सत्यमेव जयते

INDIA COOLING ACTION PLAN

OZONE CELL
MINISTRY OF ENVIRONMENT, FOREST & CLIMATE CHANGE
GOVERNMENT OF INDIA

MARCH, 2019

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Ozone Cell
Ministry of Environment, Forest and Climate Change
Government of India

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GOVERNMENT OF INDIA
MINISTER OF ENVIRONMENT, FOREST & CLIMATE CHANGE

MESSAGE

Requirement of cooling is pervasive across different sectors of the economy such as residential and commercial buildings, cold-chain, refrigeration, transport and industries. Cooling is also linked to human health and productivity. In India and other developing economies in tropical climates, cooling demand is expected to grow in the future owing to low penetration of air-conditioning, economic growth, increasing per capita income, and urbanisation.

Linkages of cooling with Sustainable Development Goals (SDGs) is well acknowledged. The cross-sectoral nature of cooling and its use in development of the economy makes provision for cooling an important developmental necessity. Additionally, cooling related activities are one of the major sectors for employment -both in urban and rural areas.

India is one of the first countries in the world to develop such a comprehensive Cooling Action Plan which has a long term vision to address the cooling requirement across sectors and list out actions which can help reduce the cooling demand. This will also help in reducing both direct and indirect emissions. The thrust of the India Cooling Action Plan (ICAP) is to look for synergies in actions for securing both environmental and socio-economic benefits. The overarching goal of ICAP is to provide sustainable cooling and thermal comfort for all while securing environmental and socio-economic benefits for the society.

The development of ICAP has been a multi-stakeholder inclusive process encompassing different Government Ministries/Departments/Organizations, Industry and Industry Associations, Think tanks, Academic and R&D Institutions.

I am sure implementation of ICAP will go a long way achieving the objectives of Sustainable Development Goals while improving the quality of life of people in India.

I congratulate all those who are part of preparation and implementation of India Cooling Action Plan.

Date: 07.03..2019

(Dr. Harsh Vardhan)

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

सत्यमेव जयते

MESSAGE

Cooling requirement is cross sectoral and an essential part for economic growth. The cooling demand is set to rise in the future. This will result in increased use of refrigerants and energy use for cooling. The Kigali Amendment to the Montreal Protocol for phase down of Hydrofluorocarbons (HFC) has for the first time recognized the linkages between refrigerant transition and energy efficiency of air-conditioning equipment within the realm of the Protocol.

Dovetailing energy efficiency of Refrigeration and Air conditioning equipment with refrigerant transition will enhance the overall climate benefit. Most importantly synergistic actions with respect to cooling across sectors will have a higher impact than actions taken in isolation.

The India Cooling Action Plan (ICAP) seeks to provide an integrated vision towards cooling across sectors encompassing inter alia reduction of cooling demand, refrigerant transition, enhancing energy efficiency and better technology options with a 20 year time horizon. The ICAP provides short, medium and long term recommendations across different sectors while providing linkages with various programmes of the Government aimed at providing sustainable cooling and thermal comfort for all. An implementation framework is also set forth to coordinate the implementation of these recommendations.

I am grateful to the members of the Steering Committee and the Committee for the development of the Cooling Action Plan for their valuable insight and support.

I take this opportunity to compliment all the representatives from government Departments/ organizations, industry, R&D institutions, academia, individual experts and think tanks involved in the development of the India Cooling Action Plan including my colleagues in the Ministry who have steered the development of the ICAP till its fruition.

[C.K. Mishra]

Dated: 6th March, 2019
Place: New Delhi

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Acknowledgement

The development of the India Cooling Action Plan (ICAP) has been a multi-stakeholder effort, with inputs from various Government Ministeries /Departments/Organizations, industry, industry associations, individual subject experts, think tanks, academia and R&D Institutions.

Ministry of Environment, Forest and Climate Change (MoEFCC) would like to acknowledge the active participation and invaluable contributions of the following organisations in the development of ICAP. A special mention needs to be made about the support provided by Alliance for an Energy Efficient Economy (AEEE) in conducting the background analysis, compiling and collating relevant chapters developed by Thematic Working Groups and finalization of the India Cooling Action Plan for publication. The important contributions of the team at Ozone Cell, MoEF&CC, in various ways is also acknowledged.

Ministry of Agriculture and Farmers' Welfare
Ministry of Housing and Urban Affairs
Ministry of Power
Ministry of Road Transport and Highways
Ministry of Skill Development and Entrepreneurship
Department of Industrial Policy and Promotion (DIPP)
Department of Science and Technology

Bureau of Energy Efficiency (BEE)
Council for Scientific and Industrial Research (CSIR)
Energy Efficiency Services Limited (EESL)
Electronic Sector Skill Council of India (ESSCI)
National Centre for Cold-chain Development (NCCD)

Alliance for an Energy Efficient Economy (AEEE)
Council on Energy, Environment and Water (CEEW)
Centre for Science and Environment (CSE)
The Energy and Resources Institute (TERI)

Automobile Component Manufacturers Association (ACMA)
Confederation of Real Estate Developers Association of India (CREDAI)
Indian Polyurethane Association (IPUA)
Indian Society for Heating Refrigeration and Air-conditioning Engineers (ISHRAE)
Refrigeration and Air-conditioning Manufacturers Association (RAMA)
Refrigerant Gas Manufacturers Association (REGMA)
Refrigeration & Air-conditioning Servicing Sector Society (RASSS)
Society for Indian Automotive Manufacturers (SIAM)

Executive Summary

Context

Cooling is linked with economic growth and is recognised as key to the health, wellbeing, and productivity of people in hot climates. India is a growing economy characterized by low penetration of air-conditioning, rising per capita income, rapid urbanization and a largely tropical climate all of which would lead to a rise in the requirement for cooling. Addressing the rising cooling requirement is both a challenge as well as a unique opportunity, necessitating synergies in policies and actions to address the cooling requirement across sectors even while making cooling sustainable and accessible to all.

Increasingly, cooling is recognized as a developmental need that is linked with achieving many Sustainable Development Goals. A large part of the cooling demand is catered through refrigerant-based cooling globally across sectors such as buildings, cold-chain, refrigeration and transport. Refrigerants used in cooling equipment are regulated under the Montreal Protocol regime.

Another important aspect related to refrigerant-based cooling is energy use, resulting in a much larger portion of the emissions – nearly 70%. According to the International Energy Agency (IEA), refrigeration and air conditioning (RAC) causes 10% of the global CO2 emissions. That being said, India has one of the lowest access to cooling across the world, 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 (Figure A).

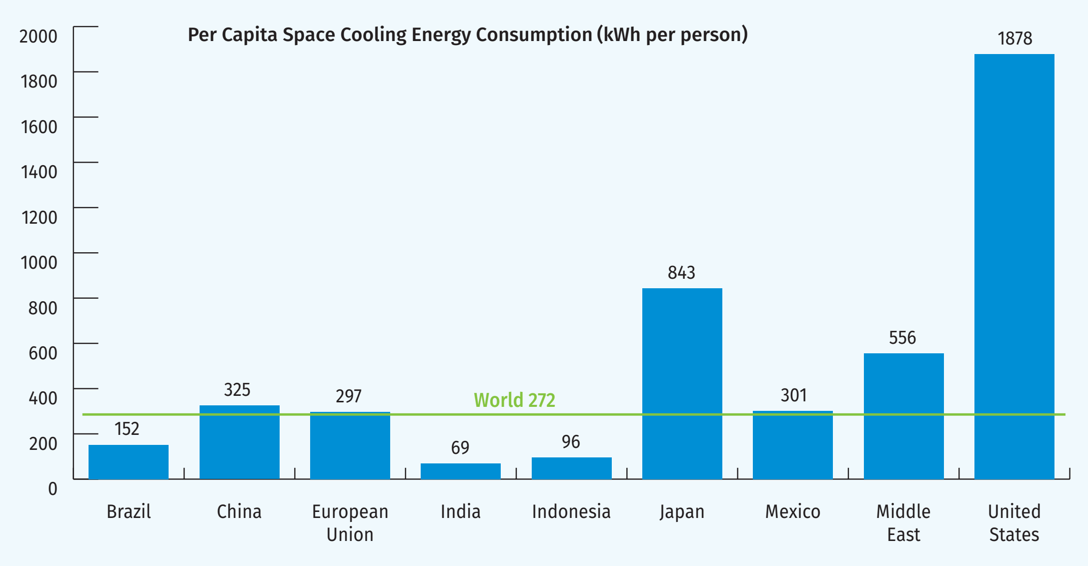

Figure A: Per Capita Space Cooling Energy Consumption (IEA (2018). The Future of Cooling.)

As part of demand side management of cooling energy use, Minimum Energy Performance Standards (MEPS) and star-rating scheme for room air conditioners are already in place in the countryand MEPS for room air conditioners are being systematically ratcheted up.These positive actions need to be further strengthened in line with the increase in energy use for addressing the cooling demand.The Kigali Amendment to the Montreal Protocol has, for the first time, recognized linkages between maintaining and/or improving energy efficiency of RAC equipment with refrigerant transition under the Protocol.

Integrated actions have a higher impact than any of the actions taken in isolation. It is therefore the need of the hour to have an integrated long-term vision on cooling encompassing, among other things, optimization of cooling demand, integration of energy efficiency and refrigerant transitioning efforts, and adoption of better technology options.

Development of the India Cooling Action Plan

Within this context, the development of the India Cooling Action Plan (ICAP) has been a multi-stakeholder, integrated and consultative process in order to synergize actions for addressing the cooling demand across all sectors. The ICAP provides a 20-year perspective (2017-18 to 2037-38) and recommendations, to address the cooling requirements across sectors and ways and means to provide access to sustainable cooling.

Given the crosscutting requirement of cooling in multiple sectors, different Government Departments and Ministries are linked with the subject of cooling. Therefore, the development and implementation ICAP has been an inter-ministerial undertaking. Some actions emerging out of the ICAP also require involvement of State Governments and Urban Local Bodies for their implementation. These linkages have been captured in the ICAP implementation framework. .

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 Country Programme of India for phase-out of Ozone Depleting Substances (ODS) - to minimize economic dislocation and obsolescence cost and maximise indigenous production for combined environmental and economic gains.

The ICAP takes a holistic and balanced approach by encompassing both passive and active cooling strategies as well as optimization of cooling loads. The ICAP, inter alia, encompasses: (a) passively-cooled building design that deploys natural and mechanical ventilation; (b) adoption of adaptive thermal comfort standards to specify pre-setting of temperatures of air conditioning equipment for commercial built spaces; (c) promoting the use of energy-efficient refrigerant-based appliances as well as not-in-kind technologies; (d) policy interventions for market transformation, including public procurement of energy-efficient RAC appliances and equipment; (e) development of energy efficient and renewable energy based cold chain; (f) national skill development programme for training and certification for RAC service technicians to complement transition to energy efficient, low-GWP refrigerants, and (g) focused R&D efforts to foster an innovative ecosystem to support development and deployment of low-GWP refrigerant alternatives.

The ICAP underscores the importance of further development and use of a robust mix of cooling technologies, including the use of energy-efficient appliances with appropriate environment-friendly refrigerants, for meeting the growing cooling requirement of the country.

While cooling is vast topic encompassing multiple aspects inter alia including technological - such as, cooling technologies, refrigerants, associated R&D; socio-economic - such as access to cooling, linkage with productivity. At present, the ICAP has covered technological aspects of cooling, in order to delve deep into this aspect and to provide an actionable roadmap for positive interventions. This involved assessment of cooling demand and to outline interventions to reduce the impacts of this growth. The ICAP is visualized as a living document that seeks to expand its horizons inter alia to address issues of access to cooling, equity etc. by directing strategies presented in the ICAP into actionable activities as it evolves.

Development Framework

The development of the ICAP involved extensive stakeholder interaction with government organizations/Departments, experts, representatives of industry associations, and think tanks. Seven different Thematic Areas were identified and Working Groups for each of the Thematic Areas with representation from government, industry associations, think tanks, and research entities were constituted for each of the Thematic Areas. The Thematic Areas are:

For each of the thematic areas, the ICAP explored two scenarios of growth in cooling demand: the Reference Scenario which assumes that the current policies and level of effort will move forward per established revision cycles (or historical trends, as applicable), and the Intervention

Scenario which factors in the positive impacts of accelerated and new interventions driven by policy, technology and market-drivers. The data with respect to cooling requirement generated by the various thematic working groups provide a trend rather than definitive estimates. In view of the limited availability of data on cooling and related aspects, which has also been acknowledged by various international publications on cooling, the numbers generated by the Working Groups are best estimates arrived at in the limited time available for setting out a plan of action.

A separate Steering Committee having inter-ministerial representation under the chairmanship of Additional Secretary (EF&CC) guided the process and reviewed the documentation prepared for inclusion in the ICAP. The draft was finally discussed in and finalised by a high-level committee chaired by Secretary (EF&CC), having subject experts and eminent representatives from think-tanks and industry.

India's Cooling Growth Trajectory: Key Findings

Based on the research and analysis undertaken for the different Thematic Groups, the following consolidated findings and highlights emerge for India's cooling growth trajectory:

A

Cooling Demand

The aggregated nationwide cooling demand, in Tonnage of Refrigeration (TR), is projected to grow around 8 times by 2037-38 as compared to the 2017-18 baseline. The building sector cooling demand shows the most significant growth at nearly 11 times as compared to the baseline; the cold-chain and refrigeration sectors will grow around 4 times while transport air-conditioning will grow around 5 times the 2017-18 levels.

The sector-wise growth in cooling requirements (in TR) under Reference Scenario is presented in Figure B. The analysis projects a range for growth, dependent on variables such as economic growth, leading to continued growth in building construction, rate of urbanisation, and improved lifestyle and aspirations. Mid-point of the ranges has been used for graphical representation.

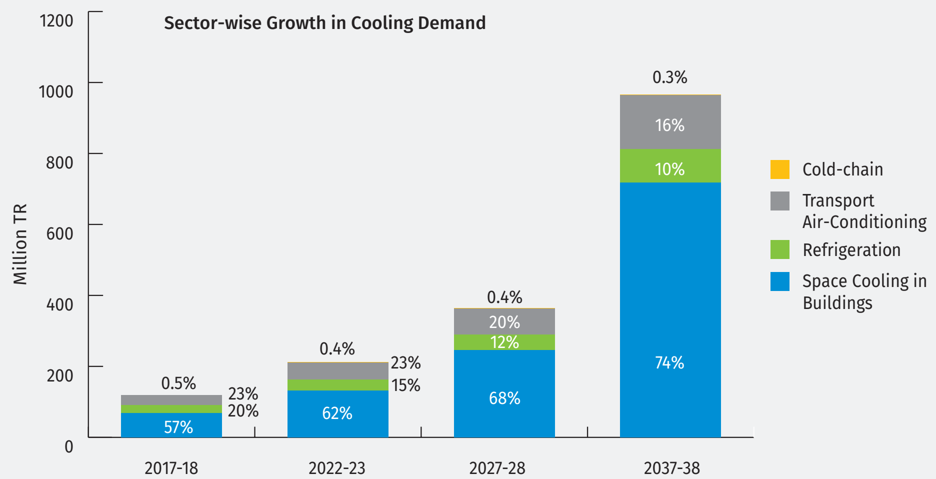

Figure B: Sector-wise Growth in Cooling Demand

B

Refrigerant Demand

The projected cooling growth leads to a 5 to 8 times increase in the aggregated refrigerant demand by year 2037-38. The Intervention Scenario suggests that through proactive measures, this total refrigerant demand can be reduced by 25%-30% by 2037-38..

C Primary Energy Supply for Cooling

The Total Primary Energy Supply (TPES) required for cooling across all demand sectors is depicted as aggregated primary energy (coal, oil, gas, nuclear, hydro, solar, wind, and other renewables) supplied for both electricity and oil products demand. The TPES requirement for cooling is expected to grow nearly 4.5 times in 2037-38 under Reference Scenario, over the 2017-18 baseline. Under Intervention Scenario this requirement can be reduced by up to 30%(Figure C)..

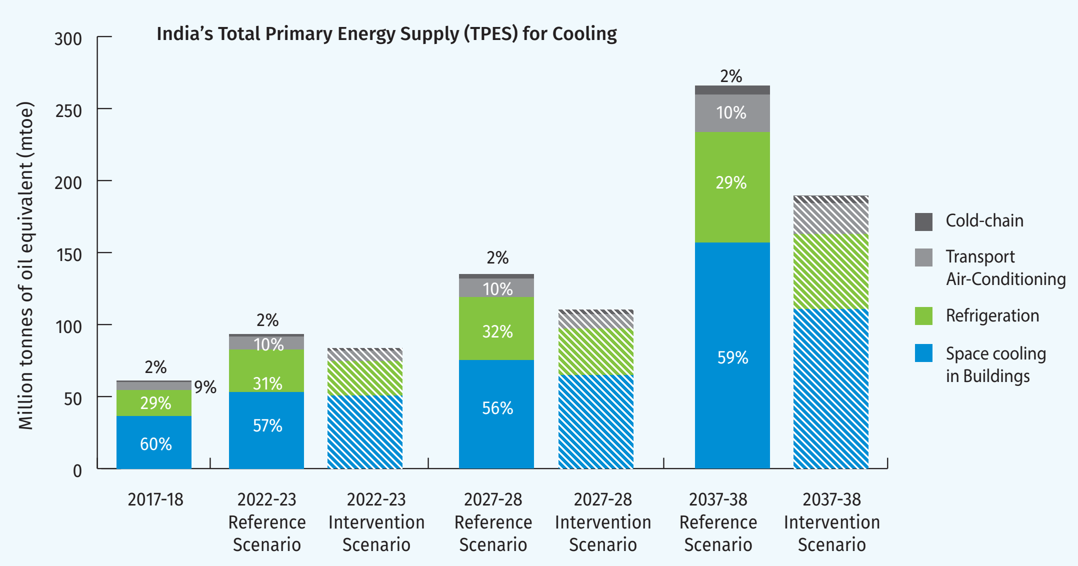

Figure C: India's Total Primary Energy Supply (TPES) for Cooling

Note: A constant primary energy conversion efficiency as per IESS Level 2 for 2017 has been assumed for all scenarios. However, the reduction in T&D losses and increased share of renewable mix shall impact the cooling related primary energy supply in future years.

Overview of Chapters

The chapters are organized to separately cover each of the demand sectors of cooling/ refrigerants. Each of these chapter provides: (i) an overview of the present cooling requirement; (ii) technologies available to cater to cooling requirements; (iii) projection of the future cooling requirement, the associated refrigerant demand and energy use under two alternative scenarios – reference scenario and intervention scenario as explained above; (iv) assumptions for the projections and source of data used for the projections are mentioned at appropriate places; and (v) the suggested interventions. While developing the India Cooling Action Plan, the best available data from government sources, industry estimates, surveys and research publications with respect to cooling requirement across sectors has been used. Demand for cooling has been projected under reference and intervention scenarios. Data analysis and projections for growth have been separately dealt with.

Separate chapters cover air-conditioning technology, production of refrigerants and domestic manufacturing, Research and Development on new and alternative cooling technologies and recommendations and the way forward.

Following are the summaries of various chapters.

CHAPTER 1 :
Introduction – A Synergistic Approach to Cooling

The chapter presents the context to cooling as a development need, which is required across different sectors of economy and also for human health, well-being and productivity, inter alia, bringing out the cross-cutting nature of cooling. This chapter also underscores the fact that requirement for cooling will grow across the country in the future due to economic growth, urbanization and increase in per capita income.

Synergistic actions taking a holistic view of the cooling requirement across sectors will have a higher impact than actions taken in isolation. This shall help in securing both environmental and socio-economic benefits. There are different developmental programmes of Government already under implementation such as Pradhan Mantri Awas Yojana, Smart Cities, Doubling Farmers Income, Skill India Mission and Mission Innovation where the activities for addressing cooling requirement could be synergized to leverage both environment and societal benefits.

Such synergies could also be looked at for international commitments. Sustainable cooling is at the intersection of three international commitments viz. Kigali Amendment to the Montreal Protocol, Paris Agreement under United Framework Convention on Climate Change (UNFCCC) and Sustainable Development Goals of 2030.

Therefore, there is a need for an integrated long term vision towards addressing cooling requirement across sectors including reducing cooling demand, refrigerant transition, enhancing energy efficiency and advancing cooling technology options and improving access to cooling in a more equitable manner.

Keeping this in view the objectives of the ICAP, *inter alia*, are

- Assessment of cooling requirements across sectors in next 20 years and the associated refrigerant demand and energy use
- Mapping the technologies available to cater the cooling requirement including passive interventions, refrigerant-based technologies, and alternative technologies such as not-in-kind technologies
- Suggesting interventions in each sector to provide for sustainable cooling and thermal comfort for all
- Highlighting focus on skilling of RAC service technicians and development of an R&D innovation ecosystem for indigenous development of alternative technologies

CHAPTER 2 & 3:
Space Cooling in Buildings

Space cooling is an important segment of the cooling demand in the country. There are multiple technologies and range of options available for addressing the space cooling demand. The space cooling demand estimation and the technologies available to address the demand are presented in two separate chapters.

Chapter 2 focuses on the Technology Landscape, discussing the prevalent and evolving technology options for space cooling, which broadly fall within three categories: refrigerant based, and non-refrigerant based, and not-in-kind technologies. Among the refrigerant-based systems, room air conditioner is the dominant technology representing ~80% of the installed capacity, with an increasing share that reaches around 87% in 2037-38. Room air conditioners find predominant application in residential sector, and currently have a fairly low penetration in India, at around 7-9%. Air conditioning systems utilised in the commercial buildings, excluding room air conditioner, can be classified into three major types – chiller system, packaged direct expansion (DX), and variable refrigerant flow (VRF) system. The non-refrigerant based cooling technologies like fans and air coolers are significantly pervasive in the residential sector, as well as in the small to medium commercial buildings, and commercial applications such as warehouses. Even with a growing penetration of room air conditioners, fans and coolers will maintain a substantial share in 2037-38 consuming nearly as much energy as the all commercial AC systems combined (chillers, DX, VRF).The not-in-kind technologies like thermal energy storage and district cooling are still penetrating the space cooling segment and shall further progress, and further diversify the air conditioning technology options.

Chapter 3 deals with Cooling Demand Projections for space cooling, discussing the existing and upcoming building stock in the country and the top-down estimation of air-conditioning demand, and secondly presenting details of a bottom-up analysis of the stock and growth of cooling technologies, related energy consumption and refrigerant use. Room air conditioners constitute the dominant share of the sector's cooling energy consumption – at around 40% in 2017-18 and growing to around 50% in 2037-38 (Figure D). Room air conditioners show the highest growth at around 11 times of the current baseline (in terms of installed TR), as well as significant potential for optimization and energy savings. The bottom up analysis on stock of air conditioning equipment and growth of various cooling technologies has been done with active collaboration of industry and industry associations. These projections are, inter alia, based upon industry estimates and also based upon interactions and discussions with subject experts. Data from Bureau of Energy Efficiency with respect to sales of different star-rated appliances, from the time star labelling has become mandatory in the country, has also been used.

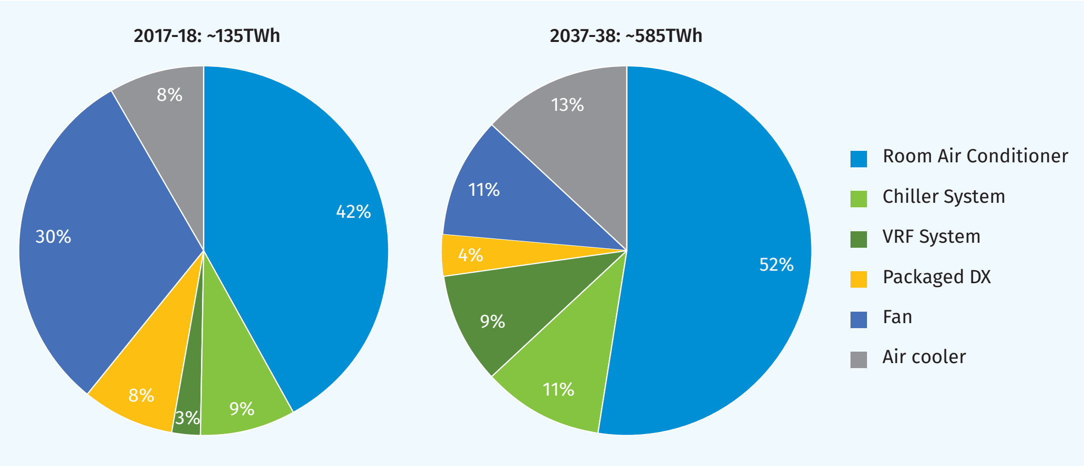

Figure D: Space Cooling Energy Consumption by Equipment

The residential sector is likely to be the driver for the growth of air-conditioning equipment in India in the next twenty years due to low existing penetration of air conditioners, increasing purchasing power, urbanisation trends etc. The Space Cooling sector presents unique opportunities for optimization of cooling demand, including through energy efficiency, since a large portion of the cooling demand is yet to come. The Intervention scenario projects that around 30% reduction in cooling energy can be achieved through improvements in cooling equipment efficiency, and better servicing and operation and maintenance (O&M) practices. Further significant energy savings could be accrued over and above the projected 30 % reduction by optimizing, and in effect, reducing the cooling load of built spaces: a reduction potential of around 20% in cooling load could be achieved by 2037-38, through climate-appropriate building envelopes driven by a higher adoption of ECBC in the upcoming commercial buildings, and through adoption of adaptive thermal comfort practices (pre-setting of lower set point temperature in air conditioning equipment)..

CHAPTER 4:
Cold Chain and Refrigeration

While the cold-chain sector represents a small portion of the aggregated cooling demand, it is poised for significant growth, significant implications for with increase in farmers' income in the country. India has a large inventory of cold storages or refrigerated warehouses, but the other elements that make up an uninterrupted cold-chain – pack houses, reefer transport and ripening chambers – are largely missing. The projected development of a robust infrastructure to provide important market linkages and create an uninterrupted cold-chain will not only help in reducing food loss across the country and ensure food security but will also be a major driver in supporting the objectives of Government of India's Doubling Farmers' Income initiative (DFI).

With around 500 pack-houses in India at present, the number is likely to grow to 55,000 in the next decade and to 1,25,000 in the subsequent decade attributing to an energy consumption of 2.4 TWh and 5.2 TWh respectively. The growth of reefer vehicles is related with increase in the pack-houses, and their estimated numbers are 1,35,000 units in the next decade and 4,00,000 units in the subsequent decades from the present 15,000 units. Cold storages would grow at a marginal rate from the existing 35 Million Metric Tonne (MMT) to 40 MMT in 2028 and to about 48 MMT in 2038. There would be a steady growth in ripening chambers from current 1000 units to 9,000 units in the next decade and to 14,000 units in the subsequent decade. These growth factors align well with the GoI's current and ongoing initiatives like DFI and will help plug the gaps in the immediate and near-term infrastructure requirement. The Intervention scenario would help obviate 12% of refrigerant usage and around 8-12% of associated energy consumption by employing efficient compressors, improved insulation, optimized operations and through retrofitting and retro-commissioning practises.

The domestic refrigeration predominantly consists of frost-free (FF) and direct-cool (DC) refrigerators with DC refrigerators being the most preferred customer choice. The domestic refrigerator sales would grow by 1.7-fold in the coming decade and 3-fold in the subsequent decade attributing to about 2.6-times and 4-times increase in the associated energy consumption. The commercial refrigeration sector primarily consists of deep freezers, visi-coolers, remote condensing units, water coolers, and, super and hyper markets. This sector is poised to grow 2-fold in the next decade and 6-fold in the subsequent decade with energy implications in the range of 2.2-times and 6-times increase. The refrigerant demand in the intervention scenario can be reduced by 20-25% in the next two decades owing to technological advancements, improved servicing practises, and enhanced insulation translating to up to 30% savings in the associated energy consumption.

CHAPTER 5:
Transport Air Conditioning

With economic growth, the transport sector is also expected to grow in an aligned manner. Rapid urbanisation and increasing income levels will drive up the ownership of passenger cars - majority of which will be air-conditioned - at an expected growth rate of almost 9% annually up till 2040. The total number of buses is estimated to grow from ~2.2 million in 2017-18 to ~ 4 million in 2037-38. The sector's growth will have a huge bearing on the fuel as well as on the refrigerant demand which is estimated to grow from ~6000 metric tonnes (MT) in 2017 to ~25000 MT by the year 2038. Strategic actions towards efficient mobile air-conditioning would lead to a reduction in energy demand as well as refrigerant demand.

As the existing trajectory of increased transport demand will be associated with significant environment and socio-economic implication, it is imperative that policy measures like improved fuel efficiency of vehicles, incentives or rebates for energy efficient technology push towards public transport, faster adoption of hybrid and electric vehicles are adopted in order to reduce cooling requirement, refrigerant consumption as well as energy demand in this sector.

CHAPTER 6:
Refrigeration & Air Conditioning Service Sector

RAC servicing sector is directly related to the consumption of refrigerants and optimum and efficient performance of in-use air conditioning equipment. This sector is largely unorganized and presents an immediate opportunity for securing environment benefits and livelihoods enhancement of RAC service technicians through training and certification. Use of good servicing practices by service technicians reduce refrigerant leakage and minimize the indirect emissions of air conditioning equipment related to power generation by maintaining the rated energy efficiency of in-use equipment.The HPMP Stage II roadmap estimates that the servicing sector consumes more than 40% of the total refrigerant consumption in the country. The TEAP Report (2018) observes that proper maintenance and servicing can curtail up to 50% reduction in performance and maintain rated performance over lifetime.

The chapter covers RAC servicing sector specifically with respect to usage of refrigerants, energy efficiency of in-use equipment's, servicing practices, market growth, the need for training and certification, availability of training infrastructure, livelihoods and social security.

The number of refrigeration and air-conditioning service technicians in the country will rise with increase in the equipment stock. As per estimates at present, there are 200,000 service technicians in the country, most of whom are in the informal sector. Training programmes for RAC service technicians, have been a continuous activity as part of the ODS phase-out programmes being implemented in the country under the Montreal Protocol framework. Separately, there have been trainings for service technicians being organized by industry associations and air conditioning equipment manufacturers.

The Ministry of Skill Development and Entrepreneurship (MSDE), Government of India is mandated with development skill ecosystem in the country and oversees and administers skilling and vocational training. The National Skill Qualification Framework (NSQF) under MSDE provides for certification of skills through National Skill Development Corporation, which implements the certification programme through Thematic Sector Skill Councils. The Electronic Sector Skill Council caters the RAC servicing sector trade. This could be further strengthened in terms of infrastructure and technical content. This system could be developed as a single certification system that has to be obtained by all technicians. MoEF&CC and Ministry of Skill Development & Entrepreneurship, GoI entered into an MoU to skill and certify 100,000 service technicians under the Pradhan Mantri Kaushal Vikas Yojana – Skill India Mission.

Training and certification of RAC service technicians have potential to provide significant environment and livelihood benefits. These could be achieved through appropriate skill development of service technicians, along with creating a market demand for skilled technicians, which shall be a key driver.

CHAPTER 7:
Refrigeration Demand & Indigenous Production

India has been self-sufficient with respect to fluorocarbon refrigerants and has a robust fluorocarbon refrigerant industry, which provides for domestic consumption and also exports to other countries. Per industry estimates, the annual indigenous production of refrigerants is around 24,300 MT in 2017-18 and is likely to grow to 1,66,000-1,81,000 MT in the coming 20 years. The phase-out of ozone-depleting HCFCs is presently underway under the constructs of the Montreal Protocol. The Kigali Amendment to the Montreal Protocol for phase down of HFCs lays down a schedule for high GWP HFCs and low-GWP alternatives including HFOs and blends of HFCs and HFOs, and natural refrigerants. Future refrigerant pathways will include an increased proportion of low-GWP refrigerants and use of natural refrigerants. The refrigerant production sector faces challenges related to Intellectual Property Rights(IPR) limitations and the lack of technically/ commercially viable new refrigerant options, which warrants focused R&D is this sector.

CHAPTER 8:
Research & Development

The development of a robust R&D innovation ecosystem in India will involve: further development of scientific manpower in the area; requisite academic and R&D institutional capacities; support for R&D activities on various facets of cooling; including but not limited to refrigerants; cooling equipment, passive building design interventions, not-in-kind technologies and new emerging technologies; industry preparedness to assimilate new technologies. Participation of the industry is the key for the success of R&D efforts on low GWP based alternative cooling technologies.

A critical aspect for sustainable cooling is the availability of cost effective low GWP and non-ODS refrigerants. Therefore, it is imperative to develop cost effective indigenously developed solutions to meet the cooling demand of the country. The R&D efforts need to be aligned with the Make in India Programme. Through sustained R&D efforts in both public and private sector the reliance on imported equipment and parts needs to be reduced. This will also require a greater domestic manufacturing base producing equipment and components specifically suited to the local needs

To this end, it will be important to leverage the diverse expertise that lies with various stakeholders including the industry and academia (IITs, NITs, CSIR-IICT, CSIR-NCR). As such, a robust enabling platform is a key need in fostering meaningful collaborations and linkages and supporting the R&D efforts.

A matrix of proposed R&D activities related to heating, ventilation, air conditioning and refrigeration (HVAC&R), inter alia, are (i) refrigerant development, (ii) HVAC technology including not-in-kind technologies and (iii) building design including passive cooling design, for short-, medium- and long-term.

Keeping in view that cooling has been recognized as a development need, and its demand is expected to see multi-fold increase in future across sectors, a separate section on recommendations provides a framework for implementation and development of R&D innovation ecosystem in the country, which, inter alia, include recognizing research and development cooling as a national thrust area under the S&T programme of the country, with a provision of dedicated R&D funding in intimate collaboration with the industry. It is also important to forge synergies with existing Government schemes such as Make in India.

CHAPTER 9:
Recommendations & Way Forward

This chapter presents the short, medium and long-term recommendations for each of the Thematic Areas, highlighting synergies with existing governmental schemes and programmes. Based on the proposed recommendations, the following priority areas are identified by the ICAP:

A

Promote development and commercialization of technology pathways, especially low-energy cooling technologies, which would reduce the energy footprint of active cooling: Through the right combination of policy and market drivers, the private sector must be enabled to lead the technology development through innovation and R&D. The technology pathways must include, inter alia, the evolution of not-in-kind technologies for scaled-up adoption.

B

Accelerate (i) reduction of the cooling load of the building sector through fast-tracked implementation of building energy codes, (ii) adoption of adaptive thermal comfort standards, (iii) ratchet-up energy efficiency of room air-conditioners and fans, and (iv) enhancing consumer awareness through eco-labelling of cooling products: In the light of significant increase (~3x) in building area by 2037-38 (over 2017-18 baseline), the role of climate appropriate design and building energy efficiency will become increasingly important in terms of reducing the cooling load requirements.

C

Public Procurement of (i) energy efficient cooling equipment and (ii) trained and certified RAC service technicians for public buildings.

D

Further government support towards targeted programmes to enable thermal comfort for EWS and LIG: The Government is implementing schemes for building affordable housing such as under Pradhan Mantri Awas Yojana with the objective of providing housing for all. These schemes would benefit by use of climate appropriate and energy efficient building design for construction of houses under EWS and LIG segments. This would inter alia provide thermal comfort for all, reduce cooling load, and provide gains in terms of energy efficiency. In this regard, the energy efficient building envelope guidelines of ECBC-R could be enforced. In addition, funding and support, where required, for initiatives providing thermal comfort such as cool-roof programs, off-grid micro-systems for cooling, and localized heat-action plans could be provided.

E

Drive skill-building of the service sector through training and certification: With major portion of refrigeration, air conditioning and heat pumping (RACHP) service technicians working in the informal sector, there is a need to bring the service technicians into the formal sector through training and certification programme. MoEF&CC should work together with other concerned ministries for up-skilling and certification of RACHP service technicians under Pradhan Mantri Kaushal Vikas Yojana. The ICAP takes cognizance of the training and skilling activities offered by the industry and government skilling activities should be in tandem with them – registering industry training centres under the National Skills Qualification Framework (NSQF) and drawing linkages with MSME-DIs are some recommended ways forward.

F

Ensure harmonization of policies: ICAP builds on the efforts of HCFC Phase-out Management Plan. There should be synergy between the existing plans to phase-out HCFCs and the new plans to phase-down the use of high GWP HFCs. ICAP is starting the new planning process to do an assessment of the timing of HCFC phase-out initiatives to ensure that costs are minimised and that the environmental benefits of both policies are maximised. Furthermore, the ICAP recommendations bring in synergies with on-going government programmes and schemes in order to maximize the social and economic co-benefits.

G **Create an ecosystem for promoting robust and collaborative R&D:** A robust, comprehensive and R&D innovation ecosystem will be critically important for effectively addressing India's cooling requirement. In this context, the role of public-private-partnerships will become important.

This chapter also briefly outlines an implementation framework for the ICAP, underscoring the need for inter-ministerial collaboration.

ICAP Goals

The overarching goal of ICAP is to provide sustainable cooling and thermal comfort for all while securing environmental and socio-economic benefits for the society. The following goals emerge from the interventions proposed in the ICAP:

1. Recognition of "cooling and related areas" as a thrust area of research under national science and technology programme to support development of technological solutions and encourage innovation challenges.
2. Reduction of cooling demand across sectors by 20% to 25 % by year 2037-38
3. Reduction of refrigerant demand by 25% to 30% by year 2037-38
4. Reduction of cooling energy requirements by 25% to 40% by year 2037-38
5. Training and certification of 100,000 servicing sector technicians by year 2022-23, synergizing with Skill India Mission

Implementation Framework

The ICAP serves to underscore the urgency of proactively and collaboratively addressing India's projected cooling growth and lays out sector-wide priorities and pathways for interventions. Given the crosscutting nature of cooling demand, the ICAP implementation will be best served by active collaboration among the relevant ministries as well as the private sector entities. Secondly, integration with on-going programs and initiatives will be key for achieving optimal benefits. Figure E provides a snap shot of multiple inter-linkages of cooling between different Government ministries/Departments/organizations along with the on-going programmes and initiatives, which intersect with the cooling agenda.

For effective implementation, the ICAP must be monitored and executed under the governance of a high level inter-ministerial framework. The already existing Inter-ministerial Empowered Steering Committee for the implementation of the Montreal Protocol approved by the Union Cabinet could be additionally tasked with the overseeing the implementation of the ICAP. Based on the actions that emerge from the ICAP recommendations, other ministries could be added to the Empowered Steering Committee. The Ozone Cell, MoEF&CC be strengthened and additionally tasked to act as a Cooling Secretariat in order to provide support to the Empowered Steering Committee and coordinate actions emerging from ICAP.

The ICAP requires implementation of actions through forging synergies with on-going programmes of the Government and also the use of appropriate policy, regulatory and financial instruments, where required. The related line ministries of the Government of India, State Governments, and Urban Local Bodies could seek additional financial resources, if required, beyond available resources to fast track implementation. Since cooling in an integral part of the Montreal Protocol

GLOBAL PRIORITIES	Climate Change Sustainable Development Goals							
Departments & Entities	Ozone Cell	BEE EESL State Designated Agencies (SDA)	CPWD NBCC State PWD Devel-opment Authorities	National Centre for Cold-chain Develop-ment NCCD)	State Transport Depart-ments State Road Transport Undertak-ings	Department of Heavy Industry	Electronics Sector Skills Council of India	Ministry of Science and Technology (DST) TIFAC
Programs & Initiatives		S&L ECBC CAFE norms BEEP ESEAP	PMAY-Housing for All Smart Cit-ies Mission Govern-ment E- Market-place	Doubling Farmers# Income (DFI) Gramin Agricultural Markets (GrAMs)	AMRUT - Public Transporta-tion Metro Rail Projects CAFE norms	FAME India	Pradhan Mantri Kaushal Vi-kas Yojana Govern-ment E-Market-place	Mission Innovation

Figure E: Indicative inter-linkages of Cooling with various Government Programmes & Initiatives

as well as the Paris Agreement, multi-lateral funding mechanisms can also make resources available.

The ICAP establishes high-level goals. The targets to achieve the stated goals require more detailed deliberations and inter-ministerial coordination and will be undertaken through the Empowered Steering Committee. The concerned Government stakeholders can come up with their own programmes, as the case may be, to move towards the goals of ICAP.

The ICAP calls attention to the escalating cooling growth, and the pressing need for ways and means to provide access to sustainable cooling while neutralizing its impacts. It serves as a call to action through inter-ministerial coordination and collaboration among the public and private sectors so as to secure environment and societal benefits.

ICAP delineates future cooling scenarios; therefore, it cannot be a static document and should respond to the evolving knowledge and technology landscape, and social and economic development in the country. To that extent ICAP is open-ended. It can identify unknowns, develop empirical evidences as it proceeds in implementation, and evolve accordingly.

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Introduction: A Synergistic Approach to Cooling

1.1 Background

Cooling is a cross-sectoral requirement and 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, population growth, urbanisation as well as low penetration of air-conditioning.

Cooling is also intimately associated with human health, well-being and productivity. The need to ensure thermal comfort for all and access to cooling across the populace is even more important considering the tropical climate of India.

A large part of the country's cooling requirements across sectors is met using active refrigeration and air-conditioning (RAC) technologies, which are based on the use of either synthetic refrigerants or natural refrigerants. Most synthetic refrigerants both have an Ozone Depleting Potential (ODP) and/or a Global Warming Potential (GWP) and are regulated for phase-out/phase-down as per agreed schedules under the Montreal Protocol on Substances that Deplete the Ozone Layer, to which India is a party.

The Montreal Protocol has been a driver for the adoption of environmentally friendly and energy-efficient technologies by the industry. In the past, while transitioning away from controlled refrigerants under the Montreal Protocol, many new technologies have been adopted by the industry. The Kigali Amendment to the Montreal Protocol was adopted by the Parties to the Montreal Protocol in October 2016 for phase-down of Hydrofluorocarbons (HFCs). These chemicals are not ozone depleting but have a high GWP values.

For the first time, the Kigali Amendment to the Montreal Protocol also provided an opportunity for maintaining and/or enhancing energy efficiency while transitioning away from HFCs within the realm of the Protocol. It is well acknowledged that a significant share of the total carbon emissions from RAC equipment are due to energy consumption and the remaining is due to refrigerant leakage. Dovetailing enhancement of energy efficiency of RAC equipment with refrigerant transition under HFC phase-down will have a synergistic impact on the overall environmental benefit including that for climate.

It is well recognised that integrated actions have a higher impact than any of the actions taken in isolation. It is thus the need of the hour to have an integrated long-term vision towards cooling encompassing, ***inter alia***, reducing cooling demand, refrigerant transition, enhancing energy efficiency, and advancing technology options.

1.2 Cooling is a Developmental Need

The linkages between cooling and Sustainable Development Goals (SDGs) such as Good Health and Wellbeing (SDG 3), Decent Work and Economic Growth (SDG 8), Sustainable Cities and Communities (SDG 11) and Climate Action (SDG 13) 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, the economy and the quality of life of the citizens of the country.

The building sector is one of the most important sectors of the economy and its growth is linked with development in the country. It is also a major consumer of energy in urban centres. The built environment is set to grow with rapid urbanisation in the country; subsequently the air-conditioning and refrigeration requirement will also grow. Building sector interventions not only offer substantial potential for bringing in energy efficiency to reduce energy consumption but also to phase-out Ozone Depleting Substances, which are used as refrigerants in RAC equipment. Energy efficiency in buildings is linked with reduction in cooling requirements and energy consumption, thus delaying the phase-in of refrigerant-based RAC equipment.

The growth in transport air-conditioning, especially in car air-conditioning, is also significant, with rapid growth in the automobile sector linked with the economic health of the country. Other modes of transport such as buses, trucks, metros will also grow, leading to increased transport air-conditioning demand in the future.

A critically important application of cooling is for the preservation of perishable foods like fruits, vegetables, dairy products, fish and meat. An uninterrupted and reliable cold-chain is required for increasing the income of farmers and most importantly to avoid food loss, which together with food wastage, is a significant source of greenhouse gas (GHG) emissions globally. For expanding the existing cold-chain system in India, new modern pack-houses, reefer vehicles and ripening chambers need to be rapidly added to complement the large numbers of refrigerated warehouses, which are already presently catering to the long-term storage demand of some crops. Cold chain also has a crucial role in maintaining the efficacy of vaccines during transport and storage. There is scope for enhancing the energy efficiency of cold-chain sector whilst selecting new refrigerants which are economically viable and environmentally sustainable. The challenge for the industry is to move towards energy-efficient and environment friendly technologies.

Cooling is one of the major sectors for employment, both in urban and rural areas. Skilled personnel are needed for installation and servicing RAC equipment. With growing cooling demand, there will be an increase in the manufacturing and assembling facilities and servicing activities. India has approximately 2,00,000 service technicians working in the RAC trade, both in the formal and the informal sector. The number of technicians is expected to grow in line with the growth in penetration of the RAC equipment in the country. With a large section of RAC service technicians working in the informal sector, there is a potential to upskill service technicians through training and certification programmes. Recognizing this need, the MoEF&CC and Ministry of Skill Development and Entrepreneurship, Government of India have entered a Memorandum of understanding (MoU) for upskilling and certification of 1,00,000 RAC service technicians under the Pradhan Mantri Kaushal Vikas Yojana (PMKVY) – Skill India Mission on 2 August, 2018.

1.3 Synergistic Actions for Securing Environmental and Socio-economic Benefits

Synergistic actions, taking a holistic view of cooling across sectors, will have a higher impact than actions taken in isolation.

Synergies with Existing Government Programmes & Initiatives

The Government of India has many policies and programmes being implemented in the 'mission mode' in energy efficiency, urban development and housing, agriculture, transport, health, R&D, skill development and entrepreneurship (e.g. Housing for All, Smart Cities Mission, National Mission on Sustainable Habitat, Doubling Farmers' Income etc.). While actions under these projects in various development sectors will proceed independently, it is imperative that synergies be forged, wherever possible, to leverage greater environmental and societal benefits.

The government is also focussing on decarbonizing the transport sector and moving towards cleaner fuels and e-mobility. There is a special focus on the development of public transport facilities including metros for intra-city movement, RRTS and railways.

There is a separate National Mission on Enhancing Energy Efficiency under the National Action Plan on Climate Change. Substantial work has been undertaken with respect to demand side management (DSM) of power; there is a Standard &Labelling (S&L) programme for cooling appliances like room air conditioners, fans and refrigerators, the Energy Conservation Building Code (ECBC) has been published and instated in several States and an energy-efficiency driven market transformation is being impacted through the bulk procurement of energy efficient appliances.

The Bureau of Energy Efficiency (BEE) has been developing and implementing policy measures to increase energy efficiency. Market transformation towards energy efficient products is used as a tool for bringing down costs. India has undertaken the first bulk procurement of 1,00,000 super-efficient air conditioners through Energy Efficiency Service Limited (EESL), a public sector undertaking under Ministry of Power, as a demand aggregation strategy that successfully drove down the cost of high-efficiency equipment.

Mission Innovation (MI) launched on 30 November 2015, during COP21 in Paris in the presence of the Hon'ble Prime Minister of India, is a global platform to foster and promote R&D for accelerated and affordable clean energy innovation. India is a key member of this global initiative and is a member of all 7 Innovation Challenges. Heating and cooling of buildings is one of the7 priority areas covered under MI.

Synergies with International Commitments

Cooling is directly linked with the Montreal Protocol on Substances that Deplete the Ozone Layer through the refrigerants used in RAC equipment. Presently, the HCFC Phase-out Management Plans (HPMPs) is under implementation. India is phasing-out production and consumption of HCFCs per the Montreal Protocol schedule (Figure 1.1).

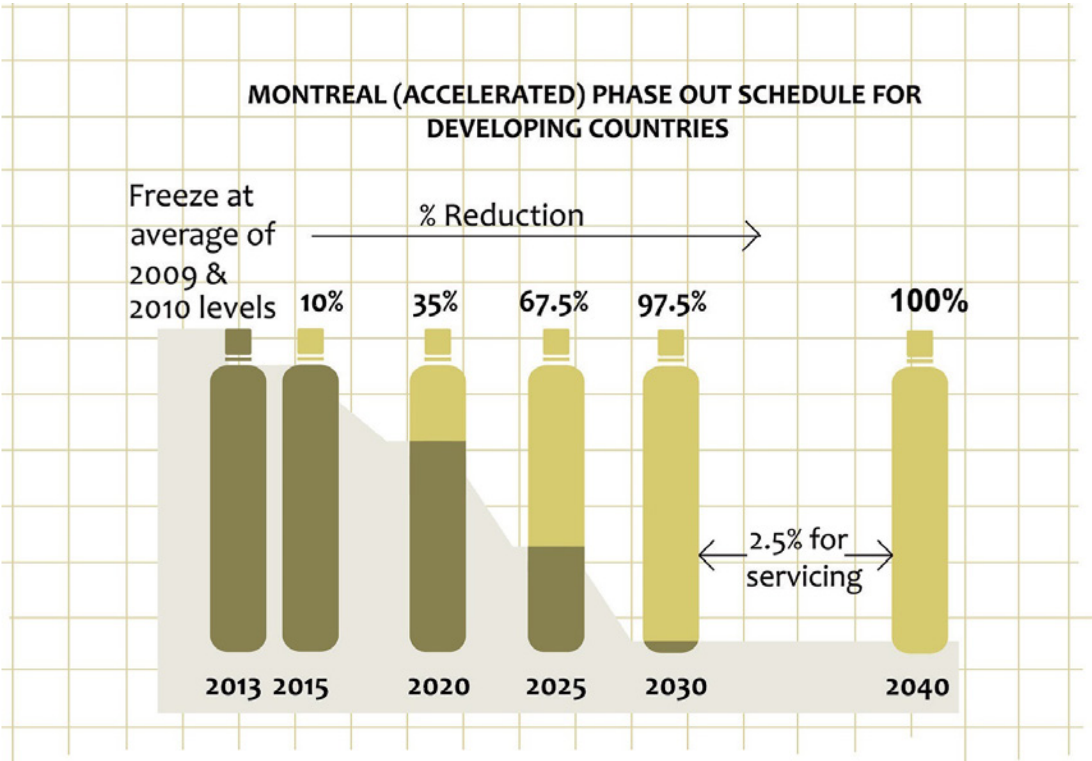


Figure 1.1: HCFC Phase-out schedule in developing countries

HCFC PHASE-OUT MANAGEMENT PLAN (HPMP) STAGE-I

The HPMP Stage-I was developed to implement the phase-out process for a period of four years from 2012 to 2016 to achieve the freeze target by 2013 and 10% phase-out targets of HCFCs by 2015 as per the Montreal Protocol.

The plan prioritized the phase-out of HCFC-141b used in foam manufacturing. HPMP Stage-I was implemented by conversion of 15 large enterprises in the foam manufacturing sector from HCFC-141b to non-ODS, cyclopentane technologies. The enterprises participating in the HPMP stage-I were large consumers of HCFC-141b and also capable of handling the alternative technology based on cyclopentane which is a flammable blowing agent. Safety measures for storage, handling and use during manufacturing of foam needed were put in place by the enterprises.

In addition, Technical Assistance (TA) was provided to 15 Systems Houses for developing HCFC-free polyol formulations with low-GWP for use as blowing agents. These indigenously developed alternatives could be subsequently used by micro, small and medium enterprises (MSMEs) in phasing out HCFCs from their operations.

The refrigeration and air-conditioning (RAC) servicing sector accounts for a significant proportion of the HCFCs consumed in the country. Activities such as development of training material, training of trainers and technicians etc. related to the servicing sector were initiated to support the HCFC phase-out targets. The HPMP Stage-I trained more than 11,000 technicians across the country.

The HPMP Stage-I successfully phased-out a total of 341.77 ODP tonnes of HCFCs. Of this, 310.53 ODP tonnes of HCFC-141b was phased out in the foam manufacturing sector and 31.24 ODP tonnes of HCFC-22 from the RAC servicing sector. By doing so, India has achieved its Montreal Protocol targets for HCFC freeze in 2013 and 10% reduction in 2015. In fact, the reductions was more than what was expected as per the schedule (Figure 1.2).

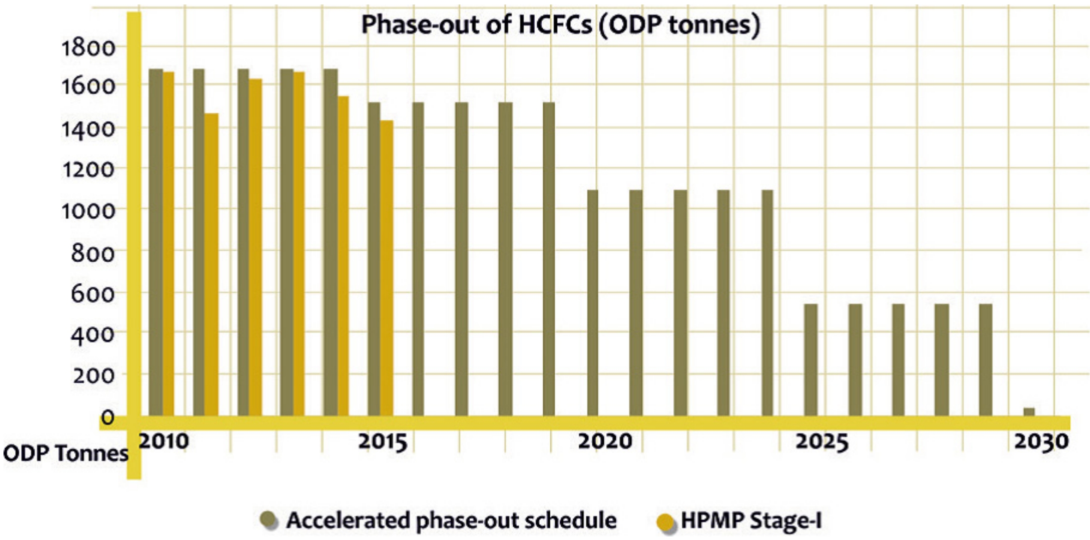


Figure 1.2: Phase-out under HPMP Stage-I

HCFC PHASE-OUT MANAGEMENT PLAN (HPMP) STAGE-II

The HPMP Stage-II was launched in February, 2017 by the MoEF&CC and targets the complete phase-out of HCFC-141b in foam manufacturing sector by 2020. Further, the target is to phase-out HCFC-22 from six major room air-conditioner brands in the country by 2022 and to train about 17,000 refrigeration and air-conditioning (RAC) technicians on alternative technologies and good servicing practices.

The HPMP Stage-II would also address the capacity building and awareness about the harmful effects of HCFCs with regards to ozone depletion and global warming both from emissions of HCFCs and energy consumption in RAC Sector. The HPMP Stage-II also prioritizes phase-out of HCFCs and increasing energy efficiency in building sector.

Successful implementation of the HPMP-Stage-II will result in reductions of 8,190 MT or 769.49 ODP tons of HCFC consumption from the starting point of 1691.25 ODP tons in 2023, contributing to India's compliance well in advance with the control targets for Annex-C, Group-I substances (HCFCs) under the Montreal Protocol (Figure 1.3).

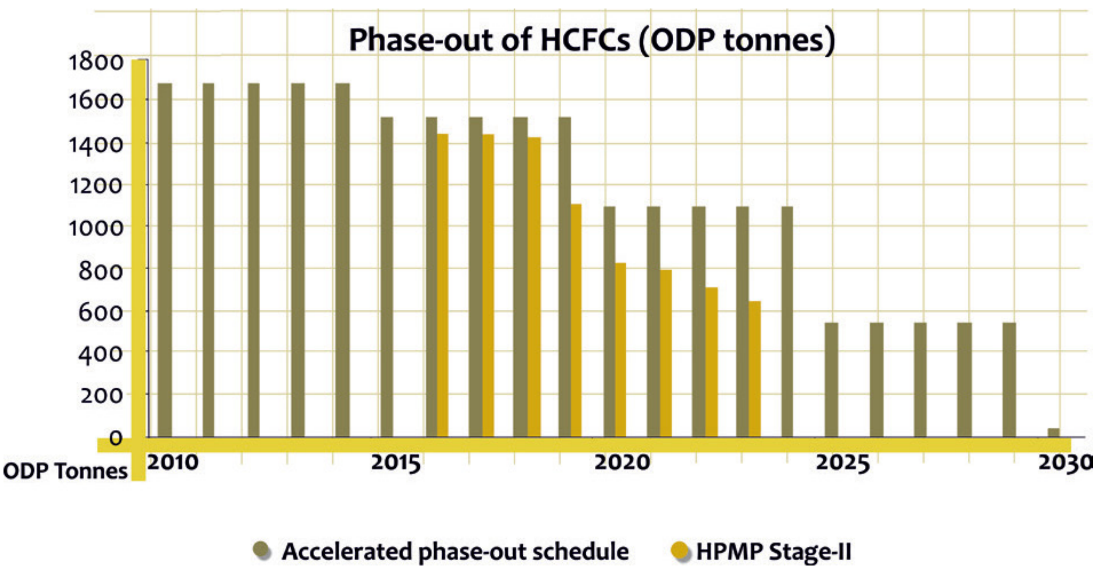


Figure 1.3: Phase-out under HPMP Stage - II

KIGALI AMENDMENT TO THE MONTREAL PROTOCOL FOR PHASE-DOWN OF HFCS

The Kigali Amendment to the Montreal Protocol has brought in HFCs as a controlled substance under the Protocol. The HFC phase-down schedule for parties operating under Article 5 of the Montreal Protocol is depicted in Figure 1.4.

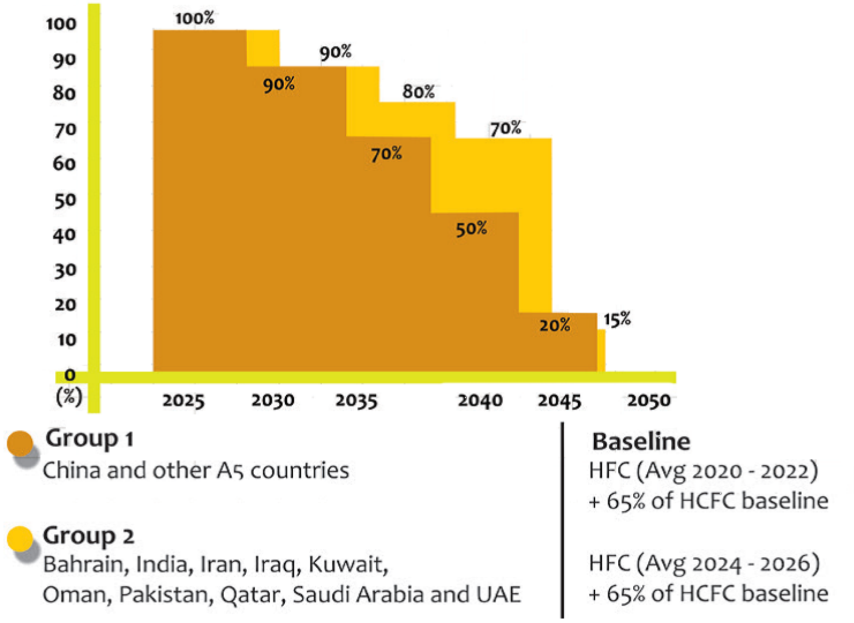


Figure 1.4: HFC Phase-down Schedule for Article 5 Parties

It has been recognized that sustainable cooling is at the intersection of three international multilateral agreements viz. Kigali Amendment to the Montreal Protocol, Paris Agreement under United Nations Framework Convention on Climate Change (UNFCCC) and Sustainable Development Goals (SDGs) of 2030. Essentially, providing thermal comfort for all is also part of the SDG 3, 9 and 10. It is an opportune time for international actions to be synergized to secure environmental and societal benefits

1.4 Development of India Cooling Action Plan (ICAP)

Against the backdrop of cooling as a growing developmental need and the international environmental agreements to which India is a signatory, the Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India, has taken an initiative to demonstrate a triple-sector approach to develop and formulate a cooling plan that will resonate with multiple stakeholders in the Government, private sector and non-profit and research organizations in India and help position India as a leader in using sustainable and smart cooling strategies linking Montreal Protocol to both phase-down of HFCs and support Sustainable Development Goals.

To this end the MoEF&CC decided to develop the India Cooling Action Plan (ICAP) in July 2016 that would provide a 20-year (2017-18 to 2037-38) outlook on how cooling demand in India will evolve and grow. Strategies and actions would be needed in the form of building and habitat design, innovation in the technology (e.g. development and launch of air conditioning and refrigerating appliances utilizing low-GWP refrigerants without compromising on energy efficiency, and low-energy cooling technologies and constitution of a collaborative research and development (R&D) platform to develop a robust eco-system to promote sustainable and smart cooling strategies while implementing the Kigali Amendment to the Montreal Protocol for Phase-Down of HFCs. The Ministry followed a multi-stakeholder development framework as shown in Figure 1.5.

Figure 1.5: ICAP Multi-stakeholder Development Framework

For the development of ICAP six different Thematic Areas were identified after stakeholder consultations. Separate working groups were constituted for each of the identified thematic areas which had representation from the government, industry associations, think tanks, and research entities. 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 Working Groups were tasked to prepare relevant documentation for the identified thematic areas under the India Cooling Action Plan. A separate Steering Committee was constituted with representatives of various stakeholders including Ministries/organizations for *inter alia* reviewing the documentation emerging out of the Thematic Working Groups. At the Apex Level an inter-ministerial committee was constituted under the chairmanship of Secretary, MoEF&CC, comprising subject experts, eminent representatives of think-tanks and industry representatives to develop the India Cooling Action Plan.

The most critical input for the development of the India Cooling Action Plan is data with respect to cooling requirement across sectors. The Thematic Working Groups used the best available information/data on the subject for estimating the cooling requirement, the associated refrigerant demand and energy consumption. While doing so, the Working Groups have used *inter alia* Government publications, where available, industry estimates, surveys and research publications. The sources of information have been referred to specifically wherever they have been used.

The following two Government databases have been used:

- Bureau of Energy Efficiency database for production volumes and energy efficiency levels for room air conditioners, ceiling fans and domestic refrigerators
- India Energy Security Scenarios (IESS) is NITI Aayog's energy model which is available in the public domain for GDP, population, per-capital income, urbanization, and % penetration of cooling appliances. The assumptions used in the ICAP analysis draw from this government model, except where new information is available that warrants updating the IESS numbers since the model was prepared three years ago

The Working Groups have used the following two scenarios while projecting the cooling requirement in future:

- Reference Scenario which assumes that the current policies and level of effort will move forward per established revision cycles (or historical trends, as applicable)
- Intervention Scenario which factors in the positive impacts of new interventions driven by policy drivers, technology and market-drivers as identified in this ICAP

For better clarity, the terms cooling capacity/requirement, refrigerant use and energy use/consumption have been explained below:

(1) Cooling capacity: The cooling growth is expressed in terms of installed TR for space cooling (refrigerant-based air-conditioning), cold chain and refrigeration and transport air-conditioning sectors. Where applicable, the cooling growth is also expressed in terms of million units of stock (such as for room air conditioners). Installed TR is defined as the cooling TR capacity in the market at any given point, after factoring in existing equipment, new equipment sales and retirement of old equipment. For the transport air-conditioning sector, the growth is also expressed in terms of the growth of stock for road-transport and the growth in passenger kilometres travelled for railway. The transport cooling growth is a seen as a derivative of the two.

(2) Refrigerant use: The refrigerant utilised towards cooling (including servicing) has been shown for each of the cooling sectors (in metric tonnes).

(3) Energy consumption: The cooling energy consumption for space cooling, cold-chain and refrigeration sectors is expressed in terms of units (TWh) of final energy, that is, the total energy consumed by the end users, excluding T&D and production losses. The cooling energy consumption for transport air-conditioning has been expressed in terms of oil equivalents utilised towards cooling.

For an overarching and relative view of nationwide cooling needs across all sectors, the cooling energy consumption for all sectors is presented in terms of units of primary energy (tonnes of oil equivalent), in the Executive Summary, and it includes consumption by the energy sector, all types of losses and, all final energy consumed.

The data with respect to cooling requirement generated by the various thematic working groups provide a trend rather than definitive estimates. This is because data used from various sources may have many underlying assumptions. In view of the limited availability of data on cooling and related aspects, which has also been acknowledged by various international publications on cooling, the numbers generated by the Working Groups are best estimates arrived at in the limited time available for setting out a plan of action.

ICAP delineates future cooling scenarios; therefore, it cannot be a static document and should respond to the evolving knowledge and technology landscape, and social and economic development in the country. To that extent ICAP is open-ended. It can identify unknowns, develop empirical evidences as it proceeds in implementation, and evolve accordingly.

1.5 Unique Features of ICAP

- A synergistic approach to holistically address cooling requirement
- Multiple stakeholder involvement across sectors (Figure 1.5)
  - Synergize energy efficiency and the transition to low GWP refrigerants
  - Takes a holistic view of policy interventions and their interdependencies
  - A balanced perspective recognising that India's cooling growth is in alignment with its developmental needs
- Identifies the scale and impact of the growth of cooling
- Collects and collates best available nationwide data and inputs from domain experts on various thematic areas of cooling.

1.6 Organization of the ICAP document

The ICAP has covered various sectors where cooling is required in separate chapters; each chapter provides (i) snapshot of the present cooling requirement, (ii) technologies available to cater to cooling requirement including both refrigerant-based technologies and alternative technologies, where available, (iii) project the future cooling requirement, the associated refrigerant demand and energy use under two alternative scenarios – reference scenario and intervention scenario as explained above, (iv) assumptions for the projections and source of data used for the projections are mentioned at appropriate places and (v) suggested interventions.

The chapter on production sector of refrigerants, RAC servicing sector and R&D have specifically dealt with the issues for bringing out the actions which would be required in the 20-year time horizon in line with the cooling requirement projections and the suggested intervention scenario. The way forward and recommendations chapter provides the linkages and synergies of actions suggested under the ICAP with various ongoing Government programmes and also summarizes the socio-economic benefits over and above the environmental benefits which shall accrue from the actions.

1.7 Broad Objectives of ICAP

- Assessment of cooling requirements across sectors in next 20 years and the associated refrigerant demand and energy use
- Map the technologies available to cater the cooling requirement including passive interventions, refrigerant-based technologies, and alternative technologies such as not-in-kind technologies
- Suggest interventions in each sector to provide for sustainable cooling and thermal comfort for all
- Focus on skilling of RAC service technicians
- Develop an R&D innovation ecosystem for indigenous development of alternative technologies

2

Space Cooling in Buildings

2.1 Introduction

Space cooling is an important component of the total cooling requirement in the country. Indoor thermal comfort, an essential for physiological and psychological well-being, can be typically provided by active heating or cooling or a combination of both – this is contingent mainly on the local weather and the seasonal variations therein. The weather conditions vary across the country. The climate map of the country shown in Figure 2.1 shows the climatic zones. It clearly depicts that, barring the few states on the foothills of the Himalayas, the need for heating in the country is quite limited, both in terms of region and in terms of the duration. Hence, in the country thermal comfort can be predominantly linked to cooling in buildings.

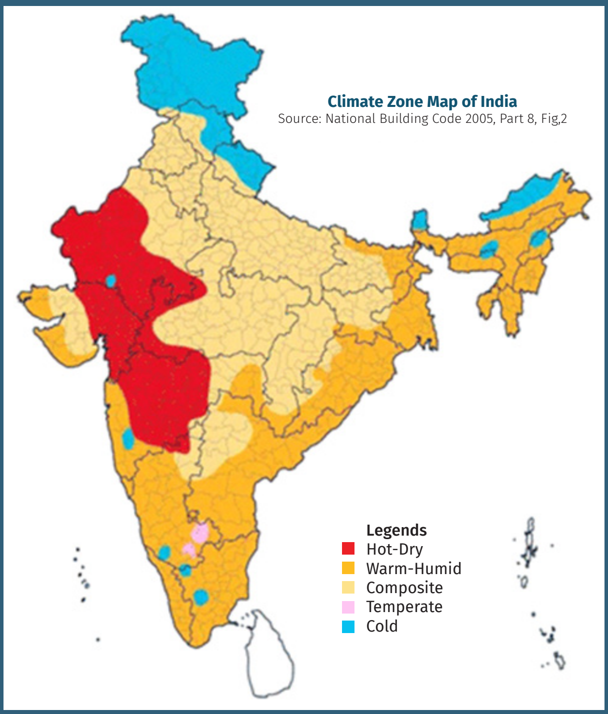


Figure 2.1: Climate Zone Map of India

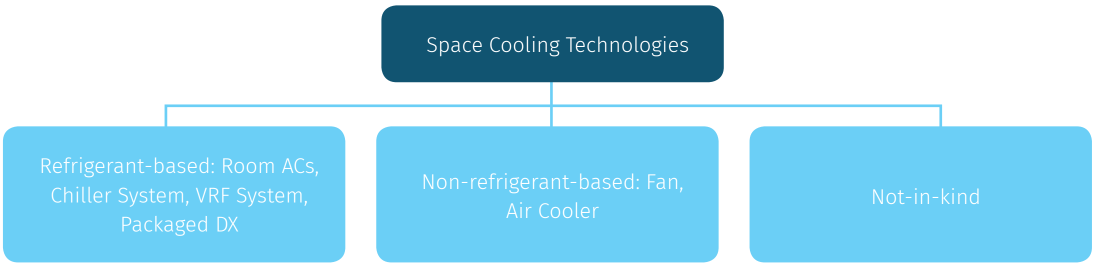
Table 2.1: Temperature and RH Characteristics of India's Climate Types[1]

Climate type	Summer time temperature	Winter time temperature	RH
Hot and dry	20°C - 45°C	0°C - 25°C	55%
Warm and humid	25°C - 35°C	20°C - 30°C.	70% - 90%
Composite	27°C - 43°C	4°C - 25°C	20%-25% (Dry) 55%-95% (Wet)
Temperate	17°C - 34°C	16°C - 33°C	<75%
Cold	17°C - 30°C	–3°C - –8°C	70%-80%

There are multiple technologies and range of options available for achieving cooling in buildings. To adequately cover the various facets influencing space cooling in buildings, this discussion is presented in two chapters: Chapter 2 focuses on the ***Technology Landscape***, discussing the prevalent and evolving technology options for space cooling; Chapter 3 focuses on ***Cooling Demand Projections***, discussing India's existing and upcoming building stock and the resulting top-down estimation of air-conditioning demand, and secondly presenting details of a bottom-up analysis of the stock and growth of cooling technologies, related energy consumption and refrigerant use, under different growth scenarios.

2.2 Space Cooling Technologies

The space cooling technologies for providing thermal cooling in buildings fall within three broad categories: refrigerant based, and non-refrigerant based, not-in-kind technologies.



Among the refrigerant-based systems, room air conditioner finds predominant application in residential sector. Air conditioning systems utilised in the commercial buildings, excluding room air conditioner, can be classified into three major types – chiller system, packaged direct expansion (DX), and variable refrigerant flow (VRF) system. The non-refrigerant based cooling technologies like fans, coolers are significantly pervasive in the residential sector, as well as in the small to medium commercial, and commercial applications such as warehouses.

2.2.1. Overview of Refrigerant-based Cooling Technologies

Room Air Conditioner: This refers to the non-ducted unitary systems, including mini- or single split (fixed-speed and inverter types) and window/through-the-wall (fixed speed type) configurations. Currently, the fixed speed systems are developed to meet up to BEE 3-Star standards, and the inverter systems are available in BEE 3, 4 and 5-star categories.

Room air conditioner is a key appliance that is central to cooling in the country in future. Currently there is a low penetration of room air conditioner in the residential sector (7-9%) but is poised that it would increase significantly in the next decade or so, owing to rapid urbanization and electrification, construction boom, a growing middle class, decreasing room air conditioner prices (in inflation-adjusted terms), and rising temperatures and extreme heat events. With the majority of room air conditioner stock in the country is yet to be purchased, now is the critical window of opportunity to put in place proactive interventions that will have a meaningful impact on the future space cooling energy consumption.

Chiller System: Chiller systems (central chilled-water air conditioning systems) are the preferred choice for large commercial buildings like hotels, hospitals, malls, office complexes and airports. Other than the chiller itself, which is the largest energy-guzzling component, the system comprises various auxiliaries including chilled water pumps, condenser water pumps, cooling tower fans, air handling units, and fan coil units.

According to inputs received from manufacturers and RAMA, chillers are either air-cooled or water-cooled, and are sub-categorized into scroll chillers from 10 to 150 TR, Screw chillers from 50 to 500 TR and centrifugal chillers from 300 to 2500 TR. The share of these categories is approximately 10%, 55% and 35% respectively. Water-cooled chillers constitute 40% of Scroll, 60% of Screw, and 100% of the centrifugal chillers.

The screw and centrifugal type chillers in the market have adopted known technologies to enhance the energy efficiency, such as high efficiency heat exchangers using enhanced tubes, flooded evaporators, and oil-free centrifugal compressors using fixed and variable speed. The scroll chiller market is fragmented with many small-scale manufacturers and continues to deploy fixed-speed technology.

Variable Refrigerant Flow (VRF) System: VRF systems are typically used in medium-size commercial buildings and high-income group residential units that have varying exposure and cooling loads. Despite its higher initial costs as compared to other comparable systems, VRF systems have been gaining popularity and strong market share, due to various advantages such as energy efficiency, quick installation, ease of operation and the flexibility of choosing from a range of indoor units. According to inputs received from the manufacturers of VRF equipment and RAMA, VRF systems are available from 2.5 to 20 TR as standalone module, and from 6 to 100 TR in multi module outdoor units, coupled together. The outdoor units are connected to multiple types and numbers of indoor units, such as wall mount, cassette, ducted and DX AHUs. The energy saving is achieved through diversity, and variable capacity, to meet the indoor heat load. VRF Systems are available with highly advanced controllers, with communication capability that offers the end-user flexibility in operations.

Packaged DX: Packages DX covers ducted and packaged systems including rooftop and indoor packaged units in commercial air conditioning segment. Also known as unitary and light commercial systems, these typically cater to small-to-medium commercial buildings to avoid the complexities associated with chiller systems. According to inputs received from RAMA and the manufacturers, these systems start from 3 TR and are available up to 24 TR, using a single compressor for up to 10 TR capacity, and multiple compressors thereafter. With low growth, technology adoption is slow in this category with some signs of introduction of inverter technology.

2.2.1.1 ADVANCEMENTS IN VAPOUR COMPRESSION TECHNOLOGY

While conventional vapour compression technologies are energy intensive, they are still expected to remain as an important space cooling technology in near future due to their relatively compact size, high reliability, scalability, etc. However, R&D in this technology should predominantly focus on 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.

Table 2.2 delineates various efficient air-conditioning component technologies as identified by US DoE (2016) .[2]

Table 2.2: Component Efficiency Improvement

AC component	Efficiency Improvements
Multi-Stage and Variable-Speed Drives/Controls	Motor controls have enabled substantial energy efficiency improvements on compressor and fan motors through variable-speed operation. By modulating motor speed on compressors, the A/C system can more closely match the part-load cooling demand and improve seasonal efficiency by reduce cycling losses that are common during the majority of the cooling season when the system's full capacity is not required. Similarly, variable-speed controls operate fans motors at their most efficient setting to meet the airflow needs of the system.
Advanced Compressors	A/C compressor efficiency and performance has steadily improved as manufacturers incrementally improved current designs (e.g., high efficiency reciprocating) and introduced entirely new compressor technologies (e.g., scroll, rotary). In addition, larger systems use multiple compressors to stage capacity and improve part-load performance. Magnetic and oil-free compressor technologies can deliver significant energy savings in the near future if they become affordable and can be deployed at scale.
Improved Heat Exchangers	Metal tube-and-fin heat exchangers are the most common in A/C systems for transferring heat between the refrigerant and air. Manufacturers have increased the size of heat exchangers to improve system efficiency, especially during part-load operation. Advanced heat exchanger designs, such as microchannel heat exchangers and other small diameter designs, have further improved system efficiency, while also reducing refrigerant charge, fan energy consumption, and physical size.
Electronic Expansion Valves	Expansion valves control the amount of refrigerant flowing through the evaporator to maintain proper system conditions. Thermostatic expansion valves (TXV) improve upon earlier static capillary tube and fixed orifice expansion devices by modulating refrigerant flow based on refrigerant superheat temperature at the evaporator exit. Newer electronic expansion valves (EEV) provide increased modulation capabilities to match more closely the needs of variable-capacity A/C systems.
High Efficiency Fans	Fan energy consumption has decreased over time as many systems have incorporated more aerodynamic component designs (e.g., fan blades, condensing unit housing), high efficiency motors, and variable-speed controls. Manufacturers have applied these innovations to axial and centrifugal fans for both heat exchange as well as distribution of conditioned air throughout buildings.
High Efficiency Motors	Electric motors are core components for A/C compressors and fans, and improved motor designs have a significant impact on overall A/C system efficiency. Electrically commutated motors (ECM) have higher efficiencies than permanent split capacitor (PSC) motors for A/C fans and operate at a wider range of conditions using electronic controls.
Advanced Controls	Beyond simple thermostatic set-point controls, A/C systems have incorporated advanced control schemes and hardware to improve system efficiency. Different occupancy sensing strategies can automatically alter thermostat set-points when building occupants are away to reduce energy consumption. Economizer controls enable A/C systems to use cooling energy from ventilation air or chilled-water cooling

2.2.2. Overview of Non-refrigerant-based Cooling Technologies

Fan: This appliance category covers ceiling, pedestal, table and wall-mounted fans. Fans are widely used in Indian homes, both rural and urban, across all income categories. The urban homes are typically fitted with ceiling fans almost as a default. Per a recent survey, even among homes that utilize room air conditioner for thermal comfort, approximately 70% tend to use fans simultaneously.[3] Fans are also widely utilized in small to mid-commercial segment. Due to their sheer volume, the total annual energy consumption of fans is currently only slightly lower than the total annual energy consumption of room air conditioner in India.

Despite a rise in the penetration of room air conditioner in households, a significant portion of the population will still not be able to afford air conditioning in the next two decades and will continue to rely on natural ventilation and fan-assisted ventilation for thermal comfort. Hence, fan should be a key appliance to focus on from an energy efficiency lens.

Air coolers: Air coolers are an important cooling appliance for users, especially across category of households and medium size commercial buildings in hot and dry and composite climates. Based on inputs received from air cooler manufacturers, air coolers of 500-1000 CFM are most widely used in residential and small commercial applications.

The cooling effectiveness of air coolers is constrained by the humidity content of the ambient air; as such the performance of air coolers will vary significantly between climate zones (hot and dry, and composite versus warm and humid) and seasons (low, medium and high relative humidity). Air coolers need adequate ventilation to function well in humid conditions.

A common argument around air-coolers is that these are water-intensive, and this can pose a limitation in water-stressed regions of India. In response, the industry has come up with technology that utilizes one-thirds of the water consumption compared to air-coolers of the past.

Market forces will need to influence consumer choice towards well-engineered and better-quality air coolers manufactured by the organised sector, rather than indigenously manufactured ones. However, price-sensitivity will continue to play a key role at least in the foreseeable future, the cost-benefit equation will remain the key driver for the consumers while purchasing air coolers. Government policy, like developing voluntary MEPS and incentivise this segment can help in the transformation of the air cooler industry towards an organized market of energy- and water-efficient air coolers.

2.2.2.1 ADVANCEMENTS IN NON-REFRIGERANT-BASED COOLING TECHNOLOGIES

BLDC ceiling fans: Typically, ceiling fans contains single phase induction motors, consume 70-80 W and deliver air at 230-250 m^3/minute. Better blade design and the use of copper (over aluminium) have increased fan efficiency to 45-50 W in BEE rated 5-star fans. A new category of fans uses brushless DC (BLDC) motors; this combined with better blade design have led to more efficient fans which consume 30-35 W and deliver air at 220-230 m^3/minute.

Cooling pads in air coolers: The patterns used on cooling pads have a significant bearing on the water absorption and evaporation process. Aspen (wood wool) pads are 75% efficient and honeycomb are roughly 85% efficient. The cooling pad area is also important – steel body coolers have a larger cooling pad area compared to fibre body ones and are more efficient.

2.2.3. Overview of Not-in-Kind Technologies

The potential of low energy cooling technologies as identified by ECBC, and their feasibility in terms of energy savings and climate applicability are presented in the table below. These technologies offer advantages of reduced cost or complexity, increased reliability, peak demand reduction, energy savings and GHG reduction. These technologies have been applied at sizeable scales in commercial buildings in India and are known to provide other non-energy benefits, which include improved indoor air quality, noise reduction and integration with Internet of Things (IoT) (for better control and monitoring). Table 2.3 summarises the benefits of these technologies, as indicated by manufacturer inputs.

Indirect Direct Evaporative Cooling System: Indirect-direct evaporative coolers (IDEC) offer the advantages of both direct evaporative coolers and indirect evaporative coolers and cool the process air without adding humidity to the supply air stream. Whilst these can be employed in all climatic zones, humid climates should be supplemented with additional air draft to realize thermal comfort. As per data received from four manufacturers of IDEC systems from 2008 till March 2015 and projections until March 2017, an aggregate capacity of approximately 43 million cubic feet per minute (air flow) has been installed in India. This equates to replacement of approximately 0.1 million TR or conventional air conditioning in more than 800 buildings.

Structure Cooling System: As per data shared by manufacturers from 2005 till March 2014 and projections up to March 2017, an aggregate of approximately 0.6 million sq. ft. built-up area in India uses structure cooling technology, replacing approximately 4,600 TR or conventional air conditioning in 28 large commercial buildings.

Radiant Cooling System: As per data received by four manufacturers of Radiant Cooling systems from 2008 till March 2016 and projections till March 2017, an aggregate of approximately 4 million sq. ft. built-up area in India is cooled using radiant cooling, replacing approximately 18,000 TR of conventional air conditioning in 73 large commercial buildings.

Solar VAM System: As per data received by manufacturers from 2007 till March 2015 and projections till March 2017, an aggregate of 0.7 million TR of Solar VAM air conditioning (replacing an equivalent amount of conventional air conditioning) is installed in India.

Table 2.3: Assessment of Not-in-kind Cooling Technologies

Technology	Energy savings (high/moderate/low)	Narrow comfort band (temperature & RH control)	Year-round application	Climate suitability	IAQ	Durability	Maintenance & component availability	Capital cost	Operational cost	Noise reduction	Compatible with IoT
Radiant Cooling	high	high temperature control, low RH control			✓	high	✓	moderate	moderate	✓	✓
Indirect-direct Evaporative Cooling (IDEC)	high	moderate temperature control, moderate RH control	✓		✓	moderate	✓	low	low		✓
Solar VAM	high	moderate temperature control, low RH control				moderate	✓	moderate		✓	✓
Structure Cooling	moderate	moderate temperature control, low RH control	✓			high	✓	low		✓	

The not-in-kind options can be integrated with the conventional vapour compression systems (to form 'hybrid systems') in order to achieve benefits of both the technologies. For example, liquid desiccant air conditioning systems decouple the sensible and latent loads and allow independent control of temperature and humidity. The desiccant systems provide the necessary dehumidification whilst the sensible load is met by a conventional system that adopts high temperature cooling.

Heat/energy recovery technologies such as energy recovery ventilators (residential) or heat pipes, run around coils, or enthalpy wheels (commercial), when included in a cooling system, can help recover energy that would otherwise be wasted.

Future Advancements: Some other future advancements in cooling presently at lab-scale are listed below. It is too premature to comment on their market viability at scale.

- Magneto-thermic cooling
- Thermo-electric cooling
- Ejector jet cooling
- Heat pipe-based DX systems
- Seasonal thermal storage
- Wearable cooling systems
- Automatic fault detection and diagnostics
- Energy insurance of HVAC systems
- Self-healing/repairing systems
- Appliances enabled for adaptive thermal comfort using IoT

2.2.4. Alternate Cooling Strategies

Further to the not-in-kind technologies described earlier, presented below are some alternate cooling strategies at different stages of market development.

Thermal energy storage: Thermal energy storage can significantly reduce energy costs by allowing cooling equipment to be predominantly operated during off-peak hours. In addition, some system configurations result in lower first costs and lower operating costs compared to non-storage systems.

Personalised cooling/conditioning systems: These systems create a microclimatic zone around the user, so that energy is deployed only where it is needed. This technology can offer up to 15% energy savings[4] over the conventional systems. However, the installation is complex and increases the cost and the complexity of the distribution system.

Trigeneration: Trigeneration or combined cooling, heating and power (CCHP) offers an optimal solution for generating air conditioning and/or refrigeration. The trigeneration systems are suitable for industrial and commercial applications where there is a continuous demand for electricity and heating or cooling at the same time. They have multiple advantages such as onsite generation of electricity, heat and power, maximum total fuel efficiency, reduced fuel and energy costs, lower electrical demand during peak time, elimination of HCFC/CFC refrigerants and emission reduction. However, its use is limited to specific applications where there is a simultaneous demand for heat and power and uninterrupted availability of fuel.

District cooling (DC): DC systems typically require about 15% less capacity than conventional distributed cooling systems for the same cooling loads due to load diversity and flexibility in capacity design and installation. The key challenges are high initial investment, lack of technical expertise for design, little policy level support, and absence of favourable financial and business mechanisms.

Through active intervention, use of district energy models and better building design, IEA forecasts an efficient cooling scenario which could reduce peak energy demand and GHG emissions by as much as 55% compared to the baseline scenario. District cooling systems enable higher flexibility to incorporate multiple energy vectors (solar cooling, tri-generation, and waste cold) to meet cooling requirements and provide ability to exploit thermal storage options or to adopt a system level management of cooling consumption. However, it is important to stress on the business models, correct application of the technology and the legal/contracting framework that need to be put in place because of the high investment requirement which would need guarantees similar to utility contracts and Power Purchase Agreements that will give the investors the confidence to invest in such large infrastructure projects.

3

Space Cooling In Buildings: Demand Projections

Growth in space cooling demand has been rising steadily over the last decade due to a combination of factors, such as rising population living largely in tropical climate, with growing aspirational needs fuelled by sustained economic growth over the last two decades. Recognising the growth in space cooling, Bureau of Energy Efficiency (BEE) developed the Energy Conservation Building Code (ECBC) in 2007 to encourage minimum energy performance in commercial buildings and instituted the Standards and Labelling programme (S&L) in 2006 to set minimum energy performance standards (MEPS) for room air conditioners, along with other consumer appliances.

3.1 Building Stock Estimation

Buildings represent a dominant share of India's overall cooling needs. India is also seeing one of the fastest construction growths worldwide. In view of the rapid increase in building stock and the associated air-conditioned area, it becomes increasingly important to reinforce the need to build in strategies and interventions to reduce the need for active cooling of buildings. By incorporating energy efficient design and construction strategies. Buildings can have inherently reduced energy consumption footprints over its operating lifetime. Existing examples of high-performance buildings in the country show that on an average, the annual energy consumption of conventional conditioned buildings could be reduced substantially.[5]

The current penetration of room air conditioners in country is low indicating the households' reliance on fans, air-coolers or passive cooling from ventilation and window shading for thermal comfort. A significant percentage of households might not be able to afford air conditioning for thermal comfort even in the next 10-20 years.[6] A thermally comfortable building design is not only important to achieve reduced cooling requirement, but also from a climate resilience perspective. Urban areas are most vulnerable to climate change impacts such as increased temperature and urban heat island effects due to their lack of access to passive cooling, thermally comfortable housing and common cooling services. Building climate-resilient housing and providing affordable and efficient cooling appliances, especially fans and air coolers, will reduce these vulnerabilities.[7]

Under national missions like Housing for All, Smart Cities and Solar Cities, country is witnessing significant increases in commercial and residential building stocks and with expected lock-in period of several decades. It is imperative to design and construct for thermal comfort using affordable and sustainable building design principles. National Mission on Sustainable Habitat (NMSH), National Mission on Enhanced Energy Efficiency (NMEEE) now renamed ROSHANEE, Energy Conservation Building Code (ECBC – both for commercial and residential) focus on building design and construction practices but require widespread and rigorous implementation to fully realise their potential.

This section maps commercial and residential building sectors' current stock[8] and its growth trajectory over the next 20 years, to comprehend the upcoming cooling demand from these sectors. The cooling demand numbers have been presented here to provide trends and are based upon industry information, surveys and research conducted by various organizations earlier except where specifically stated. It also presents a view of how this cooling demand might change with urbanisation, rising income and an increasing shift towards energy efficient building design and construction practices and technological interventions that will lead to more efficient appliances and air conditioning equipment required to provide thermal comfort.

3.1.1. Residential Building Sector

In 2017, approximately 272 million households were estimated in India which will increase to 328 and 386 million in 2027 and 2037 respectively.[9] Census 2011[10] of the country breaks down the number of households in the following segments: non-exclusive room, one room, two rooms, three rooms, four rooms and five rooms and above. Approximately 60%-70% of all the households fall in one room and two room categories. National Building Code (2016)[11] and various housing policies/ missions/ reports[12,13,14] provide a range of floor area for each category of households. Built in floor area for each household segment is estimated based on the aforementioned data and extensive discussions with experts and in the working group. The available data was extrapolated to arrive at the current and future built-up stock within each category of households. One room, two rooms, three rooms and more than 3 rooms segments cover 31%, 23%, 38% and 8% respectively in 2017 and it is assumed that similar trends would be followed for next ten years. Residential floor area CAGR from IESS was also referred to align the medium and long-term floor area for the residential sector.

For the current analysis, the share of the total households for each category that have room air conditioners were estimated using short expert surveys from building design and construction industry professionals and by reviewing trends for other appliances. According to that analysis, approximately 8% of the current households have room air conditioners. This is anticipated to rise to 21% and 40% in 2027-28 and 2037-38 respectively (Figure 3.1). As per NSSO 2011, there were approximately 1.2 room air conditioners per household, in the households which already have air-conditioners.

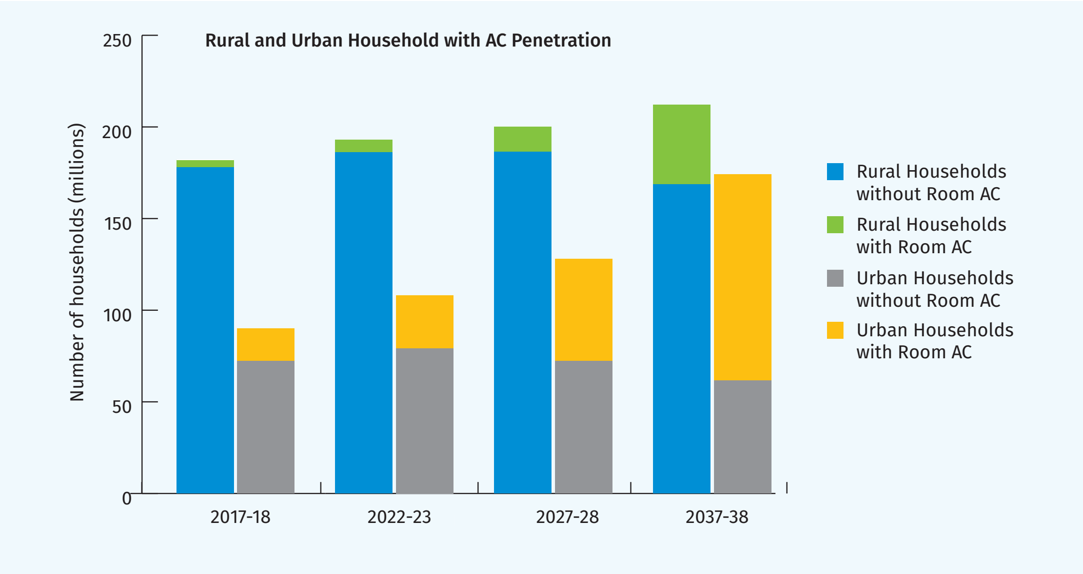


Figure 3.1: Number of Households with Room Air Conditioners

In future is expected that the new demand shall arise from purchase of first air conditioners by households not having air conditioners and also from subsequent purchase of new units by households already having air conditioners. Figure 3.2 depicts the room air conditioner stock in urban and rural households..

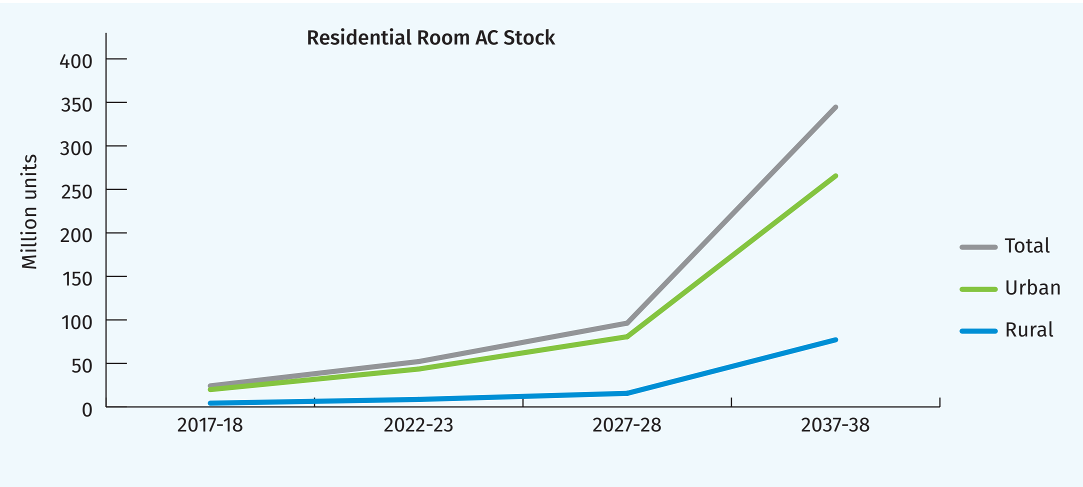


Figure 3.2: Room Air Conditioner Stock in Urban and Rural Households

Building design and construction can enhance the comfort levels considerably if built in a climate sensitive manner. National Building Code, Model Building Bye-Laws and various green building rating systems lay emphasis on building sustainably by integrating climate responsive design elements which are low cost and energy efficient. BEE's upcoming Energy Conservation Building Code – Residential (ECBC – R) Part 1 delves into designing an energy efficient envelope which helps in reducing heat transfer through envelope thus enhancing the thermal and visual comfort.[15] The following interventions can help in reducing the sharply rising cooling demand and delay the purchase of first room air conditioner in many cases:

In hot tropical climates, cooling has been recognized as an important requirement for human health, wellbeing and productivity. As per projections, significant proportion of population under LIG and EWS segment will not have access to active air-conditioning. The Government is implementing schemes for building affordable housing such as under Pradhan Mantri Awas

Yojana with the objective of providing housing for all. These schemes would benefit by use of climate appropriate and energy efficient building design for construction of houses under EWS and LIG segments. This would, inter alia, provide thermal comfort for all, reduce cooling load, and provide gains in terms of energy efficiency. In this regard, the energy efficient building envelope guidelines of ECBC-R could be enforced. In addition, funding and support, where required, for initiatives providing thermal comfort such as cool-roof programs, off-grid micro-systems for cooling, and localized heat-action plans could be provided.

- Regulatory and policy actions in the adoption of energy efficient building practices – The regulatory compliance by mainstreaming the passive building design focused on occupants' comfort can significantly reduce the cooling requirement.
- Promoting capacity building and fostering market awareness towards the need for efficient built environment and thermally comfortable habitat that would spur the demand for sustainably designed buildings from all strata of the society.

3.1.2. Commercial Building Sector

The intensity for air conditioning demand and corresponding electricity consumption intensity in the commercial building sector is significantly higher as compared to the residential sector, although the overall national electricity consumption is one third of the latter. The commercial sector has been classified under 8 major segments: hospital, hotels & restaurants, retail, office buildings, educational institutions, assembly places, transit buildings & warehouses. A bottom-up commercial building stock modelling exercise, conducted by AEEE, analysed the various commercial segments to understand the current and upcoming commercial stock[16] The current and future floor area for the commercial building sector has been estimated based on this recently published study.[17]

The projections for commercial floor area and air-conditioned area is depicted in Figure 3.3. The commercial sector floor area is expected to grow around 1.5-2 times in the next decade, and 2.5-3 times by 2037-38.

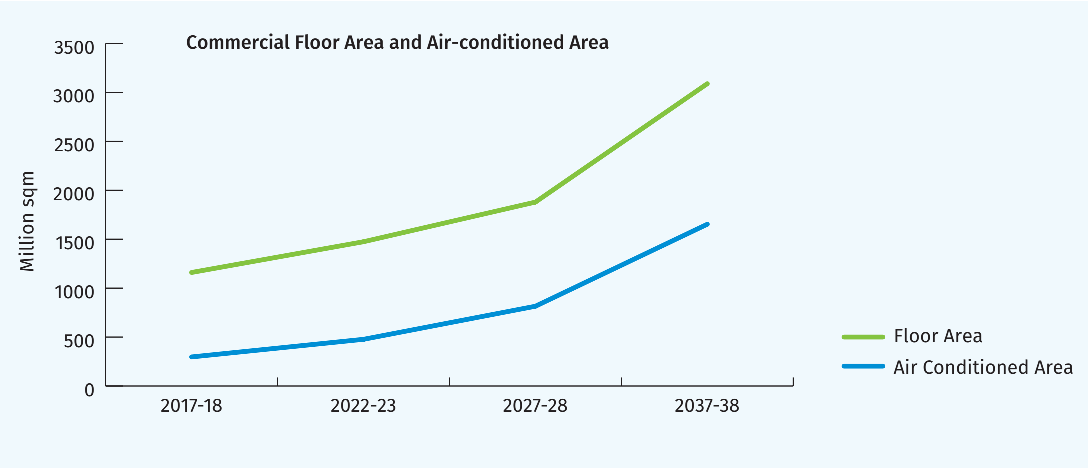


Figure 3.3: Total & Air-conditioned Area in Commercial Buildings

Based on the building stock growth, Figure 3.4 presents a top-down estimation of AC demand. It should be noted here that the operational TR arrived through this approach (Figure 3.4) shall be roughly 20% less than the total deployed air conditioner stock due to the additional stand-by capacities typically observed in large commercial facilities. The range of air conditioning systems utilised in commercial buildings includes chillers, packaged DX units, VRFs, and room air conditioners. The deployed cooling capacities of these commercial air conditioning systems have also been arrived using appliance sales and stock in Section 2.3.

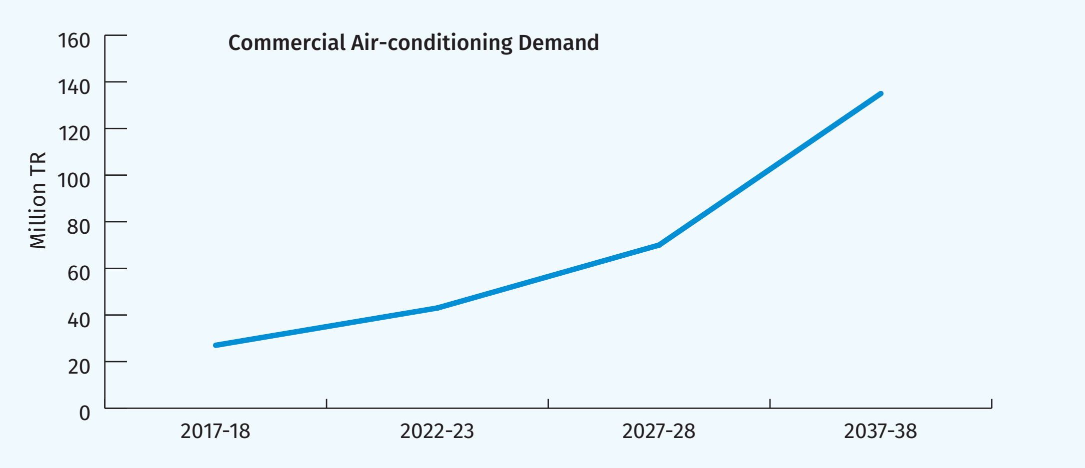


Figure 3.4: AC Demand in the Commercial Building Stock

A TR reduction potential of around 13%, which translates to around 9 million TR could be achieved by 2027-28, and around 23% which translates to around 32 million TR by 2037-38 could be realised through more rigorous implementation of ECBC in the upcoming commercial buildings in the country.

3.2 Optimising Cooling Demand through Multiple Strategies

When it comes to cooling buildings, several strategies can be applied in combination such that their positive impact, as a whole, is greater than the sum of the parts. One of the approaches for addressing space cooling requirement is a sequential approach that first reduces heat gain by passively cooling buildings, followed by installation of energy-efficient HVAC appliances/systems coupled with smart controls to efficiently meet the reduced cooling needs, and finally the deployment of green/natural refrigerants and renewable energy to meet the cooling demand.[18] The Technology and Economic Assessment Panel (TEAP) report on energy efficiency, whilst phasing-down HFCs, recommends the following measures for efficiency improvements:[19]

- Ensuring minimisation of cooling loads
- Selection of appropriate refrigerant
- Use of high efficiency components and system design
- Ensuring optimised control and operation, under all common operating conditions
- Designing features that will support servicing and maintenance

3.2.1. Role of Building Energy Efficiency

A significant volume of India's building stock is yet to be built and therefore opens a window of opportunity to optimize the future cooling requirements and thermal performance of building through energy efficient design. Efficient or 'passive' building designs can reduce the overall heat-gain in a building thereby significantly decreasing the cooling energy demand as the need for an AC system to reject this heat from the conditioned space reduces. Building codes have an important role in advancing the adoption of efficient building practices. For instance, accelerating compliance with the ECBC will assure appropriate insulation inherently reducing the cooling needs of the new buildings.

The following table highlights efficient design strategies that help reduce a building's cooling needs.

Table 3.1: Building Envelope Options to Reduce Cooling Load

Insulation	Increasing thickness and/or R-value for envelope to reduce cooling loads up to 8%[20]
Windows	Reducing heat gain by shading, installing double/ triple glazed units and/ or having low-E coating can reduce daily cooling demand by 30%[21] . Dynamic glazing technology would further reduce solar heat gains by filtering out infrared radiation while continuing to provide natural lighting.[22] Window attachments like blinds, screens and films can also be used to reduce the ingress of solar heat.
Roofing	Installing cool/ green roof will reduce solar heat gain due to increased reflection/ evapotranspiration.
Surface Orientation	Apposite building orientation and window to wall ratio can refrain direct heat gain in building indoors, thus reducing the cooling demand
Infiltration/ Exfiltration	Minimizing air exchange between conditioned space and outdoor environment while still providing adequate fresh air.

In addition to an efficient design itself, cooling loads can be further optimized through efficient operations utilizing practices such as Adaptive Thermal Comfort[1]. Per Ozone Cell, MoEF&CC, by increasing indoor design temperature from 20°C to 22°C, the saving of annual energy consumption is 12.80%, and by increasing the temperature to 24°C and 26°C, the saving has been increased to 20.10% and 28.44% respectively. Accordingly, the minimum thermostat setting could be mandatorily kept between 22°C - 26°C. Bureau of Energy Efficiency has issued guidelines to all consumers of commercial buildings are suggested to maintain the internal temperature between 24-25°C with appropriate humidity and airflow to conserve energy and for the health benefits of occupants, subject to operational and functional requirement on voluntary basis.

The future of space cooling in buildings will hugely benefit from a two-pronged approach i.e. firstly, reducing the need for active cooling in buildings using energy efficiency as a foundational building strategy, followed by meeting the reduced cooling demand using efficient cooling technologies.

3.3 Cooling Demand Projections

3.3.1. Methodology

The methodology is kept flexible in order to adapt to the unique aspects and data availability for the different technologies for space cooling. However, the underlying approach remains consistent and is essentially a synthesis exercise, drawing information from government publications and model[23,24] reliable research conducted nationally and globally[25], significant and detailed inputs from industry experts and manufacturers, and utilizing the latest data available from the government (where available), to derive our best estimate of future projections. The analysis presented in this section is a bottom-up check to complement numbers derived from the floor area-based top-down approach described in Section 2.2.

1 Adaptive thermal comfort is a theory that suggests a human connection to the outdoors and control over the immediate environment allow them to adapt to, and even prefer, a wider range of thermal conditions than is generally considered comfortable.

3.3.2. Inputs and Assumptions

Overarching growth drivers: The following growth drivers will have a significant bearing on the sales of new comfort cooling equipment, especially room air conditioners, in the following decades:

- Growth in per-capita income: Per IESS, per capita income is like to double between 2017 (INR 90,922) and 2027 (INR 178,634) (over the 2017 baseline) and then again double between 2027 and 2037 (INR 361,195) (over the 2027 baseline).
- Purchasing power of urban and rural population: There is a considerable gap in the per capita income or rural and urban population; the per capita income in 2011-12 was INR 1,01,313 and INR 40,772 respectively for urban and rural population.[26]
- Rate of Urbanisation: Per IESS, India is presently 33% urbanised and will be 39% and 45% urbanised in 2027 and 2037, respectively.

Room Air conditioners: According to the manufacturing data of star labelled appliances published by BEE[27], three important trends have been observed:

- Since 2010, manufacturing of room air conditioners has grown at a CAGR of 13%.
- There has been a sharp rise in the adoption of inverter room air conditioners since 2015 alongside a significant decline in the uptake of fixed-speed room air conditioners. Considering the trends in the uptake of fixed-speed and inverter room air conditioners observed in the past few years, it is anticipated that the share of fixed-speed room air conditioners in the future room air conditioners stock will decline rapidly.
- Growth in room air conditioner manufacturing tends to show a sharp rise every alternate year followed by almost constant or very small rise in subsequent year. Room air conditioner production peaked in 2012-13, 2014-15 and 2016-17 showing around 20-30% growth over the preceding year; the alternate years saw only 1-7% growth.

The current and future room air conditioner stock were estimated using BEE data described above along with the following underlying assumptions:

- BEE data can be used as a proxy for room air conditioner sales
- Room air conditioner life = 10 years[28]
- Room air conditioner sales will grow at a CAGR of 11% in the next 10 years and 8% in the following 10 years in a low growth scenario; and at a CAGR of 15% in the next 10 years and 12% in the following 10 years in a high growth scenario.
- A non-trivial share of room air conditioners is used in commercial spaces; it is possible that such commercial spaces and apartment complexes might transition to central air-conditioning, which might have a bearing on the room air conditioner stock – however, this has not been incorporated in this analysis.

Per a recent AEEE survey of approximately 1000 households using air conditioning, room air conditioner of 1.5 TR is the most popular consumer choice, 61% of the data-set. Previous studies by LBNL[29] and CEEW[30] also mention similar value for a typical room air conditioner. The average consumer preference for different star-rated fixed-speed and inverter room air conditioner is skewed towards 3 stars. Per inputs from room air conditioner manufacturers, responses from room air conditioner distributors and retailers, the point of deployment of room air conditioner is shifting towards the residential sector – from a share of 60-70% currently to 80-90% in 2037-38. There will be variations in room air conditioner usage depending on the climate and type of use.

BEE revises the efficiency level of room air conditioner every 3 years. If these revisions in room air conditioner efficiency level is annualised, a steady growth of 3% p.a. in room air conditioner efficiency levels (previously EER, now ISEER) can be observed.

Chiller System: The existing stock information has been arrived at by gathering two key pieces of information - chiller sales data and the estimate of the historical installed base. Chiller sales data, sourced from various market intelligence reports (BSRIA Chiller Report[31], 6Wresearch[32]) across different types of technologies has been aggregated from 2011 onwards. The estimation of installed base of chillers in commercial buildings in 2010 was made based upon consultations with industry experts and published research reports[33]. The data on estimated market size of different types of chillers in India in 2017-18 was also gathered from RAMA. As per BSRIA, commercial buildings consume approximately 80% of all chillers sold in India and the remaining 20% goes into industrial air conditioning applications. It is also observed that roughly one-sixth of the total annual chiller sales goes into replacing existing chillers.

Per RAMA's estimate, the future growth in the chiller industry is driven by growth in the retail, hospitality and infrastructure projects and is projected to grow at a CAGR of 9-10% for centrifugal, 3-5% for scroll and 6-8% for screw chillers in the next 10 years. Scroll chiller market is expected to decline and gradually replaced by screw type chillers owing to its better efficiency in the near future.

The operating hours were estimated based upon 70:30 mix of daytime versus 24-hour operating buildings which in turn was sourced from BSRIA and inputs from experts in HVAC O&M. It has also been assumed that 20% of the total deployed capacity in commercial building segment is in stand-by and at any given point of time, a maximum of 80% capacity is working.

Minimum ECBC[34] compliance requirements of IPLV (Integrated Part Load Value) have been considered for the 2017 efficiency levels of chillers. For estimating improvements in efficiency of chillers ECBC+ and SuperECBC requirements have been considered by 2027. The minimum energy performance improvement trends of ASHRAE Standard 90.1[35] from 2004 onwards (2004, 2007, 2010, 2013, 2016) were also studied. It is observed from the past trends that the minimum efficiency requirements of chillers as specified by ASHRAE 90.1, if improved at the same rate, would be at par with ECBC+ requirements by 2027. The efficiency levels of all central plant auxiliaries, including pumps and fans, derived from extensive consultations with industry professionals and domain experts were aggregated with that of the chiller to arrive at the overall chiller plant efficiency.

Variable Refrigerant Flow (VRF) System: The sales and stock numbers were gleaned using data obtained from CEEW and BSRIA report[36], interactions with industry experts and manufacturers. According to RAMA, the market size of VRF systems in 2017-18 is estimated to be around 0.44 million TR. HVAC industry experts suggest that the VRF market will grow at a CAGR of at least 15% in the next decade.

The rated efficiency of VRF systems ranges from 0.8 to 1.1 kW/TR depending upon equipment size. Per ECBC (2017), the minimum efficiency requirement for VRF systems (< 40 kW) is 0.81 kW/TR. The reduction in energy consumption is recommended primarily through energy efficiency improvements in the future. Savings of 3-5% in energy consumption is possible by improving the efficiency of the system by 10% in the next decade. Further, with the possible development of MEPS for VRF and the higher uptake of ECBC+ and SuperECBC in buildings, energy savings will be much higher.

Packaged DX: The stock and sales data for packaged DX systems were gathered from CEEW (2015) and BSRIA (2016) reports and stakeholder interactions. According to RAMA, the market size of packaged DX systems in 2017-18 is around 0.6 million TR and will grow at a CAGR of 5% in the next decade. Also, growth of indoor packaged and rooftop unit is decreasing, as VRF systems are becoming more popular. There is minimal growth in ducted and small packaged DX, rooftop DX market is very small.

Per ECBC (2017), the minimum efficiency requirement for an air-cooled packaged DX system (< 10.5 kW) is 1.25 kW/TR for ECBC-compliance and 1.03 kW/TR for SuperECBC compliance.

Fan: The fan stock numbers were estimated using household information, fan penetration, number of fans per household and their residential and commercial application. These data points were extrapolated and adapted from Census (2011), NSSO (2012), Prayas Energy Group (2010)[37] and IESS 2047. It is anticipated that the use of fans will shift more towards the residential sector, as more and more commercial spaces get air conditioned or air-cooled.

According to BEE published data, production of BEE star-rated ceiling fans has been steadily increasing at approximately 30%. With the growing uptake of star-rated fans, the overall energy efficiency of the surviving stock in use will continue to improve. While super energy efficient BLDC fans holds a lot of promise to significantly reduce energy consumed by fans, it is acknowledged that the current fan stock will only have a very small penetration of these fans.

Air Cooler: According to inputs received from air cooler manufacturers, air coolers of 500-1000 CFM are most widely used in residential and similar applications; they typically consume 200-300 W. Their stock number was estimated using household penetration of air coolers, and other available data points from industry sources i.e. air cooler sales, the split between the organised and unorganised air cooler sectors (currently 30% vs 70%, respectively) and typical equipment lifetime[38].

3.3.3. Stock & Growth of Space Cooling Technologies

Presented in Figures 3.5-3.10 are current stock and growth of prevailing refrigerant and non-refrigerant-based space cooling technologies. These graphs and charts have been constructed using mid-point estimates of identified ranges which are available in the Appendix A. Refrigerant-based equipment stock is likely to increase by around 10 times in the next 20 years; and room air conditioners will continue to dominate at 80-90% share.

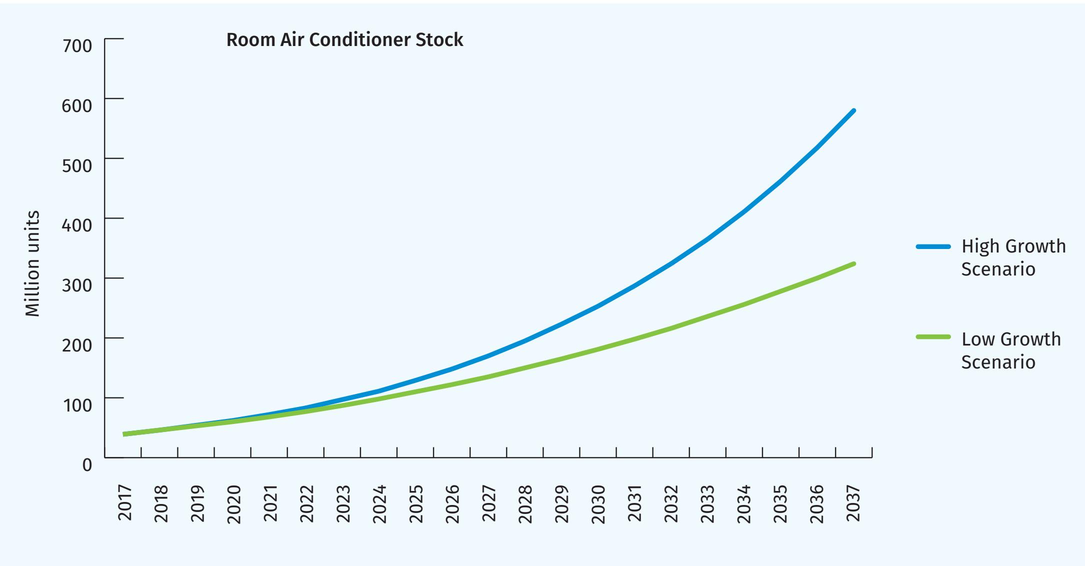


Figure 3.5: Room Air Conditioner Stock Projections under Low and High Growth Scenarios

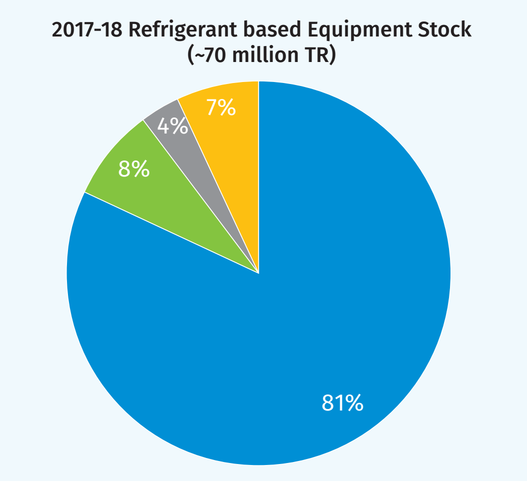


Figure 3.6: 2017-18 Refrigerant-based Equipment Stock

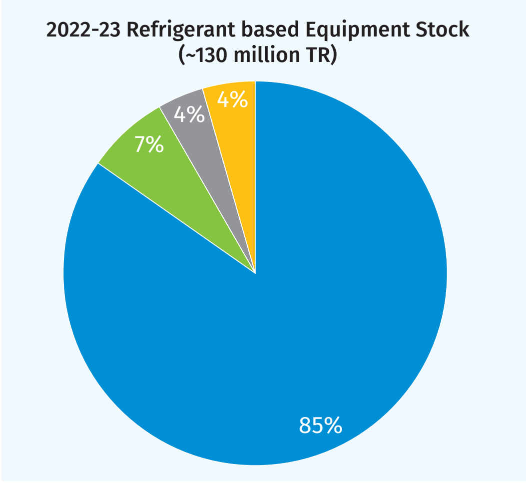


Figure 3.7: 2022-23 Refrigerant-based Equipment Stock

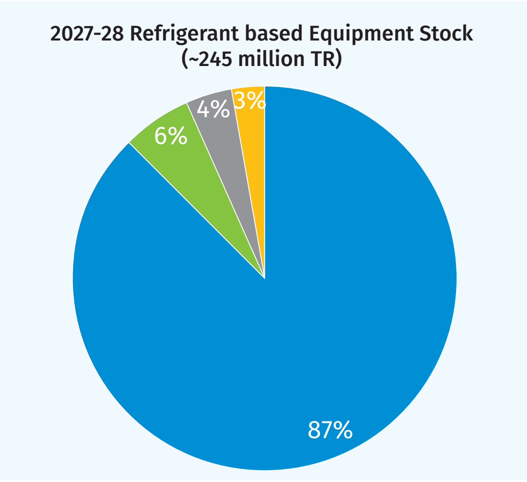


Figure 3.8: 2027-28 Refrigerant-based Equipment Stock

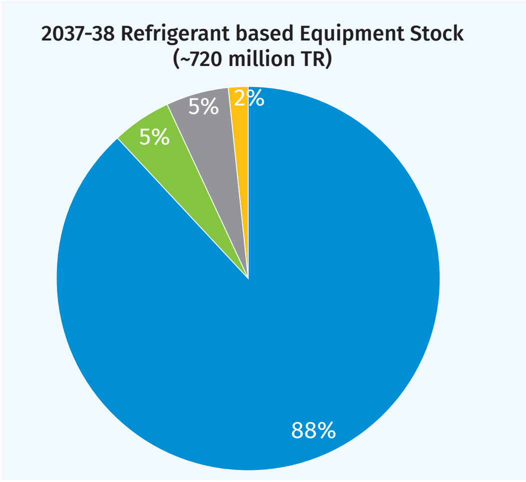


Figure 3.9: 2037-38 Refrigerant-based Equipment Stock

Room AC Chiller System VRF System Packaged DX

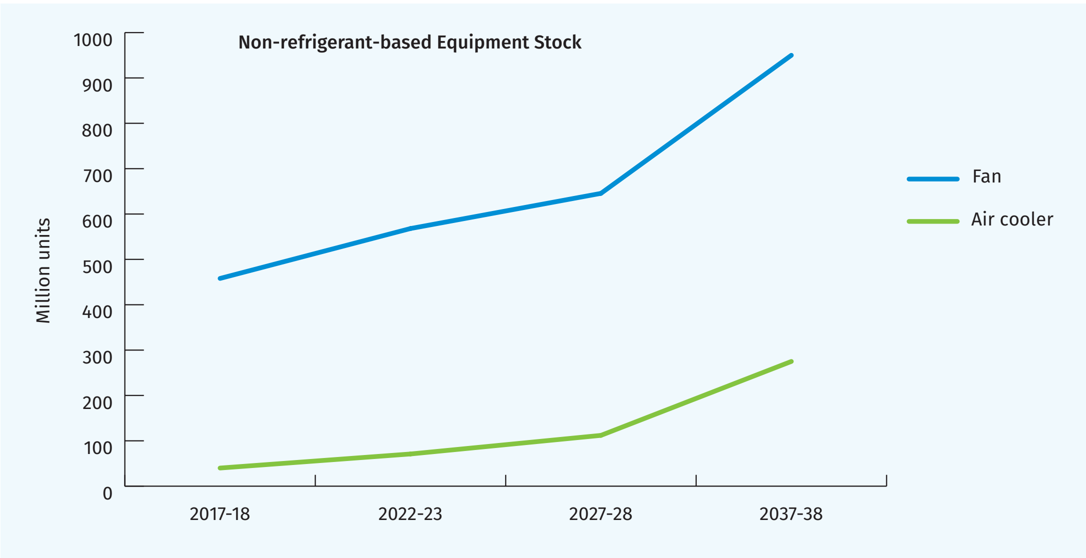


Figure 3.10: Non-refrigerant-based Equipment Stock

3.3.4. Suggested Interventions

Room Air Conditioner: Considering the dependence, importance and expected growth of the room air conditioner segment in meeting the thermal comfort demand and the significant amount of energy that it will consume, a long-term roadmap for efficiency improvements in them should be developed.

Chiller System: A national programme, patterned along the lines of Singapore that mandates operating efficiency of 0.8 kW/ton for central plants, should be conceived around retro-commissioning and retrofitting to significantly improve the operating efficiencies of the entire existing stock, while gainfully employing a cadre of trained and certified HVAC service technicians, and to bring it on par with the best possible efficiencies in other parts of the world.

With the advent of technology and combination of national and international best practices, significant scope for improvement lies in the chiller systems. The most important levers being:

- Better O&M practices with focus on capacity building through training and certification of O&M and installation professionals, and stringent commissioning and retro-commissioning practices.
- Higher penetration of Building Automation/Management Systems in upcoming medium to large constructions, including utilisation of IoT. Chiller analytics software platforms are readily available that offer more improved chiller plant system reliability, continuous commissioning, and verified energy and cost savings. These systems include automated monitoring and control capability for water-cooled chillers and fault detection and diagnostics, with propriety CPLV calculations.
- Higher penetration of high efficiency chillers and other HVAC system auxiliaries like pumps (chilled / condenser water) and fans (cooling tower, AHU).
- Uptake of ECBC-2017 with the minimum stringency levels of ECBC compliance being revised to current SuperECBC requirements by 2027.
- Retrofitting old and inefficient HVAC systems with new efficient & right-sized equipment.

VRF System: The intervention scenario primarily assumes improvements due to better O&M practices using trained and certified HVAC service technicians, such as, regular maintenance of filters, cooling coils, shading the outdoor unit and ensuring good airflow around the outdoor unit for heat rejection.

Packaged DX: Intervention scenario considers adoption of SuperECBC compliant packaged DX systems in buildings in the next decade that can lead to a savings of 9-10% in energy consumption. Mandating superior O&M practices through trained and certified HVAC service technicians can lead to significant energy savings.

Fan: If BEE S&L for ceiling fans is made mandatory, energy efficient ceiling fans of around 50W as compared to ordinary fans of around 70W will become the norm and energy saving of 10-15% will be possible in 2027-28. Thereafter, mainstreaming of super-efficient BLDC fans of 35W, which is already available in the market, can bring even greater savings.

Air Cooler: It is estimated that 10-20% energy savings is possible in the next decade, with more air coolers being fitted with energy efficient fans and pumps. Additionally, low water-consuming air-coolers can be designed in response to concerns about the excessive use of water by air-coolers.

HVAC System Design: HVAC system design is the process of right-sizing and selecting equipment to meet the requirements of comfort with the lowest lifecycle cost. It is particularly important to carry out this process carefully since it is the first step towards optimizing the energy requirements for cooling; also, once a system is designed and installed, alterations can be both difficult and expensive. Efficient HVAC system design should include the following components:

- An integrated approach to system design, such that all components work together as a complete system to leverage the interdependencies and achieve the highest possible efficiencies.
- Right-sizing HVAC equipment based on heat load calculations considering building design and construction, type of use, geographical location and climatic conditions. Conformance with Energy Conservation Building Code at the design stage is a great yardstick for assuring HVAC equipment efficiency.
- Selecting HVAC technology with emphasis on its energy efficient performance, as well as low GWP refrigerants

This intervention has led to energy savings in the order of 30%-40% in some cases. However, for the purposes of this study, its impact has not been incorporated in the numbers shown in Section 2.4.5.

3.3.5. Impact of Suggested Interventions

The intervention scenario presented in this Section (Figure 2.12-2.13) incorporate improvements in equipment efficiency and operational practices only; however, as delineated earlier, further energy savings can be accrued due to reduced cooling load: a TR reduction potential of around 13% and around 23% could be achieved by 2027-28 and 2037-38, respectively, through climate-appropriate building envelopes driven by a higher adoption of ECBC in the upcoming commercial buildings.

KEY TAKEAWAYS:

- Figure 3.11 shows the annual refrigerant demand due to new AC equipment sales and servicing. This has been estimated using new sales and typical refrigerant charge rates; per HPMP-I, 40-45% of annual refrigerant demand is from the servicing sector. The Reference Scenario has been developed considering the continuation of current technologies including the type of tubing and its diameter used in heat exchangers. The Intervention Scenario has also been developed considering the continuation of current technologies and servicing practices for the next 5 years; subsequently, technology interventions like refrigerant transition from currently used refrigerants HCFC-22 and R-410A to low-GWP refrigerants, reduced tube diameter in heat exchangers from 7mm to 5mm or large-scale introduction of micro channel heat exchangers resulting in significant reduction in refrigerant charge per unit. The Intervention Scenarios also considers the use of good servicing practices and proper installation of room ACs in the country - this will further reduce the refrigerant demand for servicing.
- Building cooling energy consumption is likely to double in the next decade and become nearly 4 times in the next two decades (over the 2017-18 baseline)
- Building cooling energy consumption can be reduced by around 15% in the next decade and by around 30% in the next two decades.
- Room air conditioner constitute a dominant share of the building sector's cooling energy consumption – at around 40% in 2017-18 and growing to around 50% in 2027-28 and 2037-38
- Significant presence of non-refrigerant based cooling from fans and air coolers at around 40%; this makes a strong case for realigning focus on fans and air coolers that will continue to be very pervasive, particularly in the residential sector and a primary means to provide thermal comfort to all.

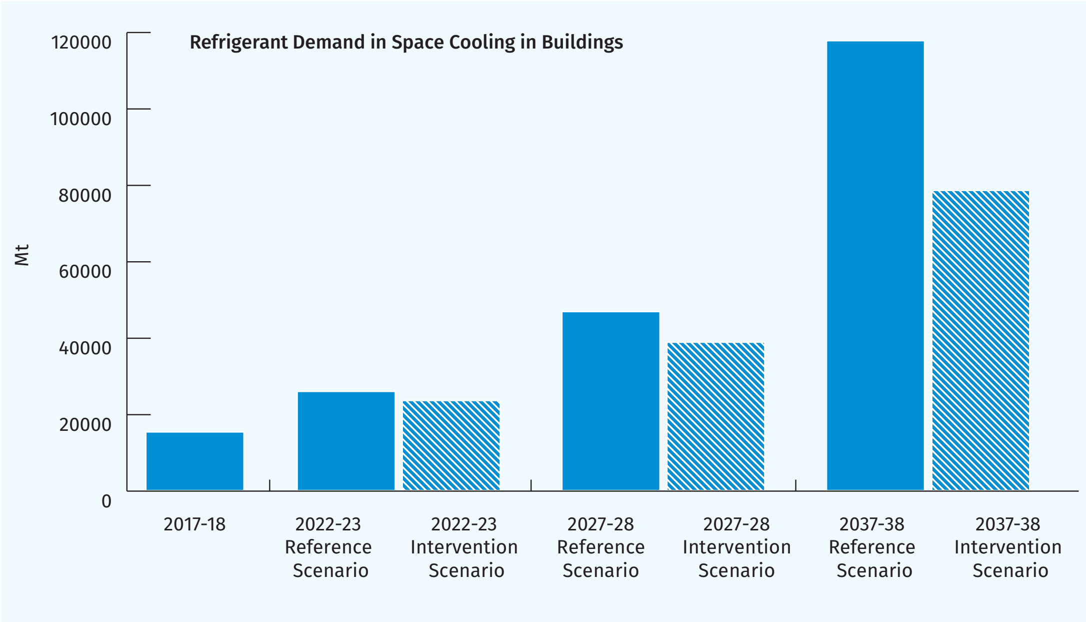


Figure 3.11: Annual Refrigerant Demand (incl. Servicing) in Space Cooling in Buildings

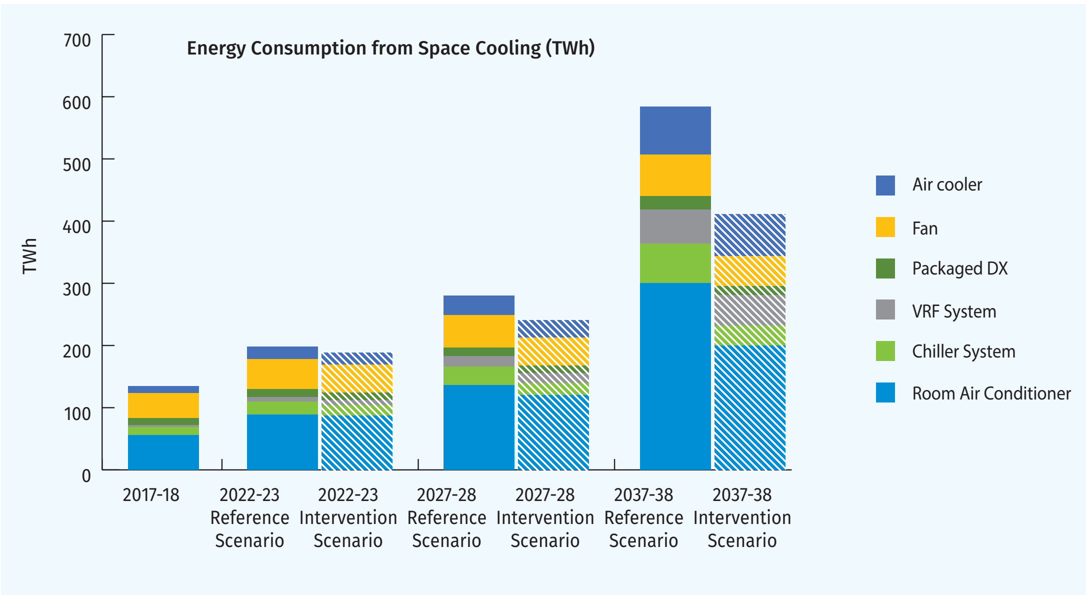


Figure 3.12: Annual Energy Consumption from Space Cooling in Buildings

3.4 Recommendations

Short-term Recommendations

1. Promote wider penetration of climate responsive built spaces to bring indoor temperatures within acceptable thermal comfort band through passive cooling thus reducing cooling load.
    - Further government support towards targeted programmes to enable thermal comfort for EWS and LIG. 20 years from now, there will still be a significant proportion of the population without access to air-conditioning or without any reliable mechanical means for cooling. Government support for affordable housing should include strategies such as: enforcing efficient building envelope guidelines from ECBC-R in the design and construction of housing for EWS and LIG to enable thermal comfort for all; funding and support for initiatives led by local municipalities and NGOs, such as cool-roof programs, off-grid micro-systems for cooling, and localized heat-action plans.

- Incorporate relevant provisions of energy efficient building design stated in ECBC to minimize active cooling needs by using passive design elements for all commercial (non-residential) buildings in conditions forming part of statutory environment clearance, where applicable.
- Nation-wide adoption and enforcement of ECBC for both commercial and residential sectors at the municipal and urban and local body level and through development of city level action plans
- Aggressive market awareness campaigns to sensitize both the construction community as well as the users towards the multiple benefits of efficient buildings – reduced operational costs, health and comfort, environmental and societal benefits.
- Develop a windows energy-labelling programme.
- Mandatory disclosures and Third-Party verification of building cooling requirement and energy use for all commercial (non-residential) buildings that have a connected load of 100 kW or higher

2. Leveraging the existing levels of technology to make it available for wider market adoption
   - Drive widespread adoption of 5-star labelled fans and room air conditioners in new and existing public buildings and running campaigns to exhort the private sector and consumers using incentives and awareness campaigns to do the same to save money and the environment.
   - Room Air-Conditioners manufacturers should be encouraged to further develop energy efficient ACs to innovate and bring about step-changes in technology.
   - Ratchet up MEPS for Room ACs while taking into account most energy efficient models available and their affordability
   - Make BEE Star Labelling of ceiling fans mandatory and introduce MEPS for Air Coolers.
   - Support information and capacity-building efforts that encourage consumers to opt for energy-efficient products and services.
   - Incentivise selective adoption of the feasible new/not-in-kind cooling technologies to displace conventional air conditioning systems.

3. Adoption of Adaptive Thermal Comfort based set-point for air conditioner operation
   - The need for shifting behavioural and psychological change towards adaptive thermal comfort (ATC) practices has already been realised by the Government of India.[40] The building codes – ECBC and NBC - in their next revision cycles should include guidelines in alignment with ATC practices specific to the Indian climate.[41] Accordingly, the minimum thermostat setting should be mandatorily kept between 24°C - 26°C in commercial buildings and corresponding temperature set-point guidelines should be issued by BEE to reduce cooling requirement and energy consumption as estimated by AEEE[42] and promote healthy living/working environment.

4. Measures to enhance operational efficiency of cooling systems
   - Retrofitting and retro-commissioning existing buildings to reduce cooling requirement and energy consumption.
   - Capacity building and training of HVAC servicing personnel who perform installation and product servicing is essential. Standardized training programs and certification is one way forward. Leading by example, the government should issue pubic procurement guidelines for trained and certified HVAC service technicians for public buildings.

5. DSM and DR programs for enhancing energy efficiency of cooling equipment
    - Institutionalise Demand Side Management programmes with DISCOMS to replace inefficient ACs with EE appliances.
    - Promote the use of Demand Response (DR)-enabled cooling technology, real-time power consumption displays in all Room Air-Conditioners and Building Automation/ Management Systems.
6. Formulation and implementation of policies at the state level
    - In line with Ministry of Finance's General Financial Rules (GFR)- Office Memorandum No. 26/6/12-PPD[43] regarding procurement of energy efficient electrical appliances for Ministries/Departments, States and Union Territories (UTs) should also issue mandatory public procurement guidelines for highest star rated energy efficient ACs, fans, chillers, etc. with low-GWP options, where ever feasible
    - All States and UTs should notify and incorporate ECBC-2017 in municipal building bye-laws for stringent enforcement and compliance in all new construction.
    - States and UTs should encourage proliferation of trained and certified HVAC O&M service technicians through capacity building and training of existing service professionals, and issue pubic procurement guidelines for trained and certified HVAC service technicians for public buildings.
7. Formation of a robust R&D team that leverages global best practices in space cooling and existing knowledge by closely monitoring pertinent policies and technology pathways.
8. Building energy data collection and reporting
    - Institute a practise of mandatory building energy and cooling demand disclosures for all commercial buildings that have a connected load of 100 kW or greater.
    - Improve data collection and statistics on energy efficiency indicators and make it part of the Open Government Data Platform put in place by the Government of India.
9. Implement Eco-labelling programme for cooling appliances in India
    - The environmental footprint of cooling equipment in terms of GWP (or ODP), GHG emissions, should be factored in combination with safety, performance, and energy efficiency, under a single eco/environmental label.
    - Add cooling appliances under MoEF&CC, Government of India's 'Ecomark' scheme on labelling of environment friendly products.
10. Institutionalize holistic and integrated approach for energy efficient building designs of commercial buildings with the mandate to minimize cooling needs under as a condition under Environmental Clearance (EC) policy.
11. Encourage development of urban heat action plans for all cities with a population of 2.5 million or more
    - Subsequent to Ahmedabad, which was the first city to prepare and implement heat action plan, 30 cities in 11 states have adopted urban heat action plans. Municipal bodies of other cities which face extreme heat waves during summer should also adopt urban heat action plan that presents actions to increase preparedness, information-sharing, and response coordination to reduce the health impacts of extreme heat on vulnerable populations

Medium-term Recommendations

12. Promote use of not-in-kind technologies including trigeneration system, district cooling, thermal energy storage etc.

13. Institutionalize installation of thermal storage with cooling systems and differential (Time of Day) power tariffs to minimize peak power requirement

14. All new construction – both residential and commercial – should be 100% ECBC compliant.

15. The minimum stringency levels of ECBC compliance should be revised periodically to ECBC+ and Super ECBC requirements.

16. Building Automation/Management Systems should be made mandatory in all new construction with a connected load of 100 kW or greater.

17. Programs to reduce cooling energy use in existing buildings through retrofits and improved O&M practices

18. Bolster national and international collaboration on cooling-related research
    - Step up funding for cooling research, focusing on emerging technologies that have the potential to drastically lower the emissions from cooling in the long term.

Long-term Recommendations

19. Large scale deployment of current new/not-in-kind and upcoming cooling technologies to significantly displace conventional air conditioning systems.

20. Greater focus on R&D in new low energy, low cost cooling technologies which could possibly be deployed on large scale.

4

Cold-Chain & Refrigeration

4.1 Introduction

The cold-chain is a logistical chain of activities involving packaging, storage and distribution of perishable food products (e.g. fruits and vegetables, milk, meat and poultry, flowers, and vaccines) from point of production to point of consumption, where the inventory is maintained in predetermined environmental parameters[43]. Typically, a cold-chain is made of 4 links: pack-houses or source point, reefer transport (vehicles or mulita-modal), cold storages, ripening chambers (for some fruits) as illustrated in Figure 4.1. Refrigeration forms an important and significant part of the food and beverage retail market. It ensures optimal preservation of perishable food. Domestic refrigeration and commercial refrigeration are the important elements of the cold chain.

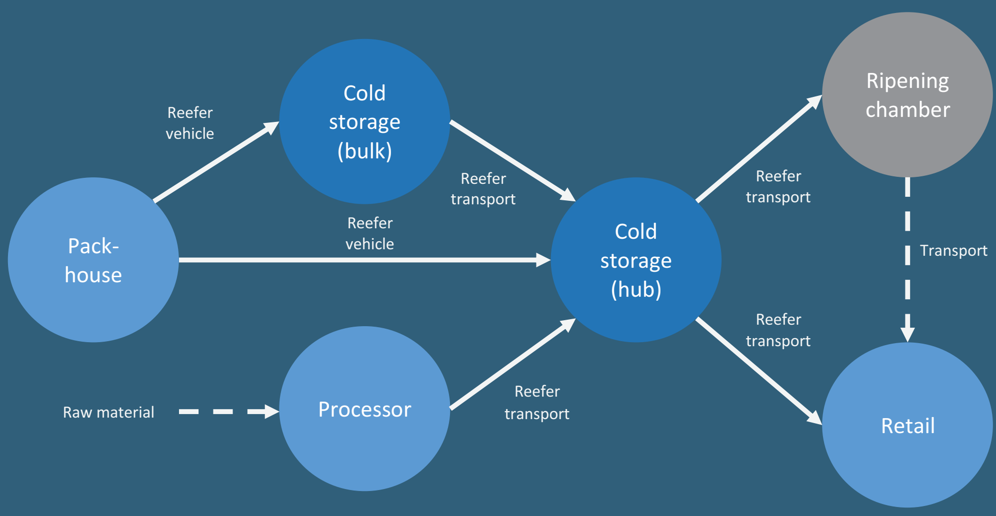


Figure 4.1: Schematic Depiction of the Flow of Produce in a Typical Cold-chain

Fresh whole food (fruits and vegetables), post-harvest and until consumption, continue to breathe, require oxygen, emit CO_2 and generate heat and moisture. The scale of these metabolic activities varies, based on the respective rates of respiration and storage temperature. Further, without the cold-chain, the produce would perish, and decompose into methane emissions. Per International Institute of Refrigeration (IIR), 20-25% of perishable foods are lost in developing countries due to the lack of appropriate post-harvest infrastructure. The carbon footprint alone of food produced and not consumed (i.e. either lost or wasted) is estimated to be 3.3 giga tonnes of carbon dioxide equivalent ($GtCO_2e$)[44]. For agri-produce, the cold-chain has to maintain the humidity, temperature and breathable air to keep the produce fresh. In case of processed products, the goods are more inert in nature and cold-chain is mainly concerned with maintaining the predetermined temperature.

In the cold-chain, the perishable produce and products are safe and kept consumable for an extended period, albeit for a limited time. The process of extending the marketable or holding life of such goods, is highly dependent upon temperature. To slow down the degradation process, there are different temperature requirements to preserve different kinds of fresh foods and extend their shelf life as shown in Table 4.1.

Table 4.1: Temperature Requirements of Different Kinds of Produce (NCCD, 2015)

Temperature requirements	Examples
Frozen (< -18°C)	Ice cream, frozen meats (fish, poultry, livestock), frozen ingredients, some frozen processed commodities.
Chilled (0-10°C)	Fresh fruits & vegetables, fresh meats, milk, butter, confectionary, some pharmaceuticals
Mild chilled (10-20°C)	Fresh fruits & vegetables, chocolates and seeds and some milk products
Normal (>20°C)	Whole onion, dehydrated foods, pickle, jams and oils and extracts

4.1.1. Overview of Cold-chain Infrastructure

Cold-chain infrastructure in the country consists predominantly of a large footprint in refrigerated warehousing space. Per National Centre for Cold-chain Development (NCCD), this capacity is primarily designed for bulk, long-term warehousing of certain crops, mainly potatoes and red chillies. Majority of cold storages are single temperature storage except a small percentage which is used as distribution hubs, at the front end of the supply chain. The other requirements from source points to market include modern pack-houses, refrigerated transport, ripening chambers and last mile transport connectivity to retail outlets.

The cold-chain for frozen products, being primarily industry driven, originates post production at manufacturing/processing factories and it captures most of the refrigerated transport and peri-urban storage capacities for market linkage. However, the significant part of the infrastructure for handling of fresh produce (fruits and vegetables) is yet to come. Hence, the cold-chain sector offers tremendous opportunity for reducing cooling, refrigerant requirement and energy consumption through improved designs including proper insulation and use of energy efficiency cooling equipment.

Table 4.2 shows that there is sufficient cold storage capacity but there is scope for addition of other critical cold-chain links which include pack-houses, reefer transport, and ripening chambers.

The holding capacity reflects the volumetric size and the actual throughput will be in multiples of the operational or holding cycles. For example, an average weekly turnaround of reefer transport units will translate the 72,000 tons holding capacity into 3.7 million tons in throughput capacity.

Table 4.2: Cold-chain – Current Infrastructure & Gap (NCCD, 2015)

Cold-chain Component	Requirement	Created	Gap
Pack-house (MT)	11,21,274	3,984	97 %
Cold storage (Bulk) (MT)	3,41,64,411	3,18,23,700	9 %
Cold storage (Hub) (MT)	9,36,251		
Reefer transport (MT)	4,94,608	72,000	85 %
Ripening chamber (MT)	91,306	8,120	91%

4.1.2. Growth Drivers[45]

Doubling Farmers' Income (DFI): There is increasing urbanization; the need for modern supply chain for perishables is bound to drive the need for a robust cold-chain infrastructure, spurring both growth and innovation. Over past few decades, the quantum and type of agricultural produce has changed, and the current logistics mechanism is not adequate for the desired free and timely flow of produce, putting the perishable produce, having a short saleable time span at added risk. The inter-ministerial committee on DFI has given premier importance to agri-logistics, as the backbone of future agricultural development as part of reforms in the market architecture.

Gramin Agricultural Markets (GrAMs): The clear need for reformed market architecture, one that enables direct connectivity from farm-gate to final markets and allows for sustained market-linked growth for farmers, is well established. To that end the DFI Committee proposed Primary Rural Agricultural Markets that will serve to aggregate and dispatch farm produce to terminal consumption, as the backbone of the new market architecture. In cognisance, the 2018-19 budget announced the government's agenda to develop 22,000 Gramin (primary rural) Agricultural Markets (GrAMs), kept outside the ambit of existing market regulations (APMC), with the aim to organise effective market linkages, starting at first mile. These GrAMs will serve two roles: (1) a platform that facilitate direct local retail, for farmers to transact sales with the near-farm consumers; (2) primary aggregation/pooling/dispatch centres of farm produce, to facilitate the onwards post-harvest movement to market destinations that are farther afield. The GrAMs will essentially be designed with pack-houses to stage and dispatch produce. The modern pack-house with precooling system is the vital first link in the integrated cold-chain for fruits and vegetables.

Agricultural Produce & Livestock Marketing (Promotion & Facilitation) Act (APLM, 2017): Historically, under the Agricultural Produce Market Regulation Act (APMR Act), only State Governments could set up markets, thus preventing private players from setting up markets and investing in market infrastructure. Agricultural Produce Market Committee (APMC) was constituted to frame the rules and enforce them. The government released the Model APLM Act, which allows cold storages to be licenced to function as agricultural markets. This initiative will boost all associated cold chain development, especially pack-houses and reefer transport. The APLM Act complements the overarching strategy to develop a unified national agricultural market in the country and promotes the development of modern and competitive agri-logistics.

4.2 Cold-chain & Refrigeration Components

4.2.1. Pack-house

The pack-house is the entry point into the cold-chain. Pack-houses are used to pre-condition the produce for market connectivity and typically serve a range of operations like sorting, grading, washing, drying, weighing, packaging, pre-cooling and staging. The Government has exempted preconditioning services from Goods and Services Tax (GST) to incentivise the development of pack-houses.

The precooling units and staging chambers require energy intensive cooling. Precooling of the produce rapidly for packaging and thereby prepare the loads for subsequent travel in the cold-chain. Depending on the produce, the pre-cooling process could be by forced-air cooling, hydro cooling, vacuum cooling, and room cooling or top-icing.

A cold staging unit is an insulated and refrigerated chamber which serves as a transient staging space and is a necessary attachment to a pre-cooling unit. A staging room frees the pre-cooler chamber to operate for sequential batches of freshly harvested produce.

The country presently has approximately 500 pack-houses (per inputs received from NCCD, Agricultural and Processed Food Products Export Development Authority (APEDA), National Horticulture Board (NHB) and other cold-chain industry experts) but growth in the creation of pack-houses is expected in the next 10-20 years, primarily driven by the Doubling Farmers' Income (DFI) mission.

4.2.2. Reefer Transport

A reefer transport unit can be a road vehicle or reefer container, with a fixed insulated body equipped with active refrigeration. There are very small numbers of reefer containers in the country. Over 95% of current existing reefer vehicles are used mainly for carrying frozen products.

A typical reefer unit is considered with a holding capacity of 10 MT and is equipped with a refrigeration unit of 3.6-5 kW cooling capacity. However, a variety of sizes are in operation, of smaller and larger capacity. There are presently about 13,000-14,000 reefer vehicles as per the industry information. The number of reefer vehicles is likely to witness a high growth of 20-25% CAGR in the next 10 years while it is expected that the growth in the subsequent decade will be significantly less. Refrigeration systems using CO_2 as a refrigerant and liquid-air based cooling systems are some of the emerging technologies for this sub-sector and are yet to be mainstreamed. Vapour Absorption Refrigeration (VAR) systems are sustainable option wherein waste heat from the prime mover can be utilized.

4.2.3. Cold Storage

A typical cold storage facility comprises a highly insulated and refrigerated warehouse designed to store perishable products to essentially maintain the temperature and humidity parameters, which were initiated at the pack-house (e.g. vegetables) or during manufacturing (egg. ice-cream). Based on the type of product and holding duration, NCCD has categorized cold storages in two categories, i.e. bulk cold storage and hub cold storage.

- Bulk cold storage is an environment-controlled warehousing space with multiple chambers intended for bulk storage of perishable produce and is often viewed as an independent refrigerated warehouse, and not part of an integrated cold-chain. The space is designed for long-term storage of a specific produce to build an inventory buffer which will serve to smoothen episodic production by stabilising & sustaining the supply lines. These are normally constructed in areas close to producing areas to facilitate quick access to farmers, for a selective set of crops. Per NCCD, the average holding capacity of a bulk cold storage is about 5000 MT. Majority of these facilities store bulk produce like potatoes and chillies.

- Hub cold storage (hub), is an environment-controlled warehousing space functioning as a distribution hub located close to consumption centres and form an integral part of the cold-chain. It is designed for short-term handling and cross docking of produce, to serve as a distribution logistics platform at the last mile. These hubs cold storage provide a platform to manage distribution and delivery activities and are vital to integrated logistics for various products with shorter marketing cycles.

The country presently has around 35 million MT of cold storage capacity (as per Directorate of Marketing and Inspection (DMI), Ministry of Food Processing Industries (MoFPI), National Horticulture Mission (NHM), NHB and NCCD), which caters to roughly 85% of the demand. The existing capacities can also be expected to service larger volume of goods as operations get modernised to optimise on higher rotation of goods from the same space.

Cold storage cooling requirements are largely met by vapour compression units using ammonia. The cooling capacity of a cold storage varies between 200-400 kW. A typical cold storage unit runs for 16 to 18 hours per day on grid power. Diesel powered generators are also used across the country and are estimated to meet up to 10-15% of energy consumption for cold storage operations[46].

The energy performance of cold storages can be optimised by using improved insulation; variable frequency drives (VFDs), efficient compressors, automation and programmable logic controller (PLC) and retrofitting and retro-commissioning practices.

4.2.4. Ripening Chamber

Ripening chambers are a front-end facility in the cold-chain, used for the controlled and hygienic ripening of certain fresh produce. In India, these are used extensively for ripening bananas and climacteric fruits like mangoes and papayas on commercial scale. The chambers may also be used for avocadoes, tomatoes, pears, and for de-greening purposes with some citrus fruit. A ripening unit usually has 4 compartments, each of around 10 MT capacity. Controlled temperatures of 15-20°C with elevated humidity levels is typically maintained refrigeration unit. A facility could be in multiples of these units.

There are presently about 1000 ripening chambers, which serve around 9% of the current requirement as per assessments carried out by NCCD. Experts predict that there will be a significant growth in ripening chambers (around 9000 units) in the next decade while the subsequent decade would witness a marginal growth. The government has taken special steps to promote modern ripening units so as to eradicate harmful ripening practices, such as use of calcium carbide for ripening.

4.2.5. Domestic Refrigeration

Domestic refrigerators are commonly used in households, commercial setups like retail outlets, offices, hotels, and hospitals for storage of perishable food, medicines, vaccines, etc., These are two types, viz., frost-free (FF) and direct-cool (DC).

The production of DC and FF refrigerators has grown at CAGR of 6% and 1% respectively since 2011 (BEE) in the country. DC refrigerators dominate the market with around 80% share of the total production from 2011 to 2017 and this trend is likely to continue in the next decade. Based on these historical trends, it is estimated that domestic refrigerator production/sales are expected to at a steady rate of 5-6%.

BEE star-rating has been made mandatory for FF refrigerators since 2009 and for DC refrigerators since 2016. The BEE labelling is progressively moving towards higher energy efficiency in this sector.

4.2.6. Commercial Refrigeration

Commercial refrigeration equipment covers equipment of different capacities: deep freezers (glass top or hard top) (<1 kW), visi-coolers (<1 kW), remote condensing units (1-20 kW), water coolers (>2 kW), super markets (60-100 kW) and hyper markets (100-200 kW) systems. Remote condenser units could either be display type employed by large retail shops or non-display for storage of additional refrigerated goods. Non-display units have racks of condensing units placed in a small machine room away from the display area. Centralised systems (where compressor racks are installed in a machine room and involve lengthy piping) used in supermarkets and hypermarkets are not very prevalent, but upcoming.

The main factors for growth in this commercial refrigeration sector will be commercial space growth, cold chain, GDP growth and technological changes in the future. Per RAMA, the market size of deep freezers, visi-coolers, remote condensing units and waters coolers in 2017-18 is estimated to be around 0.6 million units, 0.3 million units, 0.04 million units and 0.2 million units, respectively.

4.3 Analysis and Results

A flexible methodology was used to adapt to the unique aspects and data availability of the cold-chain sector. A questionnaire-based approach was also adopted to reach out to multiple subject matter experts to address specific data gaps. The analyses i.e. cold-chain infrastructure in use, typical cooling equipment, their cooling capacities and energy-efficiencies, operating hours, refrigerant inventory in use, operation and end-of-life refrigerant leakages is based on the data available in the literature including websites[47,48].

The data collated above was used to build 2 scenarios: reference (i.e. current level of effort) and intervention (heightened level of effort) to show the evolution of cold-chain infrastructure from 2017-18 to 2037-38 in the country. The intervention scenario mainly considers potential improvements in the energy-efficiency of the infrastructure and cooling equipment, choice of low GWP refrigerants and refrigerant-related servicing practices. Presented below are the key results from the analyses. These charts and graphs (Figures 4.2-4.8) have been constructed using mid-point estimates of identified ranges which can be found in Appendix B.

Figure 4.8 shows the annual refrigerant demand for new equipment as well as for servicing. This has been estimated using new sales and typical refrigerant charge rates. The refrigerant demand from this sector is assumed to reduce by 20-25% in the next 20 years, using a range of interventions: (a) Reduced cooling load through improved insulation (b) Technological improvements to reduce refrigerant charge size (like low-refrigerant charge refrigeration ammonia system) and (3) Improved refrigerant-related servicing practices during operation and end-of-life recovery.

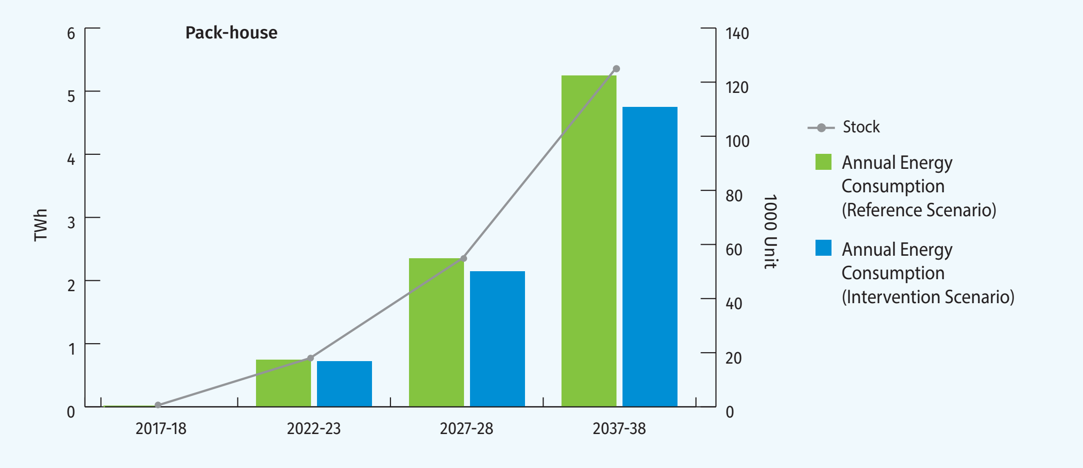


Figure 4.2: Current and Future Trends in Pack-houses

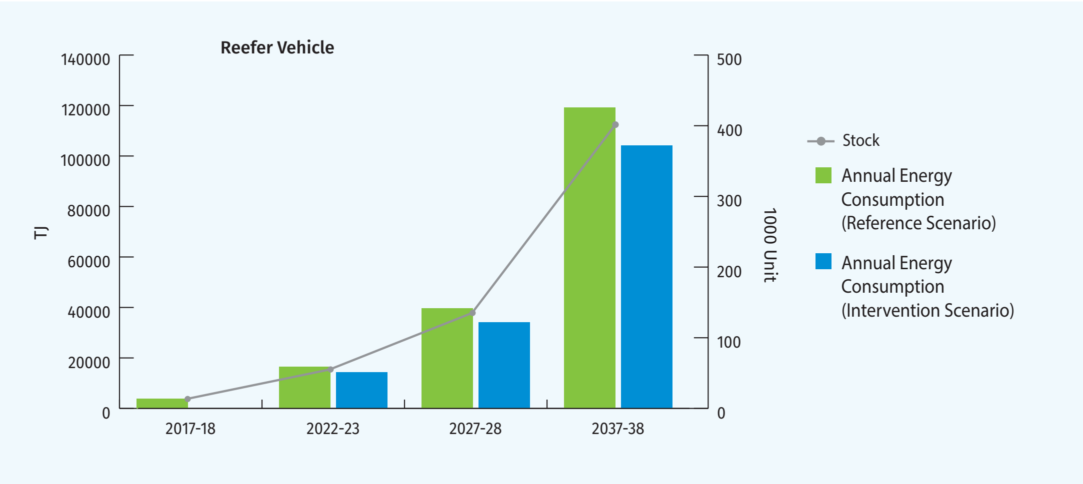


Figure 4.3: Current and Future Trends in Reefer Vehicles

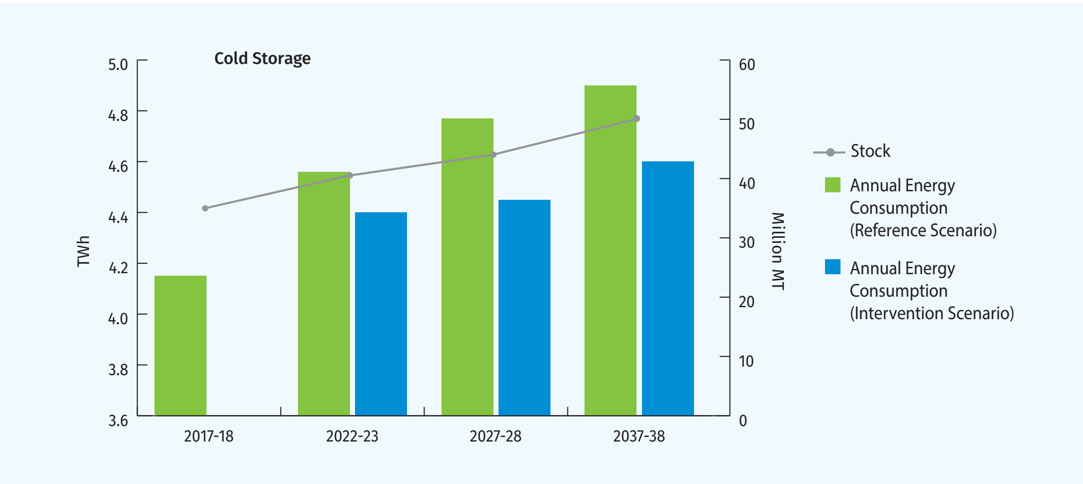


Figure 4.4: Current and Future Trends in Cold Storages

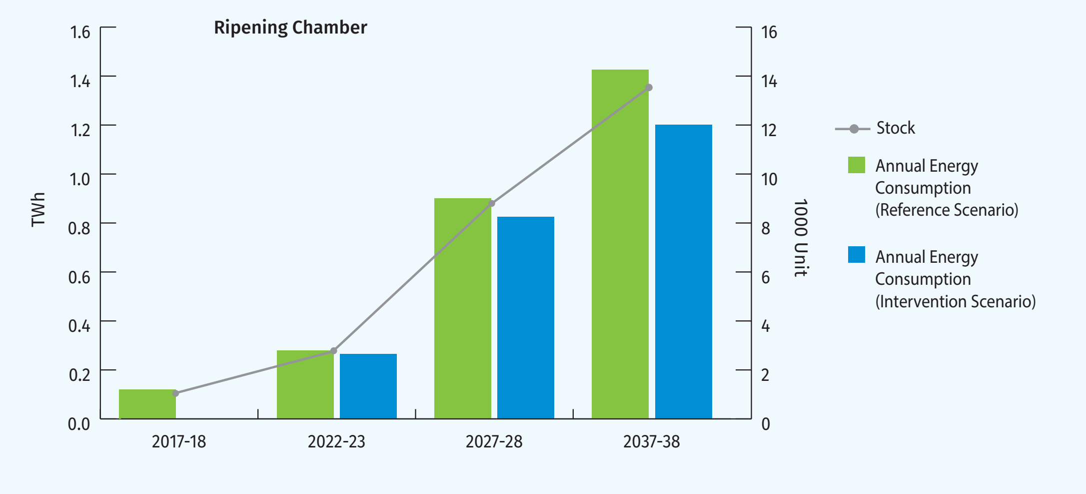


Figure 4.5: Current and Future Trends in Ripening Chambers

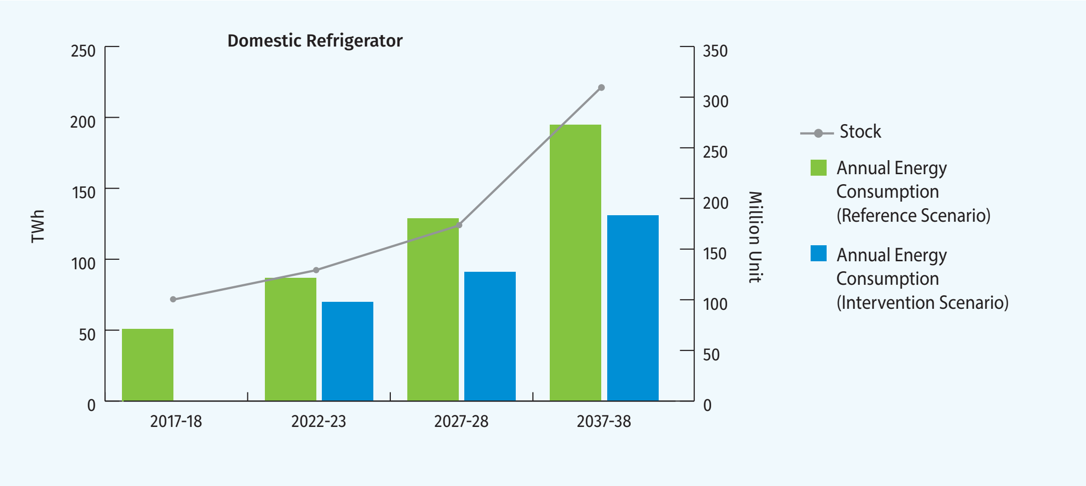


Figure 4.6: Current and Future Trends in Domestic Refrigeration

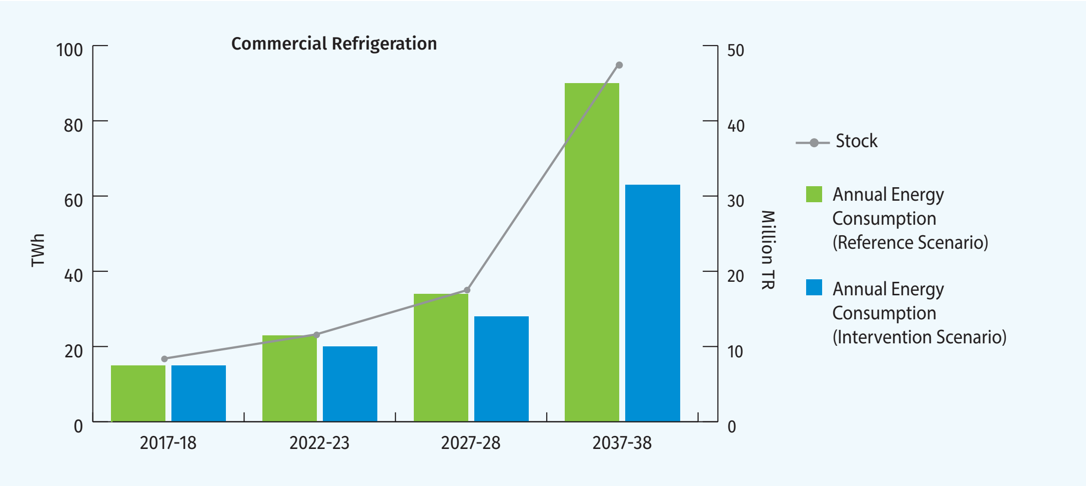


Figure 4.7: Current and Future Trends in Commercial Refrigeration

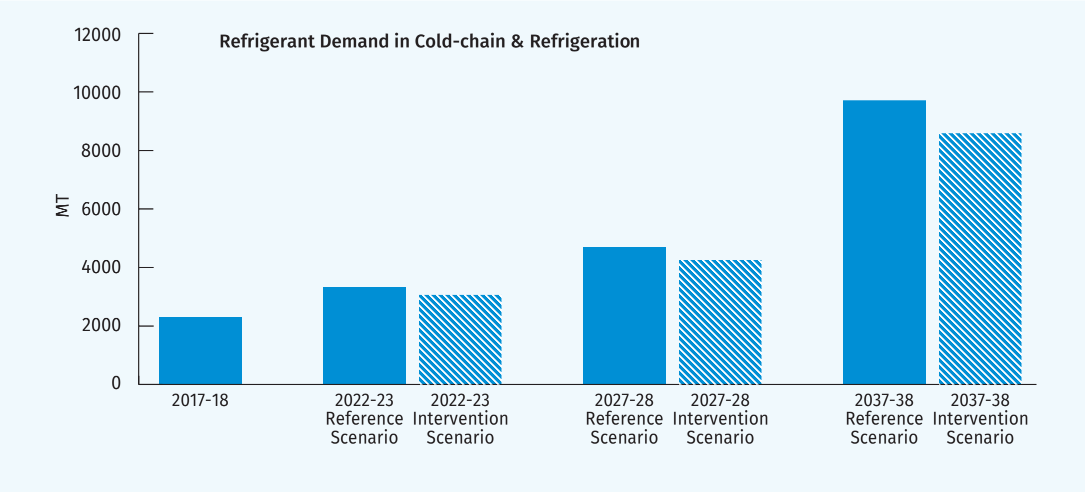


Figure 4.8: Refrigerant Demand in Cold-chain & Refrigeration

4.4 Additional Components

Described below are two other important extensions of the cold-chain & refrigeration infrastructure in India:

Cold-chain for vaccine management: The purpose of the vaccine cold-chain is to maintain product quality from the time of manufacture until the point of administration by ensuring that vaccines are stored and transported within World Health Organisation (WHO)-recommended temperature ranges. The vaccine cold-chain system equipment can be broadly classified under storage and transportation. The storage facilities include walk-in cooler/freezer, deep freezer and ice-lined refrigerator. Solar integrated refrigerant drives have also been a promising vaccine storage facility. Transportation infrastructure consists of refrigerated vaccine van, insulated vaccine van, cold box and vaccine carriers. With the advent of newer technologies in temperature monitoring, cold chain storage and transportation equipment especially using green energy, stock and inventory management, there is a high potential to improve the existing system.

India hopes to reach at least 90% full immunization coverage over the next five years, and it is critical to strengthen the vaccine cold-chain in the country. India's Universal Immunization Program is one of the largest in the world and caters to 26 million infants and 30 million pregnant women, saving 2.5 million lives each year. The effectiveness of the program depends largely on a functional end-to-end Immunization Supply Chain system. Immunization supply chain plays a pivotal role in ensuring the uninterrupted availability of quality vaccines from the level of the manufacturer to that of the beneficiary[49].

Milk chillers: Milk chillers are used in the milk chilling centres and dairy plants. Most of the chilling centres are located in remote villages to collect the milk from various local areas. The transportation of fresh milk from farms to cooling centres and processing units may take some time. The milk should be chilled within three to four hours of collection otherwise leads to spoilage.

Per cBalance[50], the installed capacity of milk chillers was around 0.4 million tonnes of refrigeration (TR) in 2015 and the market is expected to grow at a CAGR of 10%. Ammonia is the widely adopted refrigerant in the dairy sector. Intervention like precooling of warm fresh milk using water will reduce the cooling, refrigerant requirement and energy consumption in the refrigeration system.

Industrial Refrigeration: Industrial refrigeration encompasses the cooling systems for production of food, drink, chemicals, pharmaceuticals and other products. This sector also includes systems for controlling air temperature in production factories, computer centres and other process areas. Industrial refrigeration usually uses systems with cooling capacity 10kW to few MW, typically at -50°C to +20°C evaporating temperatures.

4.5 The Future of Cold-chain & Refrigeration

Liquid Air Cooling: The waste cold from India's projected LNG imports in 2022 could fuel over half a million liquid air refrigeration units. NCCD is exploring the potential liquid air based cold chains by recovering stranded cold from LNG re-gasification. An analysis - in a report for the NCCD by the energy consultancy E4tech – shows that a typical LNG terminal re-gasifying 7,100 tons of LNG/day can produce enough liquid nitrogen to provide the cooling for almost 1,100 chilled and frozen refrigerated trucks operating around the clock; and peak time cooling (three hours a day) for 7.5 million cubic meters of chilled and frozen buildings.

Liquid Air Power & Cooling: Dearman, a UK-based technology company, has developed engines that use liquid air/ liquid nitrogen to deliver zero-emission power and cooling. Such engine and cooling systems in reefer transport can be highly efficient with zero polluting emissions. This technology will reduce fuel costs (refrigeration alone consumes as much as 20% of truck's fuel).

Magnetic Refrigeration System (MRS): Magnetic refrigeration is based on the Magneto caloric Effect (MCE). MRS offers the following advantages over compressor-based refrigeration systems:

- High Coefficient of Performance (COP) reduces energy consumption by up to 40%
- No compressor/refrigerant gas used, instead water-based coolant liquid used: eliminates harmful emissions
- No gas leakage: reinforced safety and eliminates CO_2 emission

Other refrigeration technologies:

- Stirling cycle refrigeration
- Acoustic refrigeration
- Electrocaloric refrigeration
- Magnetic refrigeration
- Optical cooling
- Thermionic refrigeration

Monitoring Systems for Cold Chain:

Radio Frequency Identification (RFID): Temperature sensors combined with RFID offer spatial temperature profiling and possibility to map the temperature history across the supply chain.

Wireless Sensor Network (WSN) and Internet of Things (IoT): IoT is an ideal platform for remotely monitoring and controlling the real-time status of perishable goods across the cold-chain with very less human intervention. It enables integration of food safety systems and regulatory requirements and support specific report generation (as programmed in the algorithm).

Time Temperature Indicators (TTI): TTI's are simple and inexpensive devices, which indicate the time-temperature history of the product when they are applied to them. Logging of humidity levels are also incorporated when handling fresh produce.

The early adoption of the latest monitoring, control mechanisms and automation in data capturing will be very useful tool as cold-chain sector has a long way to go. The key to transforming this aspect is to localize the technologies to suit the scale of industry and by creating flexibility in the system to accommodate and modify the elements of complex supply chains on a need basis.

Renewable and Alternate Energy Technologies:

There are a number of renewable and alternate energy technologies that are promising especially for cold chain application. In order to deliver on their potential for a sustained period of time, these technologies will require excellent engineering and installation, high quality components, and stringent commissioning and O&M services. Cooling options using available technology include:

- Solar PV systems
- Solar thermal systems
- Biomass gasifier
- Solar/Biomass Co-generation (Waste heat Recovery)
- Thermal Energy Storage by application of phase change materials (PCM)

National Institute of Solar Energy (NISE), TERI & Thermax developed biomass/biomass–solar hybrid system. The system can provide cold storage facility for storing (at 0°C) about 25 tonnes of fruits and vegetables. The Ministry of Agriculture & Farmers Welfare supports the deployment of such alternate energy technologies in cold-chain development.

PCM based refrigeration trucks are being manufactured by TESSOL in India and the shift from usage of a diesel generator to PCM can reduce the overall transportation cost by up to 50% for the end user. Pluss Polymers is a leading Indian player in the field of PCMs designed to cater to a wide range of temperatures between -33 to +89ºC.

4.6 Recommendations

Short-term Recommendations

1. Standardisation of design, construction and associated specifications for small, medium and large cold-chain infrastructure components.
2. Link the incentives being provided for development of cold-chain infrastructure with adoption of energy-efficient design, construction and maintenance practices and low GWP refrigerant and renewable technologies
3. Commission demonstration projects for cold chain elements like pack- house, ripening chambers, etc., both for small as well as large units.
4. Address the current skill gaps through extensive capacity building and training necessary for professionals, operators and technicians to promote the proper functioning of cold chains.
5. Training farmers on better management of produce both pre-harvest and post-harvest.
6. Promote research and development of low-cost technologies, and alternate and hybrid sources of energy, to address the specific problems of local supply chain.

7. Develop Management Information System through inter-ministerial collaboration, to track relevant information on infrastructure development and e- performance monitoring to improve overall efficiency of the cold-chain system.
8. Development of safety standards for flammable and toxic refrigerants for cold storage and other segments of the cold chain
9. Drive greater proliferation of efficient refrigeration equipment by fostering user awareness on purchase cost versus equipment life-cycle (operational) cost. This can be achieved through appropriate product labelling, and the government and industry's collaboration on awareness campaigns.
10. Following proper O&M practices including basic measures such as regular cleaning of evaporator and ventilation grills holds tremendous potential to improve and upkeep operational energy performance especially for commercial refrigeration equipment. Both direct emissions from refrigerant leakage and indirect emissions from energy savings can be decreased by proper maintenance, including check of leaks and cleaning of appliances.
11. Proven market transformation mechanisms, such as EESL's replacement scheme for Room Air-Conditioners, or government-supported refrigerator retrofit/upcycle programmes in other countries, can be emulated and adapted to eliminate inefficiencies due to obsolete refrigeration equipment.
12. All super market counters or cabinets should have operable doors or proper curtains to avoid energy wastages.
13. Apply appropriate policy measures to drive equipment efficiency improvements
14. Provide capacity building for technicians with national level certification schemes. Training should cover aspects such as installation and maintenance of refrigeration plant, energy efficient operation, and safe installation, management and recycling of equipment and refrigerant.
15. In line with Ministry of Finance's General Financial Rules (GFR)- Office Memorandum No. 26/6/12-PPD regarding procurement of energy efficient electrical appliances for Ministries/ Departments, States and Union Territories (UTs) should also establish public procurement guidelines for energy efficient refrigerators for all State/UT Departments.
16. Commercial refrigeration equipment like water coolers, display cabinets, freezers, etc. to be brought under BEE star rating
17. Periodic review and enhancement of energy efficiency norms of refrigerators

Medium-term Recommendations

18. Retrofit cold storage buildings (refrigerated warehouses) by installing insulation and replacing inefficient cooling and refrigerating equipment, and install improved controls to significantly improve the EPI
19. Greater implementation of retrofitting and replacement programs for old inefficient refrigeration equipment.

Long-term Recommendations

20. Selective adoption of feasible new cold-chain and refrigeration technologies

5

Transport Air-Conditioning

5.1 Overview

An accessible and connected transport infrastructure is the precursor of socio-economic development of a country as the obstacles leading to immobility restrict market growth, increase production cost, and decrease accessibility.[51] In India, the transport sector is intrinsically diverse to cater to the needs of 1.25 billion people spread over a land area of 3.3 million km^2. One of the key characteristics of Indian transport is the dominance of land transport (both road and railways).[52] The Indian transport sector comprises one of the largest roads and rail networks in the world at 5.23 million km and 65,808 route km, respectively.[53]

India's high growth in passenger and freight traffic during the past two decades has primarily been driven by factors, such as improvement in infrastructure facilities under various programmes like the National Highways Development Project (NHDP), Jawaharlal Nehru National Urban Renewal Mission (JNNURM), National Urban Livelihood Mission (NULM), etc., coupled with rapid urbanization, increasing affordability of individuals, and presence of multinational vehicle manufacturers.

While the road transport sector in India has experienced an overall growth (including passenger-kilometre and tonne-kilometre) of over 12% CAGR in the last 15 years, rail transport has experienced overall growth of 2.5% CAGR. The current trends of growth in these sectors is expected to continue in the future years to meet needs arising due to expected rapid pace of urbanization coupled with population and economic growth. The growing transport sector also translates to increased cooling requirements in this sector due to harsh climatic conditions prevailing in the country. Mobile Air Conditioning (MAC) is growing rapidly and forms a significant proposition of the total cooling requirement in the country. Refrigerant demand for the mobile air conditioning sector has also been growing exponentially in the last three decades.

Fluorocarbons have been the choice of refrigerants in this sector HFCs (HFC -134a) (Zero ODP, High GWP) is globally used as a refrigerant in mobile air conditioning.

As the existing trajectory of increased transport demand will be associated with significant environment and socio-economic implication, it is imperative that policy measures are adopted in order to reduce cooling requirement, refrigerant consumption as well as energy (fuel) demand in this sector in the country. In this context, the chapter aims to develop a future road map required to achieve sustainable and green growth in this sector. In order to do so, the chapter discusses in detail the key trends of the transport sector in India with respect to vehicle population/stocks growth and refrigerant demand, the key issues and challenges faced by the sector that limits its growth, and also makes recommendations to push the sector on a green development path. Figure 5.1 shows the overview of transport sector in the country.

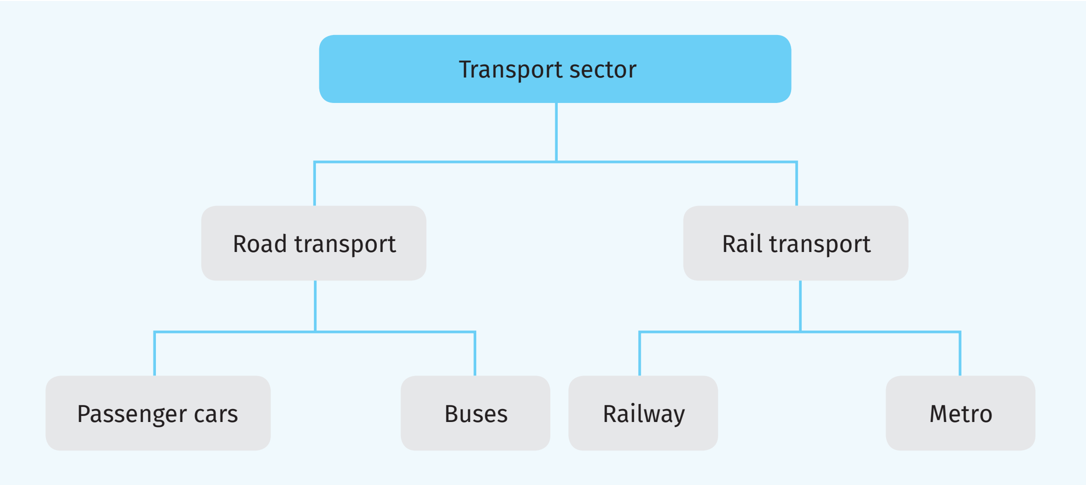


Figure 5.1: Transport Sector Overview

In this chapter, all the segments of the transport sector are considered for analysing refrigerant demand in the sector. Various modes of transport, such as road, rail, air, and shipping were taken into consideration to estimate refrigerant demand. During the course of the study it was observed that the aviation sector does not use refrigerant gases for cooling purposes rather air is used as refrigerant for air conditioning and refrigeration purposes. Also, shipping is identified as data gap, as the information on refrigerant use in the sector is not widely available, a separate study may be executed to conduct detailed analysis on the sector refrigerant demand.

In this background, this chapter considers the road and railways sector for analysing refrigerant demand. In road transport, passenger cars and bus segments have been considered while in the railways sector, railway passenger traffic and metro segment have been analysed.

5.2 Analysis

5.2.1. Methodology

Econometric techniques such as regression techniques, process models and end-use methods were used to estimate and project the end-use sectoral demands in the transport sector. The population and GDP projections were used as the main driving force for estimating the end-use demands. Schematic of the approach followed for the demand assessment is shown in Figure 5.2.

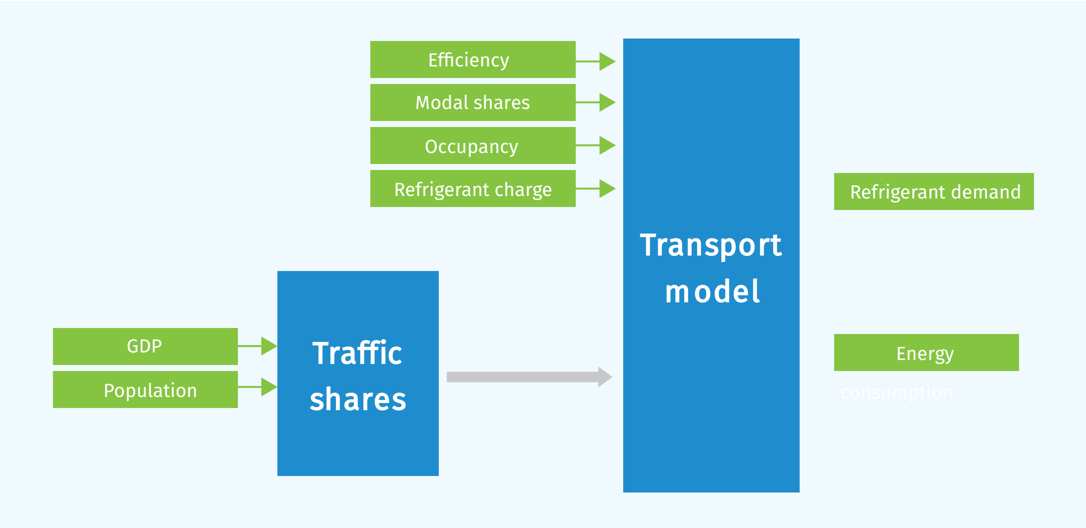


Figure 5.2: Schematic of the Assessment Model

The objective of these is to understand the sensitivities involved in demand fluctuation at varying pace of growth and development. With reference to the population, the Population Foundation of India (PFI) trajectory projects the population to rise from 1.2 billion in 2011 to 1.52 billion by 2031 and 1.75 billion in 2051. Table 5.1 surmises the assumptions made for GDP and population growth.

Table 5.1: Assumptions for GDP and population growth rates in India

Year	GDP growth rate (Average)	Population Growth rate (Average)
2001–02 to 2009–10	7.3%	1.47%
2010–11 to 2029–30	8.2%	1.23%
2030–31 to 2050–51	8%	0.75%

TERI's sectoral demand estimation model projects vehicle stock, energy demand through various socioeconomic indicators, such as per-capita income (indicator of purchasing power), population, and so on.

5.2.2. Passenger Car segment

The vehicle composition is primarily dominated by personalized modes (mainly two wheelers and cars) which account for nearly 86% of the total number of motor vehicles in the country. Two-wheelers alone accounted for 72% in the total vehicle population, followed by passenger cars at 13.5%, buses at 1.05%, goods vehicles at 4.8%, and other vehicles (a heterogeneous category that includes three-wheelers, trailers, and tractors) at about 8.25%, as on 31st March 2012 (MoRTH).

Figure 5.3 shows the demand projection for estimated on road vehicles up to 2037–38. It is estimated that India's car population will reach up to 145- 160 million by 2037-38. It is estimated that the passenger car segment may witness phenomenal growth of ~ 9% average growth during 2017–38 period. The calculation has been based on vehicles per 1000 population and GDP growth. Life of a car has been considered as 15 years. Being a developing country and will remain the same for a while, passenger cars penetration in India will not reach as developed world. However, the analysis proposes saturation level for passenger car market in India as per 200 cars per 1000 population. In the figure, Blue and red bars represent the estimated range of the vehicle stock. Range is provided on the basis of 95% prediction interval for the estimation.

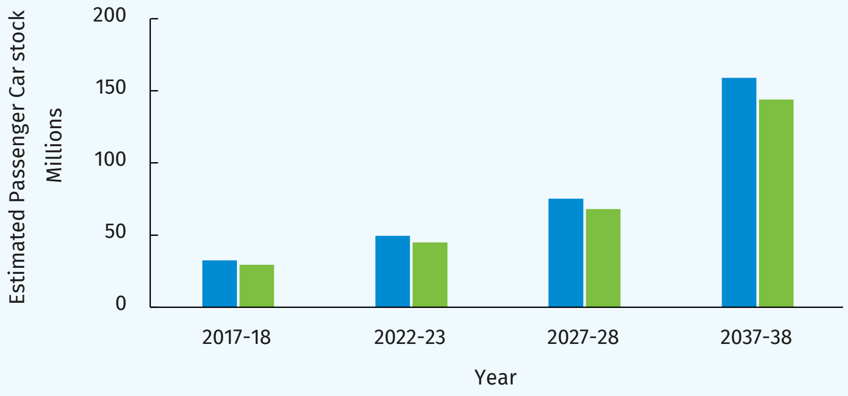


Figure 5.3: Estimated Passenger Car Stock

Vehicle AC consumes more energy than any other auxiliaries currently present in vehicles. The fuel consumption due to MAC operation can be measured if the usage and system energy consumption characteristics are known. In India, as per the TERI-UNEP study, 'Mobile Air-conditioning Assessment Study in India- 2007', share of MAC in the total car energy consumption is around 20%. This is due to high temperature and humidity, high cooling hours, smaller cars, and road congestion. Keeping in view and discussion with relevant stakeholders, we have perceived with MAC shares about 15%–18% of total energy consumption in a car which gives a range on estimated energy consumption due to MAC. Figure 5.4 elucidates the projected energy demand in the passenger car segment due to air conditioning.

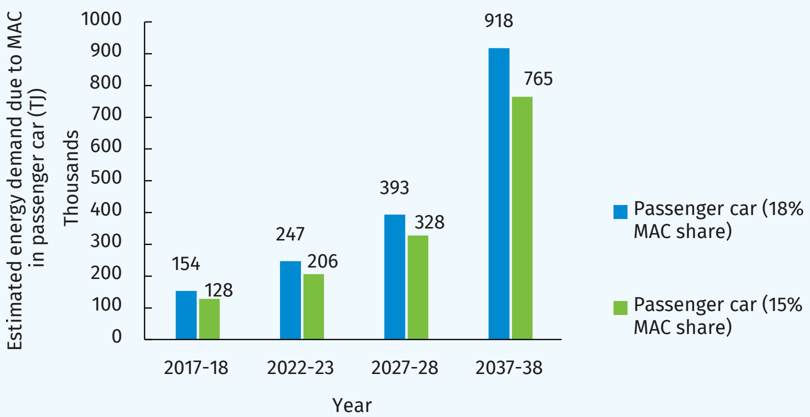


Figure 5.4: Energy Demand Projection due to MAC in Passenger Car segment

5.2.3. Passenger Bus Segment

While personal vehicles have shown a phenomenal increase, the percentage share of buses in the total number of registered vehicles has declined from 11.1% in 1951 to 1.1% in 2011–12, indicating slow growth (MoRTH). Despite, India is witnessing a significant increase in rural & urban bus population since two decades. Figure 5.5 provides insights on growth in the estimated on-road buses. However, as people are gradually moving towards personal vehicles, the population of buses will be eventually saturated around 2037–38. Range provided through red and blue bars is on the basis of 95% prediction interval for the estimation.

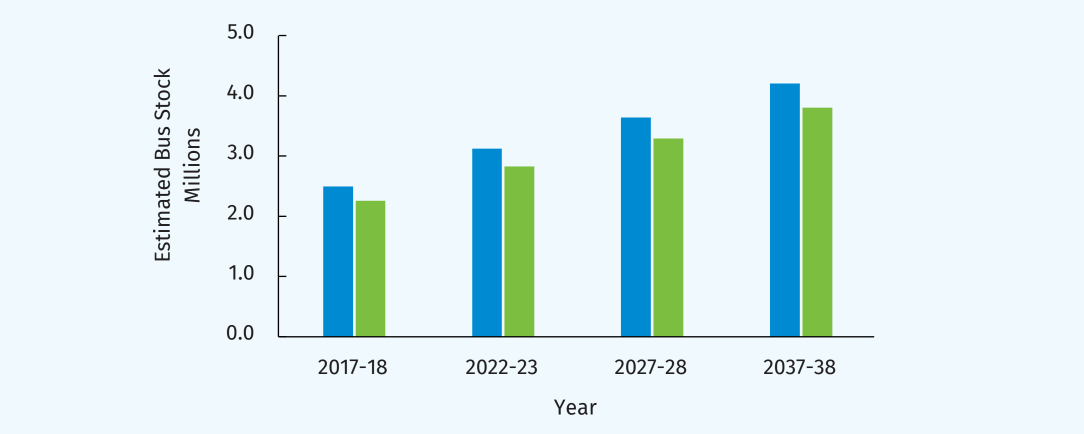


Figure 5.5: Estimated Passenger Bus Stock

Figure 5.6 presents the energy demand trajectory in bus segment considering the range as 15% - 18% share of energy consumption due to air conditioning in bus total energy consumption.

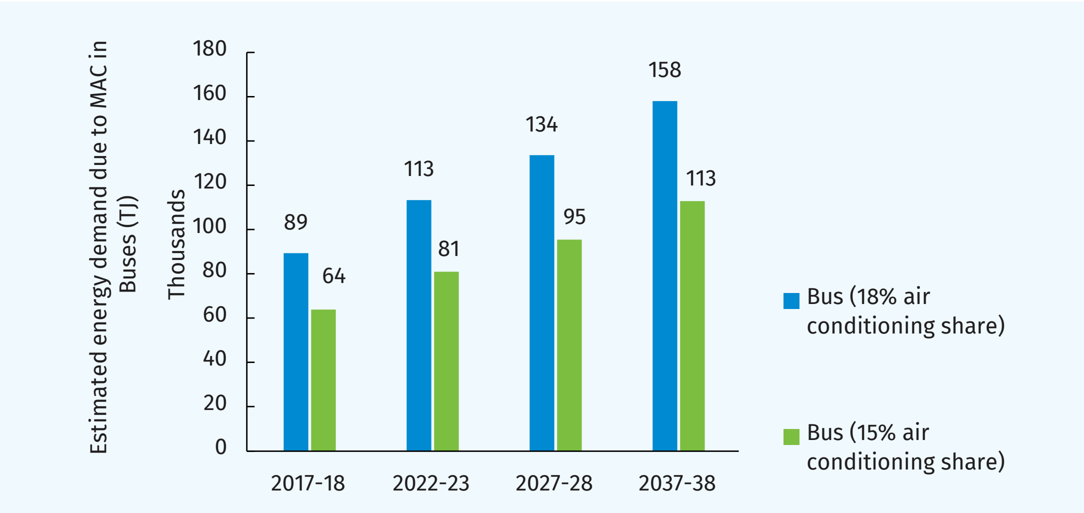


Figure 5.6: Energy Demand Projection due to MAC in Bus segment

5.2.4. Trucks

Trucks are increasingly used for transportation of goods in 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 the trucks has not been air conditioned. The proper conditioned environment is increasingly becoming necessity not only due to long distance transportation of goods leading to long service hours for the drivers in harsh working conditions but also for road safety including safety of drivers.

This sub-sector has not been covered due to lack of information available. A study will be instituted to assess the requirement of cooling, choice of technology, refrigerant consumption and the impact on fuel consumption.

5.2.5. Railway

Figure 5.7 elucidates the expected passenger traffic demand in railway sector. The blue and red bars represent the estimated range of the passenger traffic. The range is provided on the basis of 95% prediction interval for the estimation.

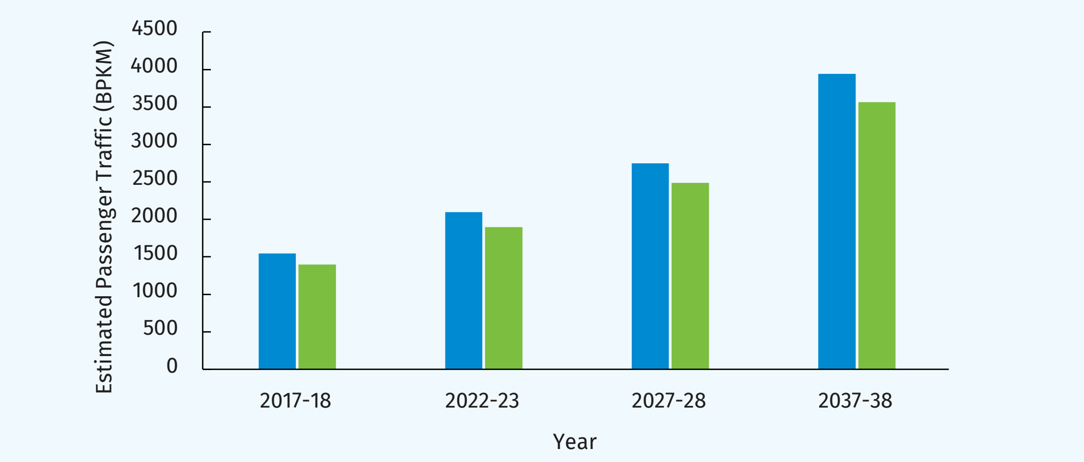


Figure 5.7: Estimated railway traffic (BPKM)

As the share of AC coaches' fleet is lower in railway segment, energy consumption due to air conditioning in total energy consumption in railway sector is quite low compared to other sectors. Figure 5.8 depicts the range for energy demand, estimated to be witnessed by railway air conditioning segment. Table 5.2 provides a summary detail of vehicle stock for all the segments of transport sector.

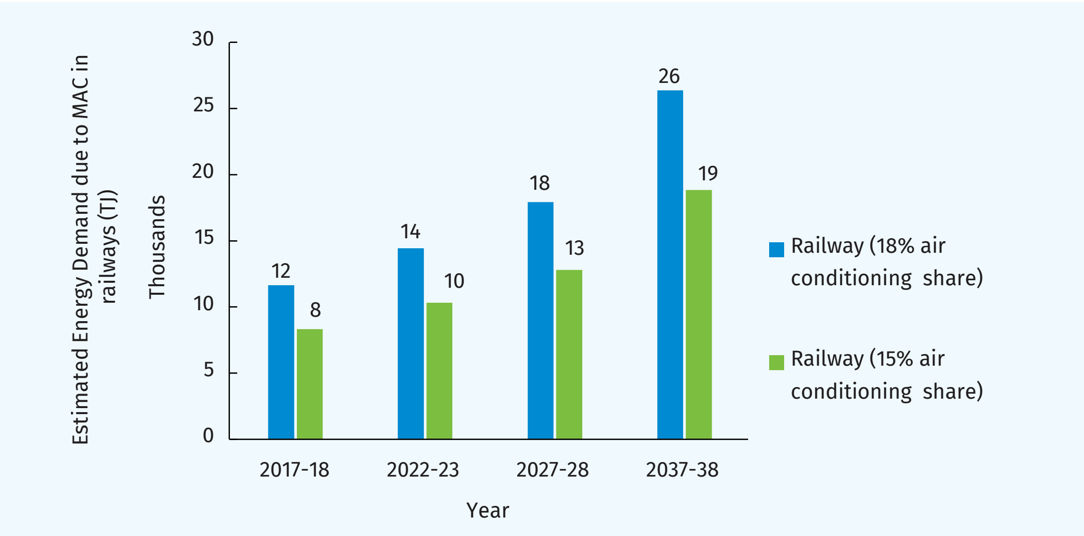


Figure 5.8: Energy Demand Projection in Railway Sector due to Air conditioning

Table 5.2: Summary of Projected Vehicle Stocks & Railway Traffic

Projected Vehicle Stocks & Railway Traffic			
Year	Passenger Car (Million Vehicles)	Bus (Million Vehicles)	Railway Traffic (Including metro) (BPKM)
2017–18	27-30	2.14-2.37	1312–1450
2022-23	45-49	2.83-3.12	1898-2098
2027–28	68-75	3.29-3.64	2485-2747
2037–38	144-159	3.80-4.20	3565-3940

5.3 Refrigerant Demand

Due to the transition from CFC to HFCs in the mid-2000s, HFC-134a quickly became the refrigerant of choice for new equipment as well as retrofits of CFC-12 designs. However, due to its high GWP, the use of HFC-134a increasingly faces restrictions around the world. The following sections provide the detailed model results for the refrigerant demand estimation. Results have been provided for the time span from 2017–18 to 2037-38.

5.3.1. Road Transport

Refrigerant demand has been projected based on yearly demand for vehicle in the year as well as servicing of the existing stock available. Necessary assumptions made during the analysis are given in Table 5.3. Assumptions have been based on various factors, such as discussions with stakeholders, available literature, and historical trajectories for the respective parameters.

Table 5.3: Assumptions for Road Transport

Parameters	Assumptions	
	Passenger Cars	Bus
Operational Life	15 years	20 years
Saturation level	200 vehicle/1000 population[54]	2.5 buses/1000 population
Refrigerant Charge Usage	0.63 kg/vehicle (cars)	6 kg/vehicle
% Share of AC vehicle in yearly production	100% (after 2015–16)	15% in 2017–18 growing to 35% in 2035 (based on the stockholder consultation)

Leaks from MAC are very high, reaching 10%–15% annually in developed countries (IPPC/TEAP, 2005). In developing countries, this is closer to 20% on average, reaching up to 40% depending on servicing and road conditions (UNEP, 2013).

Scenarios for demand in refrigerant in the passenger car segment have been estimated based on different leakage rates considering the technological improvement in the cooling system. Figure 5.9 presents refrigerant demand for two scenarios where leakage rate varies from 10%–25% over the given years. As per the estimation, refrigerant demand due to passenger cars would be around 19000-24000 MT by 2038. Therefore, it is clearly evident that meeting the projected demand will be a challenging task.

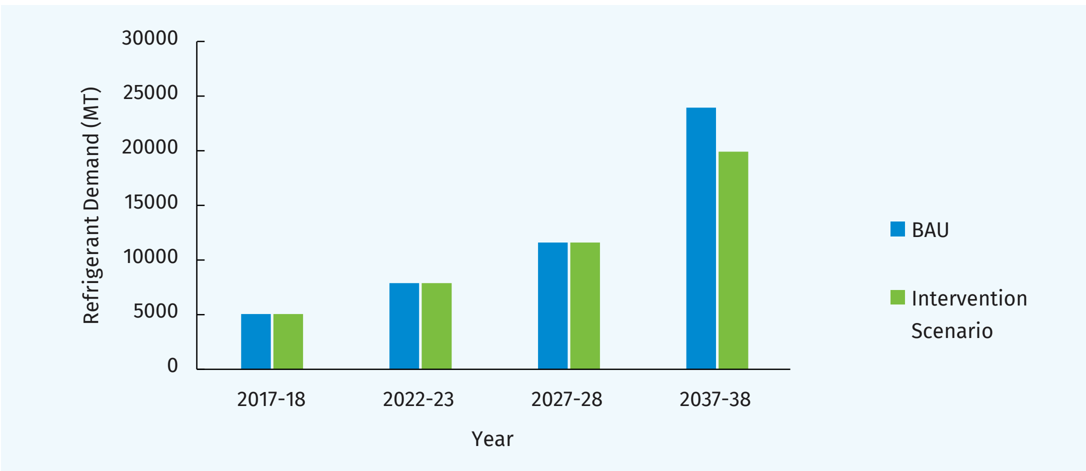


Figure 5.9: Refrigerant Demand in Passenger Cars Segment

Refrigerant demand evolves from approximately 5000 MT in 2017–18 to 12500 MT in 2027–28 and 23500 in 2037-38 provided that the same technology and leakage rate continue till 2038. However, considering technological advancement and improved MAC systems, leakage can be reduced, which is being reflected in the intervention scenario through reduced number of refilling. To have refrigerant demand estimation in the improved scenario, we have drawn results for intervention scenario (two-time refilling of the cars sold after 2020). The results show phenomenal reduction in the estimated demand, as the projected demand might be ~19000 MT (if refilled twice during the lifetime of car).

Figure 5.10 presents the refrigerant demand in bus segment where the share of AC buses in total bus segment is low (as per stakeholder consultation, 15% in 2015–16) compared to passenger cars. Government policies, such as the FAME India scheme for electric mobility, replacement and retrofitting existing urban public transport, etc., give an understanding that the government is planning to move towards electric-based public transport. Considering the above-mentioned schemes and historical trends, for the purpose of analysis, we have assumed that share of the AC bus fleet will reach up to 38% of the total fleet by 2035. This will lead to further increase in the refrigerant demand. Currently, most of the demand is being met with R 407C and R 134a.

The same exercise has been conducted to estimate refrigerant demand in improved scenario as used in passenger cars. It is being estimated that the demand might reach up to 370–510 MT by 2038. In the bus segment, we have estimated the results for BAU (3 times refrigerant refilling during lifetime of bus) and under intervention scenario considering lower leakage rate (two times refrigerant refilling during lifetime of a bus).

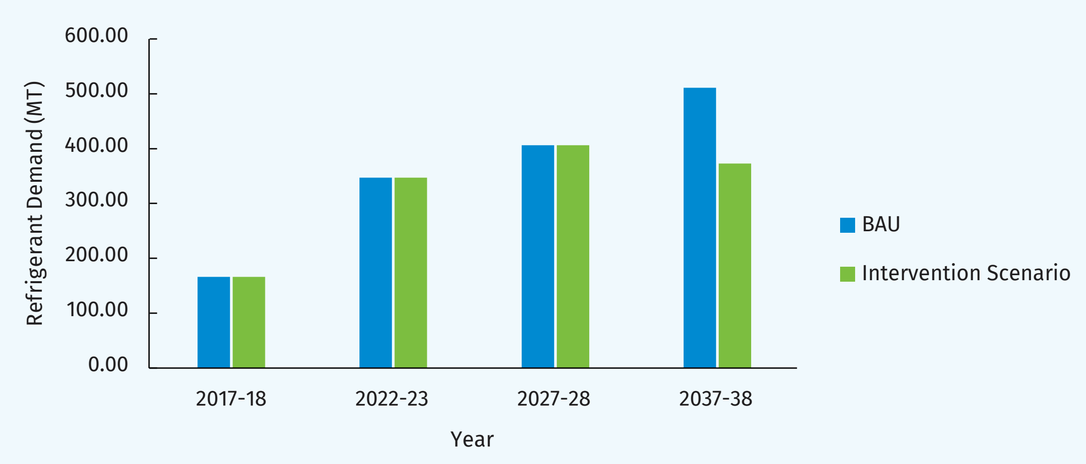


Figure 5.10: Refrigerant Demand in Bus segment

5.3.2. Railway

With the increase in average income in India over time, railway traffic has also seen a shift towards AC coaches. Also, complete air-conditioned trains have been introduced over the past few years. Parameters considered, and assumptions made during the analysis are given in the Table 5.4. As per RTOC (2014), refrigerant charge used in railway coaches is around 10 kg[55] which is used to carry out the analysis in this chapter. Figure 5.11 depicts the estimated refrigerant demand in the railway sector. Due to long lifetime of railway coaches only BAU scenario has been projected for refrigerant demand.

Table 5.4: Assumptions for railway sector

Parameters	Assumptions
Operational Life	40 years
Saturation of passenger movement on rail	2500 km/capita
Refrigerant Charge	10 kg/coach
Share of AC Coaches	20% (Railway Board, 2017) in 2015–16 and would reach up to 35% by 2035

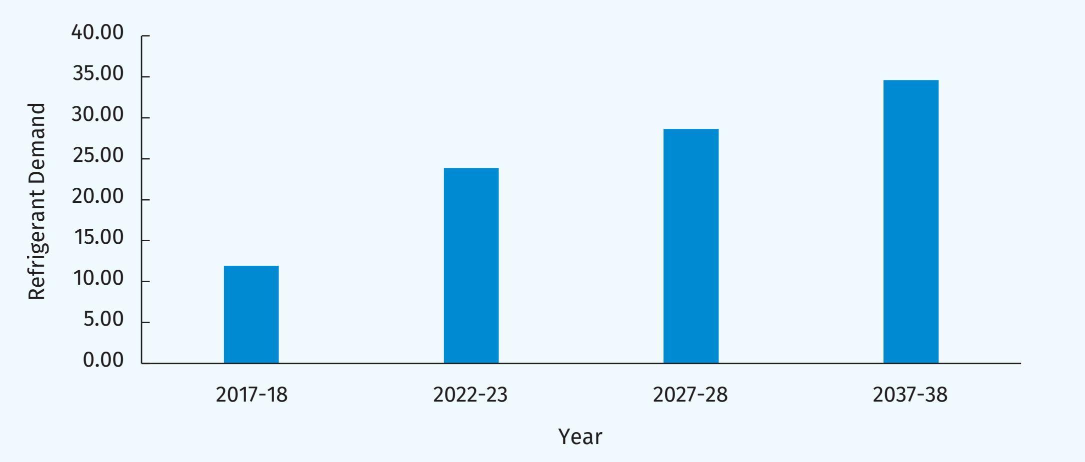


Figure 5.11: Refrigerant Demand Projection in Railway Sector

In conclusion, it can be said that India is going to foresee substantial demand increase in refrigerant consumption and transport sector will play a major role in the estimated demand. In order to arrive at a comparative analysis among the different modes of the transport sector, Table 5.5 presents the potential of refrigerant demand in all the three categories— passenger cars, buses, and railway coaches. Maximum demand is predicted to come from passenger car segment. The ranges presented in Table 5.5 signify the number of times of refilling the refrigerant which further signifies the leakage rates.

Table 5.5: Short-term, medium-term, and long-term refrigerant demand

Refrigerant demand (MT)				
Year	Passenger Car	Bus	Railway (Including metro)	Total demand (MT)
2017–18	4000-6000	140-180	10–14	4150–6194
2022-23	7500-9000	320-370	21-25	7841-9395
2027–28	10500–13000	390–450	27–31	10917–13481
2037–38	19000–24000	370–510	33–37	19403–24880

5.4 The Future of Transport Air-conditioning

5.4.1. Refrigerant Technologies and Future trends

The Mobile Air Conditioning (MAC) sector has been witnessing very high growth due to low base line and growing GDP coupled with population growth in the country. The MAC industry in the country, however, faces huge uncertainty in terms of future technologies and associated costs vis-a-vis the refrigerants. This is primarily because India has proposed 2028 as the freeze year under the Kigali Amendment to the Protocol, marking the start date to limit HFC use.

To reduce the refrigerant demand as well as global greenhouse gas emissions from mobile air conditioning, the following ways may be explored:

1. Improving the current HFC 134a-based MAC technologies and reduce the charge use capacity
2. Switching to other low GWP refrigerants
3. Explore the possibility of other non-vapour compression type technologies

Improved HFC-134a Systems: Many efficiency-improving technologies are now being used in current production of HFC-134a systems, for example, internal heat exchangers, oil separators in compressors, increased use of externally controlled compressors, etc. Internationally, with the introduction of the credit system in the USA and also upcoming legislation in Europe, more vehicle original equipment manufacturers (OEMs) are introducing technologies to reduce fuel consumption with HFC-134a refrigerants.

HFO-1234yf Systems: HFO-1234yf systems are able to achieve the same system performance and fuel efficiency as HFC-134a system if they use either an internal heat exchanger (IHX) or a condenser in which the sub-cooling area is enlarged by about 10% while keeping the same total exchange area.

Carbon Dioxide (R-744) Systems: R-744 refrigerant charge volume is typically reduced by 20%–30% as compared to HFC-134a systems. R-744, with suitable system design and control, has shown to be comparable to HFC-134a systems with respect to cooling performance and total GHG emissions due to MAC systems.

HFC-152a Systems: Due to its flammability, HFC-152a would require additional safety systems. Recent development activities have been focussed on using this refrigerant in a secondary loop, preferably in a double secondary loop system (RTOC 2010) for safe use. Refrigerant charge amounts could be reduced by 25%–30% with a secondary loop system and, typically up to 50% in double secondary loop system. Industry experts have recommended using HFC-152a, but only in a secondary loop type system. A secondary loop system uses glycol and water as the coolant in the passenger compartment. The coolant is cooled under hood by the refrigerant. A double secondary loop system uses glycol and water as the direct coolant passenger compartment and another glycol and water loop being used with the condenser. The use of two loops prevents refrigerant leaking into passenger compartment or leaking during breach of condenser during an accident.

Currently, more than one refrigerant is being used for the car and light truck air conditioning system. However, HFC-134a is the most commonly used refrigerant, while HFC-1234yf is piloted in some models and anticipated to upscale its usage in more models in the years to come. R-744 car air conditioning systems have also been developed and used commercially in some models especially in Germany. It has not yet accepted for high end car models due to its initial costs and is expected to roll out in for industrial applications.

5.4.2. MAC System Technologies and Future Trends

Significant R&D efforts focus on improving the energy efficiency of current systems by deploying efficient compressors and internal heat exchangers as well as exploring the possibility to use. Current MAC are becoming obsolete, resulting in the development of advanced and innovative systems focussing on energy efficiency, cost competitiveness, and better durability. The global automakers focus and prefer to use refrigeration systems with minimal environment effects and high safety.

The adoption of improved components (compressor and heat exchangers) and the introduction of internal heat exchangers have improved the efficiency of the system.

Certain opportunities, such as Ejector, high side pressure controller, two-stage compressor, and low leakage along with improved hose materials can also reduce fuel consumption thereby refrigerant emissions and minimize the frequency of required maintenance or service.[56]

Apart from technological improvement in MAC system, some of the passive technical solutions can be employed to reduce the cooling load resulting in optimum refrigerant usage and fuel consumption.

It is expected that the passenger cars and light duty vehicle domain is rapidly moving towards downsized turbocharged engines often coupled with different levels of hybridization to make the overall powertrain more efficient and reduce the CO_2 emissions. Increased levels of transmission gears, moving vehicles from 4/5/6 levels to 7/8/9 levels reduce the average compressor speeds, thus, implying AC capacity concerns at low speeds in some cases or to the increase of the compressor displacement or finally to the adoption of electrically driven systems (RTOC, 2014).

Also, various regulatory measures around the globe are driving to more efficient on-board systems, including MACs and to the replacement of high GWP fluid with lower GWP substances.

In this framework, the thermal systems and especially the MAC systems have a relevant role and will likely undergo a deep change where the system integration will represent a relevant evolution guideline.

Stop & Start and Hybrid Vehicles: The diffusion of vehicles able to carry out part of their mission with the combustion engine off (e.g. stop & start, extended stop & start, and hybrids) asks for new solutions for the air conditioning system to guarantee the summer and winter thermal comfort in all the operational conditions.

The majority of these vehicles will have 12 V to 48 V electric energy sources and only part of them will have higher voltage network (e.g. up to 350 V), while all will have an additional on-board electric energy storage unit with a capacity ranging from 0.2 kWh (low voltage) up to 5 kWh (high voltage).

Plug-in Hybrids and Battery-driven Electric Vehicles: For Plug-in Hybrids (PHEV) and Battery-driven electric vehicles (BEVs), vehicle air conditioning systems for cooling as well as heat pump systems for heating need to be highly energy efficient to minimize the impact on the vehicle driving range.

5.5 Policy Mapping

The government has pushed the transport sector towards green growth by promoting policies which improve the green coverage alongside highways to mitigate the air pollution concern and improve the (fuel) efficiency of the vehicles to effectively meet the fuel demand. As far as refrigerant use is concerned, road transport has already been shifted to HFCs for cooling requirement; the sector is not affected by the on-going HCFC phase out plan. It may be noted that historically, refrigerants have not been considered while establishing the sector-wise policy frame work. Policies which may have an impact on refrigerant demand are being mentioned herein.

Improved efficiency of vehicles across modes:

To reduce the average fuel consumption of new cars introduced in the Indian market, medium and long-term fuel consumption standards for new cars have been announced. The Government of India through the Bureau of Energy Efficiency has notified the CAFÉ norms for passenger cars in 2015. Phase 1 of the fuel efficiency norms have been implemented during 2017–21 and Phase 2 will be effective from 2022 onwards. The Fuel Consumption Standards provide a mandate to manufacturers to continuously reduce the average fuel consumption of cars sold by them in the next 10 years.

Push towards public transport:

The Atal Mission for Rejuvenation and Urban Transformation (AMRUT) programme of Government of India aims to develop urban infrastructure. The impact of AMRUT on the transportation sector will primarily focus on improved infrastructure facilities. It will suggest urban reforms to decentralize funds and functions, thus ensuring that positive measures to improve transport infrastructure is in the hands of urban local bodies. This will result in efficient transportation systems in the 500 cities and towns where this mission is implemented along with a rise in the level of transport activity in those cities.

As we move towards public transport, overall mobile cooling demand might witness a decline so the refrigerant as well.

Faster adoption of hybrid and electric vehicles in India:

The Government of India has launched a scheme titled FAME India '(Faster Adoption and Manufacture of Electric Vehicles in India) under the National Electric Mobility Mission Plan (NEMMP) 2020. This scheme focusses on providing incentives for the manufacturing and promotion of both hybrid and electric vehicles in India. Success of this scheme will lead to higher penetration of electric vehicles in the public transport system. Growing share of airconditioned vehicles in road transport will increase the refrigerant demand in the country.

5.6 Recommendations

In the rapidly changing world, government policies need to be flexible enough to encompass the contemporary requirements *vis-a-vis* the energy sector. The government is well intended to develop a future road map for green growth along with minimal carbon footprint of the transport sector in India. However, demand projections in this chapter regarding cooling in transport sector, impose a formidable challenge to achieve the intended objective.

Short-term Recommendations

- Improved efficiency of vehicles across modes:
  - Through efforts such as the fuel efficiency norms, there should be a continuous increase in the energy efficiency of vehicles.
  - While testing of the vehicle for compliance with CAFÉ, currently air conditioning has been switched off. Testing may be considered with AC ON, which would give a more realistic fuel consumption scenario. There is a 30%–40% improvement potential available in the passenger car MAC system (IPCC 2005).
  - Mandatory testing of all new manufactured air conditioned passenger cars with air conditioner 'ON' condition to provide realistic fuel efficiency and emissions profile for encouraging improved mobile air conditioner efficiency
  - Policies for promotion of compliance with CAFÉ standards
  - Use of new technologies in the field of mobile air conditioning should be encouraged to make the system more efficient.

- Star labelling of Passenger Cars:
  - Labelling systems for cars could help consumers to make informed choices and promote efficient vehicles.
  - In addition, other incentive and disincentive mechanisms can help push efforts in improving transport sector emissions intensity.
  - COP and fuel consumption of the mobile air conditioning system can also be mentioned on the label which will further make consumers aware about importance of air conditioning in overall fuel consumption.
- Incentivise the manufacturers while compliance with CAFÉ standards: Extra credits can be given to the manufacturers who comply with CAFÉ norms and if they use high energy efficient MAC system in their fleet.

Medium-term Recommendations

- Push towards public transport:
  - Large volume of the transport infrastructure is going to be built in the near future to provide access both in urban and rural regions. It is therefore important to ensure that the modes identified for providing access are relatively efficient and less cooling intensive.
  - Reduction of cooling and refrigerant demand by shifting the passenger traffic towards public transport.
  - Development of low refrigerant charge MAC systems including secondary loop systems.
- Incentives or rebates for energy efficient technology:
  - Investment is required in the system modification to improve the efficiency and adopt a new refrigerant. For example, changes in AC piping/hoses and internal heat exchanger to use HFO 1234yf in MAC leads to extra cost in manufacturing. At present there is no credit policy which prevents OEMs to implement new technology due to no benefit and extra cost. There is need of robust financing policy or fiscal incentive programme for energy efficiency investments.
  - Also, better coordination is required for resolving patent issues. It is significant to mention here that resolution of patenting issues from gas manufacturers can lead the way for readily available HFO gas use as refrigerant in MAC systems.
  - Promote compressor manufacturing in India and incentivise those manufacturers who produce compressors in India.

Long-term Recommendations

- Improving the MAC systems efficiency of hybrid and electric vehicles in India: Cooling requirement in EVs is high compared to conventional vehicles, as it requires secondary cooling for the battery. This may increase the refrigerant demand in the near future. Therefore, it is necessary to look for higher efficient MAC systems in hybrid and electric vehicles.
- Push towards building integrated and high-quality public transport systems in Tier 2 and Tier 3 cities to reduce the personalized vehicle demand.

6

Refrigeration & Air-Conditioning Servicing Sector

6.1 Introduction

An important implication of the rapid increase of ownership of residential and commercial air-conditioners, as well as cars, is that the market for servicing these technologies has also increased rapidly. RAC servicing sector is important as it is directly related to (i) consumption of refrigerants and (ii) optimum and efficient performance of in-use air conditioning equipment. Interventions in RAC servicing sector provide for twin benefits of environmental protection and livelihood enhancements. The HPMP Stage II roadmap estimates that the servicing sector consumes more than 40% of the total refrigerant consumption in the country Thus, Training of RAC service technicians becomes important. More so, the new alternative refrigerants while phasing out HCFCs are either mildly flammable or flammable. The technicians need to be trained on their safe handling. Besides, more service technicians are in informal sector then in the formal one.

For the RAC servicing sector, formal sector is defined as the enterprises that are incorporated under the Companies Act, or registered under Shops and Commercial Establishments Act, Micro, Small & Medium Enterprises registration, etc., while informal sector are own-account enterprises which are unincorporated or lack legal organization, as well as freelance/ self-employed technicians. It should be noted that formal sector enterprises may employ informal/ casual workers and unregistered enterprises may formally employ technicians. One important characteristic of 'formal employment' is access to social security benefits, provident fund, workman's compensation, etc.

It is important to view the servicing sector within a framework that can capture the key aspects of this sector and how these aspects influence each other. Figure 6.1 presents a framework of elements that are critical for better understanding of this sector, and devise policy interventions for preparing for the future.

Figure 6.1: Framework of RAC servicing sector

6.2 RAC Servicing Sector

6.2.1. Use of Refrigerants in RAC Servicing Sector

An important cornerstone for the development of the ICAP has been the concern for refrigerant emissions due to leaks, and the consequent ozone and/or climate impacts. Refrigerant gases leak out of the AC system and must be refilled by service technicians for the system to perform optimally. Refrigerant gases are also used for flushing the system, leading to further usage of the gases during servicing. Finally, at the end of the life of an air-conditioner or a car, the residual refrigerants in the system are typically not recovered before the system is salvaged for its parts. Due to lack of timely leak testing, practices like 'refrigerant top-up', and weather conditions that cause corrosion of tubes, actual consumption of refrigerant during operation of equipment and servicing is much higher. This is true across the globe. Wider adoption of good servicing practices by RAC service technicians shall lead to reduction in the consumption of refrigerants during servicing of air conditioning equipment.

6.2.2. Energy Efficiency of Air-conditioning Equipment and Servicing Sector

Poor servicing practices can also lead to decrease in the energy efficiency of in-use air-conditioning equipment. Even if an appliance with high potential efficiency is installed, it will not be able to realize its potential while in-use if it is not installed, maintained, and serviced properly, thus leading to increased electricity consumption. The TEAP Report (2018) observes that:

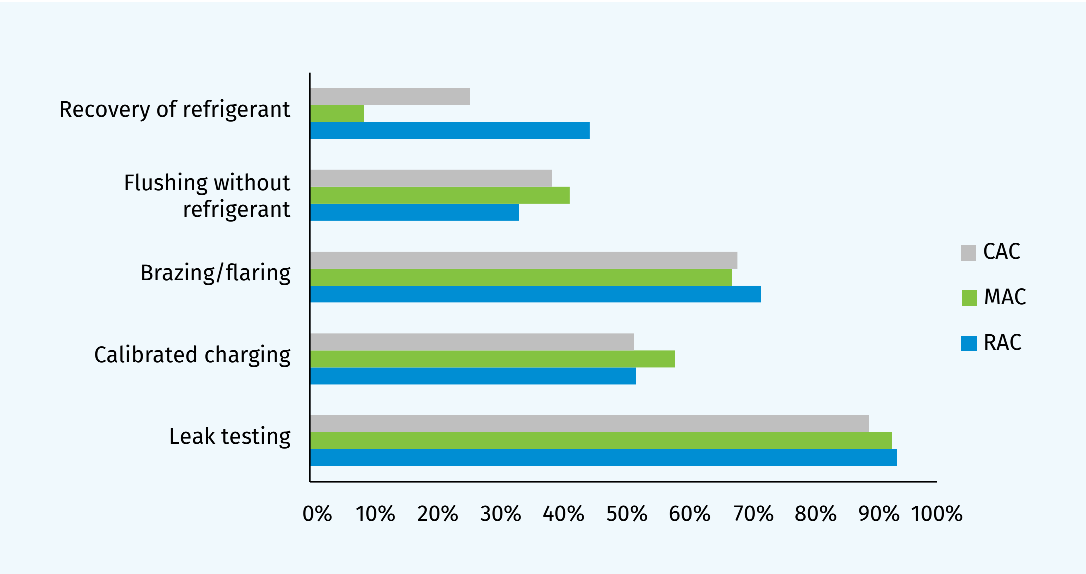
- Some energy efficiency degradation over the life time of equipment is inevitable; however, there are ways to limit the degradation through improved servicing which include both installation and maintenance.
- The impact of proper installation, maintenance and servicing on the energy efficiency of equipment is considerable over the working lifetime of these equipment while the impact on additional cost is minimal.
- Proper maintenance and servicing can curtail up to 50% reduction in performance and maintain rated performance over lifetime.

Currently, there are no policies that focus on the servicing sector for energy efficiency gains. All the energy efficiency related policies focus on the appliance related energy efficiency.

6.2.3. Servicing Practices

Given the importance of good service practices (GSPs) to the reduction of refrigerant consumption and maintenance of rated energy efficiency of in-use equipment, it is important to understand what the current level of adherence to GSPs are in the field, and what factors can improve them. A recent survey (Sridhar and Chaturvedi, 2017) of service technicians listed specific GSPs and attempted to find if servicing technicians generally follow these or not. The survey revealed that one practice that was followed across all sectors was that of leak testing. Apart from this GSP, no other GSP was followed by most technicians. Calibrated charging was followed by less than 60% of the surveyed technicians. Less than half of the technicians followed flushing without refrigerant, and even fewer followed recovery of refrigerant. Figure 6.2 shows a pattern of GSPs followed by the RAC technicians in commercial air conditioning (CAC), mobile air conditioning (MAC) and Room air conditioning in the country.

Figure 6.2: Pattern of GSPs Followed by RAC servicing Technicians



Generally, service technicians do not recover the remaining refrigerant from the leaking units in residential equipment as well as from cars due to various reasons ranging from cost of the recovery equipment, to time spent in the process, to lack of reclamation facilities in the cities. Recovery and reuse of recovered refrigerant, where possible, while servicing has the potential to reduce refrigerant consumption.

The survey's important finding was that training is an important predictor of adoption of GSPs. The way the survey defined training included long-duration training for the beginners, e.g. from ITIs, as well as short duration trainings provided by the government or other agencies. Though the research highlighted that training has a positive impact on the adoption of good servicing practices, it revealed that training is in itself not sufficient for ensuring that good servicing practices are followed.

Equipment end-user, i.e. the consumer can contribute positively or negatively to proper servicing. The survey also highlighted the importance of customer awareness, which plays a role in increasing adherence to GSPs by technicians. Technicians also reported that often customers due to time or price sensitivity, are unwilling to get their equipment properly serviced. If high efficiency equipment is not serviced and maintained properly, it will be operating below the potential equipment efficiency. The role of servicing technicians is very important part of this process, as is the role of customers who need to ensure regular servicing of their air-conditioning equipment.

Sridhar & Chaturvedi (2017) also highlights the issue of ownership of tools as being important for proper installation, servicing and maintenance of air-conditioning equipment. Though, tools are considered important, the ownership rate of the complete set of tools required for following GSPs is low, arguably due to their high cost as well as challenges in handling their transportation to servicing site, given that most technicians travel on two-wheelers. Cost of servicing tools matters, especially for technicians who have their own enterprise or who freelance. As per industry estimates, the full set of tools for technicians can cost around INR 200,000. It is critical to consider this aspect while planning for adequate servicing and maintenance of equipment.

6.2.4. Market growth: An Immediate Need to Plug the Data Gap

For planning and policy formulation for the servicing sector, it is imperative to understand the current number of servicing sector technicians, as well as their potential future growth. It is estimated that around 200,000 technicians in the stationary air conditioning service sector as per existing AC stock are present in the country (HPMP Stage II Document, 2017). Many service technicians are also involved in Car Air Conditioning (MAC) sector.

In terms formal vs informal break-up of technicians in the MAC sector, Federation of Automobile Dealers Association (FADA), reports that approximately 50% of servicing enterprises to be informal. Number of technicians employed by car dealerships falls between 40 – 50 on average according to a FADA estimate. Among the formal enterprises in MAC, about 75% are authorised service centres and remaining is constituted by multi-brand service centres. There is huge potential for employment generation in this sector.

An in-depth study is required to assess number of air conditioning and refrigeration (RAC) service technicians in residential, commercial and mobile air conditioning. Similar assessments would also be required for cold chain, and process cooling sectors which have not been separately dealt here. Irrespective of the number of service technicians, what is known with certainty is that the size of this market will grow at a fast pace in the country given the growth in ownership of air-conditioners and cars in the country.

6.2.5. Training and Certification

6.2.5.1 TRAINING

Training is critical for service technicians to properly deliver on their job. Training has to encompass various aspects of the air-conditioning system, ranging from technical operation and servicing of the system, to safety issues and occupational hazards. Given the context, training cannot be only a theoretical training, the practical training is a critical aspect of the training process. Experiences from previous servicing sector projects funded by Multilateral Fund (MLF) for the implementation of the Montreal Protocol in India have shown that technicians who have undergone training significantly improve servicing practices.

Training programmes to familiarise technicians with the ODS phase-out scheme under the Montreal protocol was first set up in India in 1998 through collaborative efforts by the Indo-Swiss-German leading towards Ecological Refrigeration in the country two projects, Ecological Refrigeration (ECOFRIG) project and Indo-Swiss project for the Human and Institutional

Development in Ecological Refrigeration (HIDECOR). National CFC Consumption Phase-out Plan (NCCoPP) funded by the Multilateral fund (MLF) for the implementation of the Montreal Protocol. About 20,000 RAC technicians were trained on GSP under these two projects. Following these, short-duration training on reducing refrigerant emissions has been carried out through the HCFC Phase-Out Management Plan (HPMP). Stage I of this plan involved training more than 11,000 technicians, and Stage II of the Plan will train around 17,000 technicians. Despite these efforts, only a small number of technicians, especially in the informal sector have received any form of training and there is a need to assess the status of skill development in the country:

Recently, the Ministry of Environment Forest and Climate Change and the Ministry of Skill Development and Entrepreneurship, Government of India, signed a Memorandum of Understanding to train 100,000 RAC service technicians in good servicing practices and the new alternative refrigerants under the Pradhan Mantri Kaushal Vikas Yojana (PMKVY) – Skill India Mission. This training of RAC service technicians has positive impact on environment in terms of reduced refrigerant leakages and better performance of in-use air conditioning equipment and on the livelihood opportunities of the service technicians.

6.2.5.2 PERCENTAGE OF TRAINED TECHNICIANS IN FORMAL AND INFORMAL SECTORS

A study conducted by Centre for Energy Environment and Water (CEEW) revealed that the percentage of trained technicians is more in the formal sector than the informal sector (Sridhar and Chaturvedi, 2017). Figure 6.3 shows the percentage of trained technicians in the formal and informal sectors.

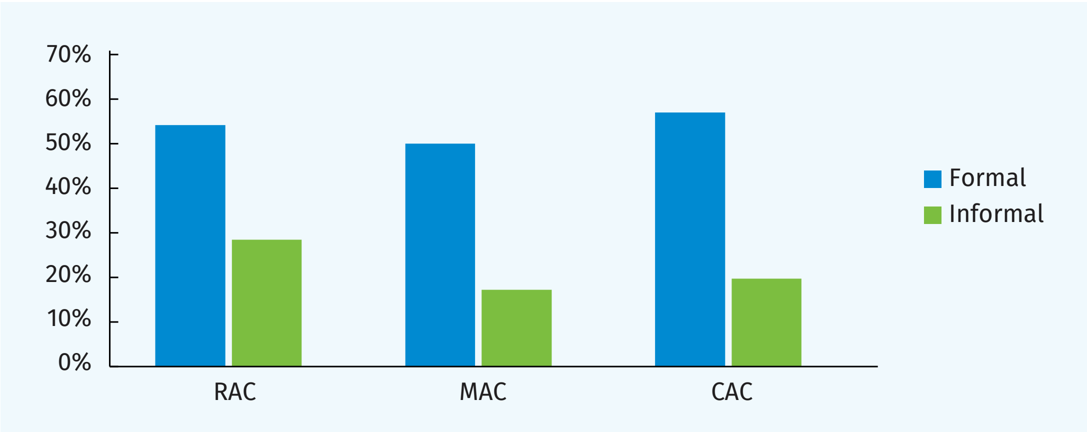


Figure 6.3: Percentage of Trained Technicians in Formal and Informal Sectors

6.2.5.3 TRAINING LANDSCAPE

Currently, there are various channels for training of technicians. Broadly speaking, trainings are available for beginners as well as short-duration refresher courses/ recognition of prior learning programmes for people who have been working in the sector for some time. Many institutes offer courses for both these categories of people. The training channels open to technicians are:

1. Private companies that train their technicians,
2. Industry and associations (ISHRAE and RASSS),
3. Ministry of Skill Development and Entrepreneurship (ITIs, Polytechnics, National Skill Development Corporation – Electronic Sector Skill Council of India)
4. Other agencies (multilateral agencies like GIZ-HPMP project).

The Figure 6.4 presents the landscape of RAC Training providers in the country.

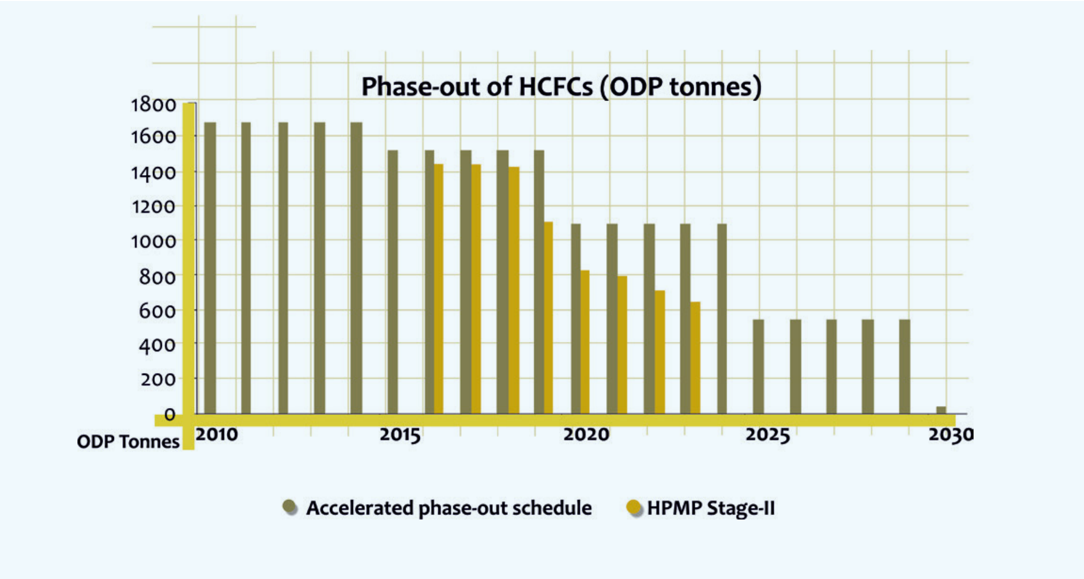


Figure 6.4: Service Sector Training Landscape

There are about 12,000 service personnel being per year trained by Industrial Training Institutes (ITIs). The duration of the course is two years after 10th standard. Polytechnics provide a three-year diploma programme, though most of these programmes are in mechanical engineering with refrigeration and air conditioning as an elective course. Most of the diploma holders are employed in supervisory positions in manufacturing industry and service personnel teams.

Most service personnel entering in RAC service field do not go through a formal vocational training. They learn while doing under the supervision of senior service personnel. In the changing environment where higher tech RAC equipment is entering the market and changing scenario with respect of refrigerants including flammable refrigerants, refresher courses have become the need of the day, while also updating the fresher diploma programmes. In summary, regardless of the beginner training programs available, a large number of technicians currently operating in the market require refresher trainings.

6.2.5.4 TRAINING INFRASTRUCTURE

Training infrastructure, i.e. quality training centers having state of the art equipment, qualified trainers, a good trainer-trainee ratio, and sufficient hands-on training are the cornerstone of any skill development mission. Two recent reports, the Standing Committee on Labor report on 'Industrial Training Institutes and Skill Development Initiative Scheme' (ITI& SDIC) and the Report of the Committee for Rationalization & Optimization of the Functioning of the Sector Skill Councils (SSC) have highlighted the areas in the training infrastructure in the country, i.e. the ITIs and Training Centers affiliated with sector skill councils which need further strengthening.

The key areas of focus include industry partnership in training, strengthening of infrastructure at training centers, updating of curriculum and trainers with recent developments in technology, increase in employability of trained technicians. These areas are also important with respect to training of RAC service technicians.

6.2.5.5 CERTIFICATION

The UNEP OzonAction defines certification as "means by which a person (or enterprise), as a result of training, education, external review and assessment, receives official approval of being able to competently complete a job or task." Certification can be after a formal assessment as explained or that of participation received by attending a course or training. The latter cannot replace a formal certification preceded by skill and knowledge assessment. While a lot of training can terminate with certification, OzonAction recommends separation of the two steps for impartial assessment.

There are many certification schemes across different countries, many of which or voluntary or mandatorily required. In India, employers consider ITI diplomas as formal training. Trainings for RAC service technicians are implemented by industry. ISHRAE also runs training programmes RAC service technicians where assessment and certification is part of the programme.

The Ministry of Skill Development and Entrepreneurship (MSDE), Government of India is mandated with development skill ecosystem in the country and oversees and administers skilling and vocational training. There is a specific focus of the Government on skilling through the Skill India Mission implemented by MSDE. The National Skill Qualification Framework under MSDE provides for certification of skills through National Skill Development Corporation, which implements the certification programme through thematic Sector Skill Councils. The RAC servicing sector is catered by the Electronic Sector Skill Council. This could be further strengthened in terms of infrastructure and technical content. This system could be developed as a single certification system that has to be obtained by all technicians. The same can be updated as per the latest technical standards and criteria.

While many technicians recognize the value of certification, few have any such certification. Furthermore, many technicians believe that such certification does not prepare them for their profession as the curriculum is largely theoretical knowledge, and on-job training becomes necessary. , The most important benefits of certification is standardization of training, a minimum level of skill, and assurance to customers and employers regarding the technicians' skills. In many countries, such certification for technicians is not only considered important, but has been made mandatory. Given the large impact of refrigerants on the environment and the increasing use of flammable refrigerants, such certification may be necessary in the long-run.

The certification system could be strengthened by the following:

- Uniform and standardised and in-depth training curriculum that is in line with latest available technical improvements;
- Sufficiently large network of training centres across the country;
- A system of checks and balances that ensure constant interaction with certified technicians for unbiased feedback, which in turn can be used to improve the assessment methods;
- Awareness among customers and employers will be required to incentivise the benefits of training.

Therefore, certification should be introduced in a gradual manner so that technicians are prepared for it and are not forced out of the profession due to lack of ability to access training.

6.3 Enterprise Characteristics

Servicing sector enterprises are an important part of the value chain. Given that the penetration of air-conditioners and cars is still very low in the country, the nature of servicing sector enterprise sector is still evolving. There are, however, some interesting characteristics of this sector in the country. Broadly speaking, there are three channels through which Room Air-Conditioners servicing is offered in the country.

6.3.1. Manufacturing Companies

The first consists of manufacturing companies. The manufacturing companies have a formal servicing setup and a pool of trained service personnel. These companies largely operate through franchised service network i.e. third-party sales and service dealers or authorized service providers, though they may have a few engineers/technicians on payroll, at supervisory/managerial levels. The company routes the service calls/requests for both installation and repairs to these franchisees. Actual service delivery is completed by these franchisees using their service technicians.

Most of the products under the category of air-conditioners are warranted for a period of one year. During the warranty period apart from assuring satisfactory performance of the product, a few proactive services are provided by almost all OEMs at site. It is also a prevalent practice that the installations are often done by a technician employed by the sales distributor/dealer of the OEM. These technicians have been trained only for installation and a certain few routine checks of the product to commission the unit after installation at the customer premises. These technicians do not have thorough diagnostic skills on the product. This practice has become popular to cater to the demand for speedy installation after the air conditioner has been purchased by the customer. After the warranty period has expired, customers generally resort to non-authorized service enterprise or freelance technicians due to the relative expense of authorized servicing.

6.3.2. Third Party Servicing Companies

The second channel consists of third-party servicing companies. These could be either formally registered or unregistered, but they do not have any franchisee relationship with the OEM. In the MAC sector, many such enterprises offer specialized services and may even be preferred by customers.

6.3.3. Freelance Technicians

The third channel is that of the freelance servicing technicians available in the country. Servicing air-conditioners is a growing opportunity, especially in the urban India. Technicians who already have a knowhow of servicing air-conditioning systems hire people interested in the trade and train them on the job. Given the informal nature of this set-up, it is difficult to estimate the number of technicians operating in this manner and their level of training. Moreover, many people employed in the sector for servicing electronics like washing machine, fridge, etc., enter into the air-conditioning servicing sector during peak season. Even technicians employed at enterprises often freelance during their free time.

6.3.4. Challenge of asymmetric information

Given the specialized nature of RAC servicing and the lack of clear information on what exactly constitutes good servicing from the perspective of the consumer, the servicing sector faces the ‘lemon problem’. The lemon problem arises due to the asymmetric information available with the buyer and seller of a service/good about the value of the service/good. For the given servicing sector context, it is impossible for the customer to differentiate between a good and knowledgeable service technician, and the one who is below par. All enterprises/technicians claim to be good. However, only after the customer has selected the technician can he or she find out the quality of the technician. In fact, for basic servicing, most times the customer will not be able to decipher the difference.

This situation leads to what is known as 'adverse selection' in the market. The lemons, or sub-par/partially-skilled technicians, reduce the average price of the market as they offer services at the lower price, and the buyer is ready to pay the price that reflects only the average quality of the market. The sellers of good quality service will not want to sell their service at the average price but are compelled to do so in the face of competition from the lemons. This forces them to either reduce the quality of their service, or to find ways to convince the customer that the quality of their service is better than that of lemons, which is a time intensive process, that eventually might or might not be successful. Policy makers and planner need to devise ways to eliminate the information asymmetry in the market, for improving the quality of the service, as well as eliminate lemons from the market.

6.4 Livelihoods and Social Security

Stable and secure livelihoods, and long-term social security, are important from the perspective of social welfare. In large unorganised sectors in developing economies, livelihoods are vulnerable to unexpected shocks. This is also true for service technicians in the air-conditioning industry. For example, a prolonged illness could lead to a significant impact on the income of a technician, as well as eat away a large part of financial savings, pushing them harder into the unorganised sector.

As the economy of the country is growing, it is imperative that the larger service sector, which includes the air-conditioning and refrigeration servicing sector, needs to strengthen its quality of delivery. This in turn implies that the mean performance of technicians ought to grow to deliver higher quality service. An understanding of current status is useful for better planning for the future.

Some aspects of the current situation are clear based on the detailed focused group discussion with the technicians, as well as discussion with sector experts.

First, there is some disparity in the annual earning of service technicians in the Room Air-Conditioners, Commercial Air conditioning (CAC) and Mobile Air Conditioning (MAC) sectors. There is also a distinct seasonal pattern to this work, with busy season lasting for six to nine months, depending on the location. During the off-season many technicians service other electronic equipment or do installation work.

Secondly, there is marked difference between average earnings for technicians working for authorised/ specialized service centres, and the average earnings of technicians working with other enterprises or freelancing, with the former earning higher than their counterparts.

Thirdly, access to social security schemes is not prevalent in the Room Air-Conditioners service sector in India. The primary reason for this is that most technicians are either self-employed or informally/casually employed by authorized service centres/registered enterprises. Only a small percentage of technicians who are employed at managerial/supervisory level by OEMs have access to the benefits associated with formal employment. A secondary reason is that many technicians are unaware of the distinct categories of insurance coverage available in the market such as health insurance, accidental insurance and life insurance or their purpose. As per a CEEW study, many technicians find health insurance to be an additional expenditure; something they cannot afford with their current earning. A lot of them were unaware of the occupational hazard associated with their line of work. In several cases, health insurance was perceived as something they would invest in at a later stage.

As RAC servicing sector is largely informal in nature there is scope to provide social security benefits. There are some pilot projects to provide insurance coverage to RAC service technicians.

The Ministry of Labour has proposed a comprehensive social security system that will be rolled out in three phases over the next ten years. Workers in the unorganized sectors will be target beneficiaries of this scheme. Through this social security system, health insurance and retirement benefits will be provided in the first phase, followed by unemployment and other welfare benefits in the second and third phases.

Fourthly, along with livelihoods and social security, occupation hazard related issues are becoming more and more important, especially in the context of flammable refrigerants. Most training sessions do discuss occupational safety, but how much of this is practiced by service technicians is uncertain and there is a need for technicians to be able to access benefits like accidental insurance, workman's compensation, etc. A recently signed memorandum of understanding (MoU) between the Ministry of Environment, Forest and Climate Change (MoEF&CC) and Ministry of Skill Development and Entrepreneurship (MSDE) provides for accident insurance through the National Skill Development Corporation (NSDC)'s scheme for all trainees under the scheme. There is a need to make such accidental insurance available widely, across the sector.

Social security benefits and occupational safety could also work as an important incentive for servicing technicians to invest in their education and training, in proper tools and equipment's, which may indirectly benefit environmental objectives as well.

6.5 Recommendations

The key objectives of the policy actions for the service sector fall under the purview of developmental and environmental goals. Five main stakeholders of the service sector make contributions at various capacities for achieving this transition: service technicians, industry, government, civil society, and customers. Depending on their role in the life-cycle of the equipment, each stakeholder has a different role to play. The government would facilitate the transition through policies, regulations, incentive schemes etc., while the industry would play an important role in increasing access to social security, training and certification for technicians. Service technicians and customers are responsible for field-level implementation of regular and appropriate servicing and maintenance practices. Feedback from service technicians and customers would be central to creating policy actions. Civil society plays an important role in advisory and research capacities. This section provides a framework of the sector keeping in mind future objectives and the abovementioned role of stakeholders.

Policy interventions can therefore have a cascading effect on this sectoral transition. The foremost issue that must be addressed is that of data gaps. Composition of the Room/Mobile/Commercial AC service sector needs to be captured through collection of country-wide data on the numbers of trained or semi-trained/untrained technicians that work in registered and unregistered enterprises. In the long-term, an accurate assessment of the number of technicians, their qualifications, annual earning, years of experience, etc. must be available. Long-term projection of the sectoral growth should also be done. In order to build training infrastructure, gaining access to accurate data is going to be imperative.

Bettering training infrastructure is perhaps the biggest contributor to improving the service sector. Through better training infrastructure, many technicians can be trained effectively and regularly. Training infrastructure would include but not be limited to quality training centres across the country, communication channels, acquiring more trainers and training sessions (short-term and long-term), certification schemes and networking opportunities. Building a suitable training infrastructure is perhaps the most challenging among the interventions to plan and implement.

Following are some suggested interventions to transition the servicing sector towards achieving the long-term environmental and developmental objectives:

Short-term recommendation

1) Institute Studies in the following areas:
   - Assess demand and availability of trained RAC service technicians across the country, as well as availability and quality of training institutions
   - Existing training infrastructure including human capital and gaps vis-à-vis international benchmarking and promoting synergies amongst the existing institutions/centres including those operating under the Skill India Mission framework.
   - Policy measures/incentives required for promoting RAC Servicing sector in the country
   - Certification models for RAC servicing technicians and proposed model for India
2) Promote involvement and greater participation of air-conditioning equipment manufacturers in designing of training programmes, development of training curricula including training material and delivery of training.
3) Develop standardized curricula and training processes including training duration, trainers qualification and training infrastructure across multiple agencies
4) Operationalize central voluntary certification scheme through a single government entity under a single framework
5) Encourage industry participation in advisory/stakeholder capacities at the MSDE, ITIs, etc. Industry to participate in training delivery and commitment to employ a fixed number of trained candidates
6) Creating an e-platform for service technicians: Given the widespread use of smartphones, an internet-based network could act as a single window information source for the RAC servicing technicians. The e-platform would also be a useful manner to collate all available trainings for technicians from different stakeholders. However, for the platform to be effective, synergies amongst different stakeholders including associations such as RASSS, ISHRAE and training centres need to be promoted. Necessary security systems also need to be built in the e-platform
7) Promoting mass awareness on the importance of regular servicing and good practices: One important reason for lack of proper servicing and maintenance is lack of customer awareness and demand for proper maintenance. Mass awareness campaign across a long period of time can change this customer behaviour, and lead to customers recognising the importance of regular and proper maintenance.
8) Public procurement of RAC services by trained and certified technicians: Promote utilisation of trained servicing technicians for all maintenance and servicing requirements of air-conditioning equipment in government ministries/departments and institutions.
9) Certification of about 50% service technicians by 2022-23

Mid-term recommendations

10) Develop a national database of RAC servicing technicians
11) Establishment/upgradation of training infrastructure: Based on the demand assessment of existing training centres and their available infrastructure, new training centres/centres of excellence and upgradation of training centres should be done that conform to latest technical requirements. Collaboration with industry may also be promoted in this initiative
12) Mandatory adherence to standardized training curriculum by all training providers: Within 5 years of developing standards, all the trainings, whether these happen in private companies, polytechnics, or undertaken by the government, all these should be based on a standard

curriculum. This curriculum should be devised with the help of intensive interactions with stakeholders and companies, and regularly updated as per technology needs. There should be periodic review and updating of curricula to address technology developments.

13) Certification for all technicians at different levels: Towards standardizing training, all the trained technicians should be certified under a single framework. The certification may be open to all technicians and be available at different levels (Installation only, Installation and Servicing, etc.) based on which, technicians would receive the required certification. Since there is already an existing set-up for skill certification, the National Skill Qualification Framework under the MSDE, the same may be harmonised with technical inputs from MoEF&CC. Awareness about the certification among customers and industries may also need to be created to incentive the training.

14) Develop and promote Online Training Courses: Internet based eLearning training modules can give critical basic ideas to budding technicians and can give refresher training on new technologies for technicians.

15) Implementing social security schemes for certified technicians: Social security schemes should be implemented on the ground with adequate health cover and life insurance. These should be given only to technicians who are certified as a way to incentivize certification. This phase should include strong monitoring and feedback system for continuous learning and upgrade to make this architecture more effective.

Long-term recommendations

16) Universal mandatory certification of technicians: In the long run, the objective is to have only certified technicians operate in the market. This implies ensuring continuous efforts to motivate technicians to go through the training process (either through public and / or private recognized certification agencies) AC companies or private training focused companies) and get certified. At this stage, the country should start moving to completely formalise the service technician sector.

17) Ensure coverage for all certified technicians through a centralized social security scheme dedicated to servicing sector technicians: Develop a robust plan to connect the technicians with existing social security schemes run by the centre as well as state governments. This can be done through regular and reliable information flow as well as awareness campaigns to motivate trained and certified technicians to enrol in these schemes and avail their benefits.

7

Refrigerant Demand & Indigenous Production

7.1 Background

India established fluorocarbon refrigerant manufacturing facility in 1960s and has not only been self-sufficient in refrigerant production but has also been one of the major exporters of refrigerants to several other countries. The fluorocarbon industry has been developing and adding products to meet the changing demand of refrigerant in the country.

The phase-out of production and consumption of Hydrochlorofluorocarbons (HCFCs) is presently underway as per the control measures set out under the Montreal Protocol. Hydrofluorocarbons (HFCs) being non-Ozone Depleting Substances (ODSs) have emerged as the alternative refrigerants to HCFCs. However, HFCs have high Global Warming Potential (GWP). The world community, recognizing the impact of growing global production and consumption of HFCs, decided to phase-down HFCs. The Parties to the Montreal Protocol adopted an amendment to the Montreal Protocol at its 28th Meeting in October 2016 at Kigali, Rwanda for phase-down of HFCs.

Since the Kigali Amendment to the Montreal Protocol, India has embarked on drawing a perspective plan for facilitating implementation of the Kigali Amendment wherein GHG gases like HFCs are required to be gradually phased down leading to a gradual shift in refrigerants from high-GWP HFCs to low-GWP/zero-GWP HFCs, Hydrofluoroolefins (HFOs) and other climate-suitable and safe substances. From the perspective of the refrigerant production sector, a long-term plan is envisaged for refrigerant use in different sectors, foaming agents and other cooling technologies under ICAP.

7.2 Overview of Production Sector

The fluorocarbon refrigerant gas producer industry, comprising 5 enterprises, have played a vital role in making India self-reliant in the development and production of fluorocarbon refrigerants, thereby contributing to the economic development of the country. The industry also exports to several other countries and provides employment, directly or indirectly, to a large number of people.

Refrigerant production facilities are capital intensive and the fluorocarbon manufacturing industry globally decide on such large investments considering the life cycle of the refrigerants guided by present and future regulatory framework. Indian fluorocarbon industry has also made such investment decisions on setting-up production facilities which have enabled India to be self-sufficient in the availability of refrigerants.

India was relatively a small player in production of refrigerant gases in the past. However, India has gradually increased its presence in international markets and has now emerged amongst the top three refrigerant producing nations of the world. Over the years, Indian fluorocarbon industry has improved their technological capability in indigenous development of production processes including new generation low-GWP refrigerants such as HFOs and blends of HFOs and HFCs. This industry has shown results and is expected to continue to strive for self-sufficiency in indigenous refrigerant development and production of low/zero GWP alternative refrigerants.

Based on the reported data under the Montreal Protocol and indigenous production data on production of HFCs, the production has grown at a CAGR of 14% in the last 18 years. Production quantities of all fluorocarbon refrigerants in 1998 was in the region of 30,000 MT and the production was approximately 75,000 MT in 2016.

7.3 Refrigerant Production

The following assumptions have been used for forecasting the refrigerant demand scenario:

- The present (2017-18) refrigerant production of 24,300 MT is per industry input.
- The total refrigerant production in the future years is estimated using a growth rate of 11% till 2027-28 and 9% for next 10 years till 2037-38. These growth rates have been estimated using the weighted average of cooling demand (million TR) growth across all cooling sectors.
- HCFC production was estimated per India's HCFC Phase-out Management Plan (HPMP-II).

Table 7.1: Refrigerant Production

	2017-18	2022-23	2027-28	2037-38
Annual Refrigerant Production (MT)	24,300	40,500-45,500	68,500-75,500	1,66,000-1,81,000

7.4 Proposed Refrigerant Pathways

One of the objectives of this sector would be to develop new low-GWP refrigerants and promote existing ones to comply with the obligations under the Kigali Amendment. Broadly, the product mix substitution to achieve compliance to the control regime for HFCs in future under the Kigali Amendment is expected to be as follows:

- Increased proportion of low-GWP refrigerants

- Use of natural refrigerants like R-290 (propane), R-717 (ammonia) and R-744 (CO_2) where possible
- Reduce usage of R-404A, R-407C (from the year 2028) and R-410A as the alternatives get developed;
- Gradual reduction of use of HFC-134a in transport air-conditioning beyond 2032; this is likely to happen post IPR limitations and indigenous production of HFO-1234yf

Currently there are a limited number of technically proven commercially available refrigerant options.

7.5 Recovery, Recycling and Reclamation

Recovery, recycling, and reuse of refrigerants are the key processes for refrigerant conservation. Recovery means the removal and temporary storage of refrigerant that has been removed from a system undergoing service or disposal. Recycling means the passing of recovered refrigerant through filters in order to make the refrigerant suitable for reuse. Recycling is not intended for used refrigerant that will be repackaged and placed back into the refrigerant market.

Reclamation involves processes that remove impurities (such as non-condensable, moisture, and acid), in essence, reprocessing of used refrigerant back to virgin specifications based on industry purity standards (e.g., AHRI Standard 700-2004 and SAE J1991). Reclaimed refrigerants could be put back in the market especially for servicing.

Such refrigerant conservation efforts should be placed on refrigerant recovery at the point of installation and continue throughout service and ultimate equipment end-of-life. Refrigerant conservation could be achieved through efforts of equipment and chemical manufacturers, as well as equipment owners/operators by developing life cycle approaches aimed at reducing refrigerant emissions. It would also include the required training of service personnel.

Recovery/recycling/reclamation processes have been implemented in developed and developing countries since the inception of implementation of phase-out of ozone-depleting substances under the Montreal Protocol. The results of recovery and recycling efforts were not encouraging during the CFC phase-out regime of the Montreal Protocol except in Mobile Air Conditioning (MAC) sector which was mostly handled by the organized sector, moreover, the quantity of refrigerant in MAC is significantly more in comparison to domestic and commercial refrigeration equipment.

India, through Multilateral Fund for the implementation of the Montreal Protocol funded projects, has trained on good servicing practices more than 30,000 technicians, mostly in the unorganized refrigeration and air conditioning (RAC) servicing sector so far. Recovery, Recycling and Reclamation were important elements of training. The use of refrigerant recovery and recycling equipment is the most essential means of conserving refrigerant during the service, maintenance, repair, or disposal of refrigeration and air-conditioning equipment. Some of the servicing technicians were also provided recovery, recycling equipment. The recovery and recycling equipment is expensive and the affordability of RAC servicing technicians is limited.

India also established 18 mini Reclamation centres, 11 in Institutional Users (Army, Airforce, Navy and Indian Railways) and 7 in private sector in various Stated/Union Territories (Chandigarh, Gujrat, Maharashtra, Rajasthan, Uttar Pradesh and West Bengal). These mini reclamation units are capable of reclaiming a number of refrigerants like CFCs, HCFCs and HFCs including some of the blends of HFCs. Each unit can reclaim up to 26 kg of refrigerant depending on the availability of recovered refrigerants.

7.6 Recommendations

1. Setting up a national R&D institutional framework for refrigerants and HVAC technology innovation
2. Develop application centres for enhancing capabilities of refrigerant manufacturers for energy-efficient and environmentally-friendly refrigerants
3. Harmonization of national regulations with international regulations in accordance with the Montreal Protocol and its amendments
4. Development of harmonized system codes for HFCs
5. Amendment of Ozone Depleting Substances (Regulation and Control) Rules 2000 and its amendment to align with Kigali Amendment to the Montreal Protocol
6. Licensing system for import and export of HFCs
7. Development of safety standards for flammable refrigerants
8. Capacity building of law enforcement officers to combat illegal trade of refrigerants including blends of refrigerants
9. Monitoring and enforcement of regulations of Petroleum & Explosives Safety Organization (PESO) with respect to use of disposable cylinders

8

Research & Development

8.1 Background

Driving Research & Development (R&D) for developing an innovation ecosystem in the country is pivotal for enabling sustainable cooling and thermal comfort for all. The development of a robust R&D innovation ecosystem will, ***inter alia***, involve: (i) further development of scientific manpower in the area; (ii) requisite academic and R&D institutional capacities; (iii) support for R&D activities on various facets of cooling, including but not limited to refrigerants, cooling equipment, passive building design interventions, not-in-kind technologies and new emerging technologies; and (iv) industry preparedness to assimilate new technologies. Participation of industry at all stages is a must for effective delivery of cooling solutions for maximizing societal benefits. R&D is also very important for supporting the Make in India programme, which encourages domestic manufacturing of goods and products.

The most critical aspect for sustainable cooling is the availability of cost effective low GWP and non-ODS refrigerants. Most of the low GWP alternative refrigerants are heavily patented by multinational companies and are very costly. It is imperative to develop cost effective indigenously developed solutions to meet the cooling demand of the country.

R&D will spur innovation to enhance the energy efficiency of refrigeration and air conditioning equipment by improving the component efficiencies of compressors, fans, heat exchangers, and expansion valves, among other things. Secondly, R&D will unlock technologies and refrigerants that best suit Indian climatic conditions. Through sustained R&D efforts in both public and private sector the reliance on imported equipment and parts needs to be reduced. This will also require a greater domestic manufacturing base producing equipment and components specifically suited to the local needs. It is important to enable a conducive R&D environment to channelize resources and to help India pursue its Sustainable Developments Goals. A simplified representation of major stakeholders in the R&D innovation ecosystem is given in Figure 8.1.

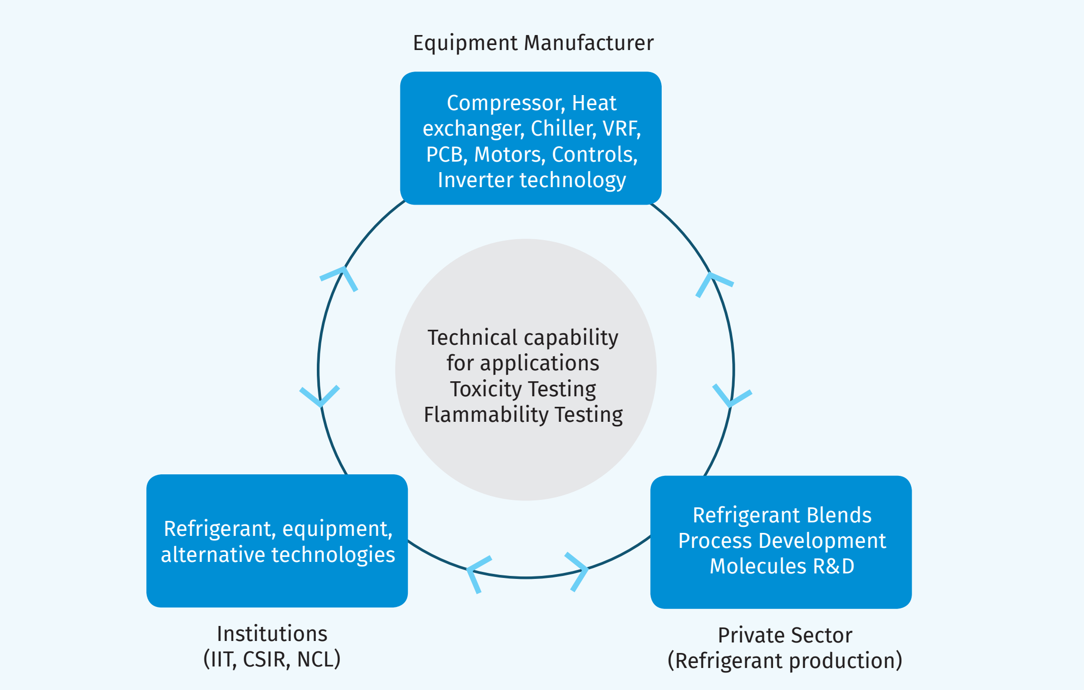


Figure 8.1: R&D Innovation Ecosystem

There is expertise available in different R&D and academic institutions on select aspects related to cooling. Important work is being carried out in Indian academic institutions, R&D institutions, and laboratories, such as the Indian Institute of Technology (IIT), National Institutes of Technologies (NITs), Indian Institute of Science (IISc), Council for Scientific and Industrial Research – Indian Institute of Chemical Technology (CSIR-IICT), and CSIR-National Chemical Laboratory (CSIR-NCL). The diverse expertise and facilities need to be explored and leveraged appropriately and linked in order to utilize the expertise and strengths of various institutions for result-based outcomes. There is a need to set up an R&D centre in India, preferably in the public sector, which is open to all stakeholders. Also, for successful R&D efforts in this area, there needs to be a concerted and coordinated mechanism between various stakeholders, including private companies with deep expertise in refrigeration and air conditioning research. As such, a robust enabling platform is a key need in fostering meaningful collaborations and linkages and supporting the R&D efforts.

8.2 Development of Refrigerants

Presently, the country is self-reliant with respect to synthetic refrigerants available through the domestic manufacturers. CSIR-IICT has adequate expertise in the area of fluorocarbon refrigerants over the years and has, in the past, been able to develop processes for development of HFC134a in close cooperation with the chemical industry. Recently the Indian refrigerant manufacturers have also developed their own R&D facilities in due course and has developed and started commercial production of lower GWP technologies like HFC-32 based on in-house R&D and supply to the market. However, the low GWP alternatives are heavily patented by the multinational companies.

A key aspect of refrigerant development is its use for a specific application. Any new refrigerant/ molecule developed by Indian industries needs to be tested for effectiveness and efficiency for application development. There is a need for testing and application centres where new refrigerants could be tested for efficiency, toxicity, flammability, and environmental impact.

The new alternative refrigerants to HCFC and HFC are either mildly flammable or flammable. These refrigerants call for additional safety standards to address issues such as pressure safety, toxicity, electrical safety, flammability and explosion protection, and general safety of machinery.

Global safety standards applicable to refrigeration and air-conditioning are mainly sourced from the International Standardisation Organisation (ISO) and the International Electrotechnical Commission (IEC), apart from some regional standards like the European Committee for Standardisation (CEN) and the European Committee for Electrotechnical Standardization (CENELEC). All refrigerant gases are classified primarily based on their toxicity and flammability per ISO 817[58], IEC 60335[59], EN 378[60] and ASHRAE 34[61].

Natural refrigerants such as hydrocarbons, carbon dioxide and ammonia are some of the low GWP refrigerant options available other than synthetic refrigerants. India is the first country globally, to commercially produce air conditioners with R-290 refrigerant. Similarly, majority of cold storages in the country operate upon ammonia. There is a recognized need to have safety standards for new alternative refrigerants including natural refrigerants. The Bureau of Indian Standards (BIS) is working on developing refrigerant safety standards for room air conditioners, especially for the natural refrigerants which are generally toxic and flammable.

8.2.1. Government Initiative for R&D for Low-GWP Alternatives to HFCs

As a first step, the Ministry of Environment, Forest and Climate Change (MoEF&CC) on 15 September 2016, announced a collaborative R&D programme to develop cost effective low-GWP alternative technologies to HFCs. This R&D initiative brings together government, research institutes, industry and civil society. Some of the key players of the initiative include the Council of Scientific & Industrial Research and its allied institutions, Department of Science and Technology, R&D and academic institutes, as well as key industry players. The deliberations for the collaborative R&D programme have further underscored the importance of undertaking R&D in the area of cooling. As part of the initiation of the collaborative research programme, the Department of Science and Technology has already sponsored a research programme for the development low-GWP alternative to HFCs at IICT Hyderabad.

8.3 Development of HVAC&R Technology

R&D in HVAC&R is conducted primarily in the HVAC&R equipment manufacturing sector. However, currently there is no formal linkage between the refrigerant and HVAC technology development sectors. Some academic institutions – Indian Institute of Technologies (IITs), IISC, and NITs - have expertise to carry out research in the field of HVAC&R: new improvised refrigeration cycles, heat transfer, compressors, energy efficient electric motors, controls and heat exchangers.

For example, the Refrigeration and Air-conditioning lab at IIT Madras has embarked on a pilot study to evaluate the performance of multi-ejector CO_2 system as an alternate to HCFC and HFC refrigerants; and, IIT Bombay has developed several patents on liquid desiccant cooling technologies and novel mobile air conditioning which can reduce dependence on conventional technologies. The Centre for Advanced Research in Building Science and Energy at CEPT University has done exemplary research in the field of building energy efficiency, covering energy-efficient design, energy-efficient building construction processes, environment friendly construction materials, resource audit and management, solar passive architecture and several green building technologies. There may be a lack of physical infrastructure for testing and evaluation, as it requires heavy investment. This gap could be filled by the industry, by extending such facilities within their own premises. This would prove to be a win-win situation, both for the industry and academic institutions. Such a model of operation is very common and successfully utilized in other countries.

8.4 Scope of R&D and Potential Areas of Technological Interventions

Production of refrigerants to meet the growing requirements of cooling while minimizing impact on climate as envisaged under the Kigali Amendment to the Montreal Protocol would require a comprehensive R&D programme in the country to minimise the economic burden on consumers. The scope of R&D should be deliberated jointly by the industry, research institutions and Ministries. The approach should identify broad areas of R&D topics where publicly funded research efforts can be directed. Work done under the existing Department of Science and Technology and TIFAC programmes (for example, Initiative to Promote Habitat Energy Efficiency, bi-lateral initiative between India and the US, and India and the UK, Heating and Cooling of Buildings under the Mission Innovation initiative) must be integrated with any research efforts. Table 8.1 gives the proposed short, medium and long-term plan for R&D activities in the country.

Table 8.1: Proposed Plan of R&D Activities

	Refrigerant development	HVAC/ Not-in-kind technology development/ Service sector	Advanced building design
Short term	• Development of low-GWP alternatives including blends for R404A / R407C/ R410A • Development and indigenous production of hydrocarbon (R600A and R290) refrigerants • Development of application laboratory for evaluation of low-GWP new generation refrigerants	• Initiate R&D for energy efficient rotary and scroll compressors • Synthesis and development of synthetic lubricating oils compatible with new generation refrigerants • State-of-the-art heat exchanger technologies including the development of heat exchangers simulation software • Solar energy-based cooling solutions • Research for improving the servicing sector along with the use of multiple refrigerants.	• Innovative passive cooling designs to minimize space cooling needs for various Indian climates • Development of advanced building materials with low U-value and embodied energy
Medium term	• Development of low-GWP alternative production process and setting up of production facility of low GWP alternatives based on indigenous R & D manufacturing set up start coming up based on our own technology • Continuation of the search for new Molecule research, possibly from two R&D institutions with clear review mechanism and incentives for corporates for molecule research • Toxicity tests of new generation refrigerants • Review regulatory/policy framework for launching the newly developed molecules in a global forum	• Initiate research on alternatives for Room Air-Conditioners • Advanced mechanical compression cycles including trans-critical cycle for high-efficiency cooling systems • District cooling using low-grade energy from thermal power plants, waste heat and harnessing other sources of low-grade energy	• Development of building materials with advanced thermal and optical properties that curtail heat ingress

	Refrigerant development	HVAC/ Not-in-kind technology development/ Service sector	Advanced building design
Long term	• Review molecule research and, application lab effectiveness progress and further strengthen infrastructure • Demonstration of bench and pilot production of newly developed molecules • Initiate commercial production based on demand assessment • Development of software for screening and developing azeotropic and zeotropic lower-GWP refrigerant blends for various applications	• Explore the development of materials including copper, aluminium, polymers, and synthetic materials for electrical winding compatible with new generation refrigerants	

8.5 Recommendations

Short-term Recommendations

1. Recognize cooling as a National Thrust Area and promote R&D for cooling including areas related to building design and materials, new molecule development, equipment, servicing, refrigerant management etc, under Science and Technology Programme and seek dedicated R&D funding to come up with technological solutions and innovation challenges and awards that will help mitigate cooling demand and address it in an energy-efficient and environment-friendly manner, while reducing the cost of technology to make it widely accessible.
2. Institute a steering committee with representation from DST, R&D institutes, policy makers from MoEF&CC (Ozone Cell), BEE and MoHUA, representatives from private sector companies (such as, those involved in refrigerant development and production, HVAC&R appliance and equipment manufacturing, HVAC controls manufacturers including IoT, data analytics and building controls), and think tanks with deep technical expertise in the segment, to identify and map the knowledge, expertise and capabilities available both in terms of manpower and lab facilities, while developing a R&D roadmap that would be in the best interest of the country. This may lead to identification of some of the areas listed below:
   - Facilitate and encourage applied research for energy efficient cooling technologies including compressors, heat exchangers, pumps, electrical motors and controls, and bench production of refrigerants.
   - Nurture and leverage the expertise available in academic and research institutes of excellence in the country like CSIR-IICT, IITs, IISC, and NITs; and challenge them to conduct research in technology that will be in the best national interest and help address the cooling challenge facing the country.
   - Identify the need for technology testing facilities, feasibility of and the return on investment on setting up of new R&D infrastructure, and outcomes expected from setting up of such testing facilities and application laboratory and their operation and maintenance.

Medium-term recommendations

3. To implement the Cooling R&D roadmap developed under the guidance of the steering committee, institute an R&D consortium using a Public Private Partnership (PPP) model with

adequate funding, to support, monitor and enable interdisciplinary research between public and private sector, with tangible and time-bound goals. Some of the activity areas may be:

- Institutionalization of funding and monitoring mechanism of the Institute of Excellence for time bound delivery of research outcomes quantified in terms of patents, publications, and commercialisation of the technological achievements, translating into quantifiable benefits for the nation and its people.
- Institutionalize mechanisms for Intellectual Property Rights (IPR) in consultation with the Department of Industrial Policy and Promotion, Ministry of Commerce, and industry and the private sector partners.
- Institutionalize consultative process and draw long term strategies to avoid undue financial burden on the industry and the country, as the fluorocarbon refrigerant producing industry is capital intensive and subject to comply with international and national environmental regulations.
- Develop and facilitate scientific and technical environment for basic research in materials and refrigerants, especially new next generation molecules and oils.

4. Broad-based research, development, demonstration and deployment of innovations contributing to thermal comfort.

Long-term recommendations

5. Setting-up of an inter-disciplinary autonomous centre(s) of Excellence for Cooling technologies housed in one of the Academic and/or recognized research institutes, capitalizing on the expertise and R&D facilities available; or recognize Centres of Excellence within existing institutes to work on specific areas, enabling active participation and engagement of the private sector.

9

Recommendations & Way Forward

9.1 Background

Acknowledging that cooling is a cross cutting requirement, an integrated and long-term vision across sectors is a prerequisite to provide "Thermal Comfort for All" and sustainable cooling across sectors including cold chain. Whilst the cooling demand in India is related to climate, population and rising aspirations and growth of economy, there are both international and domestic regulatory instruments that affect the solutions to meet the cooling demand. Additionally, there are different ongoing policies and programmes of the Government that co-relate with cooling. There are also overarching priorities and thrusts of the Government in terms of developmental objectives. Within this context, the ICAP lays out cooling demand estimates over a 20-year term in order that synergies could be forged, and cross-cutting integrated policies could be developed, where required, to secure environmental benefits while meeting the developmental needs of the country.

It is acknowledged that there is an immense potential to rationalize the rise in requirement of active refrigerant-based cooling in the country by adoption of passive cooling design strategies across sectors. Wider proliferation of thermally efficient built spaces that have reduced heat load is required inter alia using insulation, shading, and enhanced natural ventilation, to reduce requirement of active-cooling. This reduced cooling demand then needs to be met using the energy efficient and climate-friendly technologies.

Both refrigerant transition and energy efficiency standards necessitate changes in the equipment design. To provide a clear way forward for the industry, synchronization of regulatory measures for energy efficiency and refrigerant phase-out/transition, while meeting the domestic objectives as well as international commitments under Kigali amendment and Paris agreement, should be carried out wherever possible. The hallmark for success of Montreal Protocol in the country is the active participation of stakeholders including the industry. The role and collaboration of industry in embracing EE and moving towards new technologies for addressing the rising cooling requirement is most critical. A policy framework that supports and incentivizes industry involvement in the move towards sustainable cooling and thermal comfort for all will be an important requirement.

The environmental benefits of phasing out Ozone Depleting Substances under the Montreal Protocol are well recognized not only in terms of ozone layer protection but also in terms of the carbon dioxide equivalents avoided, as most current refrigerants are high GWP gases. Presently, hydrochlorofluorocarbons (HCFC) are being phased out and several large, Indian AC manufacturers are moving from HCFC 22 to HFC 32. The HCFC phase-out shall go on till 2030. This will be overlapping with HFC phase-down schedules as agreed under Kigali Amendment to the Montreal Protocol. In addition to mitigating the direct emissions of CO2 equivalent due to refrigerant emissions, an additional ~80% of the total emissions attributed to AC equipment is related to indirect emissions associated with energy use.

However, it is recognized that, even by 2038, a significant percentage of the households shall not be able to afford refrigerant-based cooling equipment. Therefore, a wider proliferation of climate-responsive and sustainably designed residential built spaces is required, to bring the indoor temperature within the acceptable thermal comfort band through passive cooling. A national temperature goal would be an aspiration to be aimed at based upon realistic ground level preparedness. This, to the extent possible, should be coupled with the availability of efficient non-refrigerant based cooling equipment, such as fans and coolers, to fulfil the cooling needs. Active air-conditioning using natural or low-GWP refrigerant must only be deployed after every effort has been taken to ensure thermal comfort through energy-efficient envelope design prescribed in the Energy Conservation Building Code (ECBC) for both commercial and residential buildings.

9.2 Short, Medium and Long-term Recommendations

Sustainable cooling can be achieved through reduction in cooling load, passive cooling interventions for buildings, moving towards more energy efficient RAC equipment, operational efficiency enhancements, and use of new and alternative technologies including not-in-kind technologies, while implementing the Montreal protocol. The move to sustainable cooling shall also be reinforced through a robust innovation ecosystem to develop and implement new technologies, and a skilled RAC service technicians' workforce.

In this chapter, major recommendations from the preceding chapters have been culled out to draw synergies with different ongoing policies and programmes of the Government. Table 9.1 has some such examples where actions related to cooling could be linked to ongoing governmental schemes and programmes. The short and medium and long terms in this table refer to the timelines of 2019-2024 and 2024-2029 and 2029 - 2038, respectively. This categorization has been done with respect to providing timelines relevant to policy formulation and implementation.

Table 9.1: Short, Medium and Long-term Recommendations

Thematic Area	Timeline	Recommendations	Synergies with existing governmental schemes/ programmes
Space Cooling in Buildings	Short Term (2019- 2024)	Promote wider penetration of climate responsive built spaces to bring indoor temperatures within acceptable thermal comfort band through passive cooling thus reducing cooling load	▪ Pradhan Mantri Awas Yojana - Housing for All, ▪ Smart Cities Mission, ▪ National Mission on Sustainable Habitats, ▪ National Mission on Enhancing Energy Efficiency, ▪ Government E-Marketplace
		Further Government support towards targeted programmes to enable thermal comfort for EWS and LIG. Wider adoption of ECBC – R in affordable housing projects	
		To incorporate relevant provisions of energy efficient building design stated in ECBC to minimize active cooling needs by using passive design elements for all commercial (non-residential) buildings in statutory environment clearance, where applicable	
		Mandatory disclosures and Third-Party verification of building cooling requirement and energy use for all commercial (non-residential) buildings that have a connected load of 100 kW or higher	
		Mandatory minimum indoor temperature settings (adaptive thermal comfort standards) in commercial buildings to reduce cooling requirement and energy consumption and promote healthy living/ working environment	
		Nation-wide adoption and enforcement of ECBC for both commercial and residential sectors at the municipal and urban and local body level and through development of city level action plans	
		Ratchet up MEPS for Room ACs while taking into account most energy efficient models available and their affordability	
		Mandatory star labelling for fans and introduction of MEPS for evaporative coolers.	
		Institutionalise Demand Side Management programmes with DISCOMS to replace inefficient ACs with EE appliances	
		Implement eco-labelling programme for cooling appliances	
		Promotion of DR-enabled cooling technology with real-time power consumption display	
		Mandatory public procurement guidelines for highest star rated energy efficient ACs, fans, chillers, etc. with low-GWP options, where ever feasible	
		Incentives coupled with awareness campaigns to drive market demand of energy efficient cooling appliances and equipment	
		Encourage development of urban heat action plans for all cities with a population of 2.5 million or more	
	Medium Term (2024-2029)	Institutionalize installation of thermal storage with cooling systems and differential (Time of Day) power tariffs to minimize peak power requirement	
		Promote use of not-in-kind technologies including trigeneration system, district cooling, thermal energy storage etc.	
		All new construction – both residential and commercial – should be 100% ECBC compliant. The minimum stringency levels of ECBC compliance should be revised periodically to ECBC+ and Super ECBC requirements	
		Programs to reduce cooling energy use in existing buildings through retrofits and improved O&M practices	

Thematic Area	Timeline	Recommendations	Synergies with existing governmental schemes/ programmes
Cold Chain and Refrigeration	Short term	Encourage development of cold chain infrastructure with use of low-GWP refrigerant based energy efficient cooling systems	■ Doubling Farmers' Income (DFI) initiative, ■ Gramin Agricultural Markets (GrAMs)
		Development of safety standards for flammable and toxic refrigerants for cold storage and other segments of the cold chain	
		Develop programme for retrofitting of existing cold storages to reduce cooling, refrigerant demand and energy consumption	
		Commercial refrigeration equipment like water coolers, display cabinets, freezers, etc. to be brought under BEE star rating	
		Periodic review and enhancement of energy efficiency norms of refrigerators	
		Standardise all design, construction and associated specifications for small, medium and large cold-chain infrastructure components.	
		Link the incentives being provided for development of cold-chain infrastructure with adoption of energy-efficient design, construction and maintenance practices and low GWP refrigerant and renewable technologies.	
		Provide specialized training facilities for cold chain professionals and technicians to promote proper utilization and operation of technology, as well as energy efficiency	
		Provide training to farmers so that they can better manage their produce both pre-harvest and post-harvest	
	Medium Term	Effective recycle/ retrofit/ replacement programs for inefficient old refrigerators	
		Retrofit cold storage buildings (refrigerated warehouses) by installing insulation and replacing inefficient cooling and refrigerating equipment, and install improved controls to significantly improve the EPI	
Transport air conditioning	Short term	Promote development of low refrigerant charge energy efficient Mobile Air Conditioning System (MAC)	■ National Mission on enhancing Energy Efficiency ■ Atal Mission for Rejuvenation and Urban Transformation (AMRUT) - Public Transportation, ■ Urban Transport Metro Rail Projects, ■ Corporate Average Fuel Economy (CAFÉ) norms, ■ Faster Adoption and ■ Manufacturing of Hybrid and Electric vehicles (FAME) Scheme
		Mandatory testing of all new manufactured air-conditioned passenger cars with Airconditioner 'ON' condition to provide realistic fuel efficiency and emissions profile for encouraging improved mobile Airconditioner efficiency	
		Policies for promotion of compliance with CAFÉ standards	
		Green Labelling systems for cars to promote efficient vehicles	
	Medium and Long Term (2029 and 2038)	Policies for improvement of energy efficiency and adaptation of low-GWP refrigerants, especially in hybrid and electric vehicles	
		Reduction of refrigerant demand, energy demand and vehicular pollution by shifting the passenger traffic towards public transport. Building integrated and high-quality public transport systems in Tier 2 & Tier 3 cities to reduce the personalized vehicle demand	

Thematic Area	Timeline	Recommendations	Synergies with existing governmental schemes/ programmes
RAC Service Sector	Short Term	Assess demand and availability of trained RAC service technicians across the country, as well as the availability and quality of training institutions	■ National Skill Development Mission ■ Pradhan Mantri Kaushal VikasY ojana ■ Government E-Marketplace
		Industry to participate in training delivery and commitment to employ a fixed number of trained candidates	
		Establish an e-platform that collates all available trainings for technicians from different training providers, as well as to address some of the key challenges such as, social security, job opportunities, etc for all the technicians	
		Establish public procurement policies for Government departments and organizations to engage services of trained & certified technicians, and creating mass awareness among the consumers	
		Develop standardized curricula and training processes including training duration, trainers qualification and training infrastructure across multiple agencies	
		Operationalize central voluntary certification scheme through a single government entity under a single framework	
		Certification of about 50% service technicians by 2022-23.	
	Medium Term	Establish new training centres/centres of excellence and upgradation of training centres	
		Promote online refresher training courses on new and upcoming technologies as skill enhancement support for technicians	
		Introduction of Social Security schemes with adequate health and life insurance coverage for the RAC service technicians	
	Long Term	Universal mandatory certification for all technicians	
		Customer awareness programmes reinforcing the need for hiring only certified technicians	
		Ensure universal coverage of Social Security schemes for technicians	
Refrigerant Demand & Indigenous Production	Short Term	Develop safety standards for flammable refrigerants considering IEC60335-2-40	Make in India
		Development and production of low-GWP alternative refrigerants to the widely used high–GWP HFCs like R-404A and R-407C	
	Medium Term	Amendment of the Ozone Depleting Substances (Regulation and Control) Rules 2000 to align with the Kigali Amendment to the Montreal Protocol and its implementation	
		Indigenous development and initiation of production of HFOs and low-GWP blends of HFO and HFCs	
		Monitoring and enforcement of Regulations of Petroleum & Explosives Safety Organization (PESO) with respect to the use of disposable cylinders	
	Long Term	Commercial Scale production of HFOs	

Thematic Area	Timeline	Recommendations	Synergies with existing governmental schemes/ programmes
Research & Development	Short Term	Recognize Cooling as a National Thrust Area and promote R&D for cooling including areas related to building design and materials, new molecule development, equipment, servicing, refrigerant management etc.	• Mission Innovation, • Start-Up India
		Develop National R&D Institutional framework for low-GWP refrigerants and RAC to make India a hub for manufacturing of energy efficient and low energy consuming cooling solutions and low-GWP alternative refrigerants and technologies	
		Constitute a steering committee for R&D with representation from the Ministry of S&T, Ministry of HRD, BEE, experts from academic and research institutions and industry	
		Nurture and leverage the expertise in academic and research institutes of excellence: CSIR-IICT, IITs, IISC, NITs, etc. for focused R&D on cooling technologies and solutions	
	Medium Term	Constitution of R&D consortium using a Public Private Partnership (PPP) model with funding support to support and monitor the inter-disciplinary research and development	
		Broad-based research, development, demonstration and deployment of innovations contributing to thermal comfort	
		Develop and facilitate a scientific and technical environment for basic research in materials and refrigerants, especially new next generation molecules and oils, and energy efficient cooling technologies such as compressors, heat exchangers, and controls	
		Institutionalize mechanisms for Intellectual Property Rights (IPR) protections in consultation with relevant stakeholders	
	Long Term	Set up an inter-disciplinary autonomous Institute of Excellence for Cooling Technologies housed in one of the academic and/or research institutes, capitalizing on the expertise and R&D facilities available	

The cooling requirement of the country could be met in a sustainable manner by developing synergies across flagship programmes of the Government for maximum impact, and development of policy interventions and programmes wherever required.

Furthermore, dovetailing refrigerant transition to low GWP options with energy efficiency of RAC appliances shall provide additional climate mitigation benefits. At the same time, it is recognized that affordability of energy efficient RAC equipment and high upfront cost to consumer is a stumbling block to higher penetration on energy efficient RAC equipment, globally. The life cycle costs of efficient RAC equipment and pay back of investment has not been able to increase the penetration substantially. A move towards low GWP energy efficient RAC equipment essentially requires addressing the issue of affordability, in order to achieve climate benefits and reduced energy consumption. This requires development of policy interventions, enabling market drivers such as incentives, and innovative business models.

Socio-economic co-benefits like livelihood improvement and job creation, which are developmental priorities in the country, could also be maximized over and above environmental benefits by synergizing actions in other sectors where cooling is required. Table 9.2 presents some of the major socio-economic co-benefits associated with actions under each of the Thematic Areas.

Table 9.2: Socio-economic Co-benefits Proposed by ICAP

Thematic Area	Socio-economic Co-benefits
Space Cooling in Buildings	▪ Thermal comfort for all ▪ Productivity enhancement ▪ Improved health and well-being ▪ Lower electricity consumption ▪ Lower operational cost to the users
Cold-chain & Refrigeration	▪ Doubling Farmers Income ▪ Food security through reduced food wastage
Transport Air Conditioning	▪ Energy efficient mobile air conditioning ▪ Reduced fuel consumption ▪ Better public transport network
RAC Service Sector	▪ Better livelihood options ▪ Safe working environment ▪ Increase in employment generation
Refrigerant Demand and Indigenous Production	▪ Boost to domestic manufacturing of refrigerants, and refrigeration and air conditioning equipment ▪ Employment generation
Research & Development	▪ Cost effective indigenously developed low GWP alternative technologies ▪ Development of greater capacity/ opportunities for research and innovation in India ▪ Development of R&D Innovation ecosystem

9.3 Implementation Framework

Given the cross-cutting nature of cooling, the ICAP has been conceived as an inter-ministerial undertaking, calling for coordinated action among ministries. Because the agenda for cooling lies in the domain of multiple ministries, the successful implementation of the ICAP hinges upon active collaboration among the relevant ministries, State Governments, and concerned departments. Secondly, integration with on-going programs and initiatives will be key for achieving optimal social and economic benefits. Figure 9.1 presents the multiple inter-linkages of cooling with the national as well as global priorities, highlighting the ministries and State Government departments, as well as the on-going initiatives, which intersect with the cooling agenda.

GLOBAL PRIORITIES	Climate Change Sustainable Development Goals							
Departments & Entities	Ozone Cell	BEE EESL State Designated Agencies (SDA)	CPWD NBCC State PWD Devel-opment Authorities	National Centre for Cold-chain Develop-ment NCCD)	State Transport Depart-ments State Road Transport Undertak-ings	Department of Heavy Industry	Electronics Sector Skills Council of India	Ministry of Science and Technology (DST) TIFAC
Programs & Initiatives		S&L ECBC CAFE norms BEEP ESEAP	PMAY-Housing for All Smart Cit-ies Mission Govern-ment E- Market-place	Doubling Farmers# Income (DFI) Gramin Agricultural Markets (GrAMs)	AMRUT - Public Transporta-tion Metro Rail Projects CAFE norms	FAME India	Pradhan Mantri Kaushal Vi-kas Yojana Govern-ment E-Market-place	Mission Innovation

Figure 9.1: Indicative inter-linkages of Cooling with various Government Programmes & Initiatives

For effective implementation, the ICAP must be monitored and executed under the governance of a high level inter-ministerial framework. The already existing Inter-ministerial Empowered Steering Committee for the implementation of the Montreal Protocol approved by the Union Cabinet could be additionally tasked with the overseeing the implementation of the ICAP. Based on the actions that emerge from the ICAP recommendations, other ministries could be added to the Empowered Steering Committee. The Ozone Cell, MoEF&CC be strengthened and additionally tasked to act as a Cooling Secretariat in order to provide support to the Empowered Steering Committee and coordinate actions emerging from ICAP.

The ICAP requires implementation of actions through forging synergies with on-going programmes of the Government and also the use of appropriate policy, regulatory and financial instruments, where required. The related line ministries of the Government of India, State Governments, and Urban Local Bodies could seek additional financial resources, if required, beyond available resources to fast track implementation. Since cooling in an integral part of the Montreal Protocol as well as the Paris Agreement, multi-lateral funding mechanisms can also make resources available.

The ICAP establishes high-level goals. The targets to achieve the stated goals require more detailed deliberations and inter-ministerial coordination and will be undertaken through the Empowered Steering Committee. The concerned Government stakeholders can come up with their own programmes, as the case may be, to move towards the goals of ICAP.

The ICAP calls attention to the escalating cooling growth, and the pressing need for ways and means to provide access to sustainable cooling while neutralizing its impacts. It serves as a call to action through inter-ministerial coordination and collaboration among the public and private sectors so as to secure environment and societal benefits.

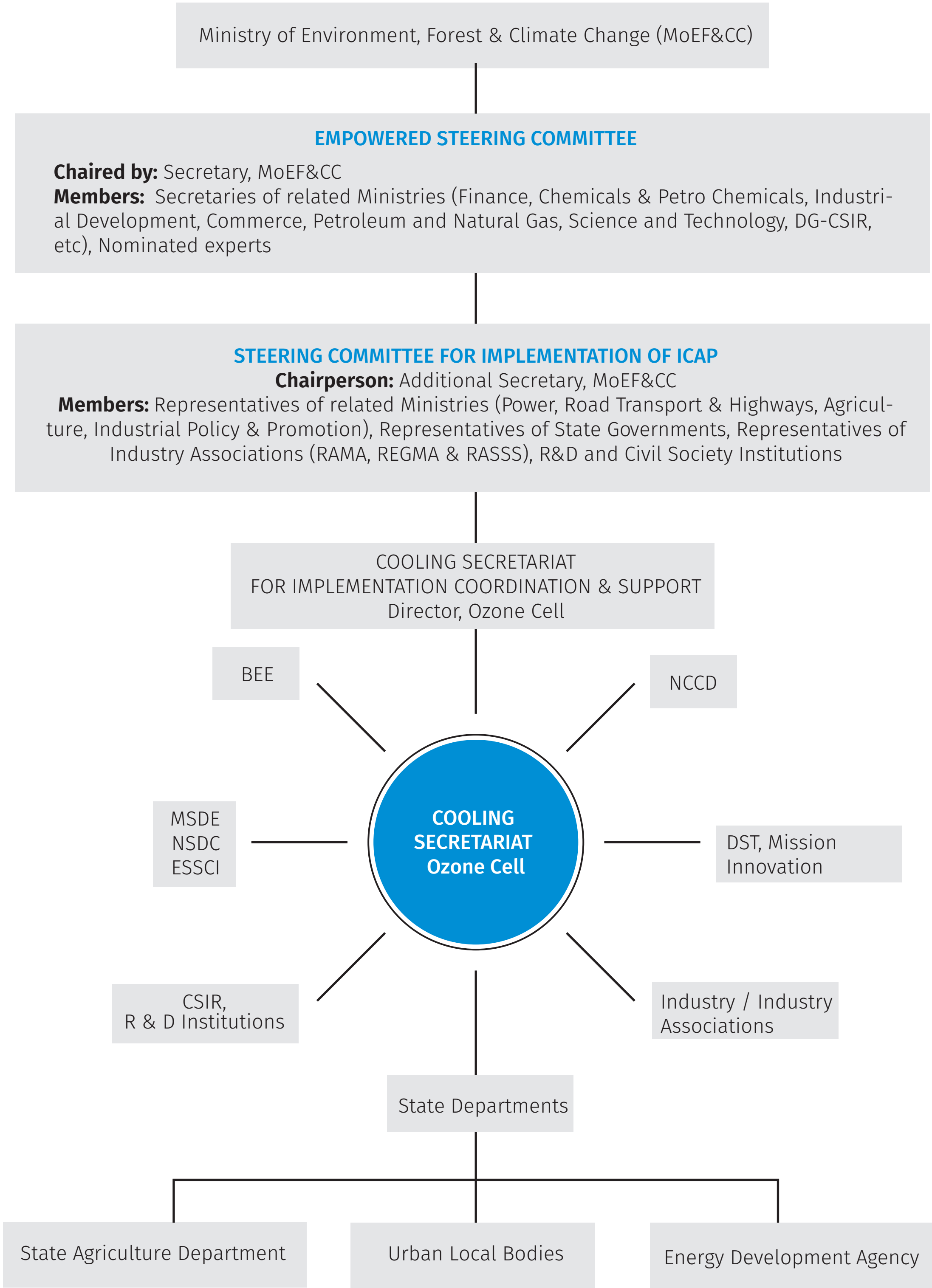


Figure 9.2: ICAP Implementation Framework

Appendix

Appendix A (Space Cooling in Buildings)

Stock

	2017-18	2022-23	2027-28	2037-38
Room air conditioner (million TR)	55	108-116	190-239	454-813
Chiller (million TR)	5-5.7	8.7-9.6	14-15.4	34.8-38.1
VRF (million TR)	2.3-2.7	4.7-5.5	9.7-11.2	35.1-39
Packaged DX (million TR)	4.6-4.7	5.4-5.7	6.7-7	10.7-11.2
Fan (million unit)	400-500	500-600	600-700	900-1000
Air cooler (million unit)	40-44	67-75	112--122	265-287

Refrigerant Demand (incl. Servicing)

	2017-18	2022-23		2027-28		2037-38	
		Reference	Intervention	Reference	Intervention	Reference	Intervention
Refrigerant demand (MT)	15,000	25,400 -25,500	23,000-24,000	42,000-52,000	35,000-43,000	90,000-1,45,000	60,000-98,000

Annual Energy Consumption

	2017-18	2022-23		2027-28		2037-38	
		Reference	Intervention	Reference	Intervention	Reference	Intervention
Room air conditioner (TWh)	56	85-92	84-91	121-152	106-134	215-385	144-257
Chiller (TWh)	11.8-13.1	19.3-21.1	17-18	29.2-31.6	19.7-20.6	61.8-66	30.7-32
VRF (TWh)	3.6-4.1	7.3-8.5	7.2-8.3	15.2-17.4	14.3-16.3	51.5-57.5	46.9-52.4
Packaged DX (TWh)	11-11.2	12.2-12.5	11.9-12.1	14-14.6	12.7-13	21.4-22.4	14.1-14.2

	2017-18	2022-23		2027-28		2037-38	
		Reference	Intervention	Reference	Intervention	Reference	Intervention
Fan (TWh)	40-42	48-50	44-46	50-54	44-48	60-70	40-50
Air cooler (TWh)	10-12	19-21	18-20	28-34	25-30	75-80	65-70

Appendix B (Cold-Chain & Refrigeration)

Stock

	2017-18	2022-23	2027-28	2037-38
Pack-houses (unit)	450-550	15,000-20,000	50,000-60,000	1,00,000-1,50,000
Reefer vehicles (unit)	12,000-15,000	50,000-60,000	1,20,000 -1,50,000	3,00,000-5,00,000
Cold storage (million MT)	35	38-41	42-44	45-50
Ripening chamber (unit)	1,000-1,100	2,000-3,500	8,000-9,500	12,000-15,000
Domestic refrigerator (Million units)	100	126-133	168-178	300-318
Commercial refrigeration (Million TR)	8.4	11.2-12	16.7-18.3	45-50

Refrigerant Demand (incl. Servicing)

	2017-18	2022-23		2027-28		2037-38	
		Reference	Intervention	Reference	Intervention	Reference	Intervention
Refrigerant demand (MT)	2200-2500	3200-3400	2700-3000	4500-4900	4000-4300	9600-9900	8400-8900

Annual Energy Consumption

	2017-18	2022-23		2027-28		2037-38	
		Reference	Intervention	Reference	Intervention	Reference	Intervention
Pack-houses (TWh)	0.02	0.74-0.8	0.7-0.75	2.2-2.5	2-2.3	4.5-6	4-5.5
Reefer vehicles (TJ)	3,700-4,000	15,000-19,000	12,000-15,000	34,000-45,000	30,000-38,000	87,000-1,50,000	75,000-1,30,000
Cold storage (TWh)	4-4.3	4.3-4.7	4.2-4.6	4.6-4.9	4.3-4.7	4.6-5.2	4.2-4.6
Ripening chamber (TWh)	0.1-0.14	0.24-0.32	0.23-0.3	0.8-1.1	0.75-0.9	2.4-2.8	2-2.4
Domestic refrigerator (TWh)	51	83-91	68-72	127-132	90-93	191-199	128-134
Commercial refrigeration (TWh)	15.5	21.7-23.4	19.6-20.7	33.5-34.8	27.3-29.5	85.7-94.5	60.9-65.8

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