard of Jag Mandir in Udaipur.

Image 2. 13: Jal Mahal (Water Palace) in Jaipur

Image 2. 14: Chand Baori, Rajasthan

2.1.5 Vegetation and Trees Around the Buildings

In ancient architectural design, outdoor spaces and courtyards were often adorned with vegetation. Integrating greenery in these areas played a pivotal role in enhancing the microclimate in the vicinity, improving the air quality and regulating the indoor temperature of a building. **Image 2.15 and 2.16.**

Image 2. 15: Trees and Garden Around Buildings

Image 2. 16: Trees and Garden Around Ancient House

2.1.6 Radiant Cooling

Stone walls were used as radiant cooling systems by utilizing their thermal mass. Thermal mass is the ability of a material to absorb, store, and release heat energy. Stone has a very high thermal mass, meaning it absorbs and stores heat energy. Radiant cooling systems are very efficient because they use the thermal mass of the building to store and release heat energy **Image 2.17.**

Image 2. 17: Stone Walls of Ajanta and Ellora Caves

2.1.7 Mud Pots (Surahi and Matka)

Ancient Indians were masters of cooling technology, and developed ingenious ways to keep themselves cool in the hot and humid climate. One of the most common methods was to use mud pots (Surahi and Matka) for keeping drinking water cool in the absence of refrigeration. These pots were made of porous clay - when filled with water and placed in a shaded spot, the water would evaporate through the pores of the clay, cooling the water inside the pots **Image 2.18.**

Image 2. 18: Mud Pots (Surahi and Matka)

2.2 Mapping of Ancient Cooling Technologies and Modern Architecture

Ancient Indian architecture, rooted in passive cooling techniques and use of natural materials, was renowned for its sustainability. In the olden times, people used natural methods such as ventilation, water features, vegetation, and thick walls to cool themselves and their homes. These methods relied on the principles of heat transfer, such as convection, conduction and radiation.

The advent of urbanization in the modern era led to a significant departure from these sustainable practices. The proliferation of commercial high-rise buildings, characterized by extensive glass facades, further posed energy efficiency challenges.

Nevertheless, the emergence of government policies, energy rating, and green building codes has initiated a resurgence of sustainable architecture in India. Contemporary architects, building designers and developers have started integrating eco-friendly materials, energy-efficient technologies and sustainable design principles in commercial and residential buildings to address the environmental and social implications of modern urbanization, and strike a balance between tradition and progress.

Ancient technologies for keeping buildings cool continue to be relevant even in today's architecture. **Table 2.1** summarizes how these sustainable cooling technologies have been incorporated into Indian commercial and residential building designs.

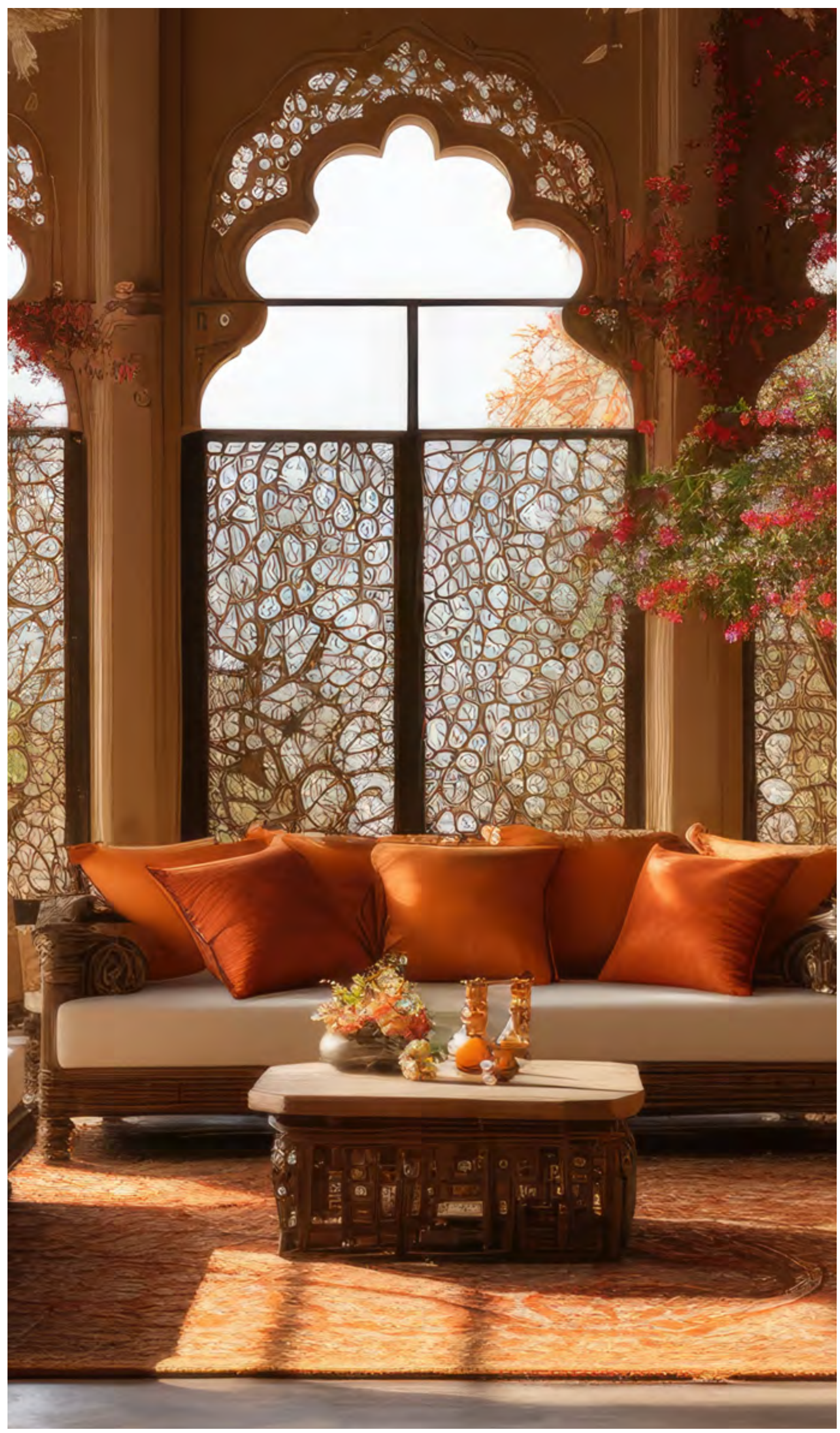


Table 2. 1: Mapping of Ancient Passive Cooling Technologies and Modern Architecture

Ancient Indian Architecture Technologies	Technology Transformation in Modern Indian Architecture
Chhajja and Jharokha: **Chhajjas and Jharokhas** are both features of Indian architecture. A chhajja is an overhanging roof or canopy that is typically found on the front or sides of a building. A jharokha is a small, open balcony that is typically found on the upper floor of a building. These protect the exterior of a building from the elements, such as sun rays, and help circulate air in and out of a building, which can help regulate temperature. A jharokha allows people inside a building to see the outside world and provides daylight.	Here are some specific examples of how the concepts of chhajja and jharokha are now being used in modern architecture: **Overhangs and canopies:** Overhangs and canopies are used to protect entrances, windows and other openings from the elements. They can also be used to provide shade and shelter from the sun. **Balconies:** Balconies are used to provide ventilation and views to interior spaces. They can also be used to create a sense of connection between the interior and exterior of a building.
Courtyards and verandas were part of passive cooling building designs used in India for centuries. They offer several benefits, including microclimate control, natural ventilation, daylight, and social spaces. Courtyards are enclosed spaces within a building, while verandas are open-air porches or terraces.	In modem Indian architecture, courtyards are used, but often in new and innovative ways, for example, as central **atriums.** Veranda is also still in use and is referred to by other names, such as Porch and Patio: **A porch** is a covered outdoor space that is attached to a building. **A patio** is an uncovered outdoor space that is typically located at the back of a house. It is often paved with concrete, brick, stone or wood.

Domes and arches were used in ancient Indian architecture to create various types of buildings, including temples, mosques, palaces, and tombs. They offer several advantages, including strength and stability, natural light and ventilation, and aesthetics.	**Domes and arches:** Some examples of domes and arches used in modern architecture are sports stadiums, airports, museums and libraries, commercial buildings such as shopping malls, and religious buildings.
Water features were prominently used in ancient Indian architectural design as sustainable cooling solutions. These features encompassed elements like Step wells, Fountains, Kund (Ponds), and Chhatris. Notably, Chhatris were open-air pavilions frequently constructed above water bodies, exemplifying the application of water features for cooling purposes.	Water features are now being used in modern architecture for sustainable cooling. They can be used in a variety of ways to create more comfortable and sustainable buildings, viz., **Cool Roofs,** using vegetation and moisture-absorbing layers, **Mist and Fog Systems:** High-pressure misting and fogging systems release fine water droplets into the air, **Thermal Ponds,** artificial thermal ponds, and pools that use water for temperature regulation. **Fountains** are used in atriums and courtyards to enhance their cooling effect.
Thermal Mass and Insulation: In ancient Indian architecture, thermal mass was skilfully incorporated to regulate indoor temperatures. Common materials like stone, mud, and thick walls were used for their high thermal mass. These materials absorbed heat during the day and released it slowly at night, helping maintain comfortable indoor temperatures. Notable examples include the thick walls of forts and palaces, step-wells, and temples.	Modern architecture has started incorporating thermal mass to reduce heat gains. **Trombe Walls:** A Trombe wall is a thick, high-mass wall placed on the south side of a building, with a glass layer in front. It absorbs and stores heat, which is then radiated into the interior. **Insulations on Wall/Roof:** Insulating materials, like fiberglass, foam board, or spray foam, create a thermal barrier that prevents heat transfer between indoor and outdoor environments. **Green Roofs:** Green roofs, covered with vegetation provide thermal mass and insulation, helping to regulate indoor temperatures. **Water Walls:** Water walls, often used with solar energy systems, act as thermal mass to store and distribute heat.

	Passive Solar Design: Passive solar design principles, strategically placing thermal mass materials to absorb and retain heat, are integral to modern energy-efficient architecture.
Radiant cooling was a principal technology in ancient Indian architecture, especially when utilizing stone as a primary building material. Its different applications included: **Thermal Mass:** Stone, such as sandstone and granite, was a prevalent building material in ancient Indian architecture. The high thermal mass of stone allowed it to absorb heat during the day and release it slowly at night, helping to stabilize indoor temperatures and keep spaces cool. **Step-wells:** A Step-well's stone surfaces and shaded depths helped keep the step-well cooler, creating a refreshing environment for people to access water. **Cave Architecture:** The famous Ajanta and Ellora caves are prime examples of stone-based architecture in India. The rock-cut structures, with their thick stone walls, showcased radiant cooling properties by keeping the interiors naturally cool.	**Radiant cooling** is a relatively less used technology, but it is quickly gaining popularity in modern architecture. It is a very efficient way to cool buildings and can also help improve indoor air quality and reduce noise pollution. Radiant cooling systems typically use a network of pipes or tubing that are embedded in the walls, floors, or ceilings of a building. Chilled water or other coolant is circulated through the pipes, absorbing heat from the surrounding surfaces. Radiant cooling systems can be used to cool both residential and commercial buildings. They are particularly well-suited for buildings with large open spaces like offices, hotels, and shopping malls.

2.3 Reducing Cooling Demand in Buildings by Adopting Traditional Passive Cooling Methodologies in Building Design

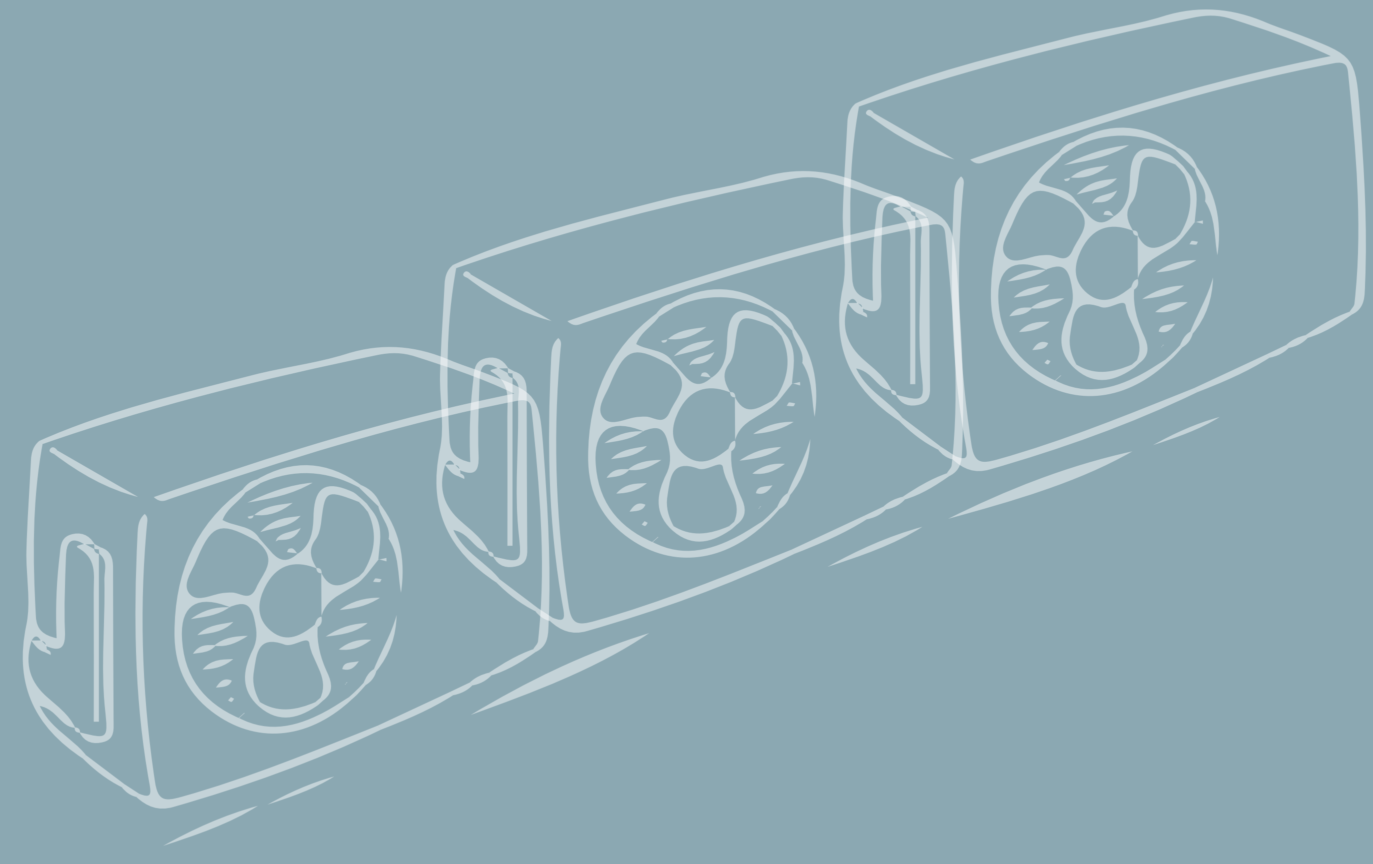
Ancient building architecture had well-developed concepts of passive cooling. Building designers and developers today design and construct energy-efficient buildings by harnessing all potential advantages from the site and surroundings and integrating the basic concepts of passive cooling used for centuries in the country. Decisions about building form, orientation, shading, ventilation etc., taken during the early design stage, have the most significant impact on the energy use of a building. Passive design strategies aim to achieve thermal comfort using as little active cooling and heating as possible. It means reducing cooling requirements during the summer and heating requirements in the winter through appropriate orientation, external shading, glazing, and natural ventilation.

Energy-efficient, climate-responsive design requires a whole-building perspective that integrates architectural and engineering concerns as early as possible in the schematic design process. An energy-efficient building envelope, coupled with an efficient lighting system and air conditioning equipment, will cost less to build and operate than a building where systems are designed in isolation.

Chapter

03

Cooling Demand In India



India is a fast-growing economy characterized by high urbanization and low access to cooling. Cooling demand is expected to increase with the growing economic and infrastructure development in order to meet the people's basic needs and legitimate aspirations, such as a comfortable living and working environment for greater productivity, health and well-being.

It has been projected that the aggregate nationwide cooling demand will grow eight times by 2037-38 compared to the 2017-18 baseline (MoEF&CC, 2019). The sector-wise growth in cooling demand is presented in **Figure 3.1.** The building sector cooling demand shows the most significant growth at nearly eleven times as compared to the baseline; the cold-chain and refrigeration sectors will grow around four times, while transport air-conditioning will grow around five times by 2037-38 from 2017-18 levels.

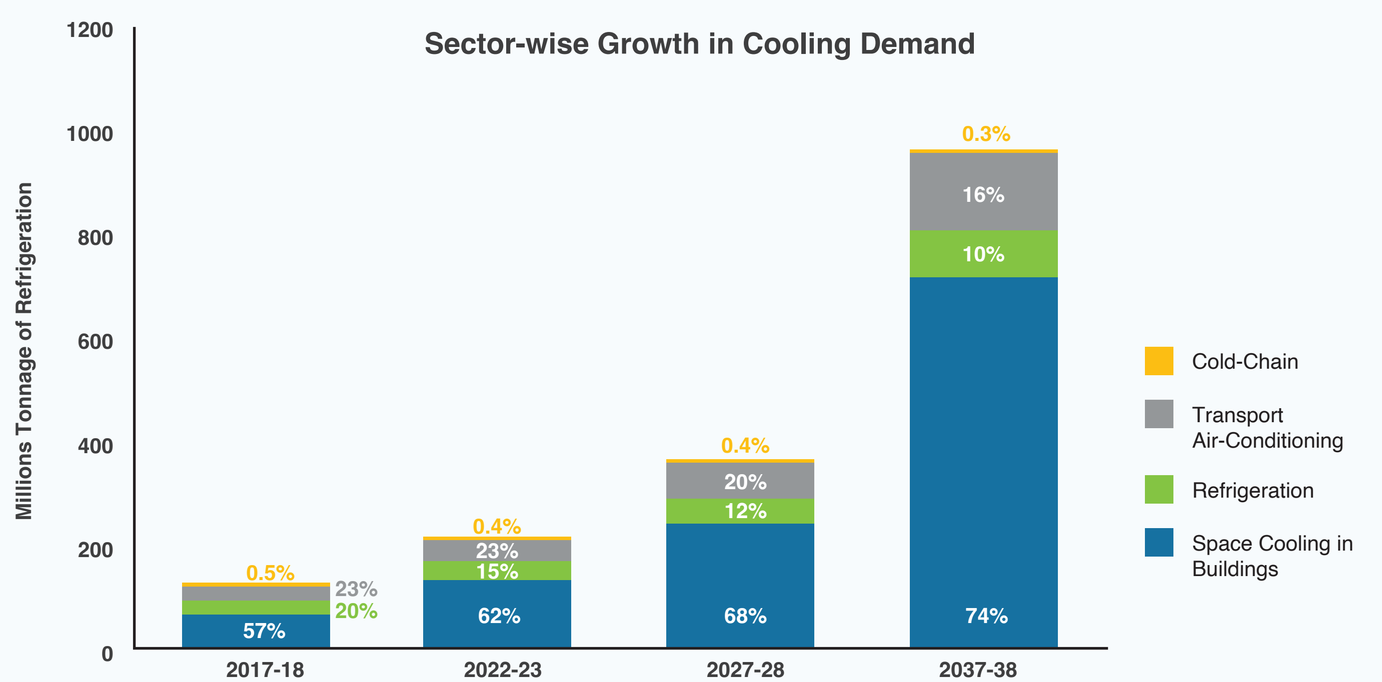
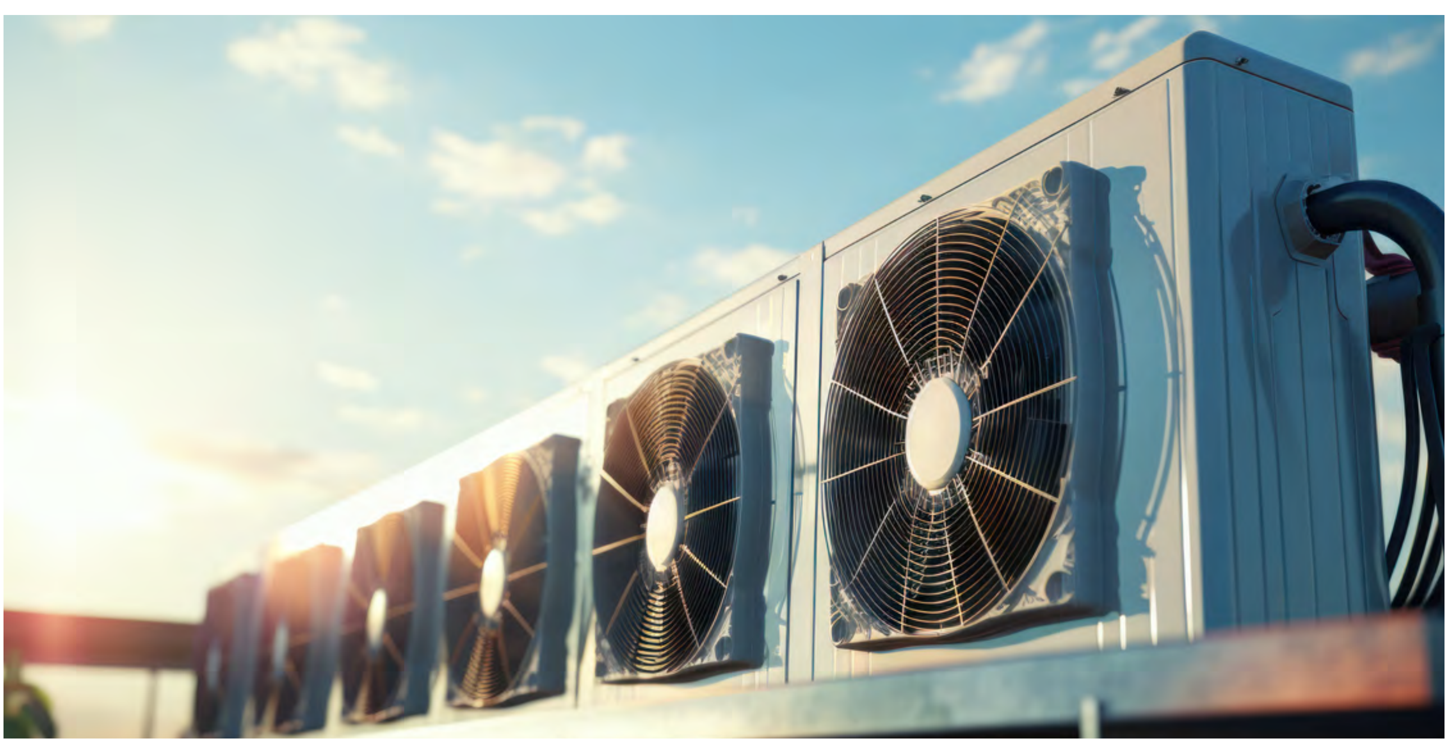


Figure 3. 1: Sector-Wise Growth in Cooling Demand



3.1 Space Cooling in Buildings

The building sector is one of the most vital sectors of the economy, and its growth is linked with the country's development. On the other hand, the sector is also a significant user of cooling in urban areas. The built environment is set to grow as a result of the rapid urbanization in the country, and it is estimated that 70% of the buildings are yet to be built (IFC, 2022). Subsequently, space cooling requirement for air-conditioning and refrigeration will also increase. However, the building sector offers huge potential for reducing cooling demand and improving energy efficiency to reduce energy consumption, refrigerant consumption, and related direct and indirect greenhouse gas (GHG) emissions.

3.1.1 Projections for Space Cooling Demand

Space cooling applications can be found in different buildings, such as offices, retail, education, hospitals, restaurants, hotels, residential houses, and apartments. These could be broadly categorized into residential and commercial sectors.

Residential Building Sector

The residential building sector's stock and its growth trajectory over the next 20 years have been presented in the India Cooling Action Plan (ICAP). It is estimated that there were approximately 272 million households in India in 2017, which will increase to 328 and 386 million in 2027-28 and 2037-38, respectively (MoEF&CC, 2019).

Also, the penetration of refrigerant-based cooling in residential buildings in 2017 was only about 8%, which is expected to rise to 21% and 40% in 2027-28 and 2037-38 respectively as can be seen from **Figure 3.2.**

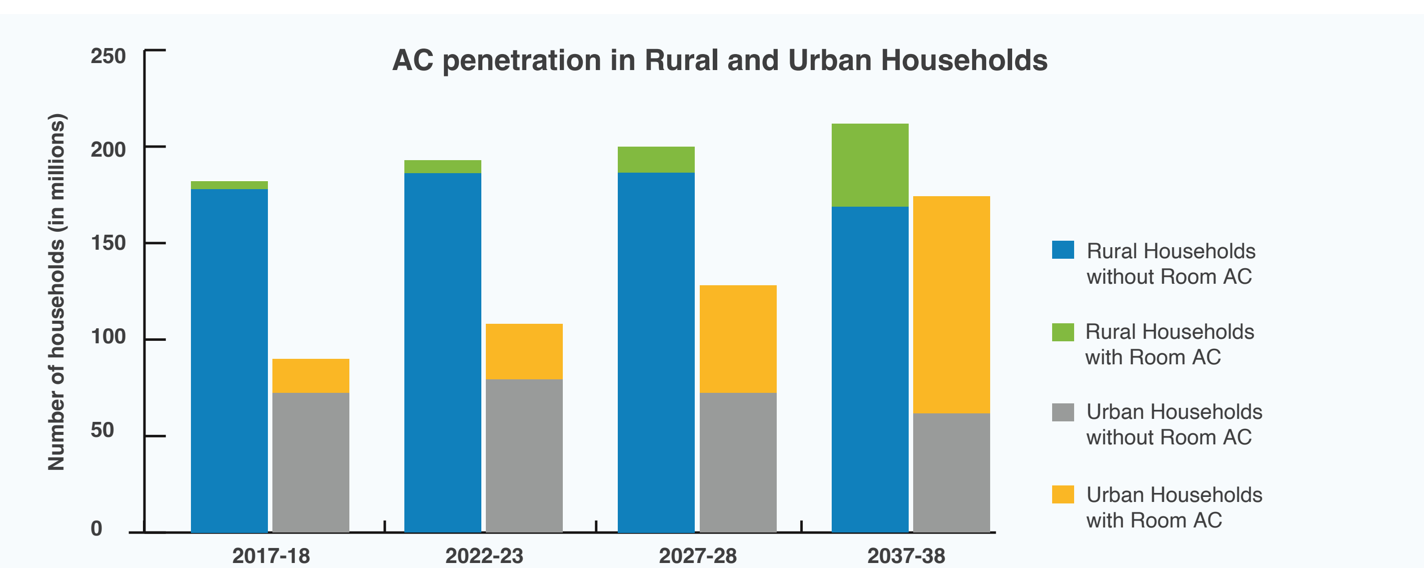


Figure 3. 2: Number of Households with Room Air Conditioners

In the future, new demand is likely to be generated from purchase of the first air conditioners by households and subsequent purchase of new units by families already having air conditioners. Figure 3.3 depicts the room air conditioner stock of urban and rural households (MoEF&CC, 2019).

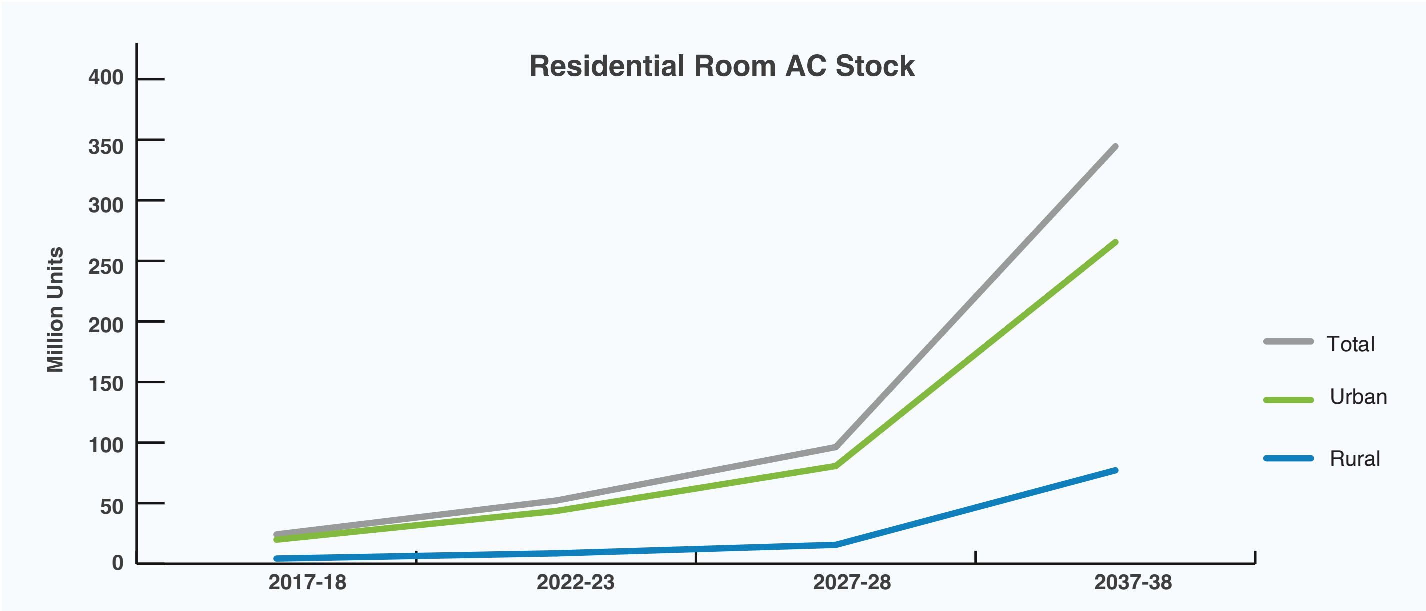


Figure 3. 3: Room Air Conditioner Stock in Urban and Rural Households

Commercial Building Sector

The commercial building sector encompasses large buildings used for a variety of purposes. Usually, these can be classified under eight major segments: hospitals, hotels and restaurants, retail, office buildings, educational institutions, assembly places, transit buildings, and warehouses. The commercial building sector floor area in 2017-18 was estimated to be 1160 million m^2 and is expected to grow 1.6 times in the next decade to 1880 million m^2 and 2.7 times the size of 2017-18 to 3090 million m^2 by 2037-38. The intensity of air conditioning demand in the commercial building sector is significantly higher than in the residential sector. The estimated air-conditioned area for commercial buildings is presented in **Figure 3.4.**

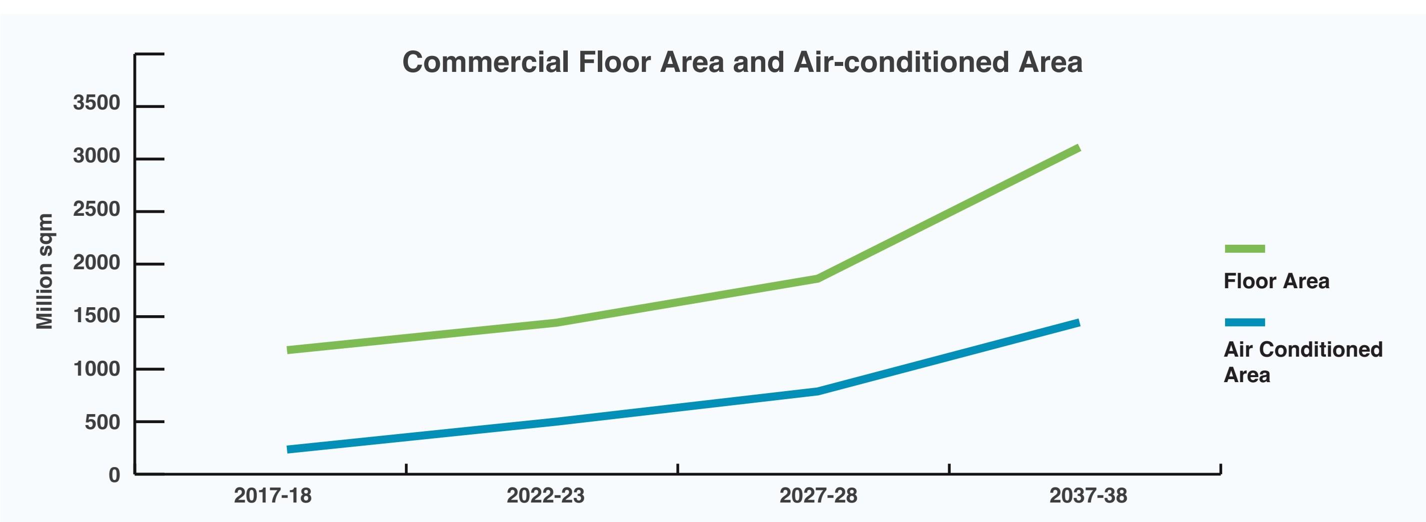


Figure 3. 4: Total & Air-conditioned Area in Commercial Buildings

Note: Room air conditioner is an appliance that is central to space cooling in the country and will continue to be increasingly used for the next few decades owing to rapid urbanization. **Figure 3.5** *presents current and future demand for room air conditioners under the low and high growth scenarios. It can be seen that the stock of installed ACs will grow from about 40 million in 2017-18 to 300-600 million by 2037-38.*

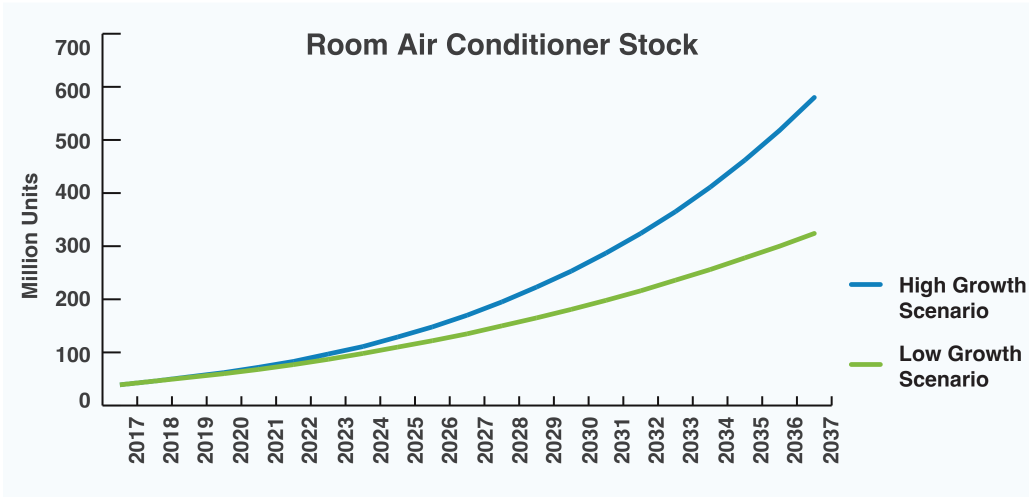


Figure 3. 5: Room Air Conditioner Stock Under Low and High Growth Scenarios.

3.1.2 Projections for Refrigerant Demand

Refrigerant-based cooling technologies are increasingly becoming prominent in space cooling in residential and commercial building applications. Refrigerants are used in new equipment manufacturing as well as servicing, with the latter accounting for about 40-45% of annual refrigerant demand in the space cooling sector. Refrigerant demand projections for space cooling are presented in **Figure 3.6.**

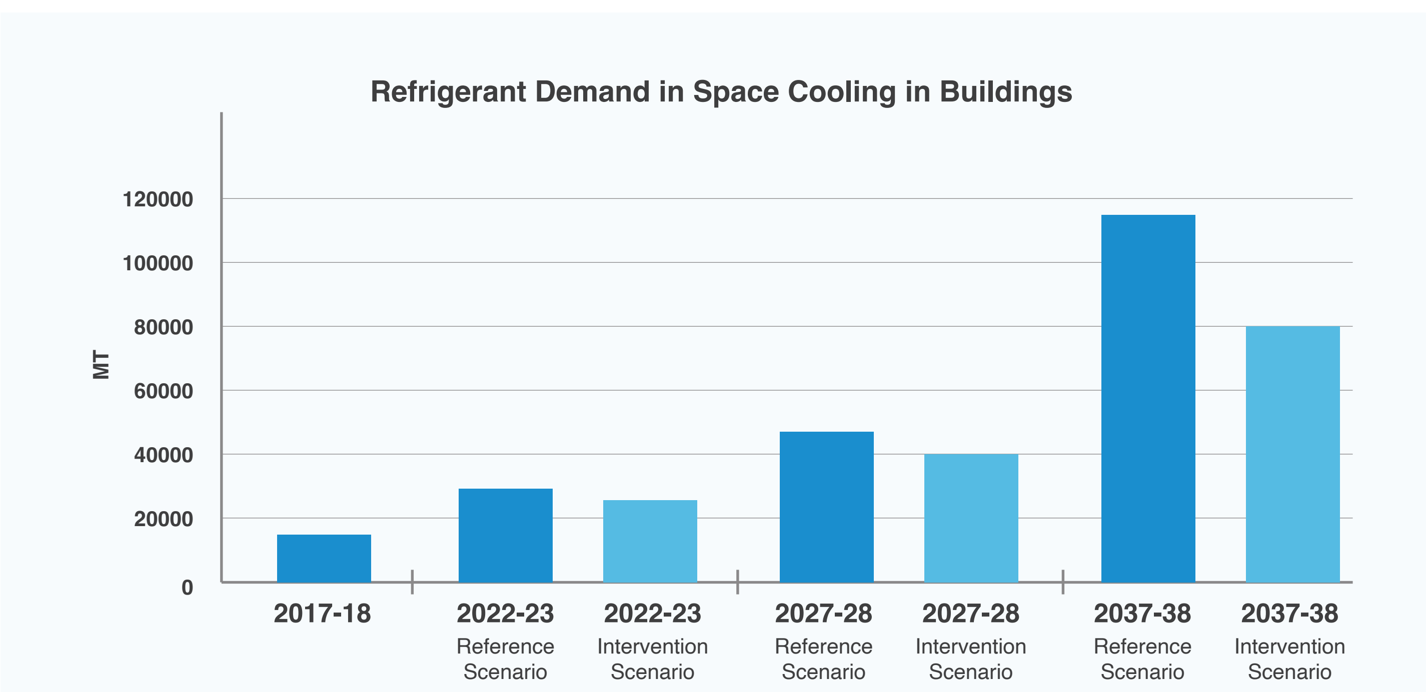


Figure 3. 6: Annual Refrigerant Demand (incl. Servicing) in Space Cooling in Buildings

3.1.3 Current Technology Trends in Space Cooling

Building space cooling uses refrigerant-based mechanical compression technologies and non-refrigerant-based technologies like air coolers. This section presents the trends of current refrigerant-based technologies. Several types of air conditioning equipment have been developed and deployed to cater to specific application requirements. **Table 3.1** presents the current technology trends for space cooling.

India is one of the countries to introduce low-GWP technologies like R-290 and HFC-32 for room air conditioners. There are chillers that are still charged with refrigerants like HFC-134a and HCFC-123, but gradually, these refrigerants are being replaced by ultra-low-GWP refrigerants.

Table 3. 1: Refrigerant Technology Trends for Space Air Conditioning Sector

Room Air Conditioners			
Technology	Ozone Depleting Potential (ODP)	Global-warming potential (GWP)	Safety Classification
HCFC-22	0.055	1810	A1
HFC-32	0.0	675	A2L
R-410A	0.0	2088	A1
R-290	0.0	3	A3
Packaged and Ducted Air conditioning units			
R-22	0.055	1810	A1
R-410A	0.0	2088	A2L
HFC-32	0.0	675	A1
R-454B	0.0	466	A3
Large Cooling Capacity Chillers			
HFC-134a	0.0	1430	A1
HCFC-123	0.02	77	B1
HFO-1234 yf	0.0	4	A2L
HFO-1224 yd	0.0	1	A1
HFO-1233 zd (E)	0.0	1	A1
R-513A	0.0	631	A1
R-514A	0.0	2	B1

Source: IIR (2022)

3.1.4 Integrated Approach for Efficient and Sustainable Cooling

Space cooling in buildings is a major and fast-growing sector, with cooling requirements growing at a CAGR of about 15%. The room air conditioner constitutes a dominant share, ranging between 80% and 90% of the refrigerant-based cooling technologies. It is energy intensive and contributes significantly to the direct and indirect GHG emissions. Another challenge associated with the space cooling sector is the limited availability of low-GWP technology options.

It is important for the sector to have an integrated long-term vision for space cooling, encompassing, among other things, optimization of cooling demand, integration of energy efficiency and refrigerant transitioning efforts, and adoption of better technology options as integrated actions are likely to have a higher impact than any actions taken in isolation.

India's integrated approach for efficient and sustainable cooling is depicted in **Figure 3.7.** It comprises of four broad verticals: efficient building design to reduce cooling, improvement in the energy efficiency of cooling equipment, mitigation of the environmental impact of refrigerants, and use of not-in-kind cooling technologies and renewable energy to reach the goal of net-zero emissions.

Integrated Approach for Efficient and Sustainable Cooling

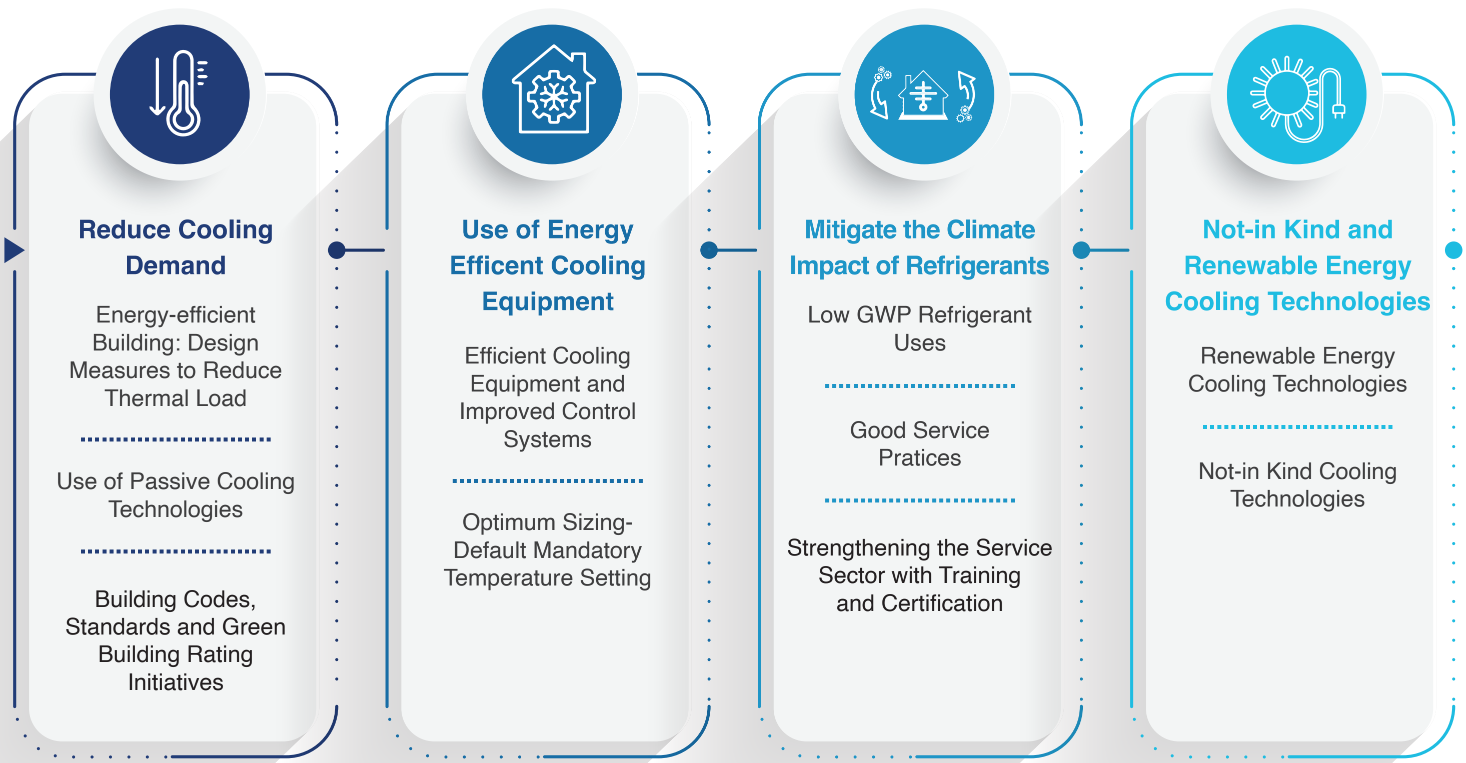


Figure 3. 7: Integrated Approach for Efficient and Sustainable Cooling

3.2 Sustainable Cooling in Cold Chain

India's cold chain is paramount to ensuring food safety and security, reducing food wastage, and supporting the pharmaceutical sector's growth. As the country's population and economy grow, further investments and advancements will be made in this critical infrastructure.

3.2.1 Growth of Agriculture, Cold Storage, Super Market and Retail Sector

India is predominantly an agrarian economy, with nearly 54.6% of the total workforce is engaged in agriculture and allied sector activities (Census 2011) which account for 18.6 % of India's GVA at current prices during 2021-22. India's agriculture sector grew at 4.1% (FY2021) and 3.5% (FY2022). Maintaining the positive momentum, in FY2023, it has grown at a rate of 3.3%. The CAGR of the sector during the 5 years ending FY2023 is 4% (PIB, 2023a).

India is the second largest producer of fruits and vegetables in the world, with a production of 277 Million Metric Tonnes (MMT), and the largest producer and consumer of milk and dairy products, with a 20% share in global milk production. The country is also the world's second largest fish-producing nation, valued at around USD 15 Billion (MoEF&CC, 2021).

According to the ICAP, different components of cold-chain infrastructure will witness substantial growth by 2037-2038. **Figure 3.8** presents the evolution of the cold chain sector in India.

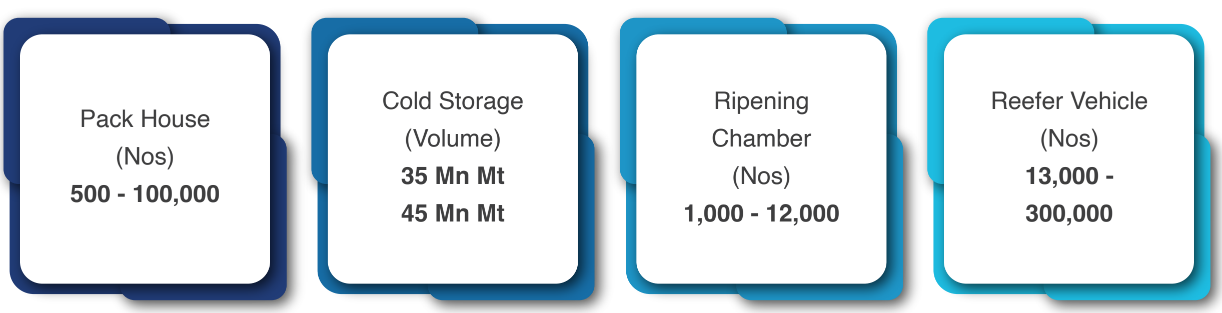


Figure 3. 8: Growth of Cold Chain Sector by 2037-38

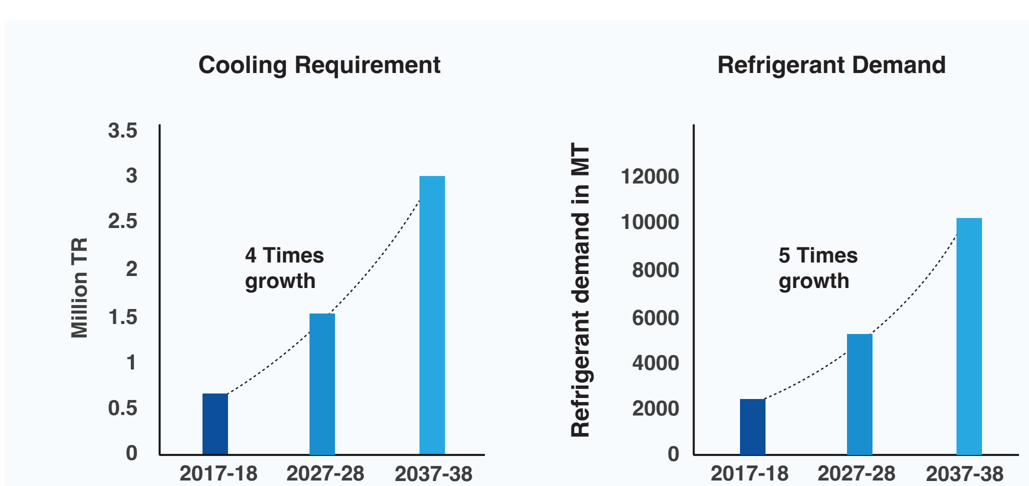


Figure 3. 9: Cooling and Refrigerant Demand in Cold Chain Sector

The energy consumption in the cold-chain sector is likely to double in the next ten years from 71 Tera Watt hours (TWh) in 2017-18 to 130 TWh in 2027-28 and increase further by 1.6 times (compared to 2027-28) to 212 TWh by 2037-38. Consequently, the refrigerant demand is envisaged to grow five times and reach ~ 10,000 MT by 2037-38 from 2000 MT in 2017-18 (ibid).

The retail sector cold chain system is growing along with commercial space growth, GDP growth, and technological changes. The CAGR of commercial refrigeration systems was estimated as follows – Deep Freezer: 12% to 15%, Visi-cooler: -2% to -8%, Remote condensing unit: 10% to 15%, Water cooler: 5%, supermarket and hypermarket system: 15%.

3.2.2 Growth of pharmaceutical cold chain

India is the world's third-largest producer of pharmaceuticals by volume. Low manufacturing costs for biosimilar development make India attractive for export-related production.

COVID-19 made it evident that to lead a healthy life in today's world, one needs to look after one's health and ensure the presence of a well-connected, strong medical infrastructure. To achieve this, one of the primary needs is for a country to have fully functional cold chains that can cater to the storage requirements of the pharmaceutical industry. While medical cold storage infrastructure in India accounts for 43.7 percent of the total revenue from the cold chain industry (Rathore, B. & Verma, K., 2022), there is still a lot more room in the market for growth as well as the need for coolers and refrigerators to store vaccines.

The storage and transportation of COVID-19 vaccines from the manufacturer up to the COVID-19 Vaccination Centre (CVC) is ensured in a temperature-controlled environment ranging from 2-8 degrees Celsius. A robust cold chain network of around 29,000 cold chain points, along with insulated/refrigerated vaccine vans, cold boxes and vaccine carriers, is used to ensure safe storage and transport of COVID-19 vaccines. Monitoring of storage temperature is also done on a regular basis to ensure that the recommended temperature can be maintained.

3.2.3 Growth of E-commerce and Supermarkets

Cold storage is an essential component of the e-commerce cold chain infrastructure. Cold storages and warehouses are designed to store perishable products and maintain the temperature and humidity parameters as per the product requirement. These serve as an essential link between farm produce and the final consumer. The current installed capacity of different types of cold storages is presented below in **Figure 3.10.**

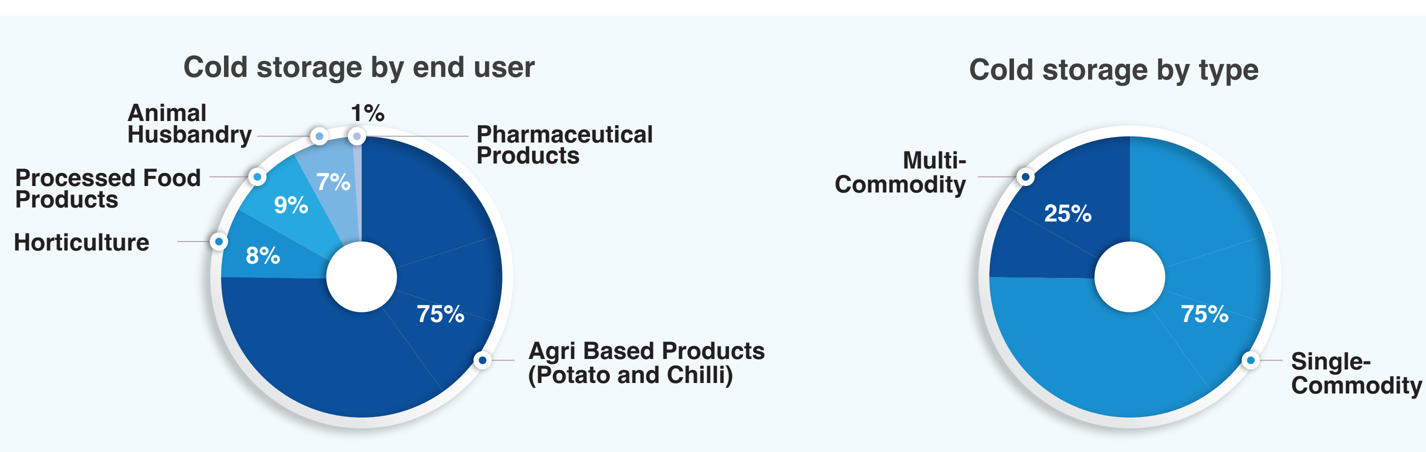


Figure 3. 10: Cold Storage by Types and End Use

Source: MoEF&CC (2021)

Supermarkets in the country are developing an effective e-commerce model with growing presence in urban and semi-urban areas. The e-commerce industry primarily uses the hyper-local grocery delivery model.

Approximately 6 MMT of the total cold storage capacity is utilised by e-commerce companies. With an estimated growth of the e-commerce sector of the order of 13%-16% CAGR from 2022–2027, the utilisation of cold storage capacity by the sector is expected to reach 12 MMT by 2027.

Image 3. 1: A supermarket in India

3.2.4 Current Technology Trends in Cold Chain

In recent years, India has recognized the significance of cold chain technologies, resulting in increased awareness and government initiatives like the Pradhan Mantri Kisan Sampada Yojana (PMKSY). PMKSY is designed to enhance infrastructure and supply chains for agricultural goods, offering financial support to establish cold storage facilities.

The National Building Code of India (NBC 2016) provides guidelines for regulating building construction activities across the country. NBC 2016 offers guidelines for various aspects of cold storage, including thermal insulation and safety. These guidelines are essential for maintaining cold storage facilities' proper functioning and safety. It serves as a model code for adoption by all agencies involved in building construction.

IS 2370:2014 is an Indian Standard established by the Bureau of Indian Standards (BIS) titled "Walk-In Cold Rooms." This standard provides specifications and requirements for the design, construction and operation of walk-in cold rooms.

The IS 13288 Part-2, titled "Freight Containers: Specification and Testing - Thermal Containers" is a standard specification established by the (BIS). This standard outlines the specifications and testing requirements for thermal containers transporting and storing goods requiring temperature control.

Mechanical compression refrigerant-based cooling technologies are predominant across various cold chain components, including pack-houses, cold stores, transport refrigeration, and retail outlets, satisfying approximately 95% of cooling requirements. These systems are favoured for their adaptability to diverse ambient conditions and wide temperature ranges, accommodating various products. The subsector-wise refrigerant technologies are presented in **Table 3.2**

Table 3. 2: Refrigerant Technology Trends for Cold-chain Sector

Pack Houses			
Technology	ODP	GWP	Safety Classification
Ammonia	0.0	0.0	B2L
HCFC-22	0.055	1810	A1
HFC-134a	0.0	1430	A1
R-404A	0.0	3922	A1
Cold Storage			
Ammonia	0.0	0.0	B2L
HCFC-22	0.055	1810	A1
R-410A	0.0	2088	A2L
R-134a	0.0	1430	A1
R-454B	0.0	466	A2L
Ripening Chambers			
Ammonia	0.0	0.0	B2L
HCFC-22	0.055	1810	A1
HFC-134a	0.0	1430	A1
R-407C	0.0	1774	A1
R-410A	0.0	2088	A1

Reefer Vehicles			
HFC-134a	0.0	1430	A1
R-404A	0.0	3922	A1
Commercial Refrigeration Cabinets and Freezers			
R-290	0.0	3	A3
R-600a	0.0	3	A3
HFC-134a	0.0	1430	A1
R-404A	0.0	3922	A1
Domestic Refrigerators and Freezers			
R-600a	0.0	3	A3
HFC-134a	0.0	1430	A1

Source: IIR (2022)

Ammonia a choice of Refrigerant technology for the cold chain sector:

Ammonia is an ultra-low-GWP trusted refrigerant used for industrial refrigeration for over a century. It is a refrigerant used in nearly 90% of the plants in the Indian cold chain industry (Shakti Foundation, 2019). Ammonia has been continuously used longer than any other refrigerant and is the most effective refrigerant available today. Despite the high toxicity of ammonia, the safety record of ammonia refrigeration systems is good.

Solutions to the challenge of ammonia's toxicity include technically sound design, manufacturing, testing, installation, operation and maintenance of the system following the latest safety standards. BIS has developed several standards related to the cold chain. It recently published a Standard on "Closed Circuit Ammonia Refrigeration Systems-Code of Practice for Design and Installation" to further strengthen the safe handling and use of ammonia in this sector.

3.3 Transport air-conditioning

India is witnessing fast-paced infrastructure development with a rapidly growing transportation network, including trains, railway stations, airports etc. This growth is in response to the surging population and urbanization trends, which have amplified the demand for increased mobility and elevated comfort levels and resulted in an uptick in personal vehicle ownership. Air conditioning has become increasingly crucial across multiple sectors of India's transportation network, including trains, stations, airports, and vehicles. The need for thermal comfort is on the rise, reflecting the growing aspirations of people. Air conditioning systems represent a substantial portion of energy consumption within any transportation system.

To mitigate the associated negative environmental impacts, the Indian government is investing significantly in public transportation, expanding metro, bus, and rail networks in major cities. Public transport is energy efficient and can reduce traffic congestion, which makes it easier for people to get around, and improves air quality. The government is also promoting the use of electric vehicles in public transportation.

3.3.1 Growth in the Transport Infrastructure Sector

India's railway system, one of the world's largest, is under single management and has shown steady growth, with revenues projected to grow at a CAGR of 5.9% (IPRS, 2022). Images 3.2 and 3.3 depict the latest infrastructure development in this area.

There has been a remarkable growth of metro rail networks during the last decade, especially in metro cities, Tier II and Tier III cities in India, which is expected to decongest road transport, discourage use of private vehicles and provide comfortable mobility to people. Such developments can be attributed to the government's efforts at making efficient and sustainable public transportation systems a vital aspect of India's urban development. In addition, the rising demand for cooling and air conditioning in urban areas has emphasized the importance of comfortable and reliable public transit options that reduce GHG emissions. **Image 3.4 and Figure 3.11** show the latest infrastructure development in the metro rail network.

Image 3. 2: Superfast Air-conditioned Train, Vande Bharat

Image 3. 3: Rani Kamlapati Railway Station, Bhopal

Source: wikimedia.org

Image 3. 4: Centalized Air-conditioned Metro Station

Item	Before 2014	Addition after 2014	Current Status
No. of cities with operational Metro Network	5	13	18
Commissioning of new metro rail lines (km)	248	454	702
Approved metro networks, including RRTS for construction (km)	659	1,059	1,718
Approved RRTS corridor for construction (km)	0	85	85
Metro passengers per day (ridership in lakh)	17	68	85

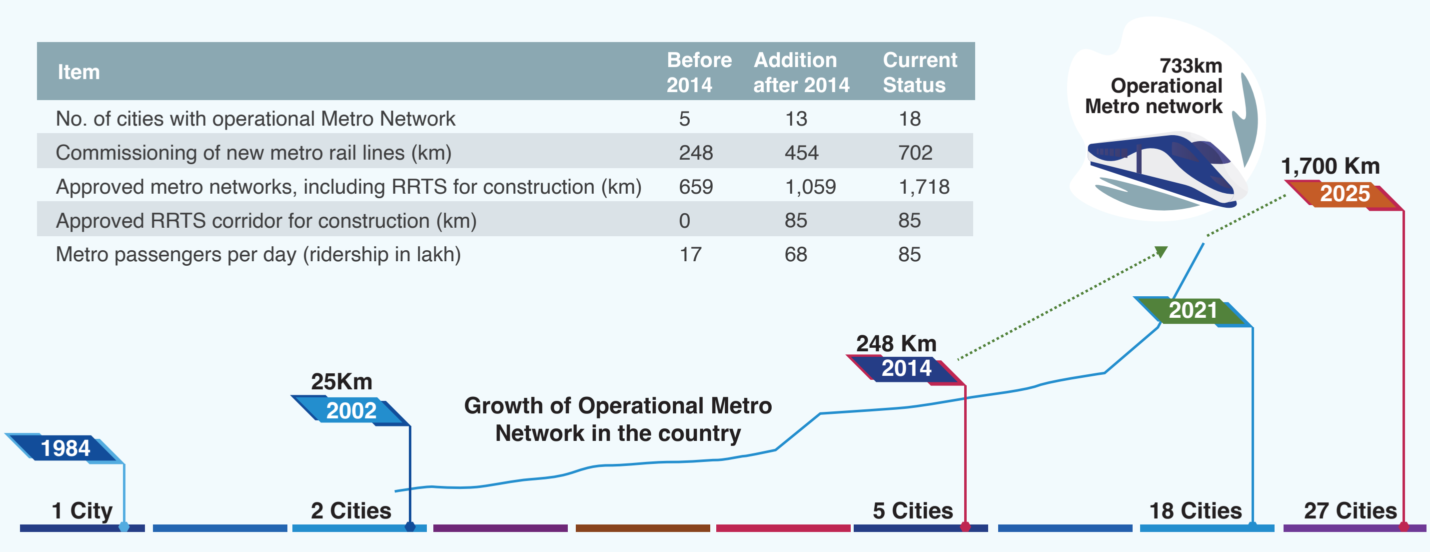


Figure 3. 11: Growth of Metro

Source: Ministry of Housing and Urban Affairs

India's civil aviation sector, one of the fastest-growing globally, continues to see consistent expansion in airports and aircraft to meet the surging demand for air travel, further emphasizing the need for cooling systems to enhance passenger comfort at airport terminals.

During 2021-22, the Airports Authority of India (AAI) handled 700,000 aircraft movements comprising 78 million passengers (AAI, 2023). AAI infrastructure consumed 322 GWh of electricity during 2021-22. Of this, about 30% was from renewable energy. AAI have installed around 40 MWp (Maximum Power Output) of solar power; the rest was procured through open access.

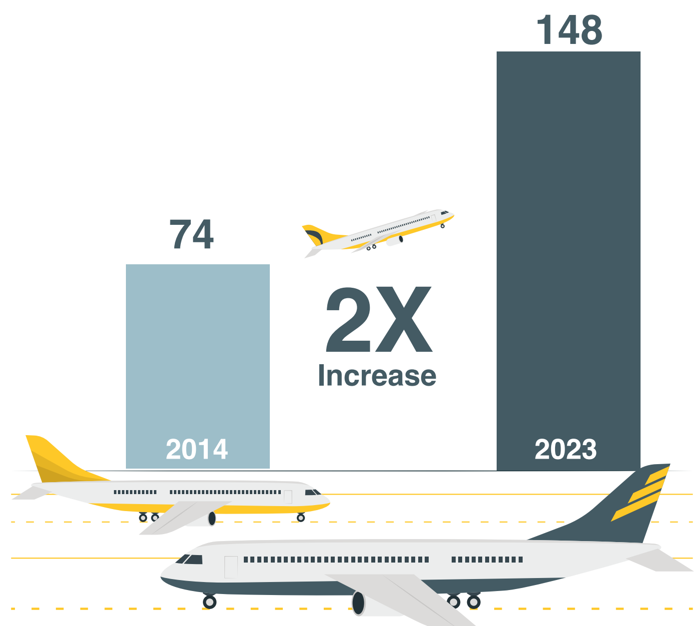


Figure 3. 12: Growth of Airports

Source: PIB (2023b)

Image 3. 5: Mumbai Airport

Rapid urbanisation and increasing income levels will likely drive up the ownership of passenger cars - the majority of which will be air-conditioned - at an expected growth rate of almost 9% annually upto 2040. The number of buses is estimated to grow from ~2.2 million in 2017-18 to ~ 4 million by 2037-38 (MOEF&CC, 2019). In this context, strategic actions towards efficient mobile air-conditioning are necessary to acheive reduction in energy demand.

3.3.2 Projections for Cooling-related Energy Consumption in the Transport Sector

The car air-conditioner accounts for around 20% of the total energy used in a car. This is due to factors like high temperature and humidity, long cooling hours, smaller cars, and road congestion. **Figure 3.13** elucidates the projected energy demand in the passenger car segment due to air-conditioning in Trillion Joules (TJ).

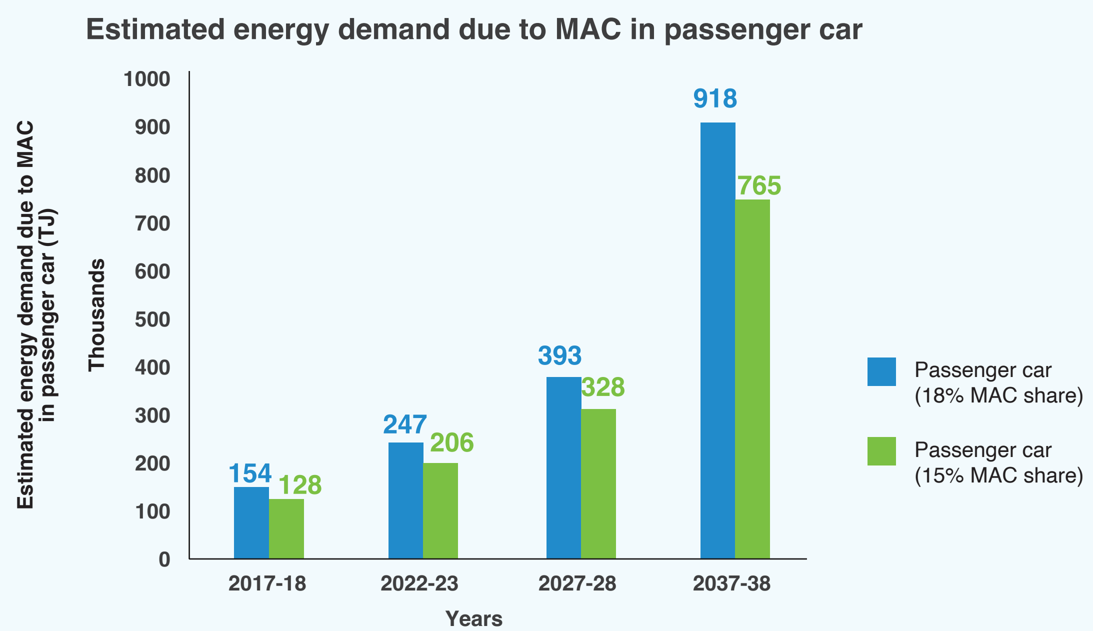


Figure 3. 13: Energy Demand in Passenger Cars

Source: MoEF&CC (2019)

The energy demand for air conditioning in the bus segment is in the range of 15%-18% of the energy consumption by the bus. **Figure 3.14** presents the projected energy demand in the bus segment due to air-conditioning in Trillion Joules (TJ).

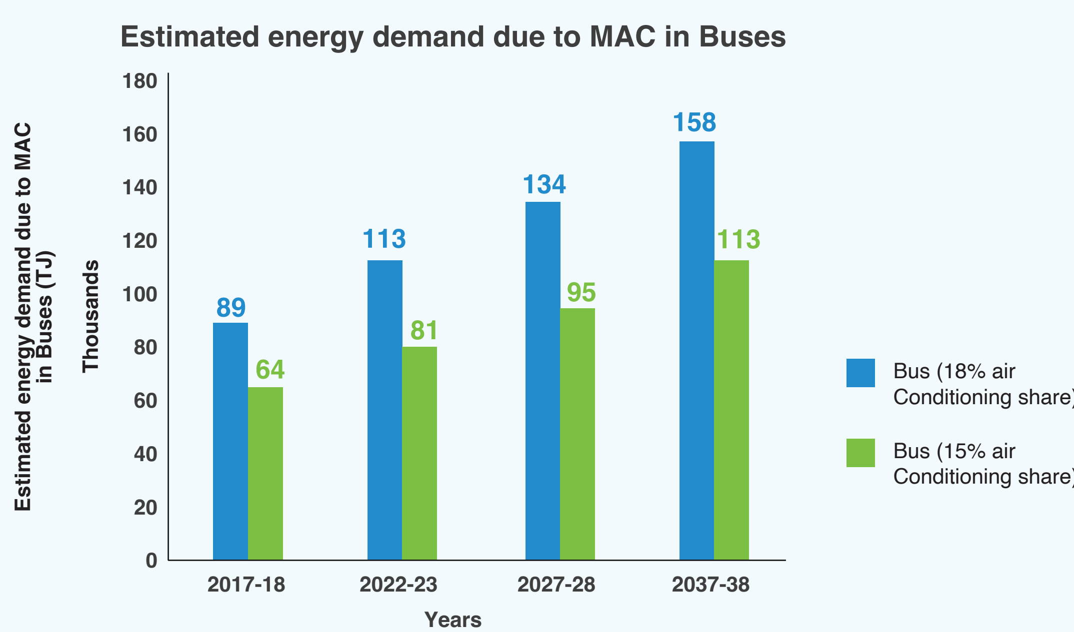


Figure 3. 14: Energy Demand in Buses

*Source: MoEF&CC (2019) *MAC- Mobile Air Conditioning*

Trucks are increasingly used for the transportation of goods across the country. These trucks cover a long distance and pass through different climatic zones, including very hot and humid zones. Currently, the driver's cabin in most trucks is not air-conditioned. A comfortable driving environment is becoming increasingly necessary not only from the point of view of the extended working hours of drivers in harsh working conditions, but also for road safety.

As far as the Indian railways are concerned, since the share of air-conditioned coaches is lower, the total energy consumption due to air-conditioning in the railway sector is relatively low compared to other sectors. **Figure 3.15** depicts the projected energy demand in the railway air conditioning segment in Trillion Joules (TJ).

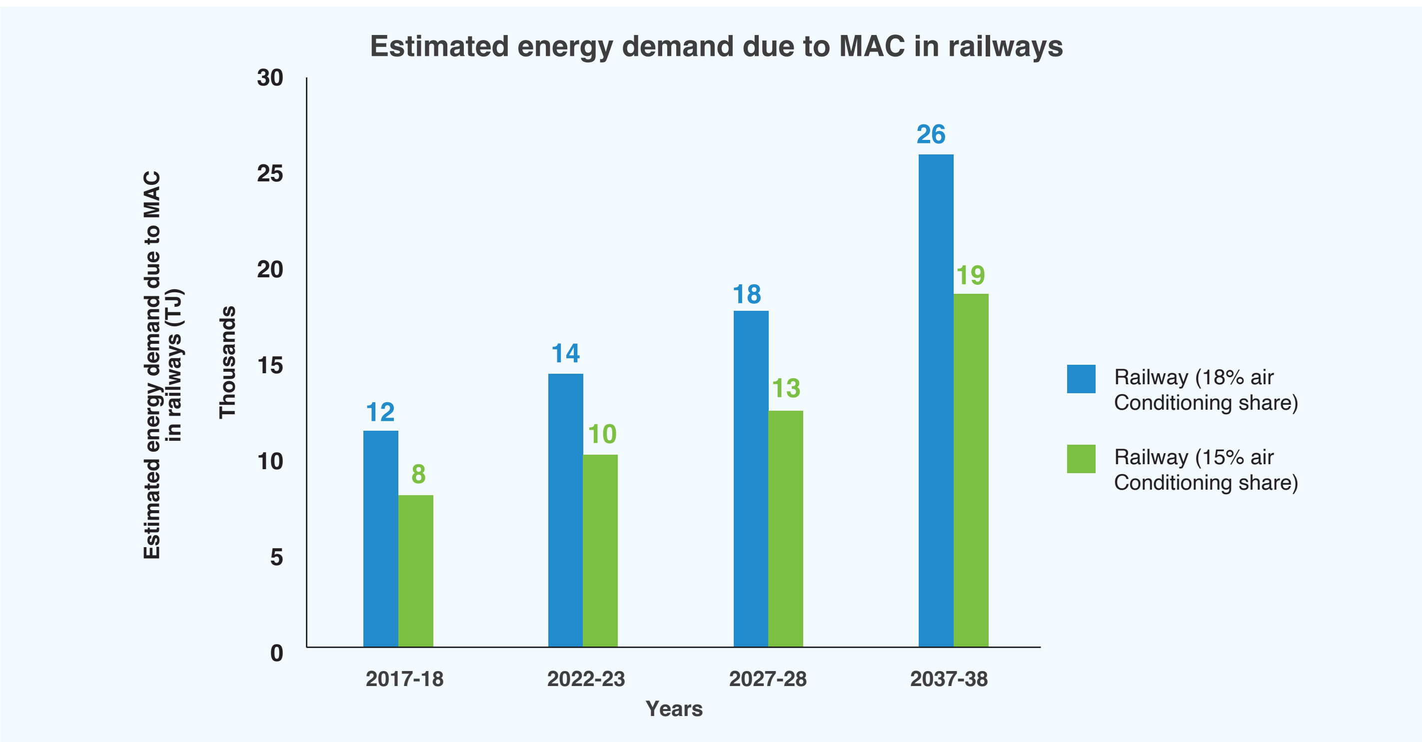


Figure 3. 15: Energy Demand in Railway

Source: MoEF&CC (2019)

Chapter

04

India's Initiatives for Sustainable Cooling

India has been taking proactive measures for sustainable cooling, primarily driven by the need to address environmental impact while providing access to cooling in a country that witnesses wide variations in temperature and climatic conditions across its length and breadth. Several government initiatives and programs have been launched to promote sustainable cooling practices. India's efforts reflect its commitment to sustainability and its recognition of the need to balance economic growth with environmental responsibility. They aim to meet cooling needs while reducing energy consumption, GHG emissions, and the use of refrigerants that contribute to global warming. The goal is to provide access to cooling for all while minimizing the environmental impact and promoting energy efficiency.

4.1

Sustainable Growth in line with International Climate Protocols and Sustainable Development Goals

While the increased access to cooling technologies across the globe including air-conditioning and refrigeration has improved the quality of life, it has also led to adverse environmental impact in terms of ozone depletion and global warming on account of the use of Ozone Depleting Substances (ODSs) as refrigerants. International efforts have strived to address these problems under several multilateral environmental agreements. Until the mid-2010s, the regulation of refrigerants was primarily aimed at protecting the ozone layer. However, recent developments such as the Kigali Amendment to the Montreal Protocol, emphasize the linkages between cooling and climate change and suggest that refrigerant regulation should contribute to preventing both ozone depletion and tackling climate change. The agreements have tried to ensure that decarbonizing refrigerants beyond reducing their Ozone Depleting Potential (ODP) emerges as a new objective of the cooling sector.

Access to sustainable cooling is critical to achieving many of the 17 SDGs to build resilience for economies and people and mitigate and adapt to climate change. The SDGs are the route to achieving a better and more sustainable future for all, regardless of current economic development status, and are intended to be delivered with no one left behind. Thus, a comprehensive understanding of the role of cooling in meeting the SDGs in relevant sectors is essential. Cooling, directly and indirectly, supports the country in meeting most of the 17 SDGs.

Cooling is essential for economic development and the well-being of people. However, increased use of cooling could aggravate climate change from increased power generation for cooling as well as the release of potent heat-trapping refrigerants such as hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs) used in cooling equipment. India is in the last stage of implementation of the phase-out of the HCFCs, as per the agreed schedule of the accelerated phase-out under the Montreal Protocol and will be initiating implementation of the phase-down of HFCs, which have been introduced as a replacement of ODSs in the Indian market.

4.2 Regulatory Framework- Ozone Depleting Substances (Regulation and Control) Rules,2000

As part of the National Strategy for implementation of the ODS phase-out under the Montreal Protocol, MoEF&CC, Government of India, notified Ozone Depleting Substances (Regulation and Control) Rules, 2000 under the Environment (Protection) Act, 1986. These rules have been amended from time to time to align with the amendments to the Montreal Protocol.

4.3 India's achievements in Montreal Protocol Implementation

India is successfully implementing the Montreal Protocol ODS phase-out programme and activities by initiating the process of phasing out the production and consumption of ODSs, thus making significant contributions towards the protection of the Ozone Layer and climate system:

- *Successfully phased out the production and consumption of Chlorofluorocarbons (CFCs), Carbontetrachloride (CTC), methyl chloroform and halons for controlled use as of 1st January 2010. India adopted a proactive approach to phase out these high ODP chemicals.*

- *The phase-out of use of CFCs and halons in new cooling and fire-fighting equipment manufacturing took place from 1 January 2003, much before the Montreal Protocol schedule. The country has not only achieved the early phase-out of consumption of CFCs and halons in the country, but also reduced the inventory of ODS-based equipment, reducing servicing requirements.*

- *The phase-out of production and consumption of virgin halons, being high-ODP chemicals, occurred as early as 2002.*

- *Accelerated phase-out of production and consumption of CFCs with effect from 1 August 2008, 17 months ahead of the Montreal Protocol schedule, except pharmaceutical grade CFCs in manufacturing of Metered Dose Inhalers (MDIs) for Asthma and Chronic Obstructive Pulmonary Disease (COPD) patients.*

- *Phase out of manufacturing of CFC-based MDIs at an accelerated pace. All the formulations of CFC-based MDIs were successfully converted to lower-GWP HFC-based formulations and placed in the market.*

In line with the accelerated phase-out schedule of the Montreal Protocol for HCFCs to achieve a 35% reduction target in the production and consumption of HCFCs, India successfully achieved a reduction of 44% from the baseline of production and consumption of HCFCs.

Indian polyurethane foam manufacturing facilities converted foam manufacturing from HCFC-141b to environmentally friendly non-ODS and ultra-low-GWP blowing agents like Cyclopentane (C5), Hydrofluoroolefins (HFOs), Methylal, Methyl Formate (Ecomate) and water to minimize environmental impact.

India has taken another pro-active action to phase out HCFCs in manufacturing of all equipment and products using HCFCs including cooling equipment from 1.1.2025. This will not only phase out HCFCs prior to the Montreal Protocol schedule, but also reduce the inventory of HCFC-based equipment.

India has taken several proactive policy actions in consultation with stakeholders, especially the industry, and adopted the best non-ODS low-GWP technology options wherever applicable. It has been estimated that by implementing the ODS phase-out programme under the Montreal Protocol, India will mitigate 778 to 1176 million tonnes of CO_2-eq GHG emissions by 2030.

India ratified the Kigali Amendment to the Montreal Protocol during September 2021 and is currently developing a national strategy including policy framework for HFC phase down in the country, which will be completed by 2023.

After ratification of the Kigali Amendment by India, the licensing system and reporting obligations have been put in place, and data reporting for HFCs has commenced from 2022 along with other ODSs per provisions of Article 7 of the Montreal Protocol.

The strategy and policy framework development comprises prioritizing the sectors and sub-sectors for the HFC phase-down by 2023. The regulatory framework, including a framework for implementing a licensing and quota system, will be developed by 2024.

The development of the national strategy for the HFC phase-down will comprise the following:

- *Outreach and awareness raising*
- *Developing a national strategy, including a policy framework for implementing the Kigali Amendment*
- *Establishing a framework for implementing licensing, quota system, and reporting obligations related to HFCs.*

In line with the Paris Agreement, as per the updated Nationally Determined Contribution (NDC), India is committed to reducing the emissions intensity of its GDP by 45 percent by 2030 from the 2005 level and achieving about 50 percent cumulative electric power installed capacity from non-fossil fuel-based energy resources by 2030, a step towards achieving India's long-term goal of reaching net-zero by 2070.

4.4
India Cooling Action Plan (ICAP)

To have an integrated long-term vision towards addressing cooling requirements in various sectors within the country, India developed the "India Cooling Action Plan (ICAP)" in 2019. India is the first country to prepare such a comprehensive plan. The ICAP provides a 20-year perspective (2017-18 to 2037-38) with recommendations to address the cooling requirements across sectors and ways and means to provide access to sustainable cooling.

The ICAP has considered the interdependencies among policy interventions and strives to harmonize energy efficiency with the HCFC phase-out and high-GWP HFC phase-down schedules. It also re-emphasizes the principles enshrined in the India country programme for phase-out of ODS to minimize economic dislocation and obsolescence cost and maximise indigenous production for combined environmental and economic gains. The overarching goal of the ICAP is to provide sustainable cooling and thermal comfort for all, while securing environmental and socio-economic benefits for society. The goals that emerge from the interventions proposed in the ICAP are presented in **Figure 4.1.**

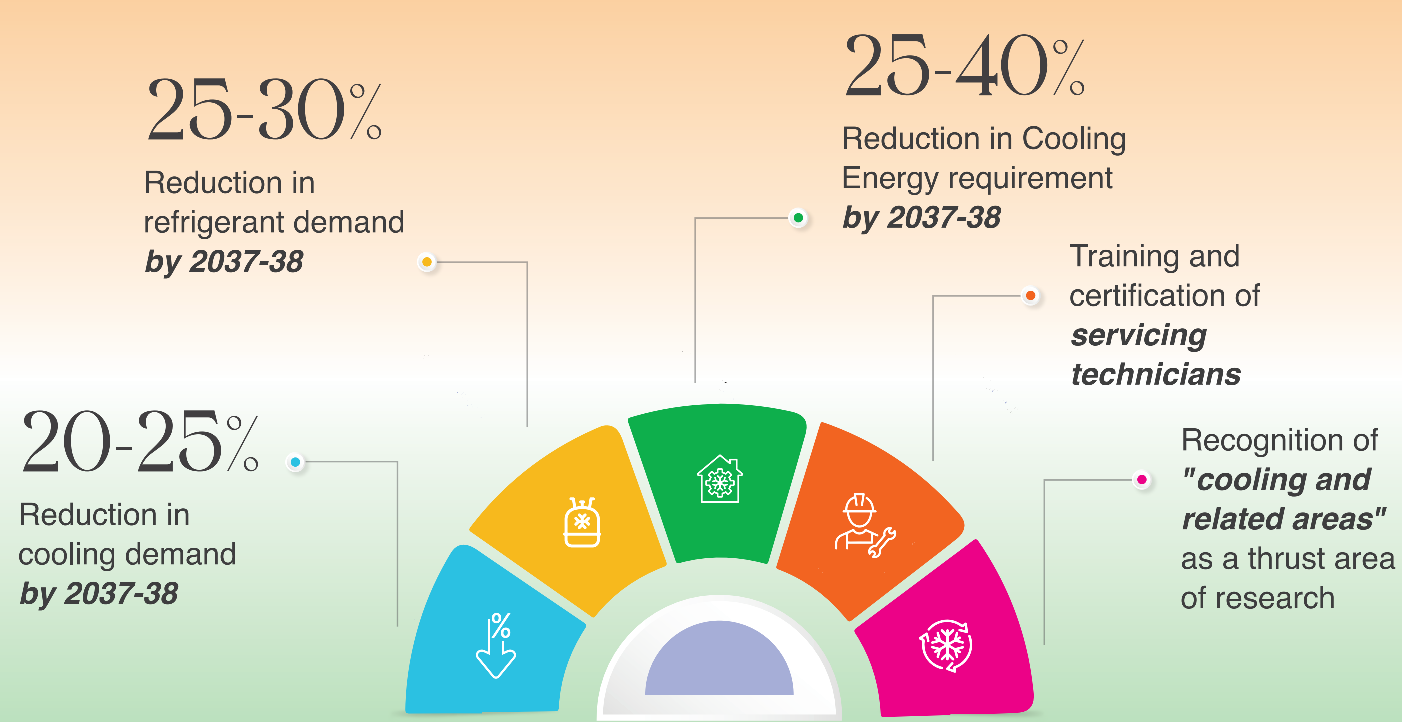


Figure 4. 1: ICAP Goals with Interventions Proposed

The ICAP encompasses several elements, including passively-cooled building design, adoption of adaptive thermal comfort standards by specifying pre-setting of temperatures in air-conditioning equipment for commercial built spaces, promoting the use of energy-efficient refrigerant-based technologies for cooling equipment/appliances, use of not-in-kind technologies, development of energy efficient and renewable energy based cold chain and national skill development programmes for training and certification of Room Air-Conditioning (RAC) service technicians to complement the transition to energy efficient, low-GWP refrigerants.

The regulatory framework proposed within the ICAP includes several key elements:

- Energy Efficiency Standards: The ICAP emphasizes enforcing energy efficiency standards for cooling equipment, such as air-conditioners, refrigerators, and other similar appliances, set by the Bureau of Energy Efficiency (BEE).
- Labelling and Certification: It encourages product labelling and certification, informing consumers about energy efficiency and environmental performance through programs like the BEE's star rating system.
- Building Codes: ICAP promotes green building codes such as Energy Convervation Building Code (ECBC), National Building Code (NBC) and energy-efficient building design, incorporating insulation, shading, and ventilation for reduced cooling demand in construction.
- Safety and Environmental Regulations: The framework stresses safety standards to prevent accidents and environmental regulations to manage refrigerants, emphasizing low-GWP options.
- Incentives and Financing: Regulatory mechanisms offer incentives and financing to promote energy-efficient and sustainable cooling technology adoption.
- Consumer Awareness and Education: It underscores the role of consumer awareness programs in promoting energy-efficient and eco-friendly cooling solutions.
- Research and Development Incentives: ICAP encourages R&D through tax incentives and grants to foster technological advancements.
- Monitoring and Compliance: Government agencies monitor compliance with standards and regulations, ensuring adherence.
- International Agreements: The ICAP aligns with global agreements like the Kigali Amendment to phase down high-GWP refrigerants, showcasing India's commitment to sustainability.

Figure 4. 2: ICAP IMPLEMENTATION FRAMEWORK

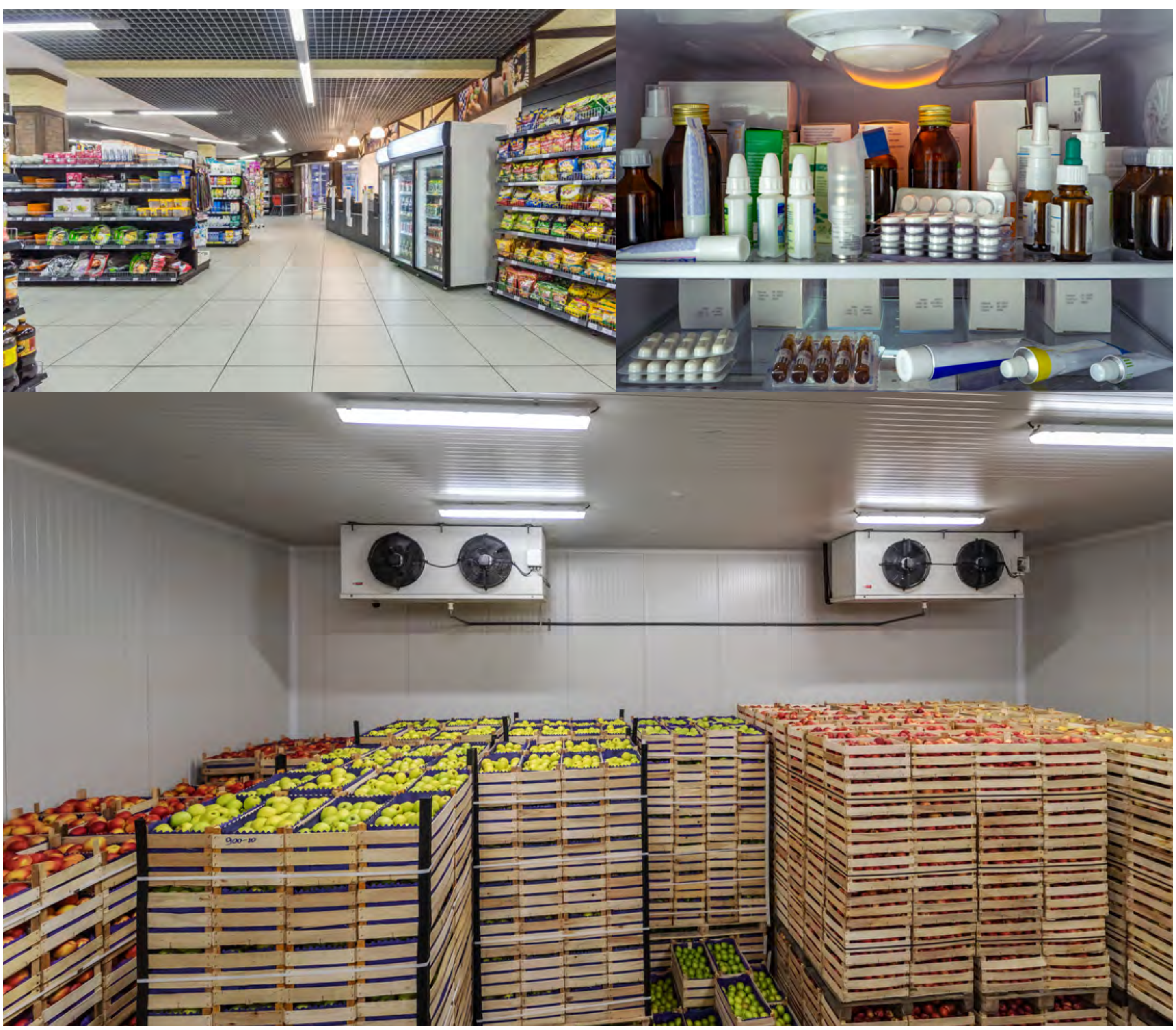
For the development of the ICAP, seven different thematic areas were identified after stakeholder consultations. Separate thematic working groups, which had representation from the government, industry associations, think tanks, and research entities were constituted for each of the identified thematic areas. The thematic areas were:

- Space Cooling in Buildings
- Air-conditioning Technology
- Cold-chain & Refrigeration
- Transport Air-conditioning
- Refrigeration & Air-Conditioning Servicing Sector
- Refrigerant Demand & Indigenous Production
- Research & Development

The Government of India is implementing the recommendations of the ICAP in the above-mentioned thematic areas to realise the goal of sustainable cooling for all.

4.5 Role/Contribution of Ministries/Departments in Achieving Sustainable Cooling

Government initiatives are crucial in promoting sustainable cooling practices. Sustainable cooling is a pressing need in India, particularly in the context of environmental conservation, energy efficiency, and enhancing the cold supply chain. Various government schemes and programs, as well as strategic collaborations with key agencies are contributing significantly in this endeavour. Some of the notable initiatives include:



- National Horticulture Mission and Small Farmer Agri-Business Consortium (SFAC): These programs are instrumental in supporting the horticultural sector. These help in improving the post-harvest handling and storage of fruits and vegetables, a vital component of the cold supply chain. These efforts contribute to reduced food waste and improved livelihoods for small farmers.

- Agricultural and Processed Food Products Export Development Authority (APEDA): APEDA actively promotes processed agricultural product exports. It also facilitates the development of cold storage and processing facilities, enabling better preservation and quality maintenance of produce.

- National Logistics Policy (NLP): The recently announced NLP is expected to strengthen the country's cold supply chain. It will streamline logistics, including refrigerated transportation, to ensure efficient and sustainable movement of temperature-sensitive goods.

- 100% FDI in Warehousing: The government has permitted 100% foreign direct investment in warehousing, including cold storage facilities. This move encourages the establishment of state-of-the-art cold storage units, thus enhancing the cold supply chain infrastructure.

- Ministry of Food Processing Industries (MOFPI): MOFPI has introduced a subsidy scheme that offers financial assistance for developing cold chain infrastructure and other value-added activities. This initiative supports the growth of sustainable cooling solutions in the food processing sector.

- MoEF&CC and Ministry of Skill Development and Entrepreneurship (MSDE): A Memorandum of Understanding (MoU) between these Ministries encourages skill development in sustainable servicing including cooling practices while ensuring safety of RAC service technicians.

- Affordable Housing Schemes: Initiatives like Pradhan Mantri Awas Yojana (PMAY) promote affordable housing for Economically Weaker Sections (EWS) and Lower-Income Groups (LIG). The construction of climate-appropriate and energy-efficient houses, following standards for building envelopes and appliances, contributes to sustainable cooling within these dwellings.

- FAME India (Faster Adoption and Manufacturing of Electric Vehicles in India): Under the National Electric Mobility Mission Plan (NEMMP) 2020, FAME India promotes the adoption of electric vehicles. This transition to electric transportation helps reduce demand for traditional internal combustion engine vehicles and in turn, greenhouse gas emissions.

4.6 Optimum Cooling System Sizing-Default Mandatory Temperature Setting

India has proactively implemented a 24°C indoor air default temperature setting for room air-conditioners to reduce energy consumption and GHG emissions, increasing the indoor air set temperature from 20°C to 26°C can save approximately 25-30% of energy without sacrificing comfort, **Figure 4.3.**

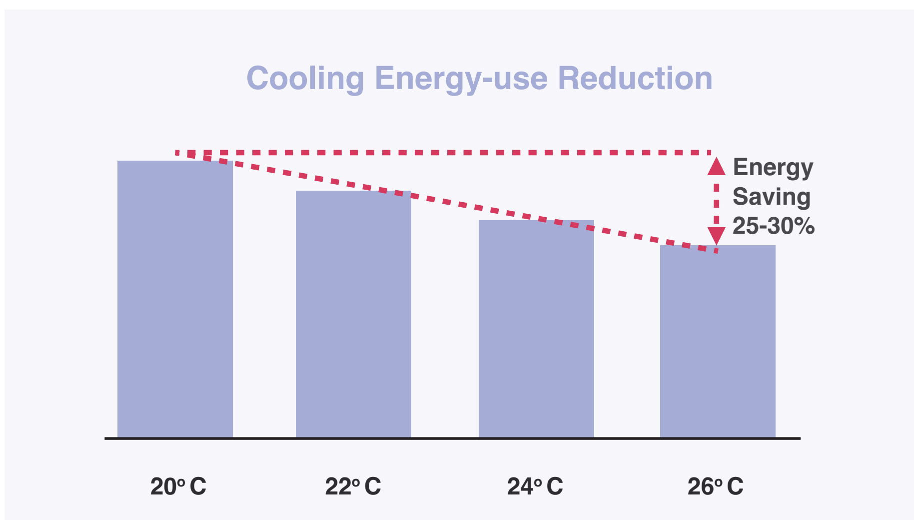


Figure 4. 3: Energy Saving in Space Cooling with Increase in Indoor Temperature

The Bureau of Energy Efficiency (BEE), Ministry of Power in consultation with stakeholders has notified new energy performance standards for room air-conditioners and the 24°C default setting has been made mandatory from January 1, 2020 for all room air-conditioners covered under the ambit of the BEE star-labelling programme.

Image 4.1 : Default Temperature Setting for Room Air-Conditioners

4.7 Manufacturing of Sustainable Cooling Equipment and Refrigerants

The Indian manufacturing industry is rapidly adapting to meet the increasing global demand for cooling equipment with a strong focus on sustainability. It includes investments in state-of-the-art manufacturing facilities to ensure sustainable practices and enable export of eco-friendly cooling equipment to international markets. As part of these efforts, small and medium enterprises, which form the backbone of the manufacturing sector, are also being supported by the government.

The Performance-Linked Incentive scheme launched by the Government of India in 2020 is set to play a transformative role, aiming to substantially increase air-conditioner production and domestically sourced components. This initiative seeks to boost local value addition, significantly reducing environmental impact. Additionally, India is a prominent global producer and exporter of eco-friendly refrigerant gases, serving various sustainable applications across multiple industries. The industry is thus well-positioned to meet the surging demand for sustainable cooling solutions and feedstock applications.

4.8 Sustainable Technologies

Historically, cooling systems have been used with various non-fluorocarbon and families of fluorocarbon refrigerants. Most of these are ODSs, primarily CFCs and HCFCs; lately, non-ODS refrigerants or HFCs have been introduced as substitutes for ODS refrigerants. Non-fluorocarbons like ammonia, hydrocarbons, CO_2, etc., are now being reintroduced in spite of their flammability and toxicity characteristics wherever applicable due to environmental considerations. Most fluorocarbon refrigerants have high GWPs, typically greater than 1,000 times that of CO_2, so the potential impact of refrigerants' direct emissions on climate change can be significant.

4.9 Building Codes, Standards and Green Building Rating Initiatives

India has taken proactive policy initiatives to design commercial and residential buildings to reduce cooling requirements and energy demand. The following energy conservation building codes and green building rating systems promote the use of passive and energy-efficient cooling methods to reduce cooling and energy demands.

- **Energy Conservation Building Code** – ECBC 2017: India's Energy Conservation Building Code (ECBC) 2017, formulated by the BEE, makes it mandatory for commercial buildings with a load of 100 kVA or more to comply with its energy-efficient standards. ECBC 2017, characterized by its uniqueness in promoting sustainable technologies, sets specific, quantifiable targets, including a substantial 30-50% reduction in energy consumption (PIB, 2017).

- **National Building Code of India (NBC):** NBC, published by the BIS, provides guidelines for construction and design practices in India, including provisions related to energy efficiency. While not explicitly focused on sustainability, the NBC sets the foundation for building regulations in India and covers aspects relevant to sustainable building design.

- **Eco Niwas Samhita (ENS), Part-1 Building Envelope:** ENS for the residential sector was developed and launched in December 2018 by the BEE, Ministry of Power. ENS is a voluntary energy conservation building code, with Part 1 focusing on the building envelope.

- **Eco Niwas Samhita Part-II, Electro-Mechanical and Renewable Energy Systems:** The Eco Niwas Samhita 2021 (Code Compliance and Part-II: Electro-Mechanical and Renewable Energy Systems) is a code specifying compliance approach and minimum energy performance requirements for building services, indoor electrical end-use and renewable energy system.

- **Green Building Ratings:** There are three prominent green building rating systems being implemented in India to promote energy-efficient cooling and sustainable design practices: (1) Green Rating for Integrated Habitat Assessment (GRIHA), (2) Indian Green Building Council (IGBC) and (3) Leadership in Energy and Environmental Design (LEED). These green building ratings provide guidelines and standards for architects, builders, and developers to design and construct energy-efficient buildings that prioritize efficient cooling, minimize environmental impact, and enhance occupant comfort.

4.9.1 Low GWP Refrigerant Technologies

Currently used refrigerants like HCFC-22, HFC-134a, R-404A, R-410A, R-407C, etc., have high GWP and, while released to the environment during cooling equipment working life and direct emissions of these refrigerants, result in a significant impact on climate.

Introduction of Hydrocarbon Refrigerants (R-600a and R-290)

R-600a and R-290 refrigerants have zero ODP and ultra-low GWP of 3, which is significantly lower than refrigerants such as R-410A (GWP =2088) and R-22 (GWP =1810).

India was one of the first countries to introduce the R-600a refrigerant in the domestic refrigeration sector, recognizing its negligible environmental impact due to its zero ODP and GWP of 3. It is one of the hydrocarbon refrigerants adapted globally for household refrigerators and small-capacity cooling appliances/freezers. Indian manufacturers offer a wide range of refrigerators with R-600a refrigerants in different sizes.

Another hydrocarbon refrigerant is R-290, a potential refrigerant for room air-conditioners, especially for small cooling capacity units. R-290, being highly flammable, Indian room AC manufacturers are evaluating it for safety considerations. One of the Indian manufacturers offers a range of R-290 air conditioners in both split and window configurations, with capacities ranging from 1 to 1.5 tons.

Leading Indian commercial refrigeration manufacturers are converting their manufacturing facilities from HFC-134a to R-290. Some of them have already started marketing cooling cabinets and freezers using R-290.

Indian industry is very proactive in the phase-down of potent greenhouse HFCs along with an aggressive HCFC phase-out schedule towards a more climate-friendly refrigerant mix, including an increased penetration of the natural refrigerant R-290. It is noteworthy that while the ICAP intervention scenario assumes a moderate penetration of R-290, a more aggressive shift towards this low GWP refrigerant in the next decade is very much within the realm of possibility with appropriate policy support from the government.

Lower-GWP Refrigerant Applications such as R-32

R-32 is a single-component refrigerant with a GWP of 675, significantly lower than refrigerants R-22 and R-410A. India pro-actively introduced R-32 as early as in 2012 in the manufacturing of room air-conditioners. R-32 is an increasingly popular refrigerant.

Several Indian manufacturers now produce air conditioners that use R-32 refrigerant. About 90% of air-conditioners manufactured in the country are based on R-32 technology. These air conditioners are typically more energy-efficient than those that use R-410A refrigerant.

Ammonia as Refrigerant for Cold Chain

Ammonia is an excellent refrigerant, barring its toxicity and mild flammability. Ammonia as a refrigerant has been used for cooling for over a century as ammonia systems are more efficient than other refrigerant-based systems. However, its use is limited due to its inherent toxic characteristics. Ammonia finds applications mainly in the cold storage and food processing industry, where systems are installed outside the city.

Ammonia (R-717) systems are used in a variety of industries in India, including:

- Food processing: to cool milk, meat, seafood, and other food products.
- Beverage industry: to cool beer, wine, and other beverages.
- Pharmaceutical industry: to cool pharmaceuticals and other medical products.
- Chemical industry: to cool chemicals and other industrial products.
- Data centres: to cool data centres.
- Ice rinks: to cool ice rinks.
- Ammonia systems are also used to some extent in a few commercial and industrial buildings for air-conditioning.

Ammonia systems are commonly used in the cold chain industry in India, with a few examples of their use described below:

- Cold storage facilities: Ammonia systems are commonly used in large-scale cold storage facilities to store fruits, vegetables, and other perishable goods.

- Food processing plants: Ammonia systems are also used in food processing plants and marine products processing, including freezing equipment and ice production on fishing boats and trailers to keep the catch cool.

- Transportation: Ammonia systems are commonly used in cargo ships.

4.9.2 Not-In-Kind Cooling Technologies

Several cooling technologies are being deployed globally to meet cross-sectoral cooling needs. India employs various conventional cooling technologies to combat the country's hot and humid climate. Mechanical compression systems are commonly used in India and globally for refrigeration and space cooling. Approximately 85% of cooling demand is met by refrigerant-based compression technology. Compression technology is still expected to remain the dominant cooling technology due to its compact size, high reliability, scalability, efficiency, etc. R&D in this technology has been focussed predominantly on the transition to low-GWP refrigerants, bringing down the equipment cost and improving the energy efficiency of the equipment to match/surpass the existing energy efficiency levels. India has also been promoting use of Not-in-kind technologie. Some of the technologies used are:

District Cooling

Gujarat International Finance Tec (GIFT) City's cooling infrastructure is designed around a District Cooling System (DCS) **(Figure:4.4)** to meet a total capacity requirement of 180,000 TR, to be achieved through three 60,000 TR plants for optimized distribution. Chilled water is distributed to buildings via underground utility tunnels. Thermal energy storage tanks are charged during off-peak hours by operating the chiller(s) at peak efficiency and discharged during peak demand to supplement air conditioning beyond the chiller's capacity. The first phase of the DCS with a capacity of 10,000 TR is in operation since April 2015.

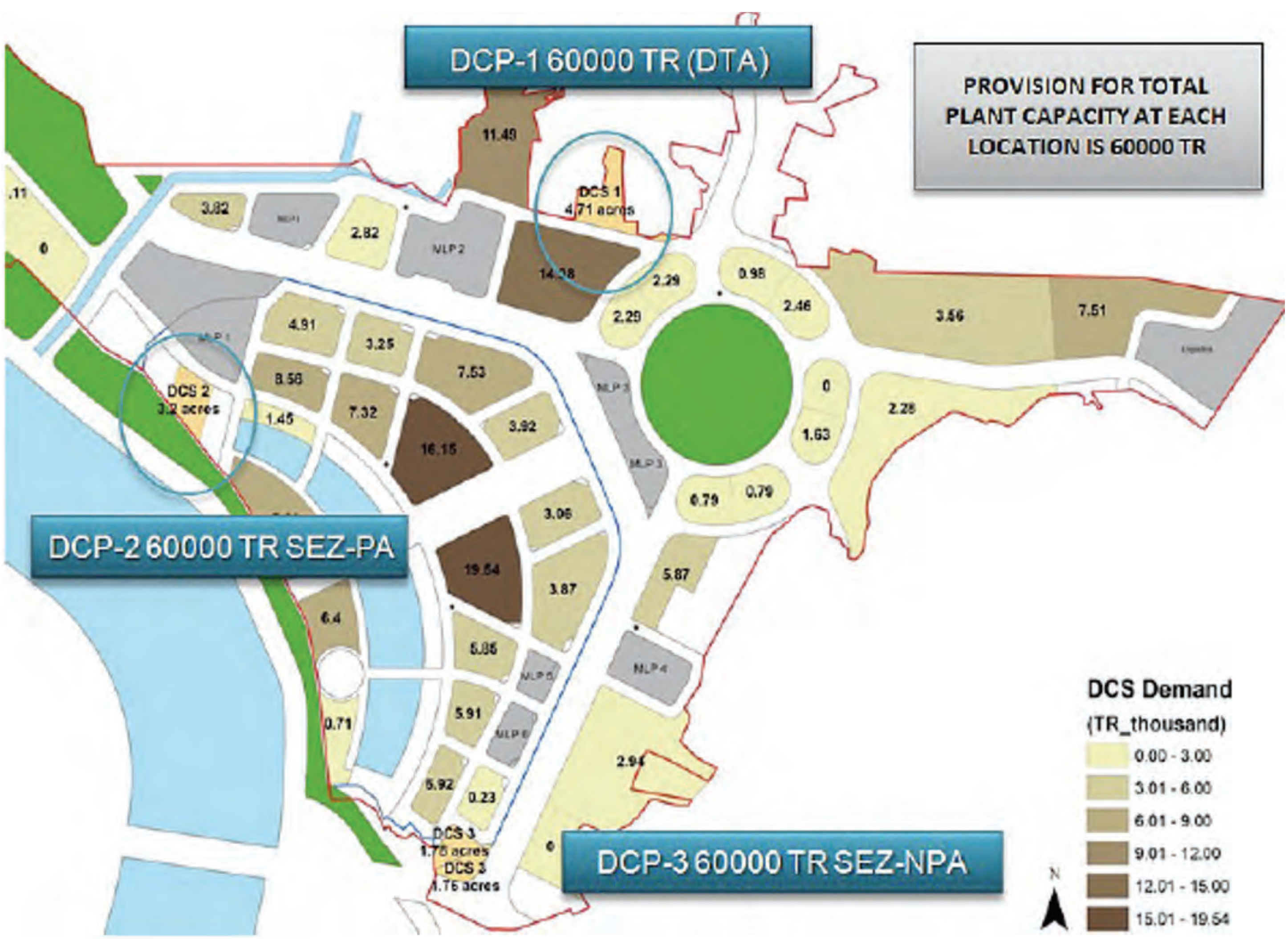


Figure 4. 4: Master plan of GIFT City with DCS plant locations

Trigeneration System

Trigeneration technology is for the simultaneous production of cooling, heating and power—from only one fuel input. The Trigeneration system at Jai Prakash Narayan Apex Trauma Centre in Delhi, India, has an electricity capacity of 347 kW, with excess electricity being fed back to the grid. The cooling load is 1240 kW, facilitated by a Vapour Absorption Machine (VAM), and there is a heating load of approximately 20 kW for kitchen and laundry facilities. The plant demonstrates impressive energy savings, ranging from 20% to 30% compared to traditional systems, resulting in an estimated reduction of 40,000 tons of carbon dioxide emissions over 20 years.

Image 4. 2: Jai Prakash Narayan Apex Trauma Centre at AIIMS Delhi uses Trigeneration System

Evaporative Cooling

Evaporative cooling in a hot, dry climate such as in Rajasthan, is a sustainable and effective solution. Orient Craft Ltd., a leading garment manufacturer in India, uses evaporative cooling in their 18,353-square-meter facility. Seventy-seven percent of the building space is conditioned using an evaporative cooling system, leading to a 35% reduction in energy consumption compared to conventional buildings. This showcases a successful example of energy efficiency, employing zero-ODP and low-GWP technologies, and sets a sustainable standard for the industry.

Image 4. 3: Evaporative cooling for Orient Craft Ltd., Bhiwadi, Rajasthan

4.10 Up-skilling of Manpower - Service Technicians

4.10.1 Good Service Practices

The Room Air-Conditioning (RAC) servicing sector is crucial as it is directly related to the consumption of refrigerants and the optimum and efficient performance of in-use air conditioning equipment. More than 40% of the total refrigerant consumption is associated with the servicing sector (MoEF&CC, 2019); therefore, the sector offers a vast opportunity for securing environmental benefits from direct and indirect emissions.

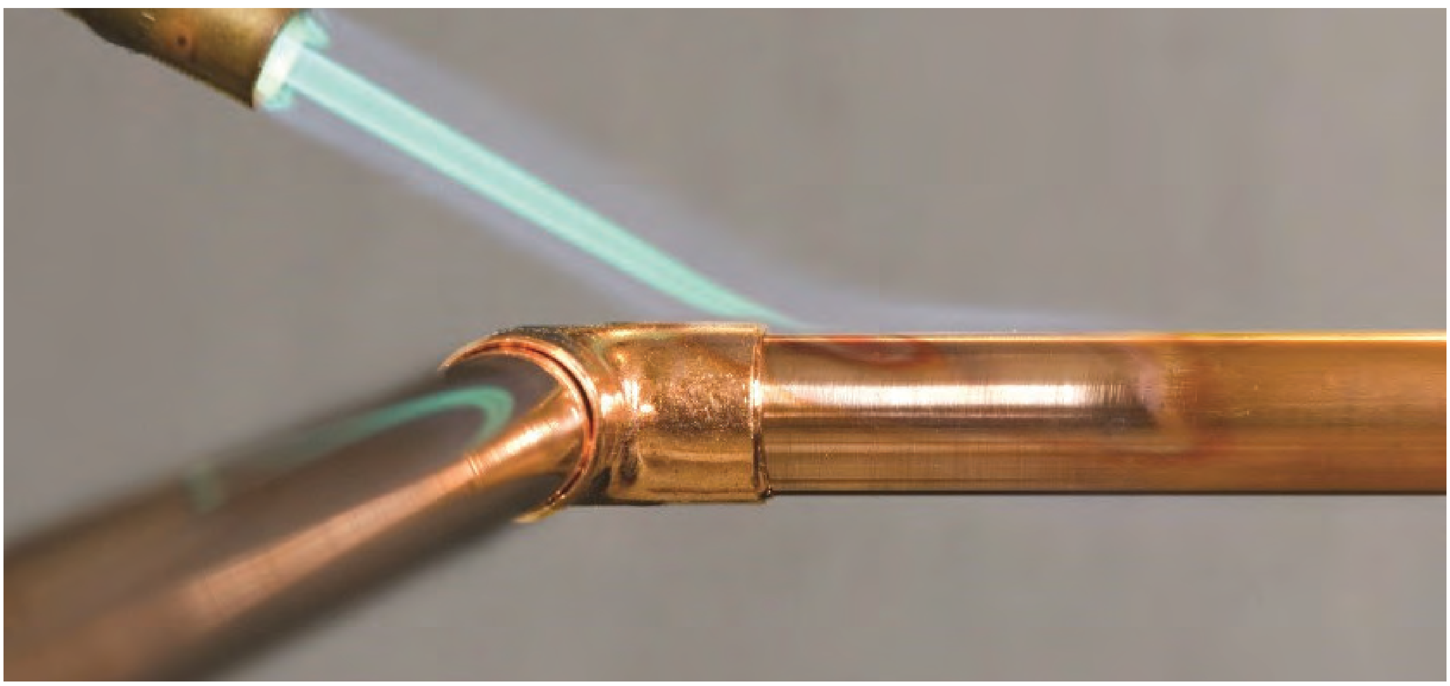
The servicing sector has been considered in implementing the Montreal Protocol during the phase-out of CFCs and the currently ongoing HCFCs. This sector will also be important during the phase-down of HFCs, where most of the new alternative low-GWP refrigerants have issues relating to flammability and safety.

As part of the ongoing HCFC phase-out implementation, 28,000 service technicians have been trained in RAC trade. There is a well-established vocational educational system set up in the country in the form of Industrial Training Institutes (ITIs). About 15,000 qualified technicians graduate annually under the RAC trade from the ITIs. The syllabus of the RAC trade has been upgraded to cater to the emerging challenges in handling alternative refrigerants, and the same is under implementation. In addition, through a MoU between the MoEF&CC and MSDE, 38,000 service technicians have been trained and certified under the Pradhan Mantri Kaushal Vikas Yojana (PMKVY).

During Stage-III of the HCFC Phase-out Management Plan (HPMP) to be implemented from 2023-2030, another 25,000 service technicians will be trained in the RAC trade. In addition, training infrastructure at the ITIs will be strengthened to address the future needs and challenges of servicing.

4.10.2 Strengthening the Service Sector with Training and Certification

The MoEF&CC in collaboration with the MSDE will soon be implementing a unified certification and training system for RAC service technicians, comprising standardized curricula, and a training and certification scheme through a nodal government entity under a single framework. This would help in developing a critical mass of trained and certified service technicians in the country for the RAC sector. A similar approach will be adopted for creating a pool of trained and certified technicians in the cold chain and mobile air-conditioning sectors.



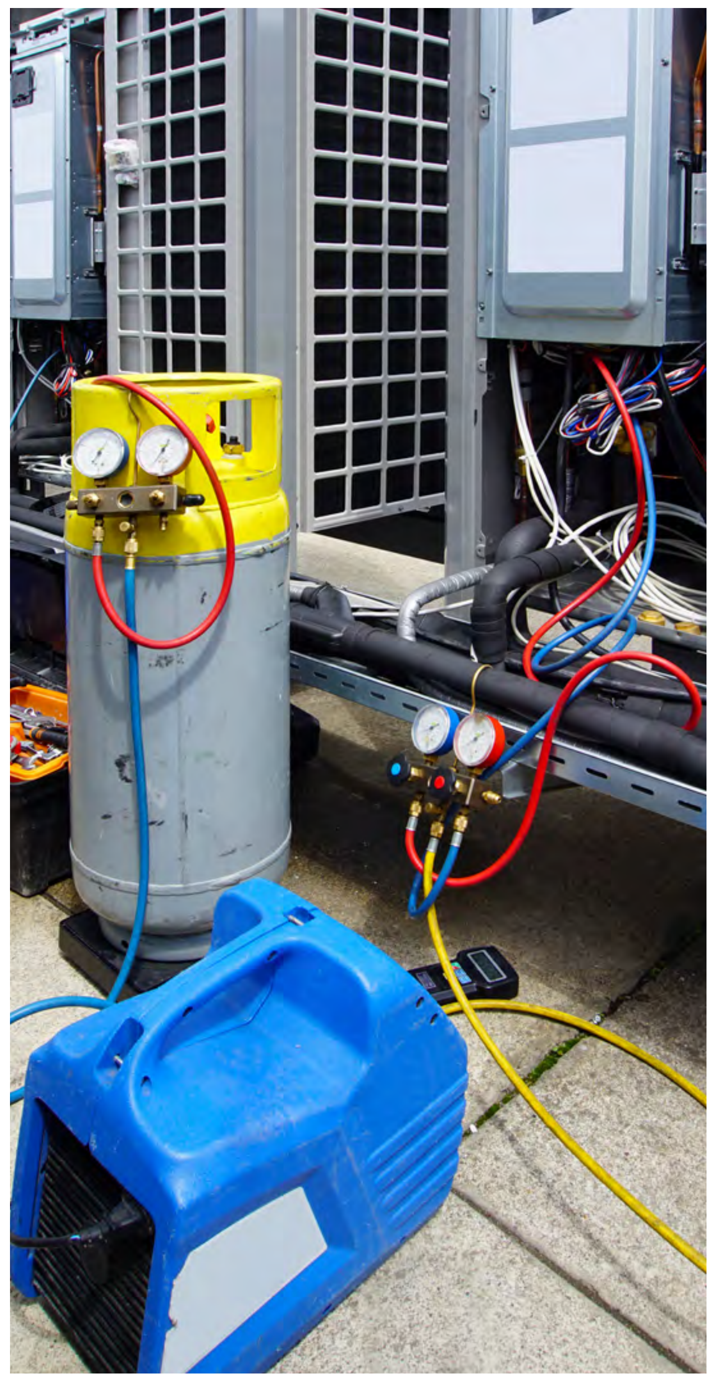
4.10.3 Other Initiatives in the Servicing Sector

In line with the recommendations of studies carried out by the Ozone Cell as part of the enabling activities under the HPMP, the Government e-Marketplace (GeM) of the Ministry of Commerce and Industry will soon be creating a service under the GeM Portal to enable procurement of trained and certified service technicians by government departments and organisations to enable them to engage these technicians for their servicing-related activities.

4.11

Management of refrigerants at the end of life of refrigeration and air-conditioning equipment

The inventory (stock) of refrigeration and air-conditioning equipment like room air-conditioners, domestic refrigerators, mobile air-conditioners, etc. is rapidly increasing in the country. Whenever a certain proportion of the equipment stock reaches its end of life, it has to be disposed of. These equipment still contain refrigerants, which are ozone-depleting and high-GWP chemicals. If refrigerants are released into the environment, they can harm the ozone layer, contribute to climate change, and pose health risks. Proper management of refrigerants at the end of life of equipment can play a vital role in mitigating direct emissions.



India has made significant progress in addressing the disposal of refrigerants at the end-of-life of refrigeration and air-conditioning equipment to mitigate environmental impacts. The practice of recovering refrigerants from equipment at the end of their life and reclaiming them for reuse or safe disposal has gained prominence. This approach aligns with global efforts to reduce emissions, ensures comprehensive waste management, and fosters a sustainable, resource-efficient economy.

The requirement for responsible management of refrigerants has been established, and applies to manufacturers, refurbishers, and recyclers throughout the product lifecycle. In addition, there's a mandate for approved destruction technologies, overseen by the Central Pollution Control Board (CPCB). This comprehensive and accountable approach strictly adheres to environmentally sound methods, clearly demonstrating India's commitment to sustainable practices and environmental protection.

End of life RAC equipment is covered under E-waste regulations. For the sound management and disposal of E-waste, India has notified the E-waste (Management) Rules 2022 under the Environment Protection Act 1986. Necessary provisions have been introduced in the E-waste (Management) Rules through an amendment notified on 24^{th} July 2023 for appropriate management and disposal of refrigerants at the end-of life of RAC equipment. Extended Producer Responsibility (EPR) has also been introduced as part of the E-Waste (Management) Rules 2016, which include provisions for managing electronic waste and associated refrigerants by equipment manufacturers. Efforts have been made by the industry to develop reclamation centres to cater to the need in this sector. Sustainable technologies for safely handling flammable refrigerants during reclamation are also being explored.

In addition, the Govt. of India’s Vehicle Scrapping Policy (VSP), which is already in place, mandates scrapping vehicles older than 20 years by June 2024. The Central Pollution Control Board (CPCB) has issued guidelines for environmentally sound facilities for handing, processing and scrapping of vehicles at the end of life, in which management of refrigerant gases has been duly addressed. This is a pro-active policy initiative taken to address refrigerants in end of life vehicles, leading to protection of the stratospheric ozone and climate system.

Chapter

05

Action Plan Towards Sustainable Cooling

India has been successfully implementing the Montreal Protocol over the past three decades and has consciously chosen a path of environment-friendly technologies and proactive policies while phasing out ODSs. Towards this, the industry, particularly the Micro, Small and Medium Enterprises (MSMEs) operating in various sectors – mainly foam, refrigeration and air-conditioner manufacturing have played a key role in transitioning to non-ODS and low GWP alternative technologies like cyclopentane, ecomate and water blown systems in the foam sector, and R-32 and R-290 in the RAC sector.

Recognizing the increasing demand for cooling due to the growing economy, rapid urbanization and rising per capita income, India has been synergizing its policies and actions to address the cooling requirement across sectors and making cooling sustainable and accessible to all.

Towards preparation for the HFC phase-down, India is developing a national strategy for lowering HFC use in line with the Montreal Protocol schedule. As per the agreed phase-down of HFCs under the Kigali Amendment, India will be completing the phase-down of the production and consumption of HFCs in four steps from 2032 onwards, with a reduction of 10% from the baseline of production and consumption in 2032, 20% in 2037, 30% in 2042 and 85% in 2047. Simultaneously, the complete phase-out of HCFCs will be achieved as on 1.1.2030 as per the accelerated phase-out schedule of the Montreal Protocol, including phase-out of HCFCs in manufacturing new equipment by 1.1.2025 as per national regulations.

In parallel, the implementation of recommendations of the ICAP will be done to achieve the goals of reducing the demand for cooling, refrigerant, and energy use by 2037-38. Accordingly, towards achieving sustainable cooling, India is following an integrated approach for the proposed initiatives within the timelines presented **(Figure 5.1).**

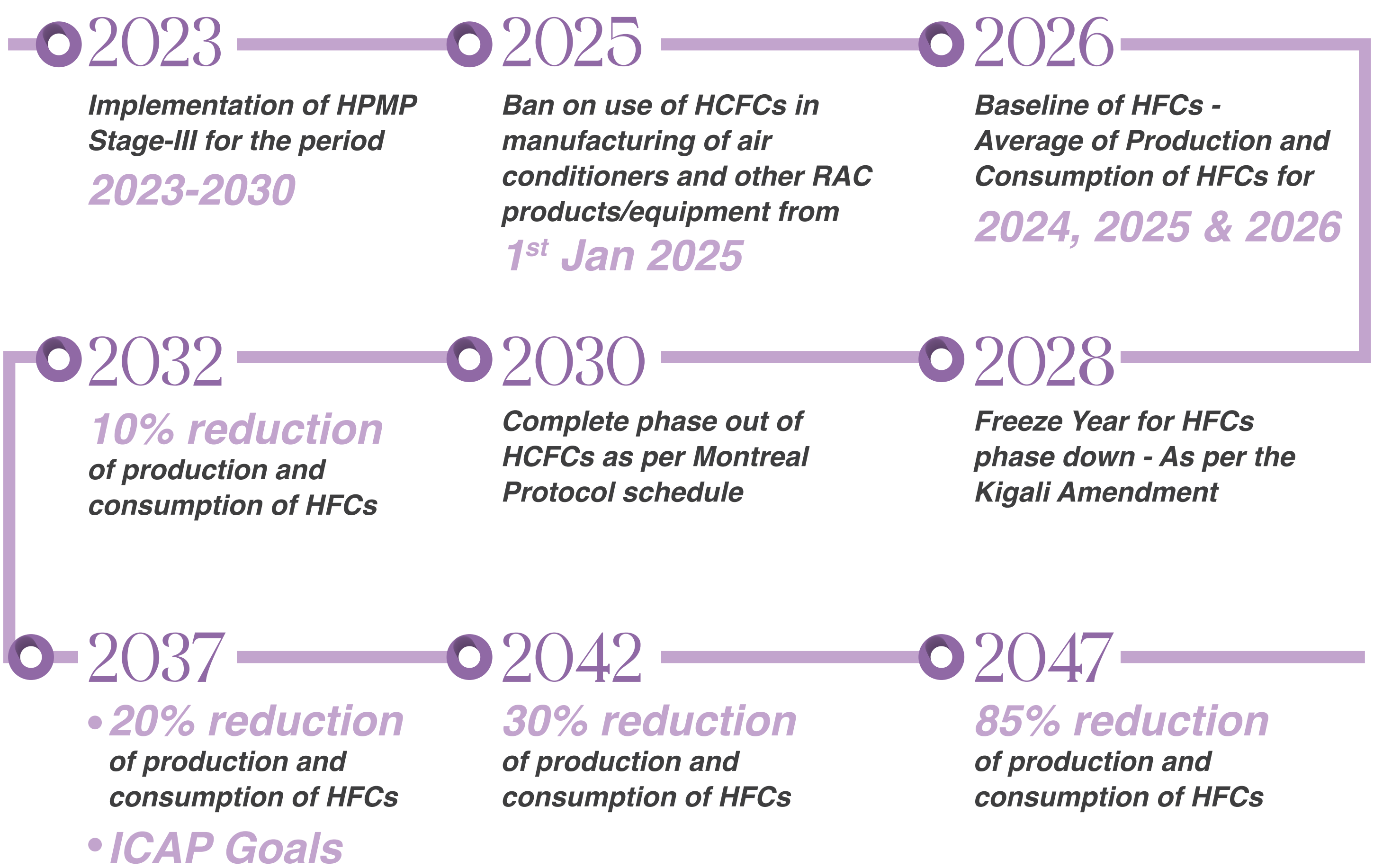


Figure 5. 1: Timeframe towards sustainable cooling

Throughout the Montreal Protocol implementation, the focus has been to have minimum economic dislocation and obsolescence, particularly for the MSMEs, maximise indigenous production for twin environment and economic gains, implement the ODS phase-out activities without adversely affecting industrial and economic growth, adopt climate friendly alternatives as far as possible from indigenous sources and explore safe and sustainable alternatives. This approach will continue during the implementation of the Kigali Amendment as well as the recommendations of the ICAP.

As part of implementation of the recommendations of the ICAP, action points in space cooling, cold chain, servicing, R&D and indigenous production thematic areas have been finalised through mapping of the recommendations in each thematic area with ongoing government programmes and schemes to promote synergies and maximize socio-economic co-benefits. Simultaneously, a roadmap along with an action plan for indigenous development, which encourages (a) domestic manufacturing of next-generation low GWP refrigerants like HFOs, R-290, R-600a etc. to be used as alternatives in various sectors and subsectors using HFCs, (b) upgradation of skill of the existing manpower for wider adoption of such refrigerants during the phase down of HFCs under the Kigali Amendment, and (c) implementation of the ICAP recommendations is being worked out through a collaborative approach with all the concerned stakeholders including line ministries/departments of the central/state government, R&D and academic institutions and industry to achieve the objective of making cooling sustainable and accessible for all.

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